Demo results assessment & data report collection

D9.7

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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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Table of Contents

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

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

List of Figures

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

List of Tables

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

List of Abbreviations and Acronyms

Acronym	Meaning
API	Application Programming Interface
BNO	Business Network Operator
CIM	Common Information Model
CRUD	Create Read Update Delete
DApp	Decentralized Application
DER	Distributed Energy Resources
DSO	Distribution System Operator
ENE	Energy Not Evacuated (Not Served)
Enedis	French DSO
FSP	Flexibility Service Provider
gRPC	Google Remote Procedure Calls
HIM	Human Interface Machine
HV	High Voltage
IAM	Identity and Access Management
ICS	Information Commercially Sensitive
IS	Information System
KMS	Key Management System
KPI	Key Performance Indicator
MV	Medium Voltage.
MWh	Megawatt per hour
NAZA	New Adaptive 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 optimization 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 optimize the amount of curtailed energy.
PDC	Private Data Collection (Documentation Hyperledger Fabric Private Data Collection, s.d.)
RTE	French TSO (Réseau de Transport d'Electricité)
TSO	Transmission System Operator

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Executive Summary

This deliverable details the computation of the KPIs for the French demonstrator and highlights the learnings of the experiment introduced in [1]. It includes a definition of the result assessment methodology as well as an evaluation of the data format used in the built experimental platform. It also provides feedback on the technology used and on the functional needs of the project.

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

Use case BUC WECL-FR-01's objective is to build and test a blockchain based platform sharing data covering the entire life cycle of flexibility orders related to congestion management, from its formulation to the monitoring of the invoicing process from their activation. The experiment's main positive takeaway has been the successful work and alignment between TSO, DSO and FSPs in order to address joint management of curtailment flexibilities.

From a functional point of view, this BUC allowed the following achievements and learnings:

- Improved data exchange, making it more standardized. The CIM standard proved relevant in our case.
- The definition of business processes, methodology and user expectations. The defined functionalities of the platform were successfully met throughout the demo run.
- The development and test a new algorithm for matching TSO-DSO activations, and a calculation methodology and engine for the energy amount not injected in the grid due to curtailment. The method was efficient in the context of the experiment.

This functional part of the use case will be reused for an inclusion of the use cases in legacy systems of RTE and Enedis, with a potential of replicability across Europe.

From a technical standpoint, building the data sharing platform offered learnings regarding the implementation of distributed ledger technology, also known as blockchain.

- Throughout the experimentation, distributed ledger technology has proved to be more complex to master than conventional technology, requiring specific expertise and leading to change the architecture throughout the duration of the experimentation. Eventually the platform meets the confidentiality requirements at the cost of a reduced performance (latencies) and a complex architecture that seems hard to scale.

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- Besides, blockchain has been found more valuable than conventional technology for multilateral exchanges involving more than two parties.

Most importantly, the project questioned the fair balance between the need for more transparency between the TSO, DSOs and FSPs on the one hand, and the strict guarantee of confidentiality and privacy regarding business sensitive data on the other hand. Although the architecture has been set up with the objective to conciliate both needs, its complexity witnessed throughout the implementation phase did not allow the direct industrialization of this technology.

Requiring a quick at-scale and industrialized answer for the management of renewable energy sources (RES) production curtailment, RTE and Enedis decided to pursue its implementation using a traditional and centralized architecture.

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1 Introduction

Constantly evolving electricity demand patterns and production leads actors to adapt to these changes by using innovative ideas and technologies. As seen in D9.1 [7], 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 the 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 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 from renewable energy sources (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) which concerns the business use case WECL-FR-01 described in the document [3].
- The study on innovative ways for TSO-DSO information exchange for DER curtailment activation (coordination between DSO and TSO order) which concerns the business use case WECL-FR-02 described in the document [3].

STAR project's objective (WECL-FR-01) was to ensure a better integration of FSPs into the French electricity grid. In this context 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, , 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 study (WECL-FR-02) concerned further TSO/DSO coordination, focusing on possible new data exchange options in order to improve both entities' flexibility usage optimizations in a broader context than congestion

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management. As a reminder, the BUC WECL-FR-02 is a study that has been detailed in OneNet D9.4 [1] by the French Demo. Hence, it will not be addressed in the present document.

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 Objectives of the work reported in this deliverable

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.

Overall, the idea of this deliverable was to provide an assessment of the results of the French demonstration and then provide a qualitative and quantitative analysis of the data report collection on the STAR platform. First, the structuring documents such as the data model and the rights matrix led to an evaluation of many aspects. Secondly, the use and relevance of Blockchain technology was assessed. Blockchain technology is an important aspect of the technical implementation of STAR, however, it is not the only technology structuring the business platform that STAR represents. In order to complete the evaluation part, it was necessary to collect feedback from the users at each of the stakeholders. Finally, key performance indicators were defined to determine the relevance of the STAR platform for potential industrialization.

1.3 Outline of the deliverable

The work conducted in Deliverable D9.7 can then be divided into five steps:

- Chap 2 - Experimentation Summary
- Chap 3 - Methodology of result assessment & data report collection
- Chap 4 - Data Exchange and Data model evaluation
- Chap 5 - Blockchain Technology Evaluation

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- Chap 6- FSP (Flexibility Service Provider) and System Operator User Evaluation and platform Run

1.4 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:

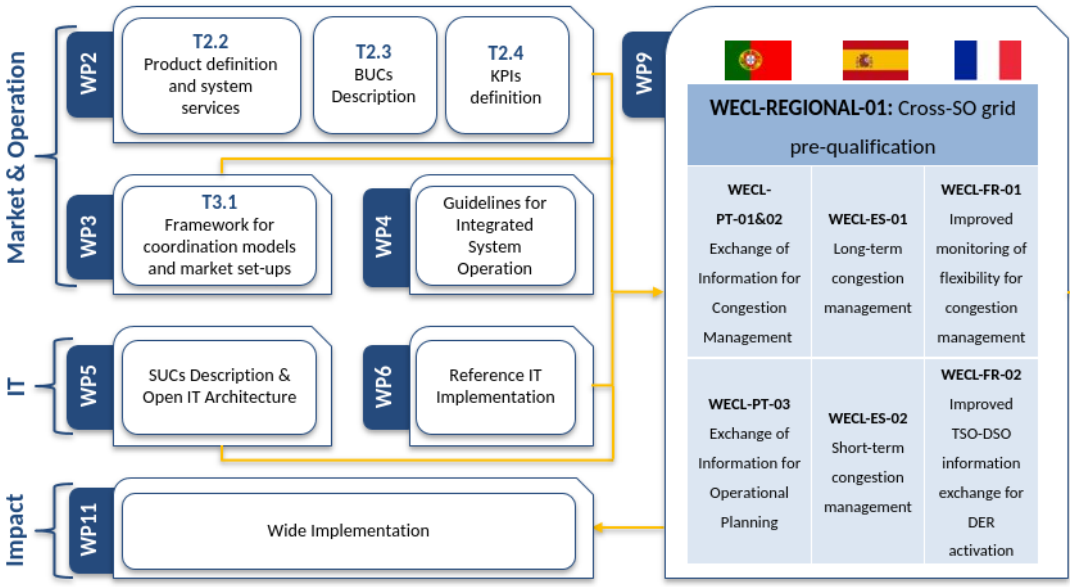

Figure 1: Interaction within WP9 and other WPs

- WP2 "*Products and services definition in support of OneNet*" provided standardized understanding of products and services [2] , Business Use Cases (BUCs) definition [3] and Key Performance Indicators (KPIs) definition and overall alignment [4].
- WP3 "*Integrated and coordinated markets for OneNet*" provided definition of coordinated and scalable markets for the procurement of system services by DSOs and TSOs [5].
- WP5 "*Open IT Architecture for OneNet*" provided System Use Cases (SUC) definition and technical requirements for platform development and OneNet system description [6].
- WP 9 "*Western Cluster Demonstrator*" deals with the demos of Spain, Portugal, and France. The alignment of theses demos was carried out by task T9.1. 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

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demo site and aggregated for further analysis in WP11 and linked to direct collaboration with different projects in WP12.

1.5 How to read this document

As mentioned in this chapter, this deliverable contains an assessment of the results of the French demonstration as well as a qualitative and quantitative analysis of the data report collection on the STAR platform. Although some attempt has been made to have this document understandable without prior knowledge of other works related to the French demonstrator, it does not contain the detailed presentation of the demo's BUCs and the thorough description of the platform. Therefore it is recommended for the reader to understand the French experiment as a whole to have a look on other OneNet deliverables articulated with this one. In particular, deliverable D9.4 [1] will help better understand the demo's methodology, platform functionalities and BUCs' details which are only summarized in chapter 2 of this document. Deliverable D2.3 could also be useful for a detailed description of the demo's BUCs.

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2 Experimentation summary

The OneNet French Demonstration is divided into two parts: the implementation of STAR (System of Traceability of Renewables Activations - BUC WECL-FR-01) and the study on innovative ways for TSO-DSO information exchange for DER activation (BUC WECL-FR-02). This document deals only with the first business use case (BUC WECL-FR-01) and both use cases are presented in more detail in [1]. Also this document does not provide an analysis of the Regional Business Use Case that will be carried out along with WP9 cluster demos using the Onenet Connector.

2.1 Overview of STAR

STAR which tracks the active power generation curtailment of renewable generators, 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 RES 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 type 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 curtailment 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. More information on the data exchange and the platform are given in [1].

The analysis of the implementation of STAR, is linked to the mechanisms used to define the network connection agreements that specify the producers' curtailment obligations and compensation. The STAR platform uses existing market and flexibility procurement mechanisms, and no new markets or flexibility procurement mechanisms are developed within this OneNet demonstrator. As mentioned in the deliverable D3.1 [5], 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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2.2 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 the use of these flexibilities 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 of the second use case WECL-FR-02 is then to reflect on future coordination means that would enhance and optimize flexibility usages, in a technically and economically efficient way. The outcome of this reflection is found in chapter 5 of D9.4 [1].

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3 Methodology of result assessment & data report collection

This section describes the methodology to evaluate the results and KPIs and qualitative criteria. Five KPIs had been defined and their detailed description are in the deliverable D2.4 [4]:

1. Number of service providers
2. Tracked flexibility
3. Available Flexibility
4. Active participation
5. Volume of Transactions (Energy)

3.1 Number of service providers

Methodology description:

In the number of service providers we consider producers who have been actively involved in the STAR platform usage through participation to the different workshops:

- On user experience,
- On the definition of the data model
- On return on experience

The demonstrator also included tracking in STAR flexibility activations from other producers not attending the workshops and not using the platform, these were not considered in this KPI.

	KPI definition template (Demo KPIs)	
	KPI DEFINITION SECTION	
Calculation information	**1. Formula**	Nb_{FSP}
	2. Variables	Nb_{FSP} : number of service providers involved in the demonstrator
	3. Unit of measurement	-
	4. 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.
	5. 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.
	6. Baseline responsible	Not applicable
	7. KPI target value	2 to 3

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	8. Calculation Methodology	Counting the FSP involved or not in the demo and computing the defined formula.
	9. KPI computation timing	M28

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 1: KPI Definition Number of service Providers

BUC	Data ID	Data Description	KPI Results
WECL-FR-01	N_FSP_FR	Nb_{FSP}	2
Result analysis	Two producers actively involved because the geographic area chosen for the experiment (corresponding to the experimental NAZA automaton action area) remains relatively small, though this is aligned with our expectation.		

Table 2: KPI Results Number of Service Providers

3.2 Tracked Flexibility

Methodology description:

We here compute the number of performed flexibility activations during the experiment (either triggered manually or automatically). For automatically triggered orders sent by the TSO that needed sub-orders to the sent by the DSO, we considered every sub-order sent by the DSO sent to concerned sites.

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	KPI definition template (Demo KPIs)	
	KPI DEFINITION SECTION	
Calculation information	**1. Formula**	NAa_{Flex}
	2. Variables	NAa_{Flex}: Number of tracked flexibility activations
	3. Unit of measurement	-
	4. 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.
	5. KPI baseline source	Not applicable
	6. Baseline responsible	Not applicable
	7. KPI target value	7 to 15
	8. Calculation Methodology	Counting manually the orders that have been registered in STAR platform
	9. KPI computation timing	M28

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 triggered manually	Inventory list	Manually through STAR platform	STAR platform	Once at the end of the project	M18-M28	RTE-Enedis	Public for OneNet project

Table 3: KPI Definition Tracked Flexibility

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BUC	Data ID	Data Description	KPI Results	Results Description
WECL-FR-BUC-01	N_FLEX_FR	Number of tracked flexibility activations	216	3 Orders triggered manually + 213 Orders triggered automatically
WECL-FR-SUC-01	N_FLEX_NAZA_FR	Number of tracked flexibility activations triggered automatically by NAZA	213	3 orders from RTE to RTE's producers 210 orders to Enedis' producers
WECL-FR-SUC-01	N_FLEX_MAN_FR	Number of tracked flexibility activations triggered manually	3	3 orders from Enedis
Result Analysis	Inside the concerned region, automated orders are the main source of activations since each NAZA algorithm's decision induces several orders to resources (usually connected to the DSO network). The final number of activations is much higher than the target value because it was originally not planned to consider sub-orders to the DSO sites in the computation, it was finally taken into account to give more detail on the results. Finally the total number of activations is aligned with what was envisioned in the experiment.			

Table 4: KPI Results Tracked Flexibility

3.3 Available Flexibility

Methodology description:

To calculate the total power, we take into account all PV and wind power plants of the geographical zone "Melle Longchamps".

To calculate the available power, we take into account the PV and wind power plants connected below the seven substations selected for the demonstration.

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KPI definition template (Demo KPIs)		
KPI DEFINITION SECTION		
Calculation information	1. **Formula**	$Flexibility\% = \sum PAvailableFlexibility / \sum PTotalinArea \cdot 100$
	2. **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)
	3. **Unit of measurement**	%
	4. **KPI baseline explanation**	N/A
	5. **KPI baseline source**	N/A
	6. **Baseline responsible**	N/A
	7. **KPI target value**	>0
	8. **Calculation Methodology**	Define the affected specific area to obtain the power to compare with the flexibility capacity
	9. **KPI computation timing**	M28

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)

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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

BUC	Data ID	Data Description	KPI Results	Results Description
WECL-FR-BUC-01	FR-PA-01	$\sum PAvailable\_Flexibility$	210.83 MW	Production site on the 7 substations which participate in the demonstration
WECL-FR-BUC-01	FR-PT-01	$\sum PTotal\_in\_Area$	550.33MW	Production site on the Melle Longchamp area
WECL-FR-BUC-01	FR_BUC_KPI_03	*Flexibility%*	36,66%	There are 2 additional DSOs located in the demo which don't take part in the demo and 3 substations which don't take part in the demo
Result analysis	36,66% of the flexibilities which are in the geographical area were activated. Some belonging to DSOs not participating in the experiment or connected to substations not considered could not be activated.			

Table 6: KPI Results Available Flexibility

3.4 Active participation

Methodology description:

To calculate this KPI, we took into account all customers who accepted to participate in the demonstration.

	KPI definition template (Demo KPIs)	
	KPI DEFINITION SECTION	
Calculation information	1. **Formula**	$R=Nactive/Naccept \cdot 100$
	2. **Variables**	R: Active participation (%) $Nactive$: Customers actively participating in the demo $Naccept$: Customers accepted to participate in the demo.
	3. **Unit of measurement**	%
	4. **KPI baseline explanation**	Naccept will include currently accepted customers plus the ones contracted by cascading funds.
	5. **KPI baseline source**	RTE Enedis

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	6. **Baseline responsible**	RTE Enedis
	7. **KPI target value**	100%
	8. **Calculation Methodology**	Compare accepted with active customers at the end of demo run
	9. **KPI computation timing**	M28

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 7: KPI Definition Active Participation

BUC	Data ID	Data Description	KPI Results
WECL-FR-BUC-01	FR-Act	*Nactive*	*2*
WECL-FR-BUC-01	FR-Acc	*Naccept*	*2*
WECL-FR-BUC-01	FR_BUC_KPI_05	*R*	*100%*
Result Analysis	The 2 candidate producers have actively participated in the demonstration and both have limitation orders tracked in the platform		

Table 8: KPI Results Active Participation

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3.5 Volume of transactions (Energy)

Methodology:

During the experiment RTE was responsible for computing the energy not served for HV flexibility activations occurring on its network whereas Enedis was to compute the ones for MV flexibility activations. This was done for each flexibility activation using internal tools, and registered manually of the platform. This KPI is thus the sum of the energies not served computed by RTE and the ones computed by Enedis.

	KPI definition template (Demo KPIs)	
	KPI DEFINITION SECTION	
Calculation information	1. **Formula**	$VTP = \sum T \sum I \, Ei,t$
	2. **Variables**	VTP: Volume of transaction considering active power (kW) Ei,t: Volume offered or cleared capacity by the i-th flexible resource at time t (kW) I: Set of flexible resources. T: Examined period.
	3. **Unit of measurement**	MWh
	4. **KPI baseline explanation**	0 (no volume of transactions)
	5. **KPI baseline source**	N/A
	6. **Baseline responsible**	N/A
	7. **KPI target value**	>0
	8. **Calculation Methodology**	Collect platform transaction information
	9. **KPI computation timing**	M28

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	Ei,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 9: KPI Definition Volume of Transactions (Energy)

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BUC	Data ID	Data Description	KPI Results	Results Description
WECL-FR-BUC-01	FR-Eit	Ei,t	Not applicable	For each flexibility activation, the energy not served was computed and manually stored in the platform, cleared power and activation time were finally not needed.
WECL-FR-BUC-01	FR_BUC_KPI_06	VTP	4 984 kWh	Sum of HV and MV flexibility activations' energies not served
Result Analysis	5 limitations tracked in the platform have currently passed the entire process of energy not served computation, therefore the KPI only takes into account these 5 activations..			

Table 10: KPI Results Volume of Transactions (Energy)

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4 Data Exchange and Data model

In this section, the business objects of the data model will be presented in detail with the list of functionalities associated with them.

4.1 Data exchange overview

Here we first recap what data exchanges are induced between the TSO, the DSO, the producers and the STAR platform after the emission of a flexibility activation order. The following two figures detail the process for the two French demo's SUCs which correspond to the cases of automated an manual orders. In both situations, the main data registered in the blockchain platform are: limitation orders, metering curves, energy not served, valuation unit tariff. A more thorough description of the activation process flow and the platform's user interface can be found in D9.4 [1].

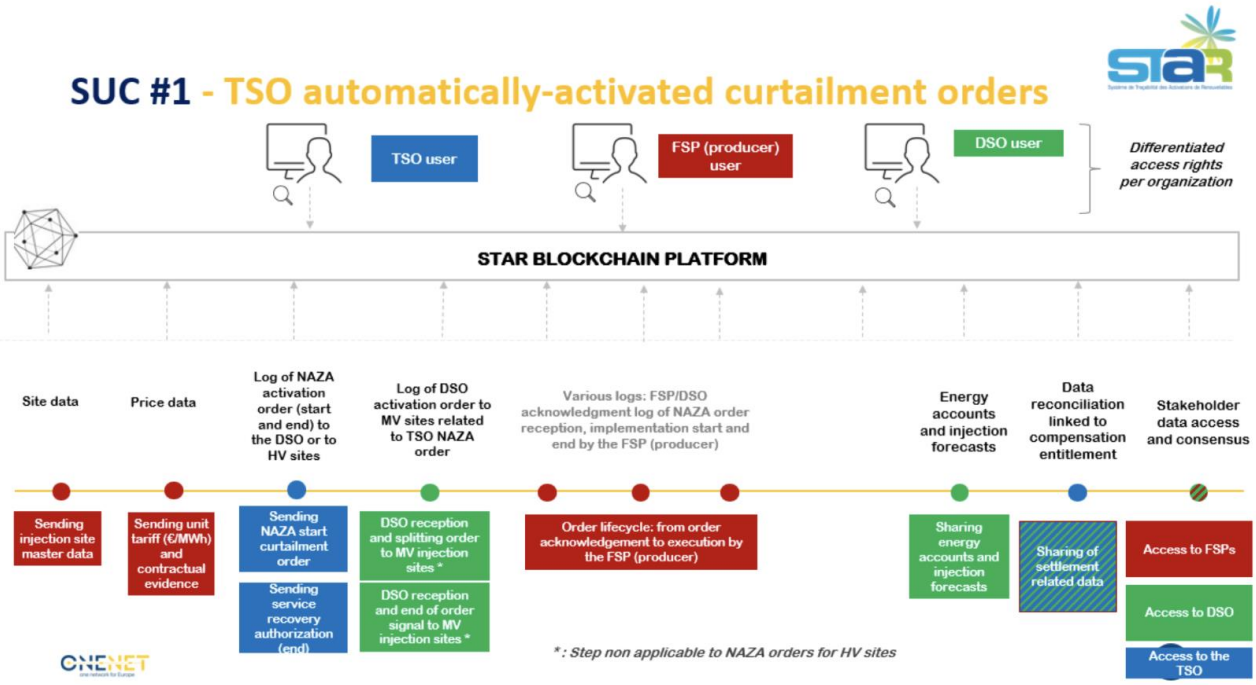

Figure 2: SUC FR-01 data exchange

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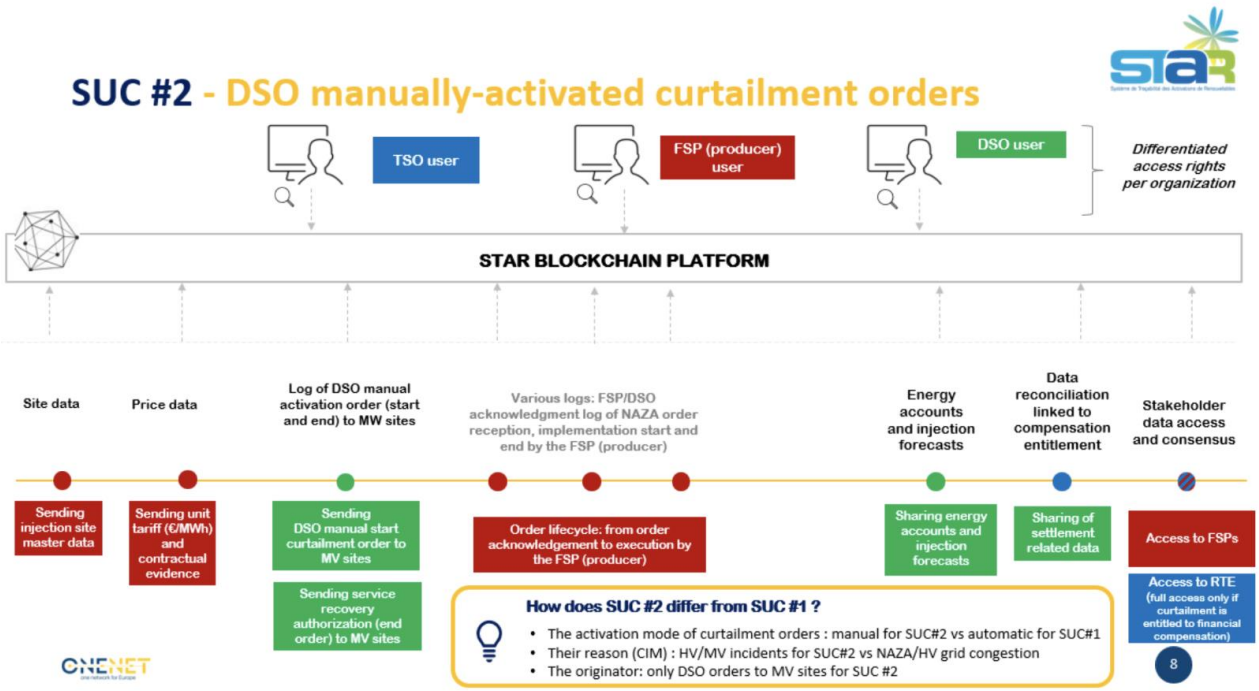

Figure 3: SUC FR-02 data exchange

4.2 Data functional description

The objective of this section is to briefly present a functional description of the main objects of our data model. These objects are taken or inspired from the CIM standard. The STAR experiment allowed us to use the CIM standard, to adapt it to our needs and to evaluate it for the operational part of the project. The Figure 4: Data Model Macro view below shows a macro view of the Data Model that was built for the STAR project. We can notice that a large majority of the objects come from the CIM standard. However, for specific needs, we have built objects while using the CIM standard typology for the attributes of these objects.

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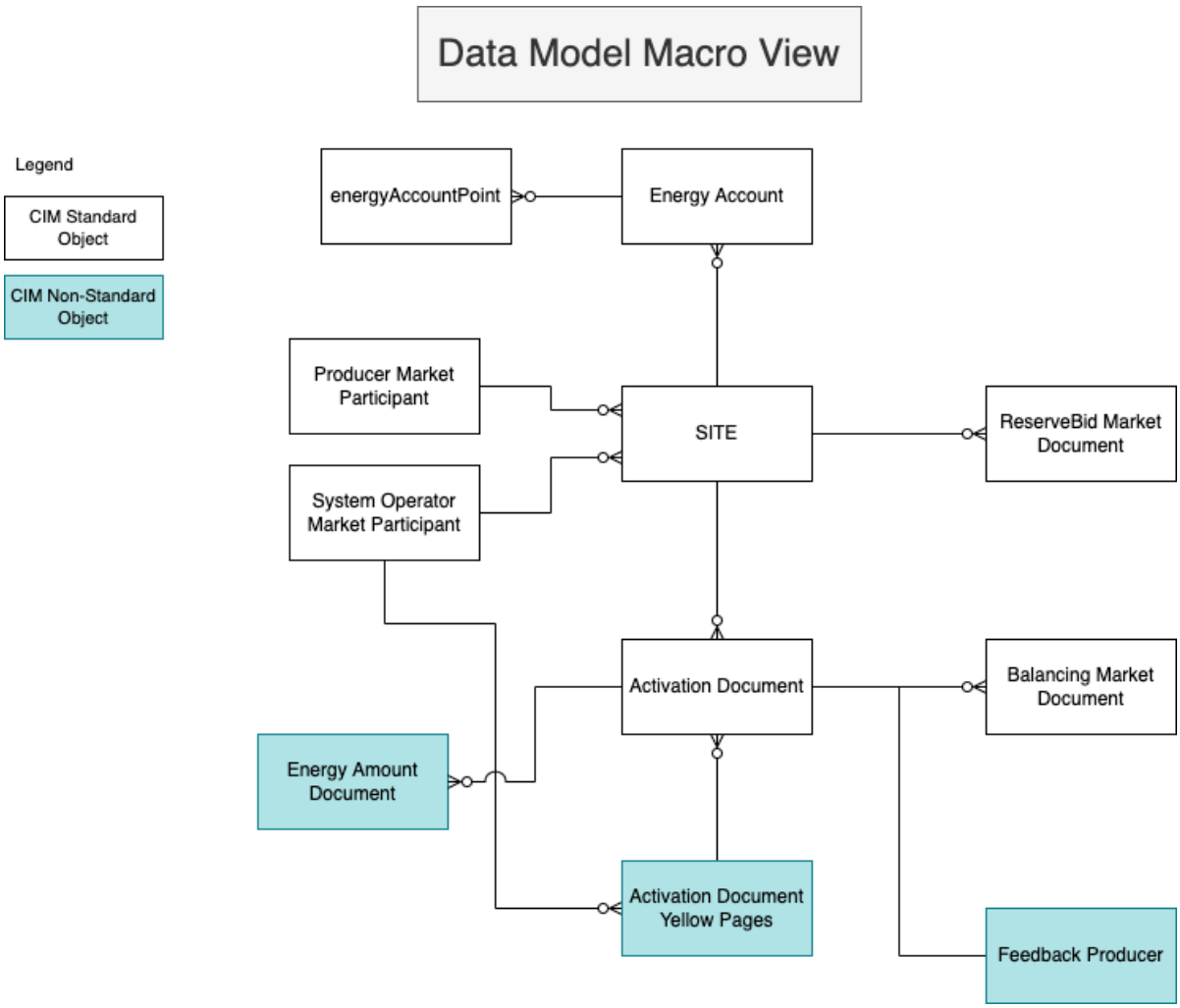

Figure 4: Data Model Macro view

4.2.1 Master Data

The master data, constructed in STAR, corresponds to the:

- ⇨ Network of actors participating in STAR: Object ***Market Participant***
- ⇨ Network of electricity production and injection sites: ***Site*** object

These objects are standard (CIM IEC62325 ESMP), each participant must be identified by an EIC code.

Market Participants can be both system operators (systemOperatorMarketParticipant) and producers (FSP) operating injection sites (producerMarketParticipant). In this master data, the identification of Market Participants is minimal.

The Site objects are the production entities owned by the Renewable Energy producer. The Site object contains a summary of the relevant information, in a standard format, for the system operator in order to be able to identify it properly.

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Table 11 - Site Production Attributes

Attributes	Example	Description	CIM IEC62325 ESMP Standard
meteringPointMrid	PRM00000000234766	Site code of the site, prefixed by PRM, PDL or CARD This parameter name is inspired by EAR, used for HV/MV Energy Account	**Yes**
systemOperatorMarketParticipantMrid	17X100A100A0001A	IEC code identifying the DSO to which the site is connected	**Yes**
producerMarketParticipantMrid	17X000001307745X	IEC code identifying the producer	**Yes**
marketEvaluationPointMrid	(code PPE)		**Yes**
schedulingEntityRegisteredResourceMrid	(code EDP)		**Yes**
technologyType	Eolien	Injection HV / Injection MV HV stands for High Voltage MV stands for Medium Voltage	**Yes**
siteType	Injection	Defines whether the site is on the production side (Injection) or the demand side (Withdrawal)	**Yes**
siteName	Ferme éolienne de Genonville	Name of the Site	**Yes**
siteAdminMrid	489 981 029	SIRET number of the Site	Yes
siteLocation	Biscarosse	Geographical location of the site	**Yes**
sitelecCode	S7X0000013077453	IEC code identifying the site	**Yes**
substationMrid	CONF6		**Yes**
substationName	CONFOLENS		**Yes**

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systemOperatorEntityFlexibilityDomainMrid	PSC4567		**Yes**
systemOperatorEntityFlexibilityDomainName	Départ 1		**Yes**
systemOperatorCustomerServiceName	DR Nantes Deux-Sèvres		**Yes**

Table 12 – Market Participant Object (System Operator)

Attributes	Example	Description	**CIM IEC62325 ESMP Standard**
systemOperatorMarketParticipantMrid	10XFR-RTE------Q	IEC Code of TSO / DSO	**Yes**
systemOperatorMarketParticipantName	RTE	Name of TSO / DSO	Yes
systemOperatorMarketParticipantRoleType	A49	Code Role Type CIM of TSO (A49 for the TSO, A50 for the DSO)	Yes

Table 13 – Market Participant Object (Producer)

Attributes	**Example**	**Description**	**CIM IEC62325 ESMP Standard**
producerMarketParticipantMrid	17X000001307745X	IEC Code of producer	Yes
producerMarketParticipantName	EolienFR Vert Cie	Name of producer	Yes
producerMarketParticipantRoleType	A21	Code Role Type CIM of producer	Yes

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In relation to the objects presented above, here is an illustration in the Figure 5: Master Data API description below of the list of APIs that are linked to these business objects.

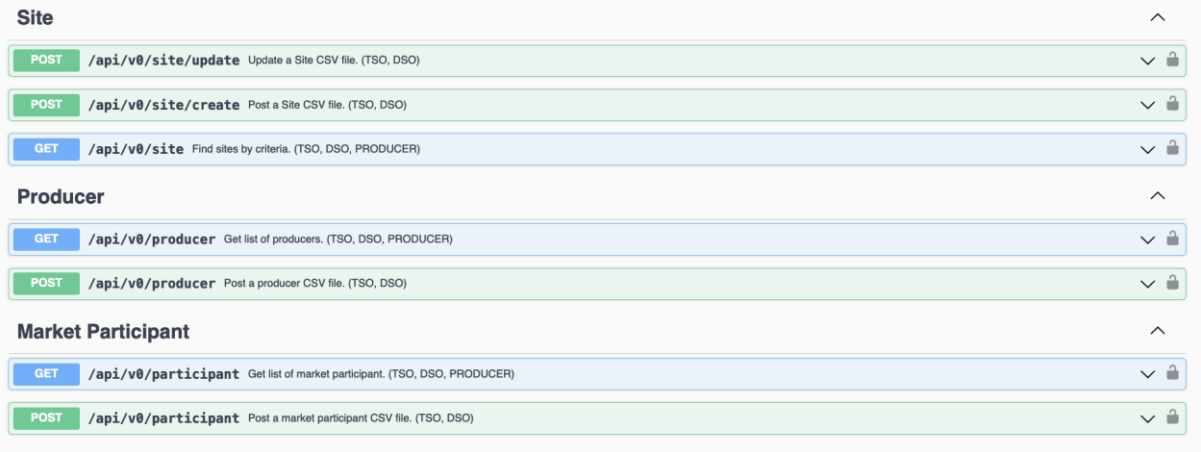

Figure 5: Master Data API description

4.2.2 Activation Document

In the STAR project, the ***Activation Document*** object is used to represent a limitation order (injection curtailment) from a system operator.

A limitation 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 producer at the level of a site connected to the MV network (Public Distribution Network)
  - RTE to a producer at the grid node of a site connected to the HV network (Public Transmission Network)

The main attributes contained in the Activation Document are:

- ⇨ originAutomationRegisteredResourceMrid: Electrical entity for which the limitation order is issued (e.g. controller, source substation);
- ⇨ registeredResourceMrid: Electrical entity that receives the limitation order (e.g. Source substation identifier, Site Code, etc.);
- ⇨ The definition of the limitation reason, thanks to the combination of three standard attributes
  - messageType: Type of order (TOR, TVC or TC)
  - businessType: Use case of the curtailment
  - reasonCode: Code of the reason for the order
- ⇨ orderValue: Value of the limitation order in power unit.

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Table 14: Activation Document Attributes

Attributes	Examples	Description	CIM IEC62325 ESMP Standard
activationDocumentMrid	*UUID generated by STAR* *Ex: 8c56459a-794a-4ed1-a7f6-33b0064508f1*	A technical ID, which uniquely identifies an order received in STAR.	Yes
originAutomationRegisteredResourceMrid	- CIVRAY AUT03 - NAZA_MELLE_LONGC	The attribute that indicates the issuing PLC/system function, or the origin of the order, as opposed to the registeredResourceMrid attribute, indicating the destination of the order	Yes
registeredResourceMrid	- AIGRE-P41 - CIVRA-P41 - ...	The attribute that indicates the destination of the order, as opposed to the attribute originAutomationRegisteredResourceMrid, indicating the destination of the order	Yes
eligibilityStatus	OUI / NON / Null	The eligibility data defines whether the limitation will result in compensation or not.	Yes

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orderValue	0.00	Target power setpoint requested by the automaton In the case of an "All or nothing" order, the order induces a setpoint at 0.	Yes
measurementUnitName	MW	Unit of power quantity (e.g. MW)	Yes
startCreatedDateTime	*Format standard ISO 8601 UTC* FSPS-MM-DDTHH-MM-SS Z	Dates and times when the NAZA automaton or an Enedis system has sent a limitation start order A NAZA RTE start order is sent in UNIX format and must be converted to ISO8601 FSPS-MM-DDTHH-MM-SS Z by the platform An Enedis order and an RTE end order will be directly in ISO8601 format	Yes
endCreatedDateTime	*Format standard ISO 8601 UTC* FSPS-MM-DDTHH-MM-SS Z	Dates and times when the NAZA automaton or an Enedis system has sent a limitation end order It is always sent in ISO8601 format: FSPS-MM-DDTHH-MM-SS Z	Yes
revisionNumber	1	Version number	Yes
messageType	See EIC codes EIC	Order type	Yes
businessType	See EIC codes EIC	Nature of curtailment	Yes

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reasonCode	See EIC codes EIC	Reason for the order	Yes
orderEnd	True / False	Field allowing to know if the order succeeds and ends a preceding order, in the case of a modulation TVC order (implicit end of the preceding order by a start order) The field is False when the order is of type TOR, simple TVC, or when it is a modulation TVC order which does not succeed and/or does not end the preceding modulation TVC order.	Yes
senderMarketParticipantMrid	10XFR-RTE------Q	The ID of the market Participant receiving the order (corresponds to the PK of the corresponding systemOperatorMarketParticipant)	Yes
receiverMarketParticipantMrid	systemOperatorMarketParticipantMrid 17X100A100A0001A producerMarketParticipantMrid Example : 17X000001307745X	The ID of the market Participant receiving the order (corresponds to the PK of the corresponding systemOperatorMarketParticipant)	Yes

In relation to the objects presented above, here is an illustration in the Figure 6: Activation Document API Description below of the list of APIs that are linked to these business objects.

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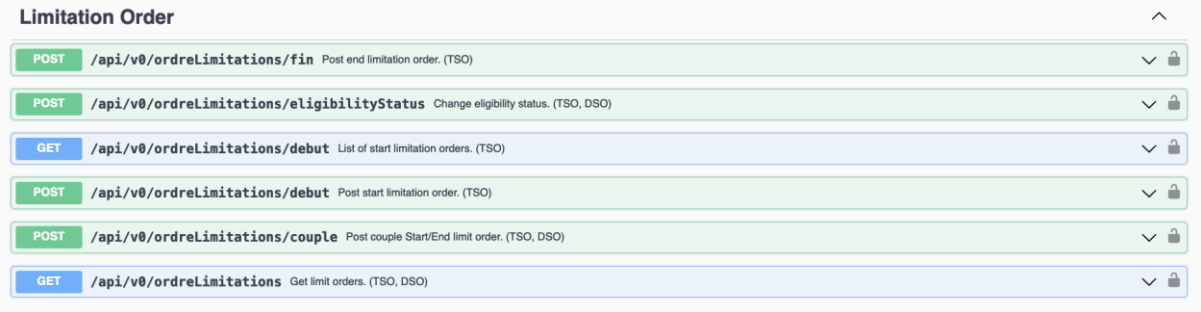

Figure 6: Activation Document API Description

4.2.3 Energy Account Market Document

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

- ⇨ Metering curves
  - The effective power injection log, at the grid of a given site (CART code for HV sites, or PRM code for MV sites) recorded by the system operator's metering tools at each time step.
  - Physical quantity: Power
- ⇨ Reference curves (specific for RTE in the pilot phase)
  - 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.
  - Physical quantity: Power

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

Table 15: Energy Account Attributes

Attributes	Examples	Description	CIM IEC62325 ESMP Standard
energyAccountMarketDocumentMrid	ea4cef73-ff6b-400b-8957-d34000eb30a3	Document Mrid	Yes
meteringPointMrid	PRM50012536123456	Site identifier prefixed by PRM (if Enedis MV site), PDL or CART (if HV site)	Yes
marketEvaluationPointMrid	{N/A}	PPE (Physical Point Elemental) site code, linked to the meteringPointMrid in the Site attributes (relation 1-1).	Yes

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		This code will only be used for RTE energy accounts.	
revisionNumber	1	Document version	Yes
businessType	A14 / Z14	A14 - Aggregated Energy Data The A14 code is proposed for the supply of load curves, at the level of the European EAR Implementation Guide. But if this is a problem, it would be possible to agree to use an experimental code on a temporary basis (e.g. Z14)	Yes
docStatus	A02	A02 - Final	Yes
processType	A05	A05 - Aggregation of measured data	Yes
classificationType	A02	A02 - Summary For the Reference Curve, this attribute will be used to indicate the calculation method used. It is therefore made mandatory for the Reference Curve.	Yes
product	Ex ample: - Active energy - Reactive energy	This attribute specifies the type of product measured in the TimeSeries: e.g. active or reactive energy)	Yes
areaDomain	17X100A100A0001A	Indicates a region or area of responsibility. This is the EIC AREA code (FSPS code) of the DSO or TSO - for RTE: 10XFR-RTE------Q - for Enedis: 17X100A100A0001A Source: https://FSPs.entsoe.eu/data/energy-identification-codes-eic/eic-approved-codes/	Yes

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senderMarketParticipantMrid	{code EIC Enedis}	Identifier of the sender of the document (EIC Code RTE or Enedis)	Yes
senderMarketParticipantRole	A50	This could be a TSO(A49) or DSO(A50) role for the sender.	Yes
receiverMarketParticipantMrid	STAR or Code EIC Producer	Identifier of the actor receiving the energy account.	Yes
receiverMarketParticipantRole	A32 or A21	The STAR platform is considered an actor receiving and aggregating market information. Market information aggregator (A32) role for STAR.	Yes
createdDateTime	2021-10-22T10:29:10.000+01:00	Date and time of creation of the EA market document. In ISO 8601 format: FSPS-MM-DDTHH:MM:SSZ For France, UTC+1 or UTC+2 depending on summer or winter time.	Yes
measurementUnitName	KW	Unit of measurement	Yes
timeInterval	FSPS-MM-DDThh:mmZ / FSPS-MM-DDThh:mmZ	In the sense of the IEC (European profile ESMP), this attribute allows to define at once an interval, defined as a start and end date each respecting the pattern ISO 8S01: FSPS-MM-DDThh:mmZ / FSPS-MM-DDThh:mmZ and the hours must be expressed in UTC hours.	Yes
resolution	PT10M	Time between each point in seconds (600 for 144 values in the time Serie). The resolution attribute expresses the number of periods into which the time Interval is divided. This corresponds to a	Yes

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		time step. It must be filled in according to the pattern PnYnMnDTnHnMnS. With P and T fixed letters, and nY, nM, nD,... nM,nS expressing the number of years, months, days... minutes, seconds of each period. Ex: a resolution of 10min will be expressed PT10M	
TimeSeries	NA		Yes

In relation to the objects presented above, here is an illustration in the Figure 7: Energy Account API Description below of the list of APIs that are linked to these business objects.

Figure 7: Energy Account API Description

4.2.4 Energy Amount Market Document

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.

Each ***Energy Amount*** is linked to a given limitation, i.e. to the activationDocumentMrid field of this limitation, identifying it in a unique way. This energy data is unique and calculated (except for STAR, by means of ENE/I calculators in the system operators' IT systems) for each limitation taking place on a generation site. TSO is responsible for the calculation of Energy Amount for HV ***Sites*** while the DSO is responsible for the calculation on MV ***Sites***.

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Table 16: Energy Amount Attributes

Attributes	Examples	Description	CIM IEC62325 ESMP Standard
energyAmountMarketDocumentMrid	UUID generated by STAR Ex: 8c56459a-794a-4ed1-a7f6-33b0064508f1	Document Mrid	Yes
activationDocumentMrid	UUID generated automatically when Activation document is created.	Activation Document Mrid : unique identifier of an Activation Document	Yes
registeredResourceMrid	Code site HTB Examples : PDL CART	The attribute that indicates the destination of the Energy Amount	Yes
quantity	12	Numerical value of measured energy	Yes
measurementUnitName	MWh	Unit of measurement	Yes
revisionNumber	1	Document version	Yes
businessType	C55	A14 - Aggregated Energy Data The code A14 is proposed for the provision of load curves, at the level of the European EAR Implementation Guide. But if this is a problem, it would be possible to agree to use an experimental code on a temporary basis (e.g. Z14)	Yes
docStatus	A02	A02 - Final	Yes
processType	A42	A05 - Aggregation of measured data	Yes
classificationType	ZXX	A02 - Summary	Yes

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areaDomain	10XFR-RTE------Q	Indicates a region or area of responsibility. This is the EIC AREA code (FSPS code) of the DSO or TSO - for RTE: 10XFR-RTE------Q - for Enedis: 17X100A100A0001A Source: https://FSPs.entsoe.eu/data/energy-identification-codes-eic/eic-approved-codes/	Yes
senderMarketParticipantMrid	{code EIC RTE}	Identifier of the sender of the document (EIC Code RTE or Enedis)	Yes
senderMarketParticipantRole	A49	This could be a TSO(A49) or DSO(A50) role for the sender.	Yes
receiverMarketParticipantMrid	Producer Mrid similar to **producerMarketParticipantMrid**	Identifier of the actor receiving the energy account.	Yes
receiverMarketParticipantRole	A32 or A21	The STAR platform is considered an actor receiving and aggregating market information. Market information aggregator (A32) role for STAR.	Yes
createdDateTime	2021-10-22T10:29:10.000+01:00	Date and time of creation of the EA market document In ISO 8601 format: FSPS-MM-DDTHH:MM:SSZ For France, UTC+1 or UTC+2 according to summer or winter time	Yes

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timeInterval	FSPS-MM-DDThh:mmZ / FSPS-MM-DDThh:mmZ	In the sense of the IEC (European profile ESMP), this attribute allows to define in one time an interval, defined as a start and end date each respecting the ISO 8S01 pattern: FSPS-MM-DDThh:mmZ / FSPS-MM-DDThh:mmZ and the hours must be expressed in UTC hours	Yes

In relation to the objects presented above, here is an illustration in the Figure 8: Energy Amount API Description below of the list of APIs that are linked to these business objects.

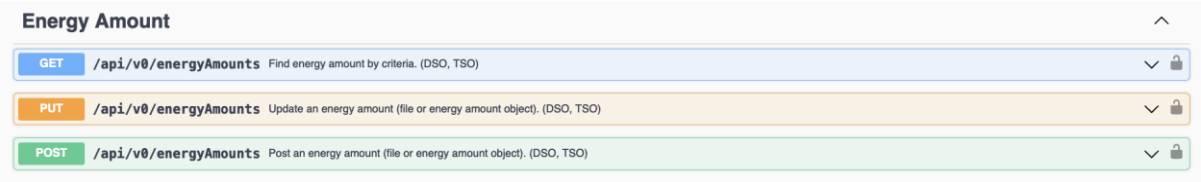

Figure 8: Energy Amount API Description

4.2.5 Reserve Bid Market Document

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

The valuation unit tariff depends on the tariff type per MWh of ENE/I. this tariff type depends on the contract between the producer and the energy supplier.

The ***Reserve Bid Market Document*** object is used as such:

- ⇨ The producer enters the unit valuation tariff for a given production site.
- ⇨ The time range of validity of the tariff is much more consequent than in market offers. It can be used on several limitations of the same production site within the validity period, to determine the amount of compensation, if the given limitation is eligible for compensation.

Table 17: Reserve Bid Market Document Attributes

Attributes	Examples	Description	CIM IEC62325 ESMP Standard

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reserveBidMrid	8c56459a-794a-4ed1-a7f6-33b0064508f1	Unique identifier of a Reserve Bid	Yes
reserveBidStatus	ongoing validated refused	Different statuses of Reserve Bid Market Document For operational needs	No
meteringPointMrid	PRM003394	Identifier of a production site	Yes
revisionNumber	1	version number	Yes
messageType	A44= price document	Nature of document	Yes
processsType	Z27		Yes
senderMarketParticipantMrid	Code IEC Producer Example : 17X000001307745X	The ID of the market Participant sending the bid (corresponds to the PK of the corresponding producerMarketParticipant)	Yes
receiverMarketParticipantMrid	Code EIC Enedis : 17X100A100A0001A	The ID of the market Participant receiving the bid (corresponds to the PK of the corresponding systemOperatorMarketParticipant)	Yes
createdDateTime	Format standard ISO 8601 UTC FSPS-MM-DDTHH-MM-SS Z	Date and time of creation of the Reserve Bid market document In ISO 8601 format: FSPS-MM-DDTHH:MM:SSZ For France, UTC+1 or UTC+2 according to summer or winter time File sending date (submission date)	Yes
validityPeriodStartDateTime	FSPS-MM-DDTHH-MM-SS Z	Validity start date / effective date of the offer	Yes
validityPeriodEndDateTime	FSPS-MM-DDTHH-MM-SS Z	Offer expiry date	Yes
businessType	ZXX		Yes

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quantityMeasureUnitName	MWh	Unit measurement for energy quantity	Yes
priceMeasureUnitName	€/MWh	Unit measurement for prices	Yes
currencyUnitName	€	Currency unit	Yes
flowDirection	Lower offer: curtailment	Nature of curtailment	Yes
energyPriceAmount	€/MWh or €/kWh	Price of the quantity of energy in the offer	Yes

In relation to the objects presented above, here is an illustration in the Figure 9: Reserve Bid API Description6 below of the list of APIs that are linked to these business objects.

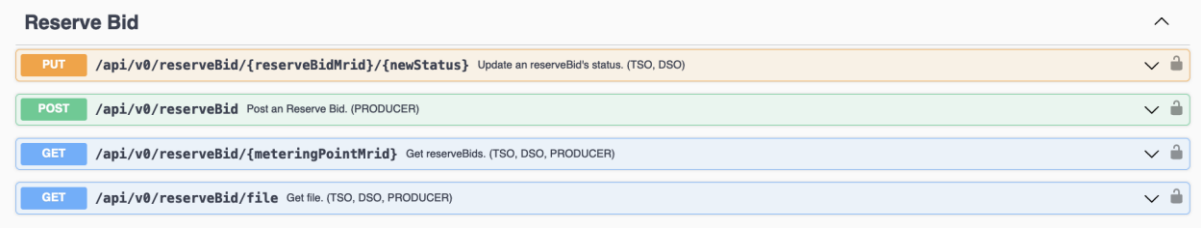

Figure 9: Reserve Bid API Description

4.2.6 Producer feedback on data

The ***Producer 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.

The object allows each stakeholder (Flexibility Service Provider, then System Operator) to comment on the data if they wish. In the market vision, standard CIM IEC6235 ESMP does not include any such feature.

Table 18: Producer Feedback Attributes

Attributes	Example (HTA Production data for compensation))	Description	CIM IEC62325 ESMP Standard
feedbackProducerMrid	UUID	Identifier of Feedback Producer Object	No

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activationDocumentMrid		Link with the Activation Document associated to Producer Feedback	Yes
messageType	B30 (notification data market document)		Yes
processsType	A42 (activation history process)		Yes
revisionNumber	1	Document version	Yes
senderMarketParticipantMrid	IEC Code Producer		Yes
receiverMarketParticipantMrid	IEC Code Enedis		Yes
createdDateTime	Format standard ISO 8601 UTC FSPS-MM-DDTHH-MM-SS Z	Creation date of document, when the Activation Document is created on platform	Yes
validityPeriodStartDateTime	Format standard ISO 8601 UTC FSPS-MM-DDTHH-MM-SS Z	Validity start date when the Energy Amount (linked with this order) is created on platform	Yes
validityPeriodEndDateTime	Format standard ISO 8601 UTC FSPS-MM-DDTHH-MM-SS Z	It corresponds to the end of the possibility for a producer to send a feedback.	Yes
feedback	Free texting	Text from the Producer to System Operator	No
feedbackAnswer	Free texting	Text response from System Operator	No
feedbackElements	Energy quantity Order timestamps Curve values	List of items on which producers want to provide feedback	No

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In relation to the objects presented above, here is an illustration in the Figure 10: Feedback Producer API Description below of the list of APIs that are linked to these business objects.

Figure 10: Feedback Producer API Description

4.3 Data rights & confidentiality rules

In order to define the business rules of the STAR project, the following actors have been identified:

- ⇨ RTE: the only electricity transmission system operator (TSO) in France
- ⇨ Enedis: the main electricity distribution system operator (DSO) in France
- ⇨ Producer (FSP): Management of renewable energy production sites (wind and photovoltaic).
    - MV producer: producer connected to the distribution network (i.e. to Enedis)
    - HV producer: producer connected to the transmission network (i.e. to RTE)

The need to define visibility rules comes from the need associated with Commercially Sensitive Information (CSI). Each producer can represent and possess sensitive data, so it was necessary to ensure confidentiality between the producers' data. But the TSO and the DSO can contain these data of their customer's producers so we had to define the rules for which some data could be made visible to one or the other of the two system Operators.

The visibility rules operate at the level of each object defined previously in the Data Model section. For this purpose, the CRUDE (CREATE, READ, UPDATE, DELETE) principle was used to obtain a rights matrix in line with the implementation of a private Blockchain project using the Hyperledger Fabric technology.

The CRUDE acceptance was then translated into a technical variation of the rights matrix, informing, at each object and for each participant, the nature of the PDC(s) (Private Data Collection) where the private data is stored.

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4.3.1 Business rules

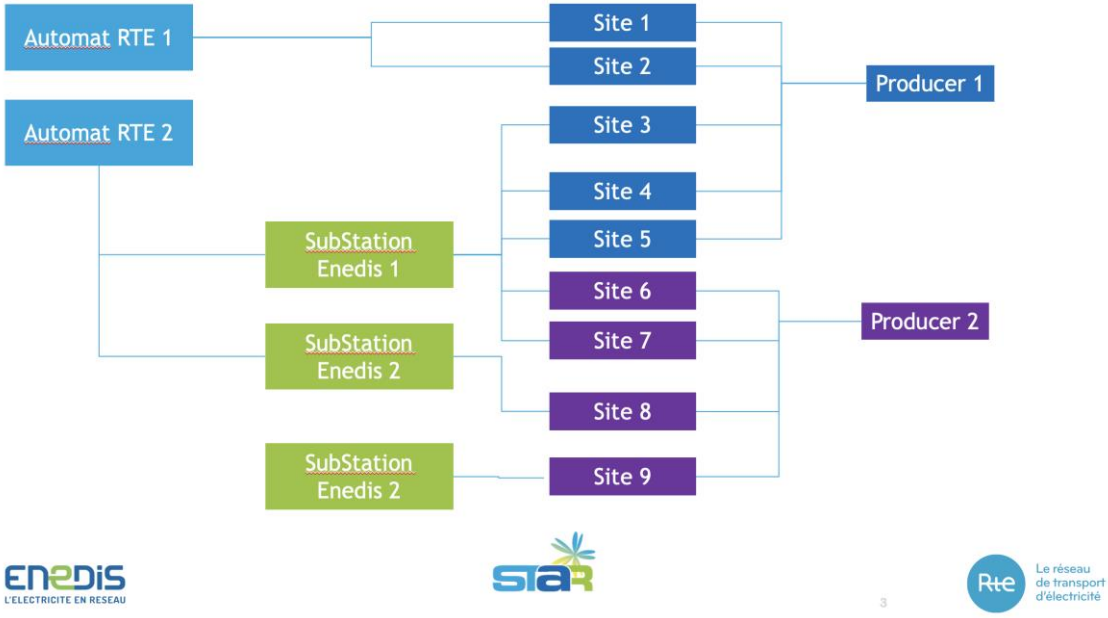

Figure 11: Network diagram

Using this very simplified schematic of the operational network of flexibilities management by RTE and Enedis, we were able to define what the visibility rules are for each actor. This schematic covers our two use cases: Sending NAZA limitation orders by RTE and sending manual limitation orders by Enedis.

Here is a summary of the cases presented above:

- ⇨ Transmission of NAZA curtailment orders by RTE:
  - NAZA Automaton 1 communicates directly with the HV sites (sites 1 and 2)
  - NAZA Automaton 2 communicates with two Enedis substations to finally send an order to MV site. Each link between a substation and a site represents a single limitation order.
    - Enedis is solely responsible for the MV sites.
    - An RTE NAZA order can be divided into several limitation Enedis orders to meet the NAZA order instruction.
    - The strategy/choice of sites to be limited is made independently of the producer responsible for a site (e.g. sites 3 to 7).
- ⇨ Transmission manual limitation orders by Enedis:
  - The Enedis 2 substation can communicate directly with an MV site (site 9) for Enedis specific needs.
  - RTE has no visibility on this type of limitation since the company is not present in the limitation chain.

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4.3.2 Confidentiality and Data Protection Rules

In terms of the use cases proposed by the STAR project, the CRUDE format matrix does not offer sufficient granularity in terms of exceptions.

Within the STAR ecosystem, there are indeed specific needs related to confidentiality, authorizing read rights for a defined object, attributed to a defined actor, only under certain conditions, or in certain business contexts.

For example, RTE can have access to data related to MV site limitations if and only if these limitations originate from RTE and are eligible for compensation. A classic CRUDE matrix indicating only Yes / No for a right to read does not allow to render this complexity and to see it effectively implemented in the development. Thus, when "Yes or No" is not enough to accurately determine the rights of an actor to create, edit, read or delete an object in STAR, 4 confidentiality rules described below complete the scope of visibility of each actor.

Table 19: Confidentiality Rules

Rule name	Rule description	Comments
CONF01_PRODUCER	Producer's scope limited to data concerning its own sites and limitations affecting them only	
CONF02_HTA_DSO	Scope limited to data concerning controllers, MV sites and limitations on those sites for the concerning DSO only.	Enedis is the unique DSO of the STAR project.
CONF03_HTB_TSO	Scope limited to data concerning controllers, HV sites and limitations on those sites for the concerning DSO only.	RTE is the unique TSO in France.
CONF04_HTA_origineRTE_et_Indemnisation	RTE can read the data on MV Sites and limitations only when: ⇨ The limitation is originated from RTE ⇨ The limitation is eligible for compensation Enedis can read the limitations' data sent by RTE to Enedis.	

4.3.2.1 Case of eligibility for compensation

Eligibility for compensation is information that indicates the compensation status of a limitation by the producer:

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- ⇨ If eligibility is set to YES: The producer will receive financial compensation for a production limitation, depending on the ENE/I (Energy Non-Evacuated/Injected) and the unit valuation tariff.
- ⇨ If eligibility is set to NO: No financial compensation will be paid by the system operator to the producer. An eligibility of NO may result from the fact that a limitation for a certain reason is not compensable or is only compensable once a contractually fixed stock of limitation hours is exceeded.

NB: The final compensation and payment process is not managed in the STAR platform.

4.4 Data model and standardization assessment

The data model meets the requirements of the two STAR use cases as well as the need for standardization, in the context of RTE and Enedis participation in the European OneNet project. This data model has been designed with the objective of converging as closely as possible to the ENTSO-E and IEC standards used in Europe. Each object has been studied with RTE and Enedis business experts to correspond to an object based on the standard (or as close as possible to the standard). The use of standard objects allows to create a robust base for the platform, in a European dimension.

However, when the philosophy of the standards used does not strictly fit the STAR use cases, or when certain elements of detail are missing, the STAR project has been forced to make certain deviations or additions in relation to the standards, while taking care to maintain a proximity to the standard labelling, as soon as possible.

The deviations from the standards, documented by object below, are mainly related to the specificity of STAR use cases, halfway between:

- ⇨ the physical and network dimension (e.g. peak orders for Renewable Energy production, metering curves), usually covered by technical data and exchange protocols
- ⇨ and the so-called market dimension, adopted by the Common Information Model (CIM), found in the design of orders (Activation Document), reference curves, energy not injected (ENI) or evacuated (ENE), eligibility for compensation and compensation amounts.

These specificities of STAR not covered by the standards will have to be covered in the future by the standards or exchanged in the framework of the OneNet project.

4.4.1 Assessment of Activation Document

CIM standard is a semantic model, describing generic business objects and contextualized with profiles. These profiles become standards validated by the IEC. The CIM ESMP (European Style Market Profile) or CIM-market is the standard Profile used and is based on a market vision. However, the generic CIM standard also covers operational and network aspects. The Activation Document model as defined by the CIM-market Profile is part of this market vision where the physical operations of the system operators (such as curtailment

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instructions resulting from the prevention of network congestion, following incidents or the start of scheduled works) result from the activation of a previously submitted market offer. The Activation Document is based on the "Electricity Markets" part of the CIM-market standard profile, called ESMP (European Style Market Profile).

In the STAR project, limitation orders are sent by the system operators without consideration of prior explicit offers from the generators concerned.

An order in STAR could be translated by the Activation Document object, since:

- ⇨ Only the Activation Document object in CIM can represent a curtailment order. This instruction corresponds in advance to a contractual arrangement between parties.
- ⇨ A STAR order can be considered as the activation of an implicit offer, not formulated by the actors, but which may be subject to financial compensation if it is eligible for compensation.
    - There is a specificity for RTE and Enedis: a pre-established contractual framework already exists in the form of CART/CARD contracts for example.

The use of the data model provided by CIM has therefore been subject to specific choices by the STAR project, at the level of certain attributes of the Activation Document object. This is the case, for example:

- ⇨ Objects using the notion of "Registered Resource" of CIM, such as originAutomationRegisteredResourceMrid and registeredResourceMrid.
- ⇨ The representation, in a single Activation document, of a start order (which can be automatic) and an end order (which can be operated manually, by recorded repeated communication), materialised by the startCreatedDateTime and endCreatedDateTime fields.
- ⇨ The absence of a Time Series, given the fact that orders in STAR are not setpoint chronicles, but fixed setpoints, terminated by an end order:
    - The Time Series is not mandatory in the Activation Document
    - Ideally, each limit order should be modelled by a Time Series. However, in relation to the previous point on delayed data sending constraints, it has been chosen to define a single value.
    - For another use case (Remote Setpoint Values), it could have been defined as a single order with n setpoints: each position of the Time Series would represent a different setpoint. The choice was made to create, in this case, n distinct orders with a single setpoint.

The Activation Document object was therefore used by the STAR project, with the necessary adjustments to compensate for CIM's market-specific approach, for a use case closer to the network and operations world than to the market world.

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4.4.2 Assessment on Energy Account and Energy Amount Market Documents

Energy Account Market Document:

The ***Energy Account*** object is a standard object of the EAR model. The choice of ***Energy Account*** for the reference curves was made after a consensus between RTE and Enedis. Other options were available, such as the use of the ***Power Planned Energy Schedule*** object of CIM, which also uses TimeSeries and models call schedules, which can be related to reference curves.

The Time Series are used to present power curves. The STAR project is adaptable to all time steps of a power history thanks to the Time Series format (e.g. PT10M: 10 minute time step, PT5S: 5 second time step).

Energy Amount Market Document:

CIM standard does not include an object to represent a single value of non-injected energy corresponding to the ENE or ENI. For the STAR project, the need is focused on a single energy data. Due to this unicity, the Time Series has been removed from the ***Energy Amount*** object. The energy value has been replaced by the quantity attribute.

An evolution is possible to insert in STAR an energy chronicle based on the load and reference curves previously loaded, by using smart contracts. In an industrialisation phase, this would imply that the calculation of the ENE/I may be done directly in STAR.

Another way of representing a single energy value to represent the amount of energy not injected in the grid would have been to send one TimeSeries with 1 position and one value point only.

4.4.3 Assessment on Reserve Bid Market Document

The standard model CIM uses the market offer principle for the ***ReserveBid Market Document*** object. These are tariff offers governed by a contract between system operator and its producer; the producer is then the direct sender of the ***ReserveBid*** object. In the scope of the STAR pilot, producers do not feed STAR with continuous market offers.

For this reason, the ***ReserveBid Market Document*** object is used as such:

- ⇨ The producer enters the unit valuation tariff at the production site level.
- ⇨ The time range of validity of the tariff is much more consistent than in the market offers. It can be used on several limitations of the same production site within the validity period, to determine the amount of compensation, if the given limitation is eligible for compensation.

There is an element that does not fit in the CIM standard on the ***ReserveBid Market Document*** object but, to meet the requirements of the STAR project, this feature has been added:

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- ⇨ The producer sends in STAR the justifying documents to his network operator in STAR (e.g. specific pages of the contract, purchase order from the mandatory buyer).

4.4.4 Assessment on Producer Feedback on Data

The ***Producer Feedback*** object allows each stakeholder (Producer, then System Operator) to comment on the data if they wish. In the market vision, CIM ESMP does not provide for any such feature. In the CIM ESMP standard, objects such as ***Acknowledgement Document*** or ***Confirmation Report Document*** are provided for. These objects do not sufficiently meet our use case because they are highly codified comments and do not allow for the possibility of free commenting.

It is possible to envision an evolution of the CIM standard to include this type of functionality. Indeed, the increase in Renewables Energy connections and subsequent limitations due to network congestion will result in a higher intensity of back-office processing of limitations. Where limitations are eligible for compensation, stakeholders will need to have the opportunity to comment before compensation is paid. It is therefore possible that CIM will take this use case and model it. STAR will adapt to it, if necessary. This Data Model object allows to trace the initialization and the conclusion of an exchange between the producer and the System Operator. There may be intermediate exchanges outside the platform.

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5 Blockchain Technology Evaluation

The STAR experiment has been the occasion to test the use of Distributed Ledger Technology, based on open source, permissioned technology Hyperledger Fabric.

In order to provide insightful technical conclusions, the section below describes the STAR architecture, defining the key terms and explaining the choices made.

A second part describes the learnings acquired throughout the project, and the conclusions regarding the fit of DLT to the business use case pursued.

5.1 Description of the functional architecture of the STAR platform

This section describes the components of STAR platform, as illustrated by Figure 12: STAR Platform Architecture below. It clarifies both the theoretical meaning of technical specific terms used, and how they have been implemented in STAR.

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, s.d.)

Table 20: Description of technical acronyms relative to architecture in STAR

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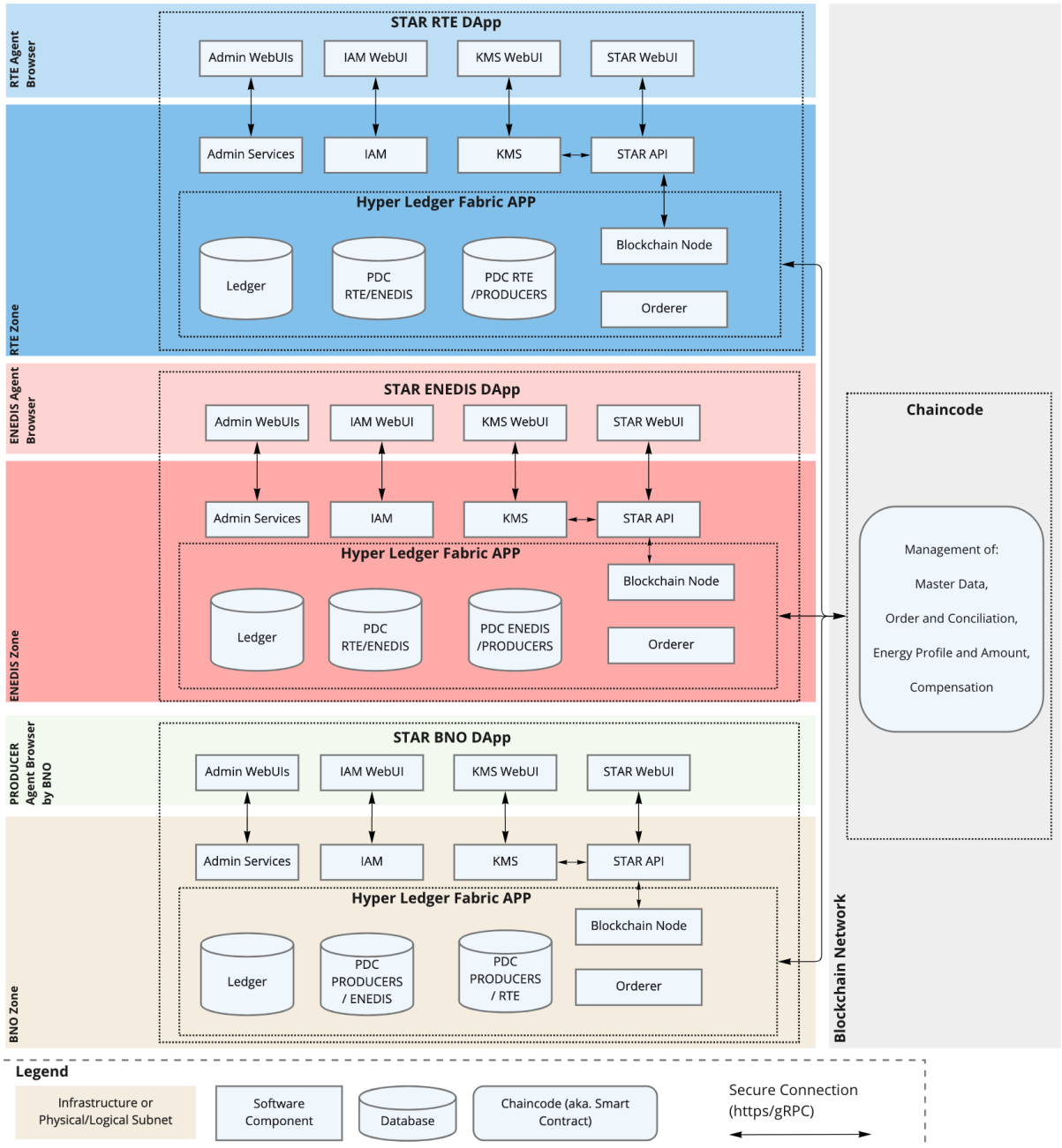

Figure 12: STAR Platform Architecture

5.1.1 Infrastructures

The colored 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.

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- Green zones are the corresponding infrastructures of the producers.
- 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.

5.1.2 STAR DApp

The STAR DApp is the application that provides all the functionalities required by this project. Each actor has its own dedicated STAR DApp deployed on his own zone, interacting with each other via the Blockchain. They differ in their feature accessibility.

The STAR RTE DApp allows RTE to:

- Authenticate RTE users
- Manage their users data and privileges
- Trace business data in the blockchain (i.e. site data, market formulation)
- Trace NAZA orders on the blockchain
- Trace Energy Account data on the blockchain (i.e. reference energy profiles and amount of energy injected, aka. ENI/ENE)
- Access data stored on the blockchain
- Manage private blockchain keys securely
- Compute compensation
- Access compensation data
- Declare whether a curtailment order is eligible to compensation or not
- Monitor the STAR RTE DApp execution and performance
- The STAR ENEDIS DApp allows Enedis to:
- Authenticate Enedis users
- Manage users' data and their privileges
- Trace business data on the blockchain (i.e. site data, market formulation)
- Trace orders on the blockchain
- Trace Energy Account data on the blockchain (i.e. reference energy profiles and amount of energy injected, aka. ENI/ENE)
- Access data stored on the blockchain
- Manage private blockchain keys securely

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- Reconcile orders
- Compute compensation
- Declare whether a curtailment order is eligible to compensation or not
- Monitor the STAR Enedis DApp execution and performance

The STAR BNO (Business Network Operator) DApp allows a FSP to:

- Authenticate its users
- Manage users' data and their privileges
- Trace price (i.e. energy bid price)
- Manage private blockchain keys securely
- Accessits its orders (i.e. Activation Documents)
- Access his Energy Accounts data
- Access compensation data
- Comment on compensation data
- Monitor the STAR producer DApp execution and performance

Each STAR DApp is composed of three main components:

- A Web User Interface
- A STAR API
- A HyperLedger Fabric node (optional for the FSPs)

The next section below describes each component that are present in each STAR DApp.

5.1.3 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. START 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 following section.

The STAR WebUI runs on the organizational member's infrastructure and the end user's computer.

The STAR WebUI interacts with:

- The end user
- The STAR API

The STAR WebUI stores nothing.

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5.1.4 STAR API

The STAR API, the central hub of the solution, corresponds to the backend service that handles interactions between the WebUI, the blockchain and services external to the STAR DApp. For instance, the STAR API in STAR RTE DApp provides an API to the NAZA System for pushing order into STAR. In order to support those interactions, the STAR API embeds the data models that are used to store information or exchange information between corresponding services. The START API also implements the specific controllers for each service.

The STAR API runs on the organizational member's infrastructure. The STAR API interacts with:

- The STAR WebUI
- An external service (i.e. NAZA) in the case of STAR RTE DApp
- The blockchain (i.e. Hyperledger Fabric)

5.1.5 Hyperledger Fabric (HLF)

Hyperledger Fabric (HLF) represents the blockchain that will act as the single source of truth to store consensual data, as well as a trustless execution environment that will process data using consensual algorithms (i.e. chaincodes). Ideally, each organizational member hosts a HLF node on its infrastructure to participate in the blockchain. However, producers that are not willing to operate and maintain a node can delegate this task to the BNO, which will act as a trusted party.

Each HLF instance embeds:

- The blockchain node that will interact with the HLF network that links all the nodes of the STAR consortium. The node also exposes an interface to the STAR API that lets the STAR DApp to interact with the blockchain to store/access data and execute chaincodes.
- The blockchain ledger, where all the transactions are notarized by their hash and timestamp.
- Private Data Collections (PDC) that store confidential data.
- The chaincodes that implement the algorithm to execute in order to process data.

5.1.6 Private Data Collections (PDCs)

Private Data Collections is a feature offered by Hyperledger Fabric to store private data in separate data bases while notarizing on the common ledger the sole data needed to ensure the integrity of the ledger. This feature has been specifically designed for sharing sensitive, personal or business data, with a high level a confidentiality.

In the first iteration of the architecture, PDCs were not introduced and all data were gathered in a single channel. With such an architecture, the segregation of data was mostly operated at an applicative level, and not at the infrastructure level. Hence, the architecture has been redesigned in May 2022 so as to address more accurately the data confidentiality rules, and thus introducing PDCs.

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Each organizational member has multiple PDCs. Each PDC stores confidential data that are relevant to and accessible by the member. For instance, RTE has:

- One PDC store orders that RTE sends directly to producers. Therefore, a corresponding PDC containing the same data is also present in the BNO's HLF.
- One PDC for orders that RTE sends to Enedis. Thus, Enedis has also the corresponding PDC on its side, containing the same data.

HLF runs on each organizational member's infrastructure. In the current architecture, all policies and governance rules are those of the default Hyperledger Fabric configuration, based on mutual trust between the different members of the network. In the case of an evolution of the architecture, for example an evolution of the network such as the integration of new external nodes for other DSOs, a review of these policies and governance rules must be done.

HLF PDCs interacts with:

- Each HLF node and the Orderer (cf. the BNO's Orderer)
- The STAR API

HLF databases store all use case data relevant to the organizational member that is representing the HLF (e.g. RTE's HLF stores data accessible to RTE, Enedis's HLF stores data accessible to Enedis, BNO's HLF stores data accessible to the Producers).

5.1.7 Chaincodes

Chaincodes are computer programs (also known as "smart contracts") 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 are able to compute the same outputs.

Chaincodes and Confidentiality - PDCs are not accessible by all the members. Therefore, chaincodes are not always 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 broadcasted among 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 are able to execute it properly and update their PDC state.

STAR embeds one chaincode responsible of:

- Master Data Manager: in charge of implementation of data access rights for Master Data stored on chain
- Order and Conciliation Manager: in charge of implementation of data access rights of orders and their conciliation

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- Energy Account Manager: in charge of implementation of data access rights of energy accounts
- Compensation Manager: in charge of computing the compensation of producers based: on the orders, their conciliation, price, energy accounts and eligibility

Chaincode runs on each HLF node.

Chaincode interacts with HLF node, Ledger and PDCs.

Chaincode stores (i.e. the ledger that stores the chaincode stores) all use case rules.

5.1.8 IAM

The Identity Access Manager is used to authenticate users, store their identity information and manage their rights to access to services and features. All users must first authenticate using this service before accessing any service. Once authenticated, the IAM provides the user an identity token that will be verified by the requested service, such as the STAR API or the monitoring service. The IAM provides its own WebUI to let administrators manage user accounts and their privileges.

The IAM runs on: the organizational member's infrastructure.

The IAM interacts with the user.

The IAM stores user data.KMS.

The Key Management Service stores securely the HLF private key and credentials representing the member on the blockchain. It is also used by the STAR API, described below, to sign transactions before their submission to HLF without having to take the keys out of the service. Indeed, each communication of the key, even to an internal service, represents a potential vulnerability for hackers. Thus, by keeping the keys in a cryptographically secure Vault and signing the transactions within the Vault, we can limit theft attempts to a minimum. The KMS provides its own WebUI to let administrators manage the secrets stored in the KMS.

The KMS runs on the organizational member's infrastructure.

The KMS interacts with the STAR API.

The KMS stores the private key(s) and HLF credentials.

5.1.9 Administration Services

The administration services provide WebUIs to the administrators of each zone that enable the monitoring and the maintenance of the STAR DApp. Those services include:

- The HLF Explorer to monitor the execution of HFL and consult the transactions that are submitted to the blockchain network through its dedicated WebUI. The HLF Explorer stores: block, transaction and channel data. The HLF Explorer interacts with: HLF.

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- The Monitoring service that collects execution and performance data of the STAR DApp services and presents those metrics in the form of a dashboard to administrators through a dedicated monitoring WebUI. The Monitoring Service interacts with: STAR API, HLF, IAM, KMS and HLF Explorer via the underlying container and container orchestrator.
- The Log Manager Service that gathers log outputs of all STAR Services. The Log Manager Service interacts with: STAR API, HLF, IAM, KMS and HLF Explorer via the underlying container and container orchestrator.
- The Backup Manager Service to perform disaster recovery, and migrate Kubernetes cluster resources and persistent volumes.

In addition to those services that we put in place in STAR DApp, administrators also have access to the services exposed by the cloud infrastructure provider, such as the resource and container orchestrator WebUI.

5.1.10 Nodes

Commonly, nodes are entry points to the solution. In terms of the decentralized architecture, a node is composed by 3 kinds of layers:

- ⇨ Hyperledger Fabric Layer: this layer manages the access to the Hyperledger Fabric. This is the smallest requirement in solutions using Hyperledger Fabric. It is composed of peers that technically check authorizations and manage the access to the services stored in the chaincodes through the different available spaces called channels (this layer is, generally, directly associated with the database).
- ⇨ Back Layer (can be called Middle Layer in other solutions) : this layer facilitates the calls to Hyperledger Fabric Layers. Even if the Hyperledger Fabric Layer is the smallest requirement, it is a technical layer : to call it, the environment and data must be configured which does not facilitate such a call. The Back Layer offers interfaces (API) that aim to make information exchanges with the Hyperledger Layers affordable.
- ⇨ Front Layer: this layer contains graphical interfaces that facilitate human manual interactions with the services offered by the solution.

The main users, like TSO and DSO, host their own node.

5.1.11 Channel

Channels allow to create different separate spaces for the project. Each channel follows its own rules and policies. The content of a channel is unique. What is found in a channel, either chaincode or data, is not found in another channel. Even the listed participants of a channel are different from one channel to the other.

The STAR project is using a single channel. Regarding the context of the experimentation, one channel seemed enough both for security and for performance.

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5.2 Key technical learnings

Context – a redesign of the technical architecture performed during the development phase.

A change of architecture was performed in June 2022 to address a more robust confidentiality implementation at infrastructure level, introducing Private Data Collections (PDCs).

Throughout the experimentation, STAR architecture has been led to evolve. Initially, STAR was set up on a common channel, where segregation of data was implemented only at an applicative level, but not at the ledger or infrastructure level. Hence, the architecture has been redesigned and prioritized by RTE and Enedis in May 2022 so as to address more accurately the data confidentiality rules, and thus introducing PDCs.

A choice has been made between the use of channels or Private Data Collections to match the needs for increased infrastructure-level confidentiality. This led to refactoring the development that has been done on the first architecture, and to implement mixing PDCs with intensive queries for user interfaces required for the portals of FSPs, TSO and DSO.

Summary of technical learnings:

In a nutshell, on a technical standpoint, STAR offered learnings regarding the implementation of distributed ledger technology, also known as blockchain.

- Throughout the experimentation, **Distributed ledger technology has proved to be more complex to master than conventional technology**, requiring specific expertise and leading to the evolution of the STAR architecture throughout the duration of the experimentation.
- Users noted a latency of a few seconds when triggering the display of the historical view of orders, that questions the capability of the platform to display in a user-friendly mode large sets of historical data, on extended time durations (e.g. multiple years of data).
- Besides, blockchain has been found **more valuable for multilateral exchanges** involving more than two parties. Eventually, the insertion of a multi-party platform must be thought from scratch in consideration to the existing industrial IS landscape.
- Most importantly, by sharing data non subject to confidentiality rules while ensuring the privacy of commercial data STAR **implements a fair balance between the need for more transparency** between the TSO, DSOs and FSPs on the one hand, **and the strict guarantee of confidentiality** and privacy regarding business sensitive data on the other hand. Although the architecture that has been set up allowed for an attempt to conciliate both needs, its complexity witnessed throughout the implementation phase has not led to direct industrialization of this technology.

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Hence, RTE and Enedis decided not to industrialize blockchain technology: it has been decided to industrialize the management of energy curtailment flexibility for renewable energy sources FSPs with a more traditional centralized architecture.

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6 FSP (Flexibility Service Provider) and System Operator: User Evaluation and platform Run

As an introduction, here were the main objectives concerning the users of the STAR platform ecosystem:

1. Simplify the integration of renewable energy producers with FSP sites to improve the back-office management of their production
2. Optimize the downstream management of flexibilities activation thanks to a traceability of events and a consensus on the data
3. Build a decentralized trust system and a new governance with the key actors of the ecosystem
4. Reduce the risk of billing disputes and the effort to resolve discussions between producers and network operators
5. Build an operational and robust platform in a specific area, meeting the needs of producers, while reconciling the imperatives of transparency and confidentiality of data, as well as standardization

To test these objectives and the functionalities of the STAR platform, reading and writing rights on the platform were given to RTE, Enedis and participating producers. The experiment ran from September 2022 until June 2023 and registered flexibility activations issued during this period. Strengths and improvements analysis were carried out for each feature, as well as global success criteria assessment (permission rules or shared governance for instance).

Summary of key functional and user learnings:

In a nutshell, on a functional and user standpoint, STAR was a successful experiment in several regards:

- The above-mentioned main objectives of building a blockchain based platform simplifying flexibility activations back-office management and ensuring transparency and confidentiality rules have been met. STAR enabled a successful TSO-DSO collaboration, allowing for joint definition of processes of management of curtailment orders between RTE, Enedis and FSPs.
- The collective works will bear fruit, have already been reused and will be reused (functional part and user interfaces). For instance, STAR has been the framework of experimenting new methods of calculation for energy amount, for algorithms of matching between RTE and Enedis in SUC-FR-01.
- STAR has mobilized producers, as representatives of FSPs, and allowed to proceed to functional scoping with them, as well as feedback collection in order to take into account their needs and user experience. Such learnings will be also used.
- STAR has been the framework of growing standardization of data exchanges in the best practices and current use for RTE and Enedis, allowing to assess to what extent are current standards a good fit for such use cases.

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Eventually, one key assumption in STAR was the possibility of a faster management of claims and a reduction of the number of claims related to curtailment orders. This assumption derived from the unique possibility of sharing with all parties a single version of the data needed to provide a full understanding of both back-office and physical dimensions of a curtailment order. Unfortunately, such an assumption couldn't be verified during the timeframe of the experimentation.

Evaluation	Comments
Successful TSO-DSO business collaboration	The shared governance between RTE and Enedis within the framework of STAR has led to a welcome alignment on the definition of common processes in the management of post-real time RE load shedding. The business work is sustainable and can be reused. The initial data perimeter has allowed to launch the experimentation, and must be extended to bring more value to the actors.
Strong interest from producers for the use case	Mobilized regularly since September 2021, producers and federations have expressed a strong and continuous interest in an industrial data-sharing platform that would accelerate and automate the back-office processing of the limitations they receive.
The reduction in back-office effort on protests cannot be verified within the timeframe of the experiment.	By providing a common and transparent vision between TSO, DSO and producers, STAR should allow for a significant reduction in the number of challenges from producers and their processing time. To be verifiable, this hypothesis requires an experimentation time extending beyond the 2023 summer limitation peak and a more significant number of producers.
A distributed registry technology that is more complex to master than a traditional technology.	Although blockchain technology has made it possible to create a framework of trust for a multi-player platform, the complexity of its implementation, as perceived by RTE and Enedis during the experiment, requires the mobilization of rare skills with technological expertise.

Table 21: Executive summary of the feedback from the experimentation

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6.1 Global criteria

	DEFINITION	EVALUATION	AREAS FOR IMPROVEMENT
PRIVACY MANAGEMENT	Strict compliance with the permission rules corresponding to the actors' requirements.	Confidentiality strictly respected at the registry level (RTE, Enedis and producer node) and at the application level (between producers). Complexity of implementation in a distributed platform considered more important than in a traditional system and requiring rare technical skills.	Review of the level of technical confidentiality management requirements. Revision of the nature of the data to be registered (raw data vs hash). Possibility of simple management of ICS data dissemination errors.
PROCESS AUTOMATION	Ability to automate all or part of a business process.	Use of smart contracts to manage business rules. The automation of financial settlements in case of compensation has not been included and tested in the scope of STAR.	N/A: value of Blockchain in terms of process automation does not seem justified in view of the complexity felt by RTE and Enedis.
ADMINISTRATION OF THE PLATFORM	Management of company and user authorizations.	Enabling circuit functional in context of an experiment. Understandable operating procedure. An incident during the reception of passwords.	Revision of the enabling circuit for better adherence to RTE and Enedis industry standards.
SHARED TSO-DSO	Collaboration between RTE and Enedis in the	Definition of a common RTE and Enedis process for the management of SO peak	Extending the scope of shared data for increased business value.

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GOVERNANCE	management of post-real time SO peak loading.	loads through STAR exchanges. Scope of shared data limited to the necessary. Joint implementation of a data model adapted to European standard exchange formats.	

Table 22: Summary evaluation global criteria

6.2 Specific criteria to a feature

6.2.1 Upstream data: integration and reconciliation orders

	BUSINESS PROCESS	OPERATIONAL PERFORMANCE OF THE TOOL	COMPLIANCE WITH DATA MODEL
ASSETS / STRENGTHS	Agreement on the rules for reconciliation of RTE and Enedis orders and on the scope of the orders loaded. Reconciliation rule implemented in a unique and verifiable way for RTE and Enedis.	Sending and reconciling functional orders according to defined business rules.	Translation of STAR use case into European CIM / EAR standards, a large part of which is reusable (flexibilities activations, metering curves, reference curves). Pivot table set up between RTE and Enedis identifiers for order reconciliation.
IMPROVEMENT	Manual order reconciliation. Possibility to update orders. Management of the right to error and complex cases (e.g. return of archived limitations or orders already reconciliated).	Need to set up a common order ID generated when orders are disseminated between RTE, Enedis and the producers. Improved performance when integrating large amounts of data.	Work on the correspondence between RTE (levers) and Enedis (substations) identifiers to improve searches, filters and reconciliation. Specificity of a limited part of the data model to the STAR

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		More granular response messages, at the level of each file	use case and not reusable in other contexts. Improvements undertaken to address shortcomings in the standards.

Table 23: Summary evaluation of upstream data criteria

6.2.2 Downstream data: Energy amount, Energy Account, eligibility

	BUSINESS PROCESS	OPERATIONAL PERFORMANCE OF THE TOOL	COMPLIANCE WITH DATA MODEL
ASSETS / STRENGTHS	Agreement on ENE/I calculation methods and compensation eligibility process for STAR.	Data visibility: ENE, ENI, metering and reference curves, eligibility. Data update possible (metering, reference): loading a curve overwrites the previous curve in case of error. Simple User Interface for loading ENE and compensation eligibility, directly linked to orders in the limitation history.	Translation of data into European CIM / EAR standards.
IMPROVEMENT	Considering the MV reference curves. Eligibility: addition of data element to enhance understanding of eligibility decisions.	Addition of data on the detailed view of the curves: setpoint, site power. Manual update of ENE data by TSO. Data export. Ergonomics enhancement of curves.	ENE/I layout: TimeSeries (standard CIM) vs. global scaled volume (implemented on STAR)

Table 24: Summary evaluation of downstream data criteria

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6.2.3 Compensation: Tariff and amount

	BUSINESS PROCESS	OPERATIONAL PERFORMANCE OF THE TOOL	COMPLIANCE WITH DATA MODEL
ASSETS / STRENGTHS	Producers to send the unit recovery tariff and associated documents. STAR allows to see the history of applicable producer tariffs by site.	Agnostic management of all types of tariffs (feed-in tariffs, remuneration complement, market valuation). Amount calculated automatically. Easy tariff update. Access to a detailed tariff history.	Translation of data into European CIM standards. Agreement on RTE-Enedis units (€/MWh).
IMPROVEMENT	Sharing of market prices between TSO and DSO to calculate the re-buy tariff in case of remuneration complement.	Considering complex business rules for valuation unit tariff	Need to identify in standards support for back-office iteration management.

Table 25: Summary evaluation of compensation criteria

6.2.4 History of limitations

	BUSINESS PROCESS	OPERATIONAL PERFORMANCE OF THE TOOL	COMPLIANCE WITH DATA MODEL
ASSETS / STRENGTHS	Agreement on the provision of data necessary for compensation to producers. Producer feedback processes on the data, to which System Operators can respond upstream of financial processing.	Producers' and SOs' access to a synchronous view of limitation history on the same tool, they benefit from end-to-end visibility of the limitation data, from upstream order to compensation.	Translation of data into European CIM standards.

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IMPROVEMENT	Addition of new data (e.g. comments from the operation of HV limitations). Extension of functional and geographical scope of STAR. Need to enhance the link with existing tools in System Operators' IT system.	Consolidation of Feedback Producer Functionality to ensure the management of complex cases, without leaving STAR. Improved ergonomics and readability of the history. Robust management of data versioning, involving tolerance of error rights and visualization of history of data uploads.	Not applicable

Table 26: Summary evaluation of history of limitations criteria

6.2.5 Prevention and management of disputes

	BUSINESS PROCESS	OPERATIONAL PERFORMANCE OF THE TOOL	COMPLIANCE WITH DATA MODEL
ASSETS / STRENGTHS	Definition of a business process to make available in a single tool a wide range of data to inform the back-office management of RE limitations, and accessible simultaneously by TSO, DSO and producer.	By providing a common view on source and timeframe of data, TSO, DSO and producers would allow: Fewer trade challenges from producers in STAR area; Less time spent on back-office processing per challenge	Standardised Data Model for exchange format that is understandable for the actors.
IMPROVEMENT	Management of all exchanges concerning disputes outside the platform (only the initial dispute and final response are recorded in STAR)	Notification system on strategic events (new order, …)	Not applicable

Table 27: Summary evaluation of disputes criteria

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7 Conclusions

The OneNet French use cases brought valuable insights. For STAR use cases, the key conclusions are that the experiment was successful in terms of alignment between TSO, DSO and FSPs in order to address joint management of curtailment flexibilities. It allowed to significantly improve data exchange, in a more standardized way, as well as regarding the definition of business processes, methodology and user expectations. The functional part of this work will be reused and possibly included in the roadmap of RTE and Enedis legacy systems.

From a technical standpoint, STAR was a case study in implementing distributed ledger technology. Distributed ledger technology has been considered as more complex to master than conventional technology, requiring specific expertise and leading STAR to evolve the architecture several times throughout the duration of the experimentation. Eventually the platform successfully meets the functional needs and confidentiality requirements but at the cost of a reduced performance (latencies) and an architecture that seems too complex to scale. Besides, blockchain has been found more valuable for multilateral exchanges involving more than two parties.

Thus, the next steps for RTE and Enedis in addressing the management of curtailment flexibility (functional process defined in this use case) will rely on a more traditional centralized database approach.

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