Platone

PLATFORM FOR OPERATION
OF DISTRIBUTION NETWORKS

Platone

PLATform for Operation of distribution NEtworks

D3.3

Delivering of technology (v1)

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Abstract

The Italian Demo aims to enable network users to participate in the grid optimized management (using services such peak shaving, energy shifting etc.) through the flexibility mechanism. Thanks to the coordination of areti and the cooperation of all the partners involved in the WP3, the Italian Demo will develop an innovative system, i.e. “a complete end-to-end local flexibility market TSO-DSO coordinated”, enabling distributed resources connected in medium and low voltage grids to provide grid services, allowing the inclusion of all the stakeholders. The solution proposed will allow the development of a new model of cooperation between citizenship and municipality, bringing multiple benefits.

This document mainly focuses on how Italian Demo wants to contribute to break down barriers to enter the flexibility market by describing the main components of the Italian Demo, the interactions among them, their functional and technical requirements. As a supporting document, it accompanies the release of the first version of the System Architecture of the Italian Demo, that will be fully operative on field starting from July 2021 (Milestone 8 Field test fully operational in Italy).

The trial will involve several areas of the city of Rome where specific portions of the electricity distribution network managed by areti have been identified and selected as representative location for the project activities. In this phase the project will carry out its research activities in two different areas of Rome involving customers and equipping them with smart appliances to monitor them and make them active in the flexibility services.

Keyword list

Access Layer; Aggregator Platform; Blockchain Access Layer; DSO Technical Platform; Light Node; Market Platform; System Architecture; Shared Customer Database; Use Case

Executive Summary

The Italian Demo of Platone intends to develop “a complete end-to-end local flexibility market TSO-DSO coordinated”. It aims to test a system capable of enabling distributed resources connected in medium and low voltage grids to provide grid services, allowing the inclusion of all the stakeholders.
Under the coordination of areti, DSO of the city of Rome, the Italian Demo will develop an innovative multi-layer technological architecture, based on the application of the blockchain approach and new grid equipment, aimed at creating a global flexibility market that will be tested in the Roman urban area.

The first version of the System Architecture will be fully operative on field starting from July 2021 (Milestone 8 Field test fully operational in Italy), and it will enable distributed resources connected in medium and low voltage grids to provide services in the flexibility market models.

The aim of this supporting document is to analyse the Italian Demo architecture, by providing a first overview and then describing all the components that compose the System Architecture, by highlighting their roles in the process:

- Market Platform, a blockchain-based platform that enables the management of flexibility requests from System Operators (SOs) and flexibility offers from Aggregators. In detail, it collects requests and offers and then match them according to predefined rules and priorities;
- Aggregator Platform, an operational platform that facilitates Aggregator to manage the flexibility assets. Here, several tools are able to analyse data coming from different distributed energy resources (DERs), evaluate and aggregate available flexibility from several points of delivery (PoDs);
- DSO Technical Platform, an innovative platform that allows DSOs to improve reliability and aspects of service by exploiting flexibility made available from DERs connected to their grids. It is also able to predict grid congestions and voltage violations;
- Access Layer, a structure composed by three main components Light Node, Blockchain Access Layer and Shared Customer Database. The Light Node and the Blockchain Access Layer compose a data exchange infrastructure among flexible DERs, platforms and stakeholders within demo architecture. The Shared Customer Database instead is a repository system where all data related to flexible PoD are collected and available to all the stakeholders involved in the process.

The supporting document intends also to represent the complex data flows built up by the partners to ensure interaction between the abovementioned platforms.

The first version of the Demo will be tested in specific target areas of the city of Rome, where specific portions of the grid managed by areti has been identified and selected for the project activities. The first areas chosen for the implementation of the Italian Demo are:

- EUR – Tor di Valle District;
- Centocelle District.

In order to pursue its objective to meet the needs of all stakeholder (system operators, aggregators and end-users) and create a massive flexibility market, the demo will involve also residential customers that will be equipped with smart appliances and equipment in order to enable them to offer flexibility services.

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1 Introduction

The project “PLATform for Operation of distribution Networks – Platone - aims to develop an architecture for testing and implementing a data acquisitions system based on a two-layer approach (an access layer for customers and distribution system operator (DSO) observability layer) that will allow greater stakeholder involvement and will enable an efficient and smart network management.

The tools used for this purpose will be based on platforms able to receive data from different sources, such as weather forecasting systems or distributed smart devices spread all over the urban area. These platforms, by talking to each other and exchanging data, will allow collecting and elaborating information useful for DSOs, transmission system operators (TSOs), customers and aggregators.

In particular, the DSO will invest in a standard, open, non-discriminating, economic dispute settlement blockchain-based infrastructure, to give to both the customers and to the aggregator the possibility to more easily become flexibility market players. This solution will see the DSO evolve into a new form: a market enabler for end users and a smarter observer of the distribution network. By defining this innovative two-layer architecture, Platone removes technical barriers to the achievement of a carbon-free society by 2050 [1], creating the ecosystem for new market mechanisms for a rapid roll out among DSOs and for a large involvement of customers in the active management of grids and in the flexibility markets. The Platone platform will be tested in three European trials (Greek, Germany and Italy) and within the Distributed Energy Management Initiative (DEMI) in Canada.

The Platone consortium aims to go for a commercial exploitation of the results after the project is finished. Within the H2020 programme “A single, smart European electricity grid” Platone addresses the topic “Flexibility and retail market options for the distribution grid”.

The continuous spread of renewable energy sources and the increased electric energy consumption require a radical change in the energy management process, which needs to be more flexible and inclusive. For this reason, the aim of the Italian Demo is to realise a fully functional system that enables distributed resources connected in medium and low voltage to provide grid services in different flexibility market models which include all the stakeholders (TSO, DSO, aggregators and end-users). The main goals of this WP are:

- Use of Blockchain technology for an efficient, democratic and non-discriminatory market model for exploitation of local flexibility in the Rome area;
- Improve and promote the consumer access thanks to Blockchain infrastructure and to the presence of Aggregators;
- Use of local flexibility to solve criticalities which can affect the distribution grid in terms of stability and security;
- To enable distributed resources to provide flexibility to transmission grid to contribute to guaranteeing that the whole system remains balanced and safe;
- To increase the grid observability for improving the network management.

To address them, the partners involved in the WP3 carried out specific activities that led to the definition of the first version of the System Architecture of the Italian Demo that will be fully functional from July 2021 in Rome (Milestone 8 Field test fully operational in Italy).

The Italian Demo of Platone intends to develop “a complete end-to-end local flexibility market TSO-DSO coordinated”. It aims to test a system capable of enabling distributed resources connected in medium and low voltage grids to provide grid services, allowing the inclusion of all the stakeholders.

In general, the DERs used in the dispatching market allow the overcoming of the traditional network management model, named “fit and forget approach”. Hence, the distribution grid may be no longer necessarily designed to guarantee the maximum power exchanged of the resources in all the conditions, but the DSO could exercise the network considering the possibility that the DERs can support the network operation providing services to solve critical issues. For instance, when the peak load is concentrated in a few hours, instead to reinforce the grid, it might be easier to use the flexibility resources, by carrying out power modulation through the grid control and regulation system.

In accordance with this novel philosophy, in the Platone Italian Demo the DSO can acquire flexibility from the users connected to the grid, by means of an Aggregator. Similarly and at the same time, the TSO can face the congestion in transmission grid by buying flexibility offered by DERs.

The System Operators use two different ways to localize the requests:

- The DSO defines the quantities for relevant grid point: Primary Substation, MV feeder or Secondary Substation, joining the PoDs list subtended to grid point.
- The TSO defines the quantities only for Primary Substation.

Moreover, in an active distribution grid the voltage profile could undergo strong variations along the lines, for instance an MV power plant can reverse the energy flow along the feeder causing a voltage increase in the point of connection and changing the voltage profile on the whole line. To solve this issue the DSO can acquire the flexibility from the resources connected to the same line to fulfil the right voltage value. But also, the TSO can use the DERs to solve the voltage violation at transmission level, in this case TSO could request to DERs modulation of reactive power. Platone WP3 Italian Demo provides market processes to manage the above described 'active grid management'.

1.1 Task 3.2, 3.3 and 3.4

The System Architecture of the Italian Demo consists of distinct components, interconnected and able to interact. For the realisation of the first version of the System Architecture, three distinct tasks have to be considered as relevant: Task 3.2, Task 3.3 and Task 3.4.

The Task 3.2 "Development of a standard Blockchain based infrastructure, implementing a Common Access Interface between all the market players" is one of the project tasks composing WP3 – Italian Demo. Task 3.2 is coordinated by areti in cooperation with Apio, Siemens, Engineering and Acea Energia. It includes the following sub-activities:

- HW/SW (Hardware and Software) development of Blockchain technologies to include customers and Aggregator in network management, led by Apio;
- Definition of communication protocols, identification of the communication channel and development of the apparatus for meter's data exchange, led by Apio;
- Development of Shared Customer Database platform led by areti.

The sub-tasks presented here are crucial to ensure a secure growth of the building management systems' market and to break the flexibility market entry barriers for aggregators.

The Task 3.3 "Implementation of a technical platform for grid state estimation and flexibility requests validation" is another project task composing WP3 – Italian Demo. It is coordinated by Siemens in cooperation with areti. It includes the following sub-activities:

- Hardware and software development related to the real time state estimation of the grid, led by Siemens;
- Definition of a telecommunication infrastructure, led by Siemens;
- Development, testing and implementation of the state estimation tool, led by Siemens.

Thanks to all the data gathered from the hardware/software implemented on the customers' side and the weather forecasts, historical data and network topology knowledge, the technical platform will be able to determine the grid state and the related operating constraints.

The Task 3.4 "Solutions to enable Aggregators to provide flexibility: Aggregator platform and customer involvement" is coordinated by areti in cooperation with Siemens, Engineering, Acea Energia and B.A.U.M. It includes activities aimed at developing a local flexibility market in which end-users can be considered as market actors, thanks also to the role of the Aggregator.

The sub-activities composing the Task 3.4 are reported below:

- Aggregator Platform development and integration, led by Siemens;
- Solutions to enable local flexibility market, led by areti;
- Customer engagement techniques led by Acea Energia in cooperation with B.A.U.M.

The sub-task mentioned will ensure an integration at every level of the Aggregator Platform and the acquisition of relevant data from the architecture regarding the flexibility analysis.

1.2 Objectives of the Work Reported in this Deliverable

The D3.3 Delivering of Technology aims to present and describe how the Italian Demo works through an analysis of its composition and structure. Through the study of the Roman distribution grid status and the explanation of the process implemented in the Italian Demo, the deliverable will report the market solution proposed by Platone. Furthermore, it presents the structure of the entire System Architecture elaborated by the partners, by defining its functional and technical requirements, and the communication mechanisms that connect all the actors involved in the process within the Platone Open Framework. The deliverable will focus then on each platform details, in order to explain how they interact with each other and their particular roles in the Platone complex framework.

WP3 Italian Demo fully implements the Platone Reference Architecture in all its components and functionalities, both from a technological point of view and from a market structure point of view.

1.3 Outline of the Deliverable

This introductory chapter explains the Platone reference context and the specific project task linked to the present deliverable, also providing indications about the objectives and characteristics of the document. Chapter 2 titled “Italian Demo Architecture” will provide a presentation of the philosophy that stands behind the Italian Demo and its composition. Chapter 3 analyses how the Italian Demo works, by focusing on the interaction among the System Architecture components. Chapter 4 offers an overview of the grid managed by areti, illustrating some of the significant numbers and describing the specific target areas in which the Italian Demo will be implemented, and how Customer will be involved in the trial. Chapter 5 shows the Project KPIs identified by the partners within WP1 activities linked to the Italian demonstration site. Chapter 6 closes the document with conclusions. It is followed by the list of tables, the list of figures, the list of references, the list of abbreviations and the list of Annexes that describe more in details each platform.

1.4 How to Read this Document

This document is self-consistent and it can be read independently from other Platone’s deliverables. However, it is strongly linked to other important results and deliverables of the whole Platone project. In details, interesting links for deepening the understanding of the progress and evolution of the technology throughout the project from its start as of today, can be made with the following Platone deliverables:

- D3.1 “Internal operational plan and WP3 roadmap” [2], released by Areti on Month 3 (November 2019) as confidential detailed work plan and roadmap ofWP3. Within D3.1, a first description of the Italian Demo architecture was implemented listing the main objectives and the structure of the architecture.
- D2.1 “Platone platform requirements and reference architecture (v1)” [3] released by Engineering on Month 12 (August 2020) as public detailed work on the Platone Open Framework. Within D2.1, Engineering describes the Platone Open Framework, a relevant element for Platone Demos and so for the Italian Demo.
- D1.1 “General functional requirements and specifications of joint activities in the demonstrators” [4] released by E.DSO on Month 12 (August 2020) as a public report on the Use cases of the three Platone demonstrations. D1.1 sums up and compares the use cases in the different demos.
- D2.3 “Platone Market Platform (v1)” [5] released by ENG on Month 18 (February 2021) as a public demonstrator that accompany the software delivery of the Platone Market Platform with an architecture overview and explanation of a demonstration setup.

2 Italian Demo Architecture

2.1 Overview

Italian Demo is based on the common Platone architecture depicted in D2.1, represents its full implementation on field and in a real distribution grid.

Concerning platforms, the Italian Demo uses the Blockchain Service Layer (including Market Platform) developed in WP2 adapted to the Italian requirements as necessary, while the Aggregator Platform and DSO Technical Platform developed by Siemens and Access Layer developed by APIO are implemented within the Italian Demo.

The Italian Demo Architecture is shown in Figure 1.

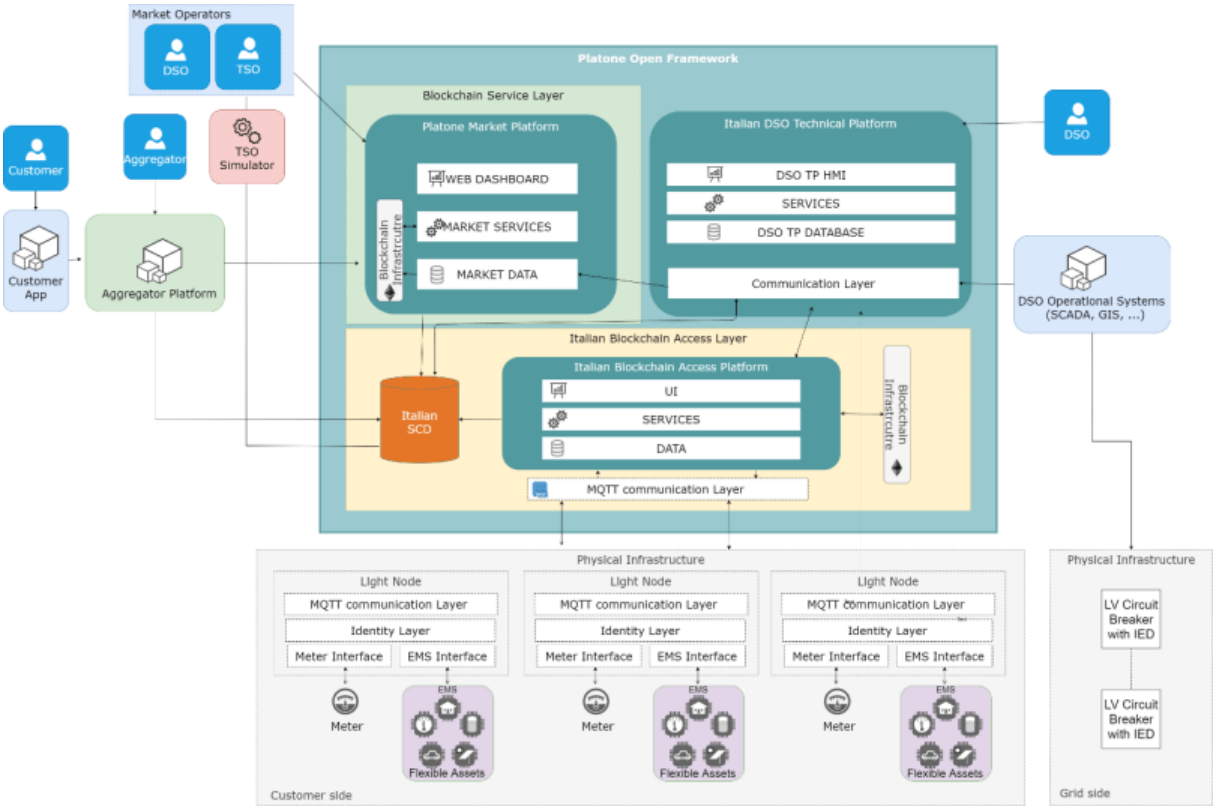

Figure 1: Italian Demo Architecture

Here follows a brief description of the platforms used in the Italian Demo.

2.2 Market Platform

The Market Platform is a blockchain-based platform, developed by Engineering, enables the management of wide geographical area flexibility requests from SOs and flexibility offers from Aggregators. More in detail, the Platform collects requests and offers, then matches these according to predefined rules and dispatching priorities.

The market is arranged in Day Ahead and Real Time markets. Day Ahead consists in 1 session related to services to be delivered in the 24 hours of the day after, while Real-Time consists in 6 sessions each one related to services to be delivered in the next 4 hours.

Figure 2 shows the timeline of described markets sessions and how these are coordinated with processes of the other platforms.

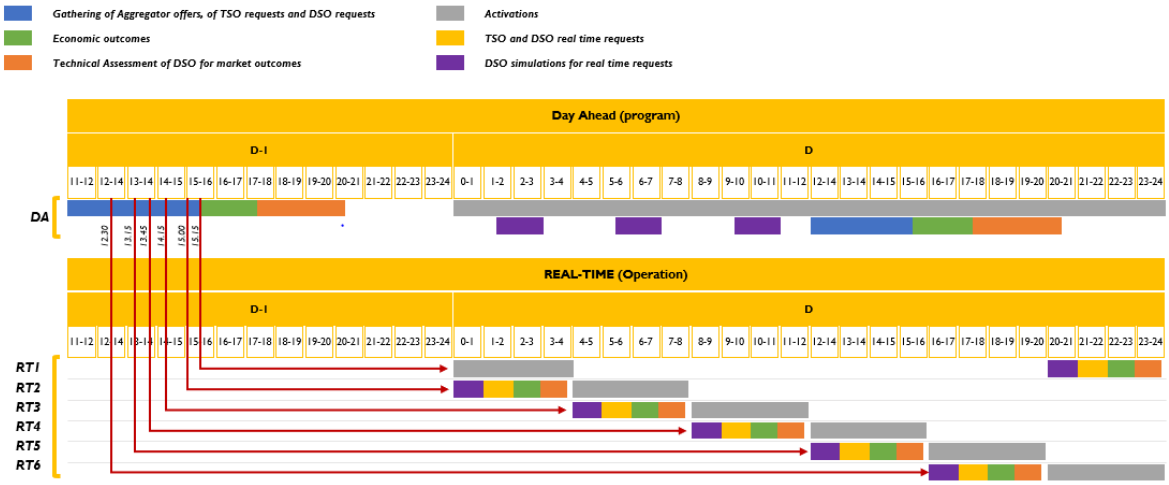

Figure 2: Italian Demo Market Sessions and time coordination with other platforms

- **violet:** "flexibility request support" (Day Ahead + Real Time)
- **orange:** "flexibility assessment" (Day Ahead + Real Time)
- **white (immediately before grey):** setpoint carrying out (Real Time)

All the market operations are registered and certified within a blockchain service layer, ensuring a higher level of transparency, security and trustworthiness among all the market players.

The first prototype of the Platone Market Platform was released as open source and more details can be found in D2.3.

For additional details concerning Market Platform architecture, features and functionalities refer to Annex A.1.

2.3 Aggregator Platform

The Aggregator Platform is an operational platform that facilitates aggregators to manage the flexibility assets. It consists in several tools able to analyse data coming from different types of DERs (i.e. generation, consumption and storage), evaluate and aggregate available flexibility from thousands of different PoDs, and provide optimal algorithms to optimize market strategy and flexibility offers.

The core of Aggregator Platform is the DEOP (Decentralize Energy Optimizer), developed by Siemens, that allows the management of the single units/PoDs, the aggregation of the offers, the definition of the baseline, the definition of flexibility services activation setpoint, the market interaction and all the consequent activities, including the economic settlement.

For more details concerning Aggregator Platform architecture, features and functionalities refer to Annex A.2.

2.4 DSO Technical Platform

The DSO Technical Platform is an innovative platform, developed by Siemens, allowing DSOs to improve reliability and quality of service by exploiting the flexibility made available from DERs connected to their grids. Moreover, the Platform, through interactions with Market Platform, is able to avoid activation of flexibility offers requested by TSO that could cause issues in the operated distribution grid.

More in detail, the Platform, performing forecasting of state estimation of distribution grid, is able to predict grid congestions and voltage violations, define flexibility requests to solve the forecasted issues

and verify that all market outcomes, including the ones related to TSO requests, are in compliance with grid constrains.

To perform state estimation forecast and define flexibility requests, the Platform uses several grid data and measurements coming from DSO's Operational Systems, such as Supervisory Control and Data Acquisition (SCADA) and Geo Information System (GIS) and data of flexible DERs from the Shared Customer Database. Once grid issue is forecasted, the Platform forwards the flexible request automatically defined by the Platform, to the Market Platform.

Finally, the Platform deals to carry to each PoD the flexibility services activation setpoint defined by Aggregator Platform.

For more details concerning DSO Technical Platform architecture, features and functionalities refer to Annex A.3.

2.5 Access Layer

The Blockchain Access Layer and the Light Node form the Access Layer, a data exchange infrastructure among flexible DERs, platforms and stakeholders within demo architecture.

The Light Node is a device, installed at DERs' premises, able to gather PoD metering data from Low Voltage (LV) and Medium Voltage (MV) meters, receives Setpoint from DSO Technical Platform and makes it available to Customers Activation Systems such as Energy Management System (EMS), smart appliance etc. to activate flexibility.

The Light Node certifies "from the original source" (PoD of the flexible DER) all managed data and sends, through the Blockchain Access Layer, to the Shared Customer Database.

The Blockchain Access Layer then connects the Light Node to the Shared Customer Database ensuring, through timestamping features, the immutability of data along the whole path.

For more details concerning Access Layer architecture, features and functionalities refer to Annex A.4.

2.6 Shared Customer Database

The Shared Customer Database is a repository system where all data related to flexible PoD are stored and made available to demo platforms and stakeholders.

The Database stores data such as PoD general data (connection voltage level, contractual power etc.), PoD Baseline, PoD available flexibility, PoD measurements, PoD setpoint, Market outcomes, etc. Some of these data come from the Light Node (e.g. metering data), some others from the Aggregator Platform (e.g. PoD Baseline), others come from the Market Platform (e.g. market outcomes), others from the DSO Technical Platform etc.

Data are organized according to predefined schemes and can be read by authorized platforms and stakeholders followed by authentication procedures. Data updating is allowed, after authentication, only for some types of data: for example, PoD Baseline for day after can be updated by the Aggregator, while Market Outcomes cannot.

Moreover the Shared Customer Database is a connection point between the two blockchains within the demo, i.e. the Access Layer and the one of Market Platform; indeed, data stored in the Database are used by smart-contract and then token running on both blockchains.

For more details concerning Shared Customer Database architecture, features and functionalities refer to Annex A.5.

3 How Italian Demo Works

3.1 Uses Case Description

As already declared in introduction, one objective of the Italian Demo is to develop and test a complete system supporting TSOs and DSOs to manage their electrical network.

Once the System Architecture is made operative, the Italian demo will execute two main use cases in the target areas regarding “Voltage management in transmission and distribution systems” (refer to D1.1 as UC-IT-1) and “Congestion management in transmission and distribution systems” (refer to D1.1 as UC-IT-2).

In detail, the demo makes available to SOs the flexibility services Voltage Management and Congestion Management offered by DERs, by means of market processes that take into account also technical constrains of the grids. This will guarantee that activation of the flexibility services will not generate issues in any grid.

The processes of Congestion and Voltage Management tested in the Italian pilot, are broken down into different phases. The identified main areas regarding the development of these services are:

- Design of needs
- Information exchanged
- Interaction and coordination between system operators
- Interaction between system operators and market parties

The Figure 3 illustrates the main phases of the process with respect to the market-based solutions, adopted in the demo.

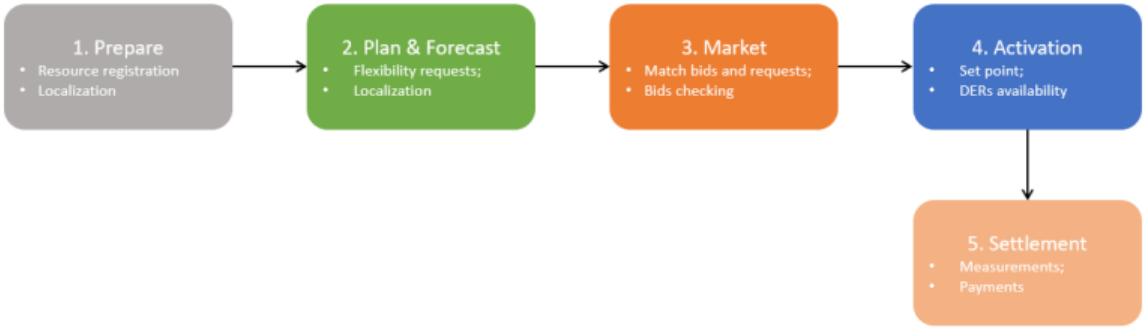

Figure 3: Main phases of Platone Italian Demo

1. Preparatory phase: includes the registration and the localization of the resources. In the registration the Aggregator defines the services that the unit can perform according to the requirements set by the system operator and grid localization, to determine where the resource is able to deliver energy. Once the services and the providers are qualified, the system operators can use the bids of these parties to solve the network issues.

2. Forecasting phase: the system operators plan the grid utilisation forecast (day-ahead and near real rime) defining the flexibility requests that can be used for dealing with the issues. Forecasting is undertaken in different timeframes, so the accuracy of the predicted flow of electricity in a certain area improves as the time passes. The forecasts are updated and performed up until real time sessions (using real-time weather data and remote monitoring devices on the grids). It is necessary for system operators to have access to good schedules

with relevant locational information, to perform proper forecast for grid management and make efficient and secure decisions.

3. Market Phase: the bids and the requests can be collected and matched for day ahead session and for soft real time sessions. The available bids are efficiently sorted in a merit order list to ensure economic efficiency. Afterwards, the technical evaluation of the bids is done by the DSO checking the local grid limits.

4. Activation Phase: After collecting and evaluating the bids in the market phase, the flexibility bids are activated, sending the set-points to DERs located in the critical area and the congestion or the voltage violation is monitored. The evaluation of the bids will be continued also after activations, so that a granular monitoring of the energy moved is guaranteed. This is done based on real-time measurements.

5. Settlement Phase: The measurements of the activated flexibility should show whether the service is delivered. When a service is delivered by the Aggregator the amount of flexibility must be established, and the flexibility must be paid by the system operator. If the service is not delivered or does not respect the agreed parameters, a penalty is possible. The amount of flexibility delivered is determined by evaluating the data coming from smart meter at the connection point and compared with a baseline. The baseline is the total energy, without the flexibility invoked. The difference between the baseline and the measurements is allocated to the Aggregator.

3.2 Communication and Data Flows

Platforms and device whitin Platone Italian Demo interact each other exchanging several data. Data flows are depicted in Figure 4.

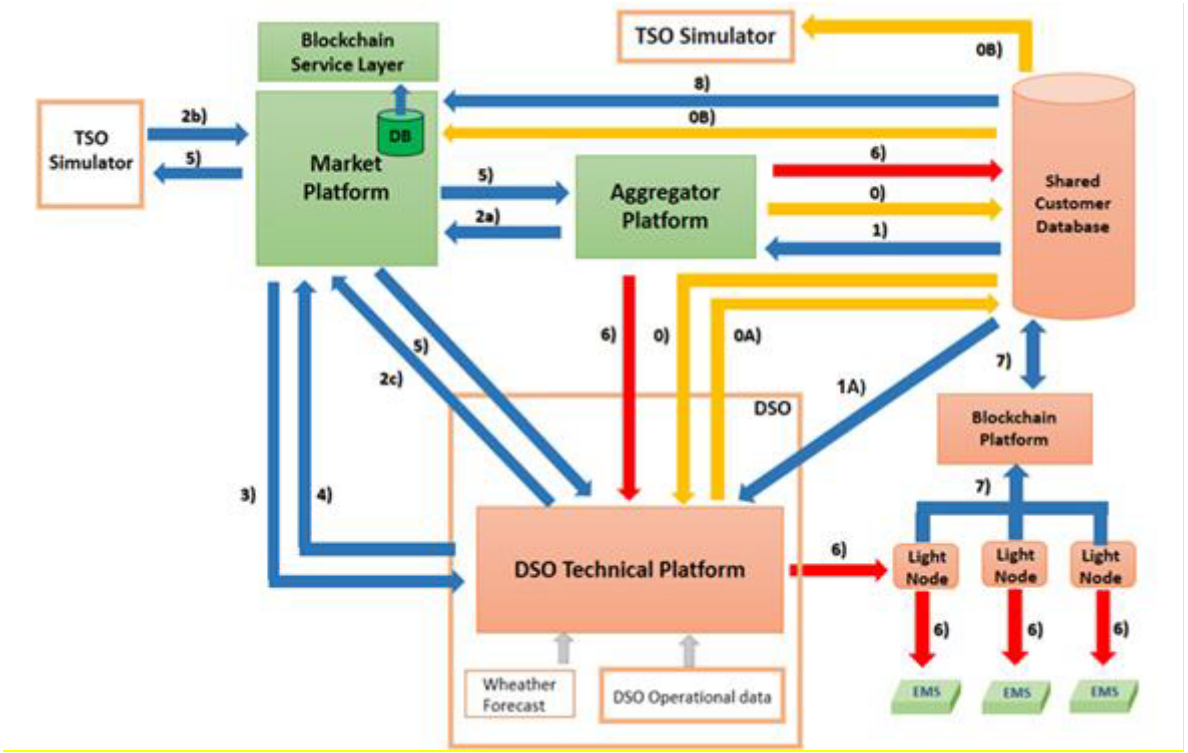

Figure 4: Data Flows within Platone Italian Demo

Table 1 provides additional information including adopted communication mechanisms and data flow descriptions. Moreover, for each flow the related data model is available specified by related file that can be easily analysed by a common text reader (e.g Notepad etc.).

Table 1 Communication and Data Flow specifications

Flow	Sender	Receiver	Communication Method	Data Model	Description
0	Aggregator Platform	Shared Customer Database	REST API	aggregatorApi-v1.3.yaml	Flexible PoD registration
0	Shared Customer Database	DSO Technical Platform	REST API	dso-scd_v1.yaml	Flexible PoD registration
0A	DSO Technical Platform	Shared Customer Database	REST API	dsoApi-v1.3.yaml	Flexible PoD - PoM association
0B	Shared Customer Database	Market Platform TSO Simulator	REST API	market_platform_flusso_0b_v2.yaml	Flexible PoD data
1	Shared Customer Database	Aggregator Platform	Apache Kafka	aggregatorMessageSchema-v1.3.yaml	Flexible PoD data (15min)
1A	Shared Customer Database	DSO Technical Platform	REST API	dsoApi-v1.3.yaml	Flexible PoD data (more than 15min)
2a	Aggregator Platform	Market Platform	REST API	market_platform_flusso2_v2.yaml	Flexibility offers
2b	TSO Simulator	Market Platform	REST API	market_platform_flusso2_v2.yaml	Flexibility requests
2c	DSO Technical Platform	Market Platform	REST API	market_platform_flusso2_v2.yaml	Flexibility requests

Flow	Sender	Receiver	Communication Method	Data Model	Description
3	Market Platform	DSO Technical Platform	REST API	dso-flusso3-v1.0.yml	Market outcomes for technical validation
4	DSO Technical Platform	Market Platform	REST API	market_platform_flusso_4_v1.yaml	Validated market outcomes
5	Market Platform	Aggregator Platform TSO Simulator DSO Technical Platform	Apache Kafka	market_platform_flusso_5_v1.yaml	Market results
6	Aggregator Platform	Shared Customer Database	REST API	aggregatorApi-v1.3.yaml	Setpoint
6	Aggregator Platform	DSO Technical Platform	REST API	dso-flusso6-v1.0.yml	Setpoint
6	DSO Technical Platform	Light Node	MQTT over TLS	dso-flusso6-v1.0.yml	Setpoint
6	Light Node	Customer Activation Systems (e.g. EMS)	REST API (Smart Objects) MQTT over TLS (Smart Objects) Z-Wave (Smart Home) Modbus TCP (UPM) Modbus RTU (Storage and PV)	(Depends from receivers)	Setpoint

Flow	Sender	Receiver	Communication Method	Data Model	Description
7	Light Node	Blockchain Access Layer (Blockchain Platform)	MQTT over TLS	 in flow-7_v2.0.json	Measurement data & Setpoint
7	Blockchain Access Layer (Blockchain Platform)	Shared Customer Database	REST API & Apache Kafka	 in flow-7_v2.0.json	Measurement data & Setpoint
8	Shared Customer Database	Market Platform	Apache Kafka	 marketMessageSchema-v1.3.yaml	Measurement data & Setpoint

4 Italian Demo Target Area

4.1 areti Grid Overview

The energy grid managed by areti has very peculiar characteristics that cannot be found in other cities, due to the huge metropolitan area rich of history and cultural heritage. Besides, the presence of a large number of important archaeological sites and protected natural areas makes the urban context very complex.

The city of Rome is divided in 15 Municipalities, in turn divided in 155 urban areas. The urban areas were founded in 1977 with statistic, planning and territorial management purpose, following uniformity urban criteria. The boundaries are identified along the continuity solutions marked on the urban territory as shown below:

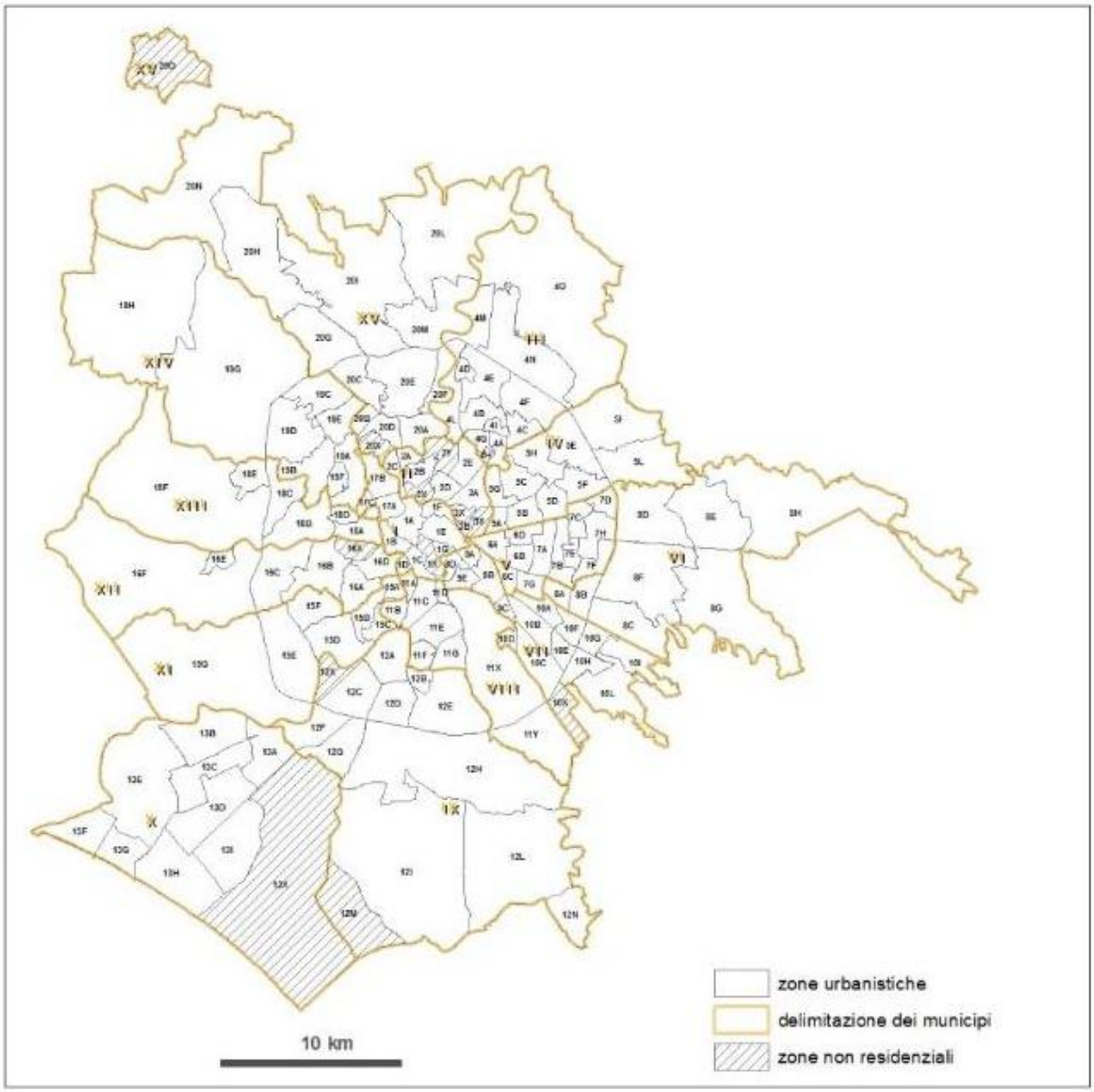

Figure 5: Municipality of Rome composition

The electric energy grid covers the entire municipality of Rome, consists of almost 31.000 km of electric lines and it is able to generate energy for almost 2.8 million of inhabitants. At the moment, areti

distributes electric energy to 1.6 million final users, on almost 1.310 km^2 area. The energy fed in the grid in 2019 was 10.609 GWh, corresponding to 2.113 MW of peak of annual power provided.

Areti has a primary grid composed by 150 kV voltage lines and stations (unified and prevailing voltage) and 60 kV (installation that will be overcome soon), in addition to stations connected to the 220 kV transmission network (RTN - Rete Trasmissione Nazionale). It is functional to the distribution a considerable portion of RTN of 150kV and 220 kV voltage.

Areti High Voltage (HV) lines are considerable and equals to 525,7 km (10kV and 60kV lines), of which 282,4 km in overhead conductors and 243,3 km in underground cables. The abovementioned HV grid feeds primary substations, in which the HV is transformed MV. The further transmission takes place along 10.570 km of MV lines, constituted at 96% of underground cables. This MV grid feeds almost 13.238 secondary substation, in which MV is transformed to LV and/or to which MV users are directly connected. From the secondary substation the energy is distributed along the low voltage distribution grid with an extension of almost 20.059 km, for 92% constituted of underground cables. The table below details the physical overall of the grid.

Table 2 areti grid composition

Type of plant	unit	Qty on 31-Dec-2019
HV Lines	km	**526**
overhead	km	282
underground cable	km	243
Primary station/Receivers	number	**70**
MV Lines	km	**10.568**
overhead (bare conductors)	km	422
Cable (overhead or underground)	km	10.147
LV Lines	km	**20.059**
overhead (bare conductors)	km	1.642
Cable	km	18.417
MV/LV Station	number	**13.238**

4.2 Implementation Target Area

The trial involves several areas of the city of Rome. Specific portions of the electricity distribution network, adequately representative in terms of voltage levels, transformer size, number of users and cable length have been identified and selected. Some secondary substations are equipped with smart technologies interfaced with the central operational system, allowing to increase the observability and to improve the grid simulation.

The first areas selected for the Italian demo implementation and use cases execution are the following:

- **EUR – Tor di Valle District.** Located near the river Tiber, this is a residential area hosting one of the biggest European Wastewater Treatment plant powered by a high efficiency cogeneration plant. Tor di Valle is a “green neighbourhood”: the houses located in the area are connected to

the district-heating network fed by the cogeneration plant heat. In this area, there are several prosumers who use the energy provided by rooftop solar power plants for self-consumption, and some buildings interested in realizing collective self-consumption. In Tor di Valle area, voltages issues could be mainly due to the increasing penetration of Renewable Energy Resources (RES), expected for the next years, especially during the hours of low consumptions. The grid congestions, instead, can be caused by the electrification of the load (heat pumps, induction hobs, boilers and electric vehicles). The use of flexibility can help to manage congestion and voltage violations avoiding investment needs for upgrading the system.

- **Ostiense District.** This is a central and historical neighbourhood of Rome, but it is also an important railway junction attended every day by thousands of people. The zone includes the Aventino Hill; downstream there are the infrastructures for industrial and social activities, such as Acea's headquarter, several service companies, a bus station and a railway station; upstream, there are the residential zones. For the last two years, Areti has been upgrading the grid of this area, by installing secondary substations technologies to increase the observability. In this area, the Italian demo aims to improve the simulation tool and test the flexibility provided by smart EV parking located in the district, to solve local congestion that occurs during the hot season when the cooling loads are at their highest.

- **Centocelle District.** This is a large and popular neighbourhood located in the southeast of Rome. Here, the residential buildings usually host ten apartments each and shops located in the ground floor. Customers involved in the Italian demo belong to an already existing Citizen Energy Community (CEC) managed by ENEA. The users of the virtual community are distributed over a broad territory, and it is therefore very important to implement a coordination activity, thanks to the role of the Aggregator. The Italian demo aims at testing the demand response of the CEC to respond to the local flexibility requests, in order to solve the congestion and the voltage issues.

4.3 Customer Involvement

Platone Italian Demo does not consist only in system and market operator platforms. To create massive flexibility markets where all the resources, regardless from the size and technologies, will be enabled to offer their flexibility, it is necessary to test the proposed solution involving all customer categories. For this reason, in addition to industrial customers (such as Wastewater Treatment plant in Tor di Valle), customer engagement activities [6] within the demo are performed, to involve in the project also the typical customers of a distribution system, i.e. the domestic customers.

Houses of domestic customers accepted to take part to the demo have been equipped with the following devices:

a) Smart Meter 2G: 2nd generation smart meters able to measure by high frequency (up to 1s) electrical quantities at grid connection point (PoD) and make them available in (close)real-time to Light-Node (by means of PLC communication technology)

b) Light-Node: it certifies and makes available smart meter measurements to customer devices and to Platone platforms; moreover, it receives the Set-point to be activated by customer activation system (e.g. EMS, Storage, EV charger etc.) to deliver flexible service

c) App: a smart-device application designed to perform several functions to monitor Smart Meter measurements, monitor flexibility service delivery, set available flexibility etc.

d) Micro photovoltaic system: a PV generator system with Power up to 300W

e) Storage system: a domestic storage system able to modify its operation (charging and discharging) according to pre-set algorithms or external setpoint

Only installation of equipment at point a), b) and c) are mandatory for the demo; the others are optional since they can be installed based on customer preferences and house features (e.g. sun exposition, available space etc.).

5 Key Performance Indicators

Table 3 presents the list of Key Performance Indicators (KPIs) calculated for the Italian demo, its domain and specific use cases each KPI corresponds to. The first four KPIs are Project KPIs identified within WP1 activities led by E.DSO [7]. The last three are Demo specific KPIs identified within Italian Demo.

As the Italian demo aims to test the entire Platone Architecture, the calculated KPIs are related to all focus areas: flexibility, observability, customers' engagement, market.

Table 3 List of KPIs in Italian demo

No.	KPI ID	KPI Name	KPI Domain	Use case
1	KPI_PR_01	Participants' recruitment	Social	UC-IT-1, UC-IT-2
2	KPI_PR_02	Active participation	Social	UC-IT-1, UC-IT-2
3	KPI_PR_03	Flexibility Availability	Technical	UC-IT-1, UC-IT-2
4	KPI_PR_04	Flexibility Effectiveness	Technical	UC-IT-1, UC-IT-2
5	KPI_IT_01	Market Liquidity	Technical	UC-IT-1, UC-IT-2
6	KPI_IT_02	Forecast reliability – customer profile	Technical	UC-IT-1, UC-IT-2
7	KPI_IT_03	Forecast reliability – grid profile	Technical	UC-IT-1, UC-IT-2

The complete description of the KPIs is available in Annex B.

6 Conclusion

The work carried out was divided into separate work streams. These, working in a synergic way and under the coordination of areti, created the first version of the System Architecture of the Italian Demo, its component and devices, accurately indicating the flows and interactions between the various components.

The first version of the System Architecture, which will be operational from July 2021, represents a first fundamental step towards breaking down the barriers to the flexibility market, guaranteeing to all distribution grid users the possibility of becoming partners with System Operators in the energy value chain. In this way, by being able to provide local flexibility to the grid, it will be possible to optimally manage the grid itself.

The market thus conceived is an efficient, open and non-discriminatory market model, capable of exploiting the potential of local flexibility by making use of the Blockchain, while guaranteeing certainty in the transactions that will be carried out. The participation of end-users will also be facilitated by the provision of a device fully developed within the Italian Demo, the Light Node, able to interact with user's systems such as storage and micro photovoltaic, to ensure that users can easily monitor their consumption and provide flexibility services to the grid. Moreover, the Light-Node, together with the Shared Customer Database and the Blockchain Access Layer, contribute to increase grid observability.

Thanks to the effort of the partners involved in the development of the System Architecture, all the platforms developed will be perfectly fit in a perfectly oiled mechanism, where:

- The Market platform will allow the Market operators, and in particular the DSO, to solve issues that can occur within their networks;
- The Aggregator platform will allow the management of the single units/PoDs, the definition of the offers, the definition of the baselines, the market interaction and all the consequent activities, including the economic settlement;
- The DSO Technical Platform will be able to perform grid state estimation, defines flexibility requests and sends these to the Market Platform, validate flexibility offers and send set-point to Flexible resources;
- The Access layer as a common interface between customers and market players that has been designed specifically to give the opportunity to customers to offer flexible services to the grid and to guarantee data sharing and data access to the stakeholders involved, improving observability of flexible resources;
- The Shared Customer Database as a storage of all the energy data that provides the access to them to all the stakeholders involved in the flexibility mechanism, implementing data security, data privacy and data access policies mechanisms.

The work realised so far led to the release of the first version of the technology that will be fully functional from July 2021 in Rome (Milestone 8 Field test fully operational in Italy).

7 List of Tables

8 List of Figures

9 List of References

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10 List of Abbreviations

Abbreviation	Term
CEC	Citizen Energy Community
DEOP	Decentralize Energy Optimizer
DER	Distributed Energy Resources
DSO	Distribution System Operators
DSOTP	DSO Technical Platform
EMS	Energy Management System
EV	Electric Vehicle
HV	High Voltage
KPI	Key Performance Indicator
LV	Low Voltage
MV	Medium Voltage
PoD	Point of Delivery
RTN	Rete di Trasmissione Nazionale (National Transmission Network)
SO	System Operator
TSO	Transmission System Operator
WP	Work Package

Annex A Platforms Descriptions

A.1 Market Platform

A.1.1 Overview

Here is described how the Platone Market Platform is functionally integrated within the Italian Demo Architecture. The Platone Market platform is one of the core components of the Platone Open Framework (as described in D2.1). The Market Platform is a blockchain-based platform that enables the management of wide geographical area flexibility requests from TSOs and local flexibility requests from DSOs. The flexibility requests are matched with offers coming from aggregators accordingly to pre-defined rules and dispatching priorities, in order to solve grid issues. All the market operations are registered and certified within the blockchain service layer, ensuring a high level of transparency, security and trustworthiness among all the market players.

In the Italian Demo context, the Market Platform allows the Market Operator and in particular the DSO to solve two possible issues that can occur within the network: grid congestions and voltage violations. In order to make this, a set of functional requirements have been identified for the Market Platform.

A.1.2 Architecture

The Market Platform consists of a three-layer architecture:

- **Data Layer** provides the management of the market data and the registration of the market operations within blockchain infrastructure
- **Services Layer** provides the business logic, including the market-clearing tool, the flexibility services, the settlement services and smart contract services
- **UI Layer** includes a web dashboard that allows market players (DSOs, TSOs and aggregators) to manage their own market operations and Market Administrator to handle all the Market Platform features

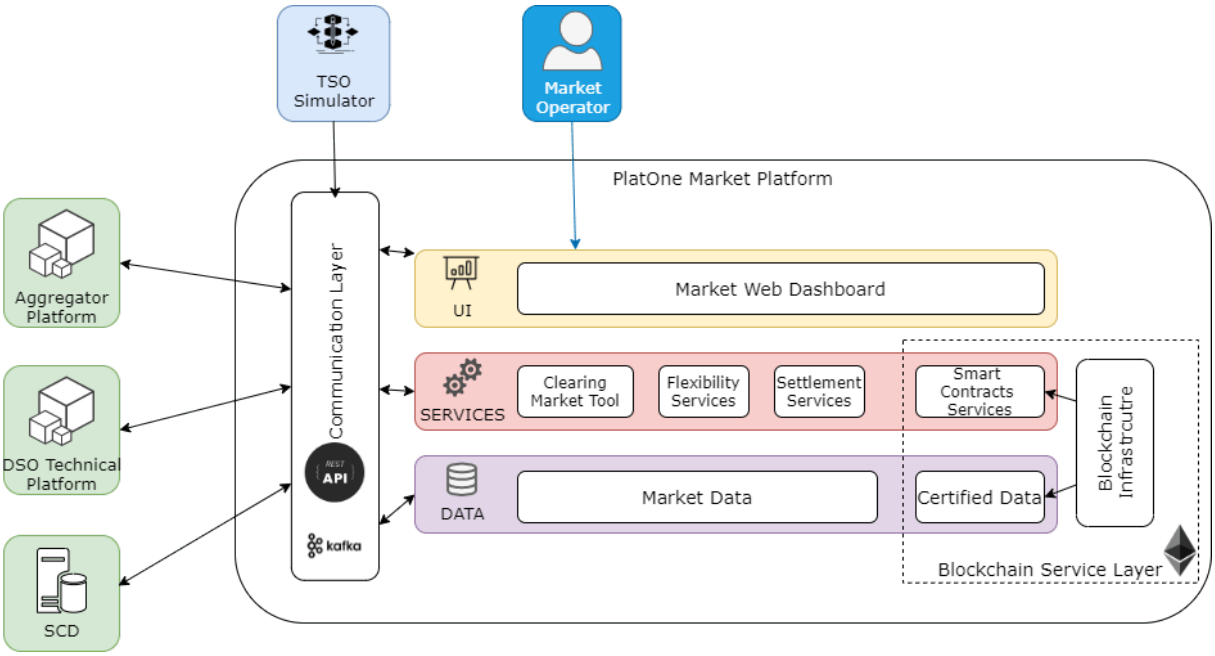


Figure 6: Market Platform Architecture

In addition, two other layers allow the integration of external platforms and blockchain infrastructure: the communication layer and the blockchain service layer.

The **communication layer** allows the integration of external components and internal communication among the different layers within the Market Platform. It provides both synchronous communication interfaces (REST APIs) and asynchronous communication interfaces (Message Broker).

The **blockchain service layer** consists of a blockchain infrastructure based on Ethereum blockchain nodes that enable the deployment of Smart Contracts.

The Market Platform architecture is shown in Figure 6.

A.1.2.1 Data Layer

The Data Layer manages all the necessary data for the implementation of the Market Platform services and it includes a NoSQL database (i.e. MongoDB) for the storage of the data. Furthermore, this layer implements the business logic for the certification of the market data on the blockchain service layer.

A.1.2.2 Service Layer

The Service Layer is the core of the Market Platform and it includes all the services that implement the functionalities offered by the Market Platform. It is based on Node.js and Express.js architectural stack.

The services implemented in this layer are:

- Flexibility Services
- Clearing Market Tool
- Settlement Services
- Smart Contract Services

A.1.2.3 UI Layer

The UI Layer includes the User Interfaces available for all the market participants. In particular, it includes a Web Dashboard, based on HMTL5, CSS3 and Vue.js framework accessible by DSOs, TSOs and Aggregators for monitoring their activities (flexibility request and offers, market results, settlement results, etc.).

A.1.2.4 Communication Layer

The Market Platform architecture includes a Communication Layer, a specific component that provides two different communication mechanisms: synchronous and asynchronous.

A specific architectural component dedicated to communication mechanisms, provides a greater flexibility to the Market Platform, which is able to cover different solutions and integrate different external systems.

In particular, the communication layer offers an interface for the integration of the DSO Technical Platform, the Shared Customer Database, the Aggregator Platform and the TSO Simulator. Furthermore, this layer allows the communication among of the internal layers of the Market Platform.

More in detail, the synchronous communication is implemented in the API Gateway via REST APIs. The API gateway is the entry point for every HTTP request that is being launched by the external systems.

The API gateway, is developed using open source framework Express.js [8] and Express Gateway [9].This central component, shared by the whole Market Platform, allows to centralize some middleware functionalities, i.e.:

- Authentication
- Logging
- Caching
- Security
- Load Balancing

The asynchronous communication is implemented in the Message Broker. The Message Broker is implemented using Apache Kafka [10], an open-source distributed event streaming platform.

A message broker (or queue manager) is a software where queues can be defined, applications may connect to the queue and transfer a message onto it.

A message can include any kind of information. For example, it could include information about a process/task that should start on another application (that could be on another server), or it could be just a simple text message. The queue-manager software stores the messages until a receiving application connects and takes a message off the queue. The receiving application then processes the message in an appropriate manner.

A message broker can act as a middleware for various services (e.g. different external systems). They can be used to reduce loads and delivery times by web application servers since tasks, which would normally take quite a bit of time to process, can be delegated to a third party whose only job is to perform them.

Message queueing allows web servers to respond to requests quickly instead of being forced to perform resource-heavy procedures on the spot. Message queueing is also good when you want to distribute a message to multiple recipients for consumption or for balancing loads between workers.

A.1.2.5 Blockchain Service Layer

The blockchain service layer is based on a blockchain infrastructure that includes Ethereum blockchain nodes and smart contracts services.

In particular, the smart contracts ensure that all the processes and data flows included on the Market Platform are certified thanks to blockchain infrastructure as well as to “tokenize” the settlement outcomes enabling a token-based remuneration process that the DSO and/or TSO can exploit for payments.

The remuneration process is implemented with the usage of ERC-20 tokens as a way to reward or penalise users involved in Market Operation. In particular, the tokens will be defined in a specific smart contract and assigned to prosumers in exchange for the flexibility provided. The policy for the token assignment is completely customizable and the aggregator will be responsible for specifying these policies.

All these characteristics enable a blockchain-driven energy marketplace that:

- Ensures energy transactions certification
- Tracks and controls the registration and validation of energy data and market data
- Publishes bid/offer actions by Market Participants
- Performs energy bids/offers matching and clearing price computation

A.1.3 Requirements and Technical Specifications

A.1.3.1 Actors

The Market Platform foresees the participation of many different actors, both persons and external systems.

Persons

- Market Administrator, (s)he is the administrator of the Market Platform, (s)he has access to web dashboard and (s)he is able to manage all the functionalities of the Market Platform
- Market Operator, that includes:
    - DSO, (s)he has access to the web dashboard and (s)he is able to view all the results of the market in the UI
    - TSO, (s)he has access to the web dashboard and (s)he is able to view all the results of the market in the UI
    - Aggregator, (s)he has access to the web dashboard and (s)he is able to view all the results of the market in the UI

External Systems

- DSO Technical Platform, it is the system in charge of the creation of the DSO flexibility requests, the technical validation of the market outcomes and the creation of the service activation requests.
- Aggregator Platform, it is the system in charge of the creation of the flexibility offers

- TSO Simulator, it is the system in charge of the creation of the TSO flexibility requests
- Shared Customer Database, it is the system that provides information about the creation/update of the PoDs and the data for the settlement phase

A.1.3.2 Use Cases

The Market Platform implements three high level Use Cases:

- Flexibility Services Management
- Smart contract and Blockchain
- Settlement

Flexibility Services Management

The Market Place is a “virtual” place in which Market Players can participate to the flexibility market, in different market sessions, in day-ahead and real time market.

Before starting a new market session, the Market Platform receives the configuration of the network, including PoDs information and PoD/PoM association, as stored in SCD. This information is fundamental to perform all the processes within the Market Platform.

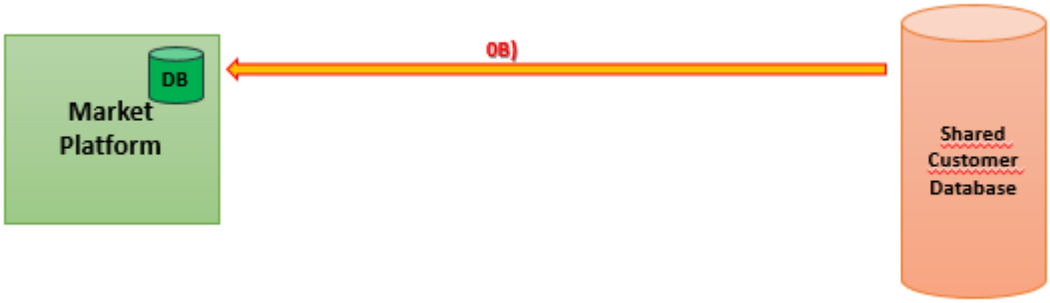


Figure 7: Market Session Initialization

In particular, as shown in Figure 8, in each market session (Day-Ahead and Real Time), Platone Market Platform is able to receive flexibility services requests from DSO (2c) and TSO (2b) and flexibility services offers from Aggregator Platform (2a). At the end of the market session, the Market Platform performs an economic phase of the Market Clearing, matching the DSO and TSO request with the Aggregators offers (2a).This clearing activity has the main purpose of satisfying the request of the DSO and TSO, giving a higher priority to DSO requests.

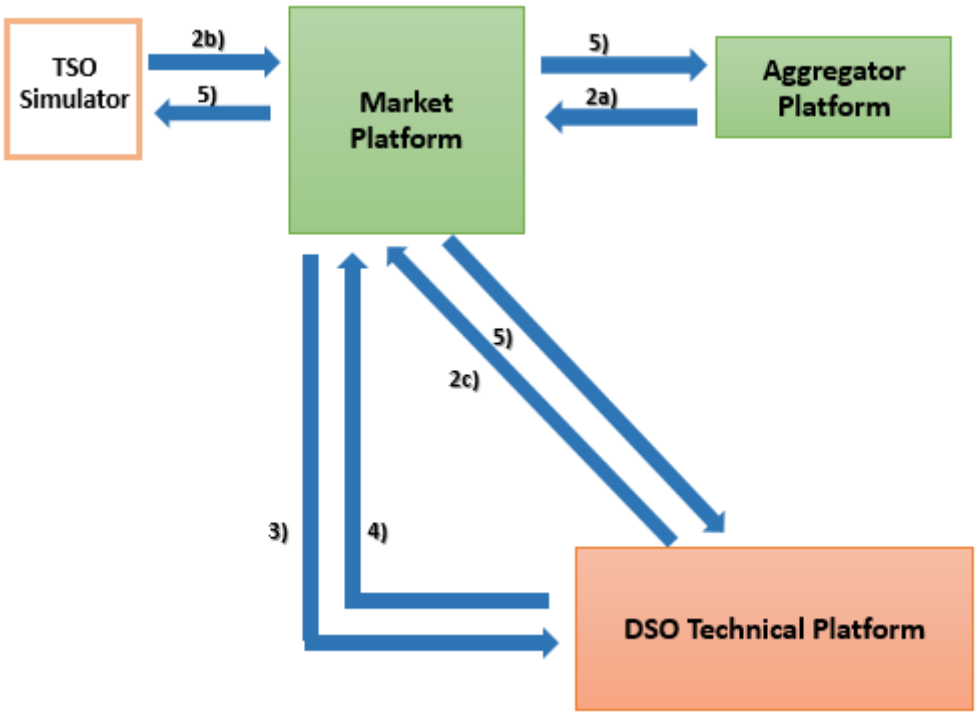


Figure 8: Flexibility Services workflow

More in detail, the Market Platform first step is to find, among the various offers of the aggregators, those that meet the DSO request. All the offers that accomplish the request are ordered according to an **optimisation algorithm, based on a configurable multi-objective function**. This optimization algorithm is based on a **Non-Dominated Sorting Genetic Algorithm (NSGA-II)** which provides a set of optimized solutions characterised by different suitable values with respect to the different objective functions of the optimisation process. The objective functions are defined following the indications coming from the user requirements and in particular from the DSO and could include for example, in addition to an **economic factor, also an index of reliability of the flexibility providers involved** (Aggregators and PoDs).

Once the DSO request is satisfied, the Market Platform also tries to satisfy any remaining TSO requests. At the end of the clearing phase, the platform will present the entire list of offers to the DSO platform, for technical validation and selections (3-4).

After receiving the validated technical outcome, the Market Platform performs the final clearing phase based on the technical results and then sends the Validated Market Outcomes (including both market and technical validation) to all the market participants (5).

In the Real Time Market, the collection of flexibility requests and offers is identical with respect to the Day Ahead market. During the clearing step, the Market Platform considers both the results of the RT session and those of the DA session for the following 4 hours.

The Validated Market Outcomes provided in the RT session (5) are the input for the service activation in the following 4 hours, performed by the Aggregator Platform.

In Figure 9, a high-level Use Case diagram, that represents the Market Players and the functional requirements of the Market Platform related to flexibility services mechanisms.

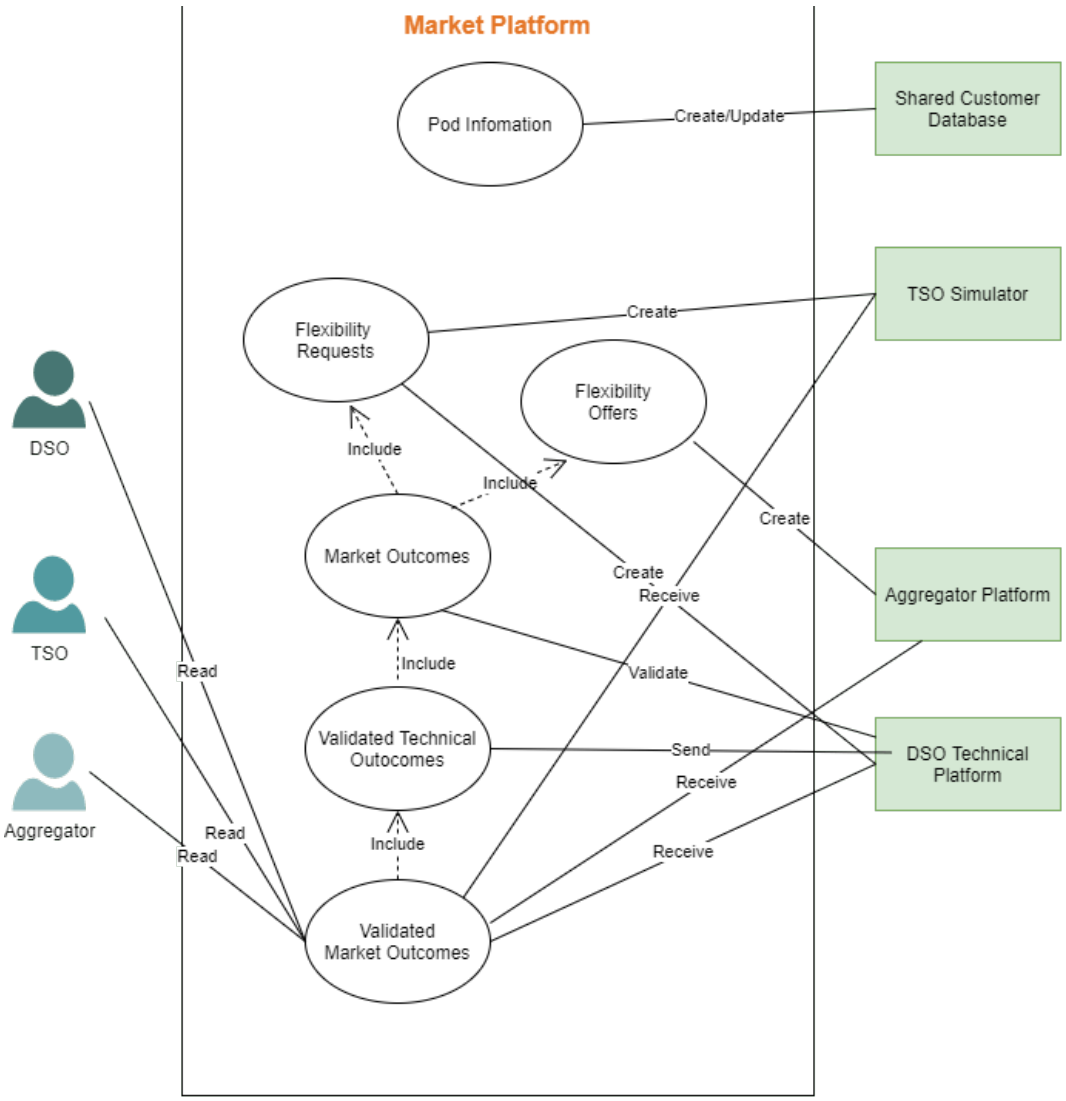


Figure 9: Flexibility Services UC Diagram

Based on the described actions and information flows, key-functional requirements for Flexibility Services Use Case have been identified and described in Table 4.

Table 4: PoD Registration and Baseline Definition Technical Requirements

Requirement Id	FR_MP_I_1
Description	The Market Platform is able to receive PoDs information and PoM association from SCD in order to initialize a new market session
Implementation	1. Market Platform, exposes an authenticated REST API for receiving the PoDs registry from SCD at the start of the market session 2. Market Platform updates the list of the PoDs in its database 3. Market Platform create a new market session (day ahead or real time) in its database 4. Market Platform starts the market session (day ahead or real time) at the set time
First Release	Partially (Only Day Ahead Market)

Requirement Id	FR_MP_FS_1
Description	The Market Platform allows Market participants to create flexibility requests and offers in an automatic way
Implementation	1. Market Platform exposes an authenticated REST API for the creation of new flexibility requests from DSO Technical Platform and TSO Simulator and in a specific market session 2. Market Platform exposes an authenticated REST API for the creation of new flexibility offers from Aggregator Platform 3. Market Platform collects all the flexibility services (requests and offers) in a market session and store them in its database 4. In base of the duration of each market session (4h for day ahead and 2h for real time), at the end of each market session, Market Platform closes the session and starts with matching algorithms
First Release	Partially (Only Day Ahead Market)

Requirement Id	FR_MP_FS_3
Description	The Market Platform is able to match flexibility requests and offers through clearing market algorithms
Implementation	1. Market Platform retrieves all the flexibility services (requests and offers) from its database and starts with matching algorithm 2. Market Platform applies a clearing price mechanism, matching requests and offers, giving priority to the DSO requests. 3. Market Platform applies NSGA-II algorithm, specifying the objective functions, for retrieving the best set of solutions 4. Market Platform stores in its database the result of the process as Market Outcome
First Release	Partially (Only Day Ahead Market and clearing price mechanisms – No NSGA-II)

Requirement Id	FR_MP_FS_4
Description	The Market Platform is able to provide the Market Outcomes (results of market clearing) to the DSO Technical Platform for the technical validation
Implementation	1. Market Platform retrieves Market Outcome of a specific market session from its database 2. Market Platform sends via REST API the Market Outcome to the DSO Technical Platform
First Release	Partially (Only Day Ahead Market)

Requirement Id	FR_MP_FS_5
Description	The Market Platform is able to provide the Validated Market Outcomes (after both economic and technical validation) to all the Market Players
Implementation	1. Market Platform exposes an authenticated REST APIs for receiving a Technical Outcome from DSO Technical Platform. Each Technical Outcome is uniquely related to a Market Outcome 2. Market Platform store in its database the Technical Outcome of a specific Market Outcome 3. Market Platform create the Validated Outcome and store in its database 4. Market Platform provides to DSO Technical Platform, TSO Simulator and Aggregator Platform the Validated Outcome filtered in base of the Market Participant. 5. The Validated Outcomes are published in different topics on Apache Kafka, one for each Market Participant
First Release	Partially (Only Day Ahead Market)

Smart Contract and Blockchain

The Platone Market Platform is integrated on a Blockchain Service Layer that allows to implement a set of functionalities through Smart Contracts. In particular, the Smart Contracts ensure that all the processes and data flows included on the Market Platform are certified thanks to blockchain infrastructure.

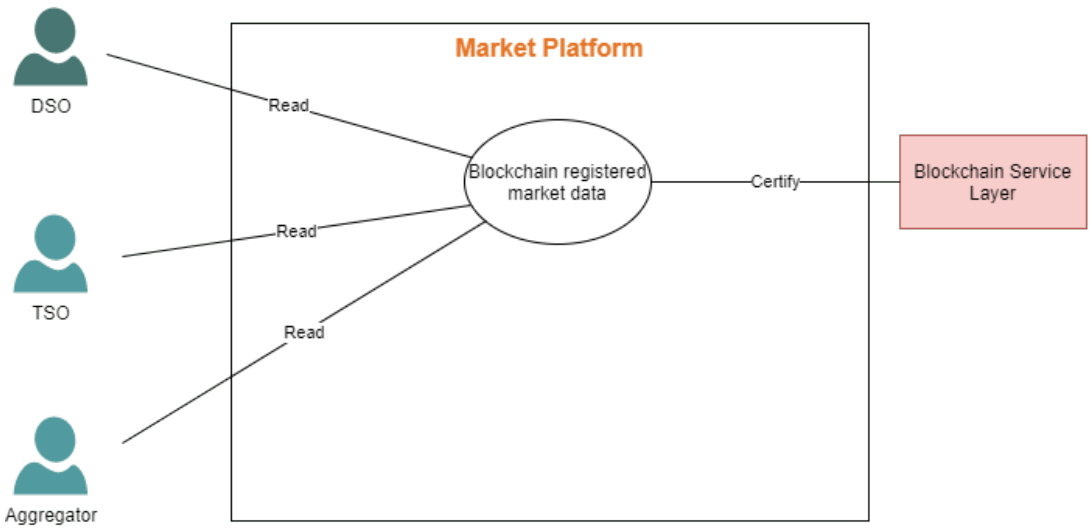


Figure 10: Blockchain Services UC Diagram

Based on the described actions and information flows, key-functional requirements for Blockchain Services Use Case have been identified and described in Table 5.

Table 5: Blockchain Services Technical Requirements

Requirement Id	FR_MP_BC_1
Description	The Market Platform is able to register on the blockchain all the market data trough Smart Contracts based functionalities
Implementation	1. Blockchain Service Layer includes a specific smart contracts for market data notarization 2. Market Platform stores the market data in off-chain data storage 3. Market Platform registers an hash of all the market data into blockchain service layer using the smart contract
First Release	No

Requirement Id	FR_MP_BC_2
Description	The Market Platform allows Market participant to verify all the market data registered in the blockchain
Implementation	1. Market Platform provides an authenticated UI for visualisation of the Certified Market Data for each market participant 2. Market Participants are able to login to the Market Platform UI with username and password 3. Market Participants can visualise the list of their certified market data
First Release	No

Blockchain integration and Smart Contracts development specifications will be defined in a later stage.

Settlement

After the execution, the Market Platform acquires the data from SCD (8), analyses this data together with the respective validated market outcomes, creates the Settlement outcomes, and communicates them to the DSO, the TSO and the Aggregator.

In order to perform the settlement, the Market Platform must know the remuneration mechanisms for each PoD. This information is provided by the Aggregator (a) and registered on the blockchain through specific smart contracts. Each smart contract can be associated with a single PoD or a cluster of PoDs in base of their type (0 and 0b).

At the end of the settlement phase, DSO (or TSO if the related service was requested from it) receives all the necessary information that allows him to pay for the received flexibility service (c).

In the blockchain ecosystem, the Market Platform is able to “tokenize” the settlement outcomes enabling a token-based remuneration process that the Aggregator can exploit for performing the settlement of the flexibility resources under its jurisdiction (c).

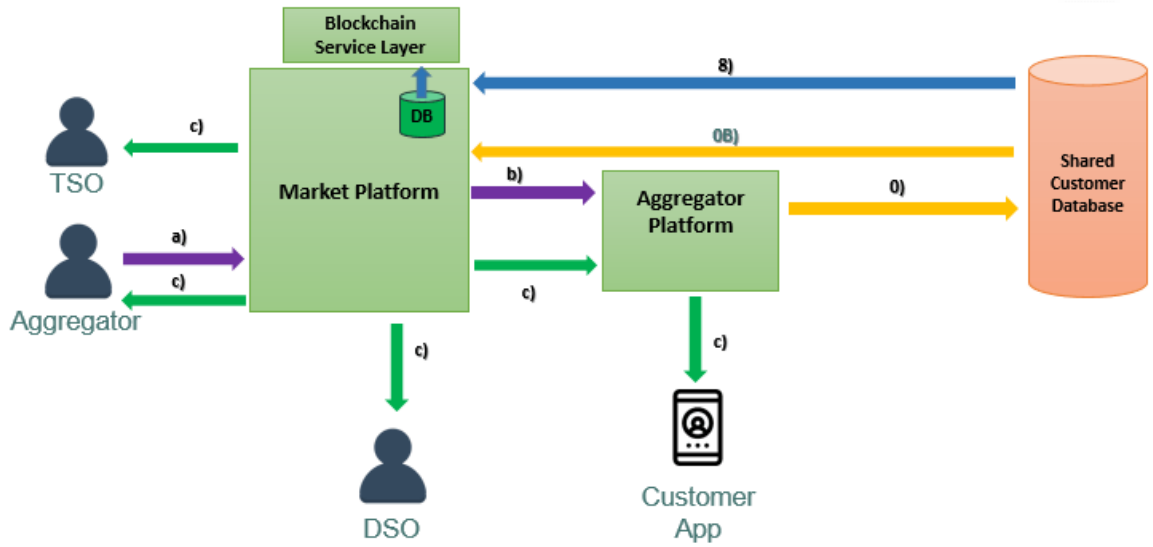


Figure 11: Settlement workflow

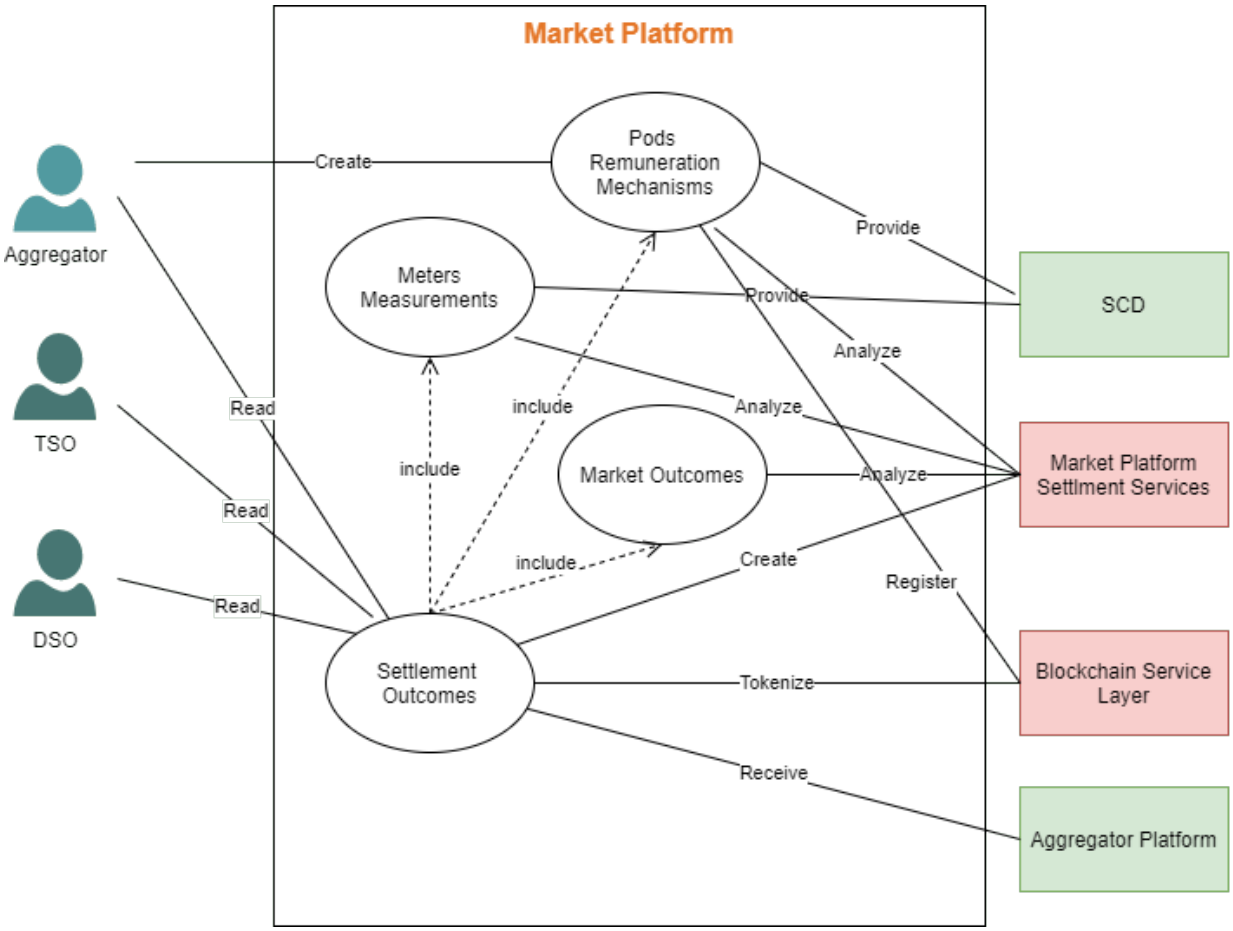


Figure 12: Settlement UC Diagram

Based on the described actions and information flows, key-functional requirements for Settlement Use Case have been identified and described in Table 6.

Table 6: Settlement Technical Requirements

Requirement Id	FR_MP_SET_1
Description	The Market Platform allows the Aggregator to create new smart contracts with settlement mechanisms via UI
Implementation	1. Market Platform provides an authenticated UI section for creating new settlement mechanisms 2. Aggregator is able to login via username and password into the Market Platform 3. Aggregator can visualise existing settlement mechanisms via UI 4. Aggregator creates a new settlement mechanism via UI 5. Market Platform stores the new settlement mechanism in its database 6. Market Platform creates a new smart contract into the blockchain service layer with the settlement mechanisms
First Release	Yes

Requirement Id	FR_MP_SET_2
Description	The Market Platform provides to the Aggregator Platform a list of available Smart Contracts with settlement mechanisms
Implementation	1. Market Platform exposes an API, for retrieving the list of smart contracts with different settlement mechanisms filtered by Aggregator Id
First Release	Yes

Requirement Id	FR_MP_SET_3
Description	The Market Platform is able to read meters data and PoD/Smart Contract association from SCD
Implementation	1. In case of PoD creation/update, Market Platform receives the information about PoD and Smart Contract association (see FR_MP_I_1) 2. At the end of the day, Market Platform receives PoDs measurements and set points form SCD via Message Broker 3. The Market Platform stores the measurements and the set points in its database
First Release	Yes

Requirement Id	FR_MP_SET_4

Description	The Market Platform is able to analyse meters' measurements and flexibility offers for creating settlement outcomes
Implementation	1. Market Platform retrieves from its database all the information necessary for performing the settlement: list of PoDs that participated in the flexibility, measurements, set points, settlement mechanisms 2. Market Platform applies the settlement mechanisms for each PoD and creates the settlement outcomes 3. Market Platform stores the settlement outcomes in its database
First Release	Yes

Requirement Id	FR_MP_SET_5
Description	The Blockchain Service Layer is able to provide tokenization system for the settlement through Smart Contracts functionalities
Implementation	1. Market Platform retrieves settlement outcomes from its database 2. Market Platform assigns tokens in the blockchain based on settlement results (gain and/or penalty) 3. Market Platform updates customer wallets in blockchain
First Release	Yes

Requirement Id	FR_MP_SET_6
Description	The Market Platform allows DSO, TSO and Aggregator to read the settlement outcomes via UI
Implementation	1. Market Platform provides an authenticated UI section for visualisation of settlement results 2. DSO, TSO and Aggregator are able to login into Market Platform UI with username and password 3. DSO, TSO and Aggregator can visualise the settlement results filtered by date, week or month 4. DSO, TSO and Aggregator can download the settlement results filtered by date, week or month in a standard format (CSV and/or JSON)
First Release	Yes

Requirement Id	FR_MP_SET_7
Description	The Market Platform provides to Aggregator Platform the settlement outcomes in automatic way
Implementation	1. Market Platform exposes an authenticated REST API for allowing Aggregator Platform to retrieve settlement outcomes
First Release	Yes

A.1.3.3User Interfaces

Login

The Login section allows access to the Market Platform web dashboard for both the administrator user and to the market participant users (DSO, TSO, and Aggregator). The system transmits the credentials to the server, which according to the type of the user give access to the related section.

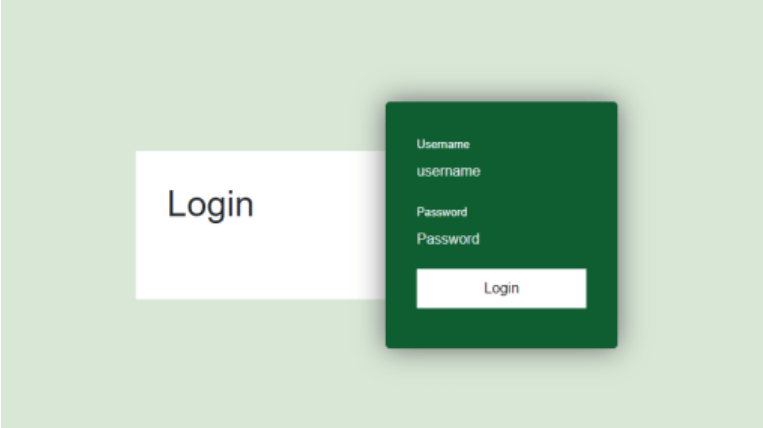


Figure 13: Login Example

Dashboard

The Market Platform web dashboard is the Home Page of the Market Platform UI. It allows to a Market Participant to visualize all the historical market data related to him: flexibility services (requests or offers) created, validated market outcomes and settlement.

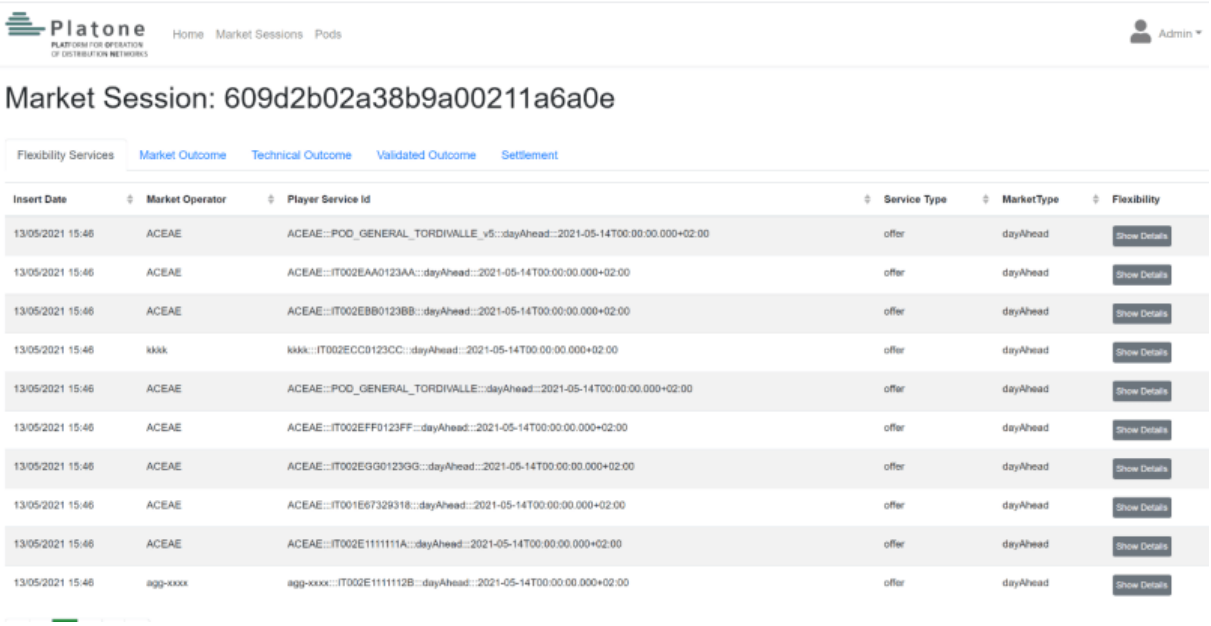


Figure 14: Dashboard Example

A.2 Aggregator Platform

A.2.1 Overview

The Aggregator is a relatively new actor in the electricity market who can bundle different type of DERs, i.e. generation, consumption, storage, to provide flexibility services to interested stakeholders and to enable DER's access to the established power markets. Managing such units with their constraints and flexibility offers, requires a monitoring strategy and a suitable dispatching system, but also new management tools that enable the inter-exchange of data measurements and balancing requests to and from the market parties (DSO and TSO and others).

The Aggregator Platform (AP) is an operational platform that facilitates flexibility asset management by gathering the required data measures, aggregating available flexibility from thousands of different PoDs, and by providing optimal algorithms to optimize market strategy and flexibility offers.

DEOP (Decentralize Energy Optimizer) is the Aggregator Platform developed by Siemens and used in the Italian Demo. This operational platform allows the management of the single units/PoDs, the aggregation of the offers, the definition of the baseline, the market interaction and all the consequent activities, including the economic settlement.

A.2.2 Architecture

DEOP has a micro-service-based architecture with all services orchestrated via Kubernetes. It has been designed as a layer architecture, as depicted in Figure 15, with the following structure:

- **Service Layer** (Micro-services-based Core Applications Layer)
- **Data Layer**
- **User Interface Layer** (Presentation Layer)
- **Communication Layer**

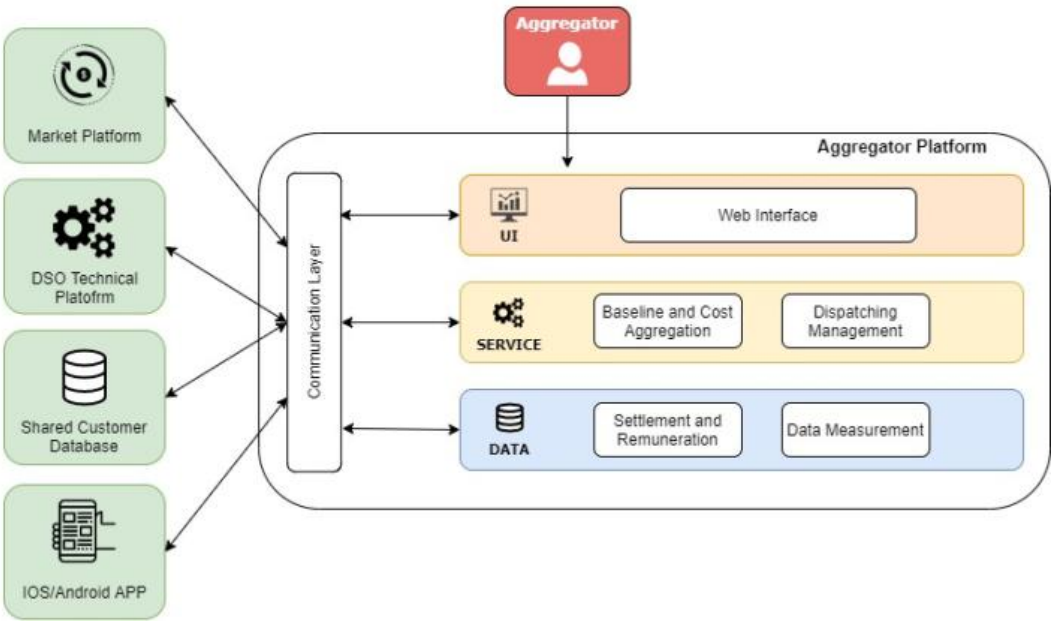


Figure 15: Aggregator Platform Architecture

The main operational functions in DEOP, represented in Figure 15, can be summarized in the following list:

- Baseline and Cost Aggregation
- Dispatching Management

- Settlement and Remuneration

Baseline and Cost aggregation

This functionality collects the measurement data of the contracted PoDs and it allows to keep track of the historical behaviour of the flexible units; building on the measurement data extracted from the external databases, the AP defines the baseline for each flexible unit and it defines the cost for deploying flexibility. The cost depends on variable factors (power market variables, meteorological conditions, maintenance costs, operative costs of the energy unit, market strategy) and on fixed factors (initial investment for building the energy resource). The cost definition for each unit leads to the definition of the aggregated cost of flexibility which is the starting point for the definition of the single/aggregated flexibility offer.

The Baseline is one of the key-elements, not only from the operational perspective (e.g. for the market bidding strategy) but also for the settlement part of the Italian Demo, because it will determine the actual flexibility activation and the consequent remuneration for it.

In the Italian Demo, the Baseline is calculated by the Aggregator and it is shared among all the stakeholders as a building block of the future settlement activity to set the entire economic revenue.

Using DEOP, the baseline can be managed in 3 different ways:

- defined manually by user using Web interface;
- charged automatically by import base from external system;
- calculated using a basic forecast algorithm based on typical consumption.

Based on the defined baseline for each flexible unit, the AP calculates the flexibility available from each single units/PoDs and it returns the aggregated price curves to support the Aggregator when offering flexibility in the market. Thus, the main output of this calculation is a series of price steps relating a certain quantity of power (downward or upward flexibility) with its relative price. This curve (Figure 16) is determined for each MTU (Market Time Unit: quarter-hour in the Italian Demo) and it takes into account variable and fixed costs, in addition to the flexibility constraints of each single unit.

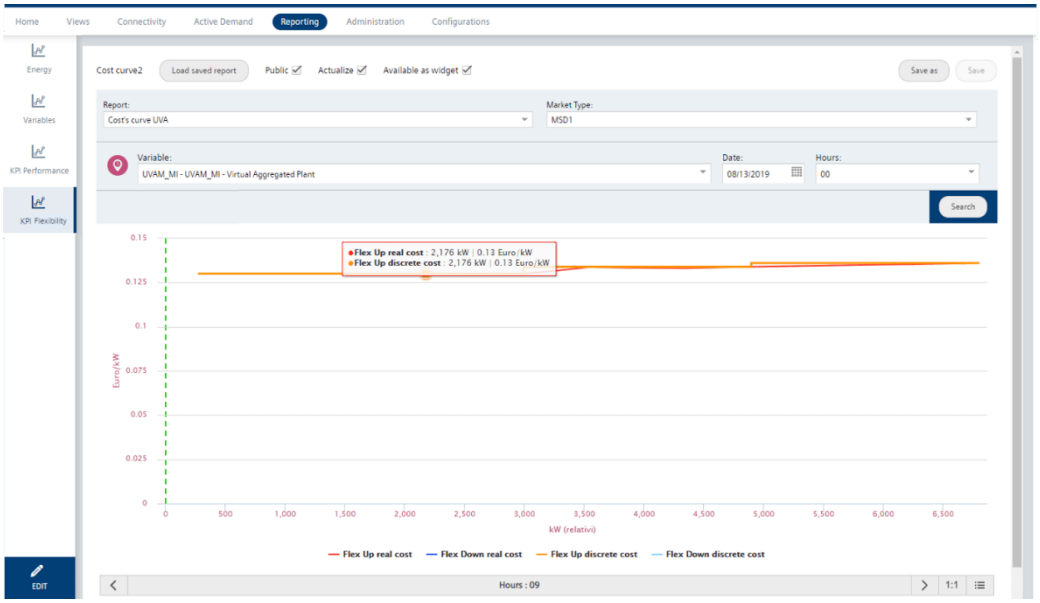


Figure 16: Flexibility & Cost aggregation report

Dispatching management algorithm

The capability of receiving a flexibility request from the Market Platform and defining set-points to the single units is a fundamental functionality of the AP; the dispatching management function receives the market output from the Market Platform and consequently calculates the set-points for each DER. The Aggregator Platform directly communicates with the local energy management system of the flexible resource.

This functionality provides the optimal power curve to be provided by each unit that is part of the Virtual Aggregated Plant in order to fulfil the flexibility request coming from the Market Platform. The functionality implemented is particularly useful when different types of units are aggregated, i.e. consumption, generation, storage, so that it would be difficult to schedule each of them according to the flexibility offered and their technical data provided.

The algorithm in fact, is able to take into account start-up time, response time and gradient of each single unit. It is an essential component since it will be the functionality defining the set-points to be forwarded to the Light Nodes of the single units.

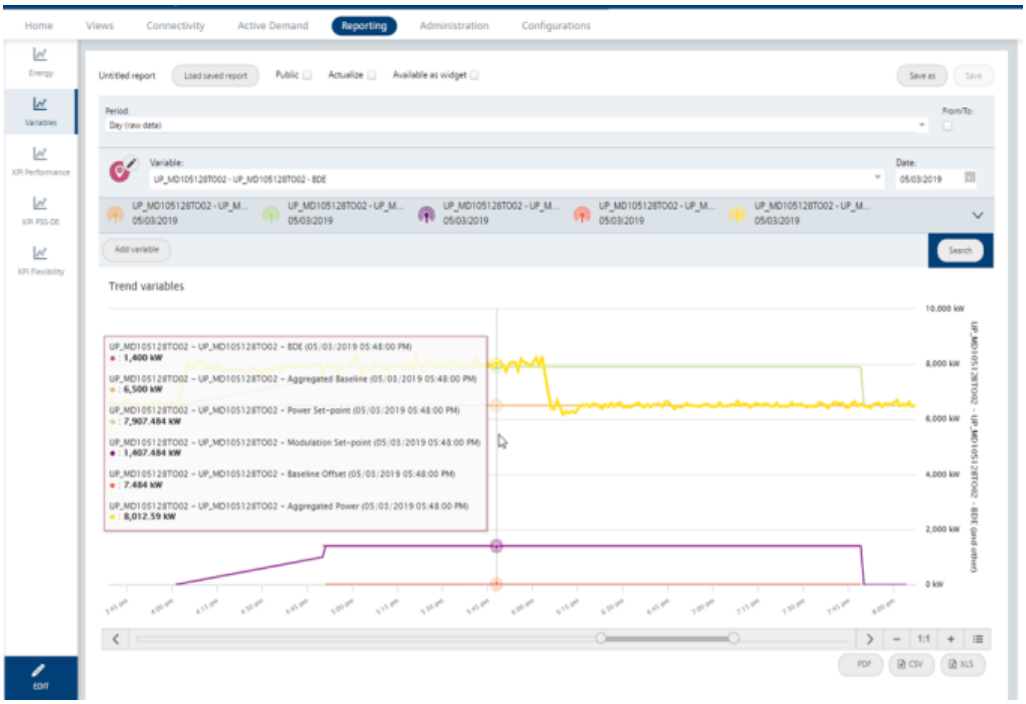


Figure 17: Variables report: baseline & flexibility curves

Settlement and Remuneration

The AP needs to record all the flexibility offers, all the market outputs received from the Market Platform and the actual flexibility activations. The AP records whether the requested and activated flexible service was successfully performed and accordingly defines penalties/rewards to customers for the flexibility service provided.

This function allows to the AP to keep track of the accepted/rejected flexibility offers and of the activated flexibility requests. This section contains also the contractual details in place between the Aggregator and the Customers. In particular, the contract in place defines the remuneration of the end-user and this functional block performs all the needed calculations to define premiums/penalties. In the Italian Demo, the Market Platform certifies the economic settlement among market parties. The Market Platform acts as a validator via blockchain technology, guaranteeing that all contractual relationship are respected and the right remuneration is ensured to the right market party (including end-users and flexibility resources' owners). The AP is able to perform its own economic calculation in order to compare it with the economic outcome arriving from the Market Platform.

DEOP General Features

In the context of the Italian Demo, the DEOP platform is available on cloud and it responds to specific technical and operational requirements, including:

- High availability
- Scalability

- Flexibility and modularity
- Automatic deployment
- Centralized monitoring and logging
- Reduced operational cost

In order to satisfy all these requirements several key architectural principles have been followed:

- Orchestrated Micro-services
- Multitenancy
- Strong decoupling
- Openness
- Security
- Continuous Supervision (monitoring and logging)

A.2.2.1 Data Layer

The AP Data Layer refers to the DEOP data management.

This layer ensures fast performances and is compliant with security policies (cryptography). The data model is persisted on a MongoDB Cloud cluster enabling redundancy, replication, balancing of relevant information.

The depth of historicized data depends on the project needs and is therefore defined for each case.

All entities involved have one or more dedicated tables/collections in which related data and info are stored as shown in the following Table 7.

Table 7: Data stored in the Data Layer of the AP in the context of the Italian Demo

Entity	Type of info stored
PoDs	➢ General Info ➢ Baseline ➢ Flexibility ➢ Cost ➢ Measurement ➢ Enabling to participate to flex market ➢ Set-points ➢ Smart Contracts
Offers	➢ List of PoDs offered to the Market ➢ List of PoDs acquired by the Market
Settlements	➢ List of PoDs with tokens earned ➢ Economic settlement with Market Platform, DSOs and TSOs

A.2.2.2 Service Layer

The AP Service Layer corresponds with the DEOP Core Applications Layer that is structured into several micro-services orchestrated by Kubernetes.

It provides all base functionalities needed by the platform such as:

- Authentication/Authorization
- Service Discovery and micro-services communication
- Time-series services
- Event Services
- Device and Asset Management
- Alarm and Notifications

- Algorithms engine and Formula engine

The orchestrator allows to efficiently instantiate and run several instances of the platform. Micro-services contribute to assure the high availability and scalability of the system.

Synchronous communication is based on REST API. Every DEOP micro-service offers a REST API to access its data and interact with it. The API model can be divided in two macro API sets:

- Private REST API, that can be accessed only internally
- Public REST API, that can be accessed through the API Gateway and after obtaining the Auth Token (the public REST API is the same API used by DEOP UI layer)

Asynchronous communication between micro-services is based on Apache Kafka. DEOP declares a set of topic and payload used to implement service availability, scalability and data durability.

Apache Kafka also decouples the data acquisition services (on-premises / edge or from other systems) to the on-cloud back-end micro-services. Once data are on the bus, they are handled by a set of micro-services that are able to scale-up based on system load requirements.

Traditional messaging models fall into two categories: Shared Message Queues and Publish-Subscribe models. Both models have their own pros and cons. Neither could successfully handle big data ingestion at scale due to limitations in their design. Apache Kafka implements a publish-subscribe messaging model which provides fault tolerance, scalability to handle large volumes of streaming data for real-time analytics. Apache Kafka bridges the gaps that traditional messaging models failed to achieve. Kafka implements concepts from both models, overcoming their disadvantages while also having the flexibility to incorporate both methodologies at scale.

The DEOP Service layer is based on the following technologies and protocols:

- Node.js/JavaScript
- Kafka
- Redis
- Prometheus / Grafana
- ELK (Elasticsearch)
- Docker
- Kubernetes
- MQTT (v3)

A.2.2.3 UI Layer

The AP UI Layer corresponds with the DEOP Presentation Layer. The standard user interface is a browser-based Web Application, easily customizable and extendible given the adoption of standard web technologies. This UI is fully decoupled from the Core Applications Layer and consumes the DEOP public REST API.

DEOP Presentation Layer is based on the following technologies:

- JavaScript
- CSS/SCSS
- React
- Sencha ExtJS
- Ionic

The DEOP UI, often referred to as DEOP HMI (Human Machine Interface), is a cutting-edge Web Application based on the SPA (Single Page Application) standards and built on the ExtJS framework. Starting from a solid shell that manages authentication, authorization and communication with the backend API, the frontend architecture is structured in functional modules. The modules as well as features with finer granularity can be enabled and disabled depending on the user profile. This profiling capability combined with the possibility of adding modules or custom widgets makes the DEOP HMI adaptable to the most diverse needs.

The main DEOP HMI modules are:

- Dashboards
- Views & Model

- Reporting
- Administration

The Dashboards area of the HMI is where users and maintainers can configure DEOP private and shared dashboards. A dashboard is a collection of widgets (generally charts, tables, maps or KPI) that summarize a consistent set of data related to the DEOP views and models. The users also have the possibility to publish entire DEOP dashboards or even just a few individual widgets on external web portals. A screenshot of the homepage is reported in Figure 18.

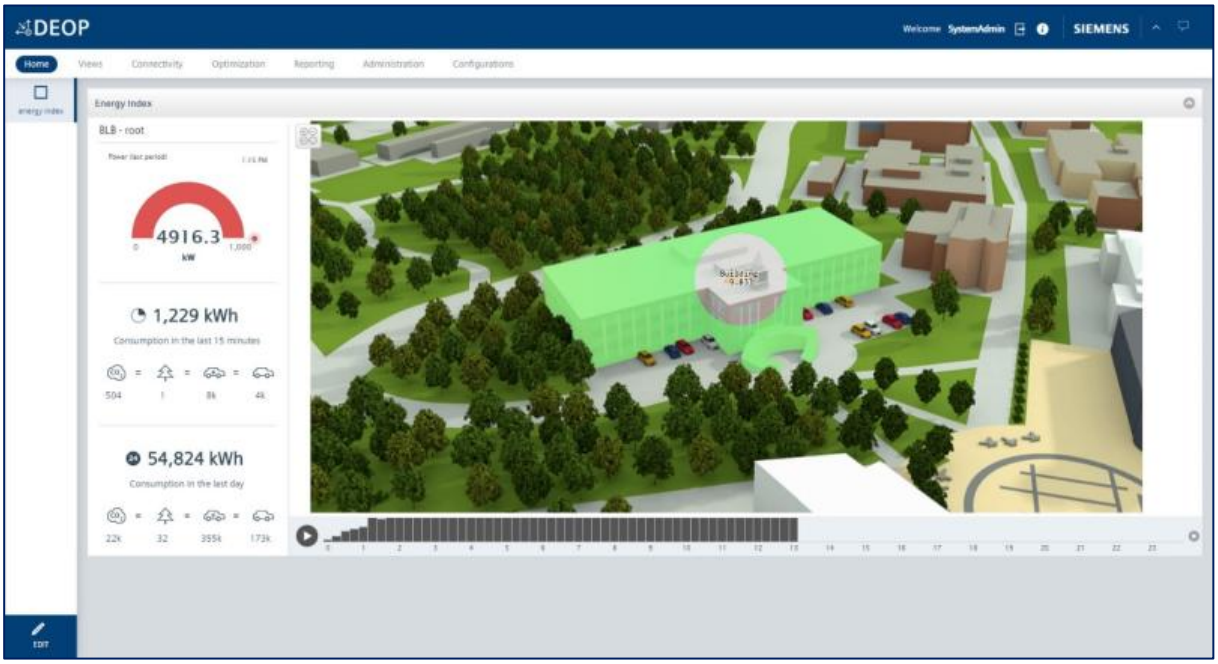


Figure 18: DEOP Homepage & Dashboards

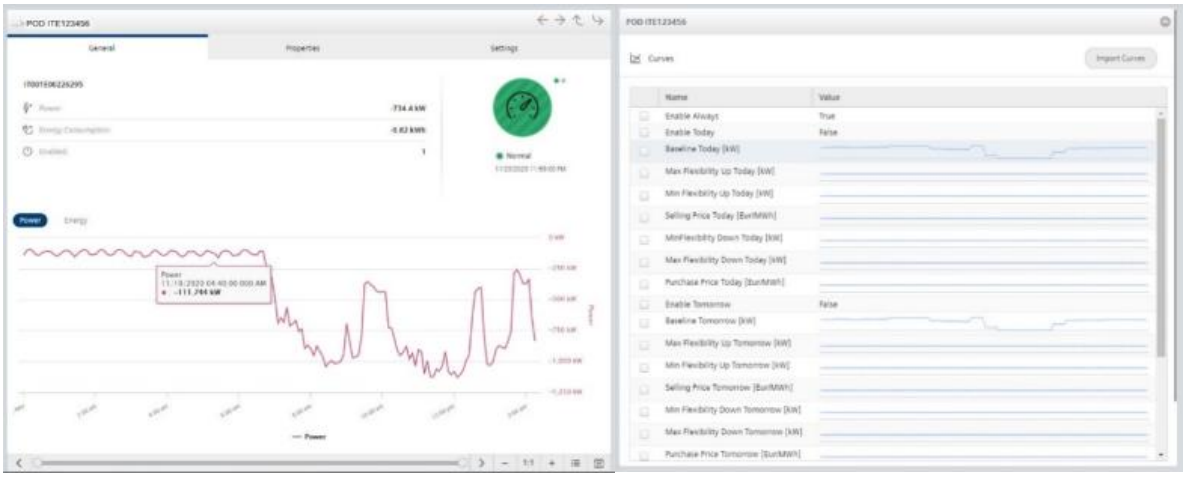


Figure 19: DEOP View & Model detail (PoDs setting and data)

The Views & Model (see Figure 19) area of the HMI is where users can manage assets and organize them using different hierarchical views. Assets are an abstraction; an asset can also be an aggregation of different PoDs. Assets as well as single PoDs have dynamic attributes named Properties.

The Reporting area was designed to provide a feature-rich and user-friendly web interface for managing reports within the platform. It provides different reports that can be used to get analytics about collected data. Reports can be saved, exported or used to feed dashboard widgets. The Reporting module can

also provide a flexible and extensible API that allows to build own reports and tools. The core idea behind the Reporting API is to provide a solid foundation so that other developers can use the framework to share and express data analysis.

The Administration area, as shown in Figure 20 allows to initialize the platform configuration defining three important types of objects including Stakeholder and User. Stakeholders define the belonging groups of the users in order to characterize their usages. In order to login the system, the operator has to be configured as a User. This section allows to create and manage users with their respective roles, profiles and permissions. The login-page is presented in Figure 21.

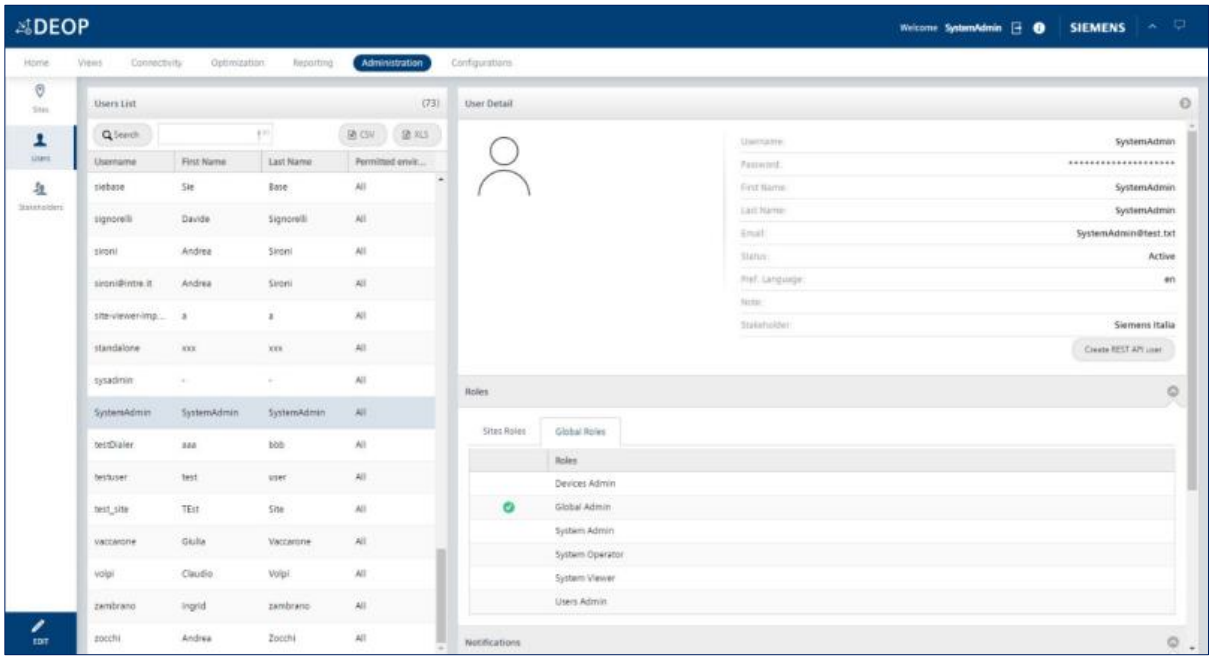


Figure 20: DEOP Administration

Figure 21: DEOP login page

A.2.2.4 Communication Layer

The Aggregator Platform architecture includes a Communication Layer, a specific component that provides two different communication mechanisms: synchronous and asynchronous. In particular, the communication layer offers an interface for the interaction with the Market Platform, with the DSO

Technical Platform, with the Shared Customer Database and with the Customer App. Furthermore, this layer allows the communication among the internal layers of the AP.

More in detail, the synchronous communication is implemented in the API Gateway via REST APIs. The API gateway is the entry point for every HTTP request that's being launched by the external systems.

The asynchronous communication is implemented in the Message Broker. The Message Broker is Implemented using Apache Kafka, an open-source distributed event streaming platform.

In DEOP there are three possible ways to exchange data to the platform:

- Using a MQTT Broker
- Using an Importer
- Using an API Gateway

The MQTT Broker is the main component of the Data Acquisition Package. It is an entry point for the system, but for MQTT packets and signals in general. It supports both the inbound and the outbound communications and it is updated to the MQTT version 3.1.1. The security model behind the client data transmission is guaranteed by tunnel-encrypted channel which supports both Certificates and PSK (Pre-Shared Key) mode. The Broker accepts a packet payload based on a DEOP proprietary JSON schema. To offer the best performance the clients can send to the broker topics single packages, blocks of packages or even high frequency packets (where a single signal can contain values with precision lower than a second). This kind of packet is sent as compressed binary data.
The Broker guarantees the authentication of the client connected and the data received, the validity and consistency of the received packets and their durability. Once verified that the package is valid, the Broker queues it on a persistent Kafka queue, and here it will be saved until DEOP have the certainty of having it correctly stored in the time-series and processed by the various services.

The Importer imports feeds data (time series data) from CSV, JSON or XML export created by a third-party or previously exported from DEOP. The importer can ingest data both from file and from remote HTTP resources (e.g. a REST API).

The API Gateway acts as a single-entry point into the system. It is responsible for request routing, hiding the micro-services to the client applications. The API Gateway component shall be adopted for the access to the services by the internal and external systems. The API Gateway (DEOP Façade Service) segregates all the micro-services from the web, assure authentication logic, centralize and trace all the API interactions and guarantees the scalability and dynamic life cycle of micro-services.
To access the API the user needs to acquire an Authentication Token. This happens using the /login API or other SSO integration like OpenID. Once the user obtains the token then it is able to pass through the API gateway. The API gateway resolves the user data and the authorizations info, then forward the public request to the proper service.

The DEOP platform follows the Openness architectural principles. This means that it is open to be integrated into a larger ecosystem of applications, including business intelligence and data analytics. This is guaranteed by the systematic usage of non-relational databases such as MongoDB alongside its SQL Connectors, and by the provision of dedicated REST APIs/Connectors.

All the DEOP services are accessible and inter-operable exploiting a REST API. The public API can be also consumed by third-party's systems for integration purposes. Every DEOP API is fully documented using the OpenAPI Specification (OAS) also known as Swagger Specification.

DEOP distinguishes two different kind of API: the public API and the private API. The first one is simpler and generally used for system integration, while the latter is an advanced APIs that allow the extension and customization of DEOP. If needed, with the proper security token, users can fully access to the private DEOP API and use the same functionality as the DEOP HMI does.

A.2.2.5 App for Customers

The End-User is enabled to follow and direct the entire process of initialization of the contract, market offering and flexibility activation by using the app ***Flessibili***. The main functionalities of the customer app are listed below:

- easily perform a double-check of contractual details and configure all the details concerning the flexibility preferences (the amount of flexibility which is made available for the Aggregator) defined in the first place;
- notify the client whenever his/her flexibility is accepted in the Market Platform and what will be his/her required contribution; the client receives a further notification also in real-time, when the flexibility is actually activated;
- Give the possibility to the end-user to make available/unavailable his flexibility for the next day;
- Provide economic overview on how the flexibility is remunerated, by assigning token according to the Smart contract deployed on the Market Platform.

The high-level architecture of the customer app is represented in the following scheme (Figure 22):

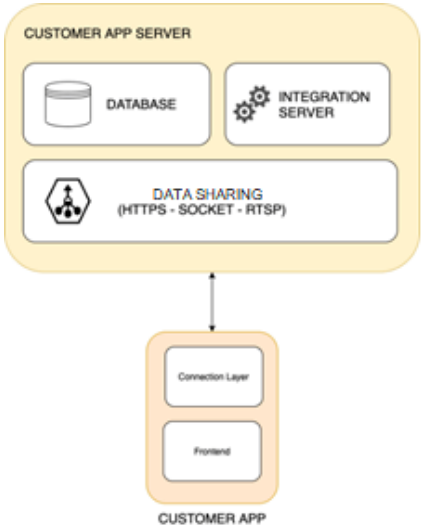


Figure 22: Structure, main components and layers of the Customer App

The main characteristics of the Android/IOS App, needed for the data management and for the management of the DER assets are the following:

- ***Customer App:*** will be available in the ***main stores***, which allows the end-users participating in the Italian Demo to manage all the data-exchange with the Aggregator and easily exchange information about their flexible assets;
- ***CUSTOMER APP SERVER*** allows the management of the client's resources including the user personal data, the data-exchange with external software, (smart meters, Aggregator Platform). The server allows also *the integration with the Shared Customer Database and Aggregator Platform through the Integration Server.*

A.2.3 Requirements and Technical Specifications

A.2.3.1 Actors

The Aggregator Platform is essentially a complete tool that allows the aggregator to manage its entire flexibility value-chain, from the registration of the characteristics of the PoD to the valorization of the aggregated flexibility. Persons and external systems interacting with the AP are listed in the following paragraphs.

Persons

- Aggregator is the actor in charge of managing the Aggregator Platform, (s)he has access to the web dashboard and to the entire package of functionalities described in paragraph A.2.2.

External Systems

- DSO Technical Platform, is a system, which is in charge of the creation of the flexibility requests, the technical validation of the market outcomes;
- Market Platform, is a platform that collects flexibility bids and flexibility requests, performs the clearing of the market and ensures the blockchain-validated economic settlement;
- Shared Customer Database, is a system that provides data about the creation/update of the PoDs and that drives the measurement of the active PoDs to the whole architecture.

A.2.3.2Use Cases

In the Italian Demo, the AP has several tasks and we individuated four main use-cases:

- Pod Registration and Baseline Definition
- Market Offers Definition
- PoD Activation
- Settlement and Remuneration

PoD Registration and Baseline Definition

In the Architecture of the Italian Demo, the Aggregator Platform has information flows with the Market Platform, with the Shared Customer Database (SCD) and with the DSO Technical Platform (TP).

The first step is the PoD registration and baseline definition: the Customers data are registered in the Aggregator Platform (after the confirmation from the end-user through the customer app), which then proceeds to define the baseline for each PoD according to the known information and shares the PoD registration details with the SCD.

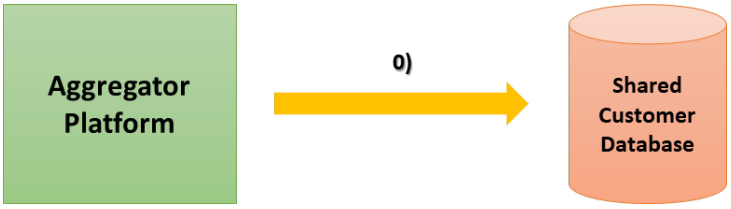


Figure 23: POD Registration and Baseline Definition workflow

The data-exchange with the SCD occurs in 5 different cases:

- When the PoD is registered for the first time in the Shared Customer Database of the flexibility market
- When the Aggregator wants to update the user's baseline
- When the Aggregator needs to update the available flexibility and the remuneration value of the flexibility
- When the PoD information is modified
- When the PoD is unregistered

A data-exchange is established (as depicted in Figure 24), so that all the information concerning the PoDs participating in Italian Demo and providing flexibility are available to all stakeholders, by accessing

the Shared Customer Database; this information includes the maximum available flexibility, the baseline, the type of remuneration.

Moreover, thanks to the Baseline and Cost Aggregation function, the AP is able to write on Shared Customer Database the Baseline of the PoD, in order to make it available to all the stakeholders.

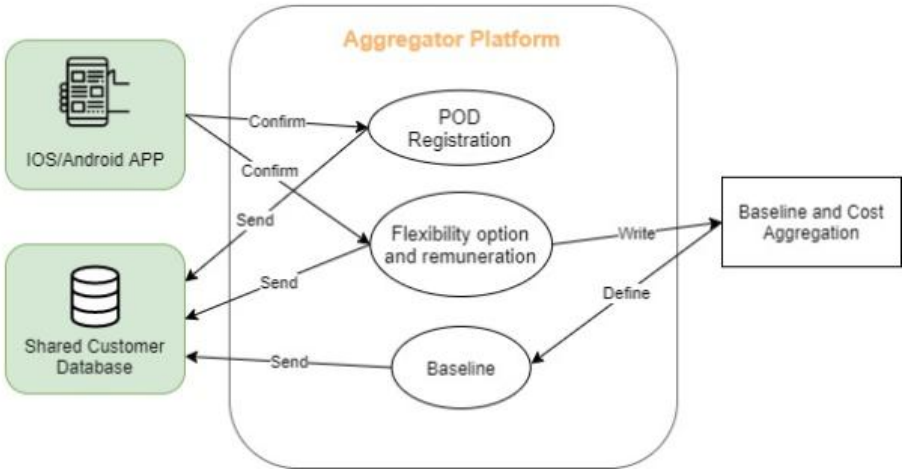


Figure 24: PoD Registration UC Diagram

The information flow between the AP and the SCD contains several key-information: the baseline, the maximum upward and downward flexibility, the Smart Contract ID (defining the type of remuneration) and other attributes characterizing the PoD.

Based on the described actions and information flows, key-functional requirements for the PoD Registration and Baseline Definition Use Case have been identified and described in Table 8.

Table 8: PoD Registration and Baseline Definition Technical Requirements

Requirement ID	FR_AP_PR_1
Description	The Aggregator Platform is able to receive confirmation from the customer app concerning the details of the flexibility contract
Implementation	1. The aggregator operator has an interface to specify all the information related to customers who want to participate to flexibility market. One of this info is the Smart Contract ID 2. The AP get the list of all Smart Contract ID from Market Platform via REST API 3. The Aggregator Platform creates a new contract in its database 4. When the contract has been created the mobile APP can get via REST API all the related information and show details to final customer 5. The final customer can decide to participate to accept the contract details, so the customer app post this info to Aggregator Platform via REST API 6. Aggregator Platform updates the list of the contract in its database
First Release	Yes

Requirement ID	FR_AP_PR_2
Description	The Aggregator Platform is able to take as input PoD characteristics and flexibility details and to output the baseline to share among all stakeholders
Implementation	1. When a user contract is registered on the Aggregator Platform, an object that models the PoD is also created in the database 2. The PoD has characterized by Power, Flexibility, Price and Baseline curves: a. Installed Power is defined by the contract between Aggregator and customer b. Flexibility is valorised by the AP user c. Baseline can be valorised by the user or it is calculated by the Aggregator Platform using a load/generation forecast algorithm that takes into account all PoD's available information. 3. The AP user has always the possibility to upload and or modify the Baseline curve for the next available market session
First Release	Yes

Requirement ID	FR_AP_PR_3
Description	The Aggregator Platform is able to write data on Shared Customer Database
Implementation	1. The AP post all PoD characteristics to SCD via REST API. This can be made: a. on demand (by a manual command raise by the AP operator) b. triggered by specific event (modification of PoD information). 2. When the Baseline and or Flexibility changes, the AP post this information to SCD via REST API 3. When other PoD characteristics change, the AP post this information to SCD via REST API 4. When user contract is unsubscribed, the AP post this information to SCD via REST API
First Release	Yes

Market Offers Definition

In the DA phase, after defining the market strategy, the Aggregator elaborates the flexibility offers and sends them to the market. These interactions between the Aggregator Platform, the SCD and the MP are represented below in Figure 25.

Figure 25: Market Offers Definition workflow

Detailing the tasks of each functional block within the AP (Figure 26): the AP receives the measurement data concerning the flexible PoDs in its portfolio and write the measurement in the Baseline and Cost Aggregation function. Then, it proceeds with the building of the flexibility offer for each contracted according to the available flexibility. Lastly, the flexibility offers are sent to the Market Platform. The data measurement received from the SCD are also sent to the IOS/Android APP of the customers.

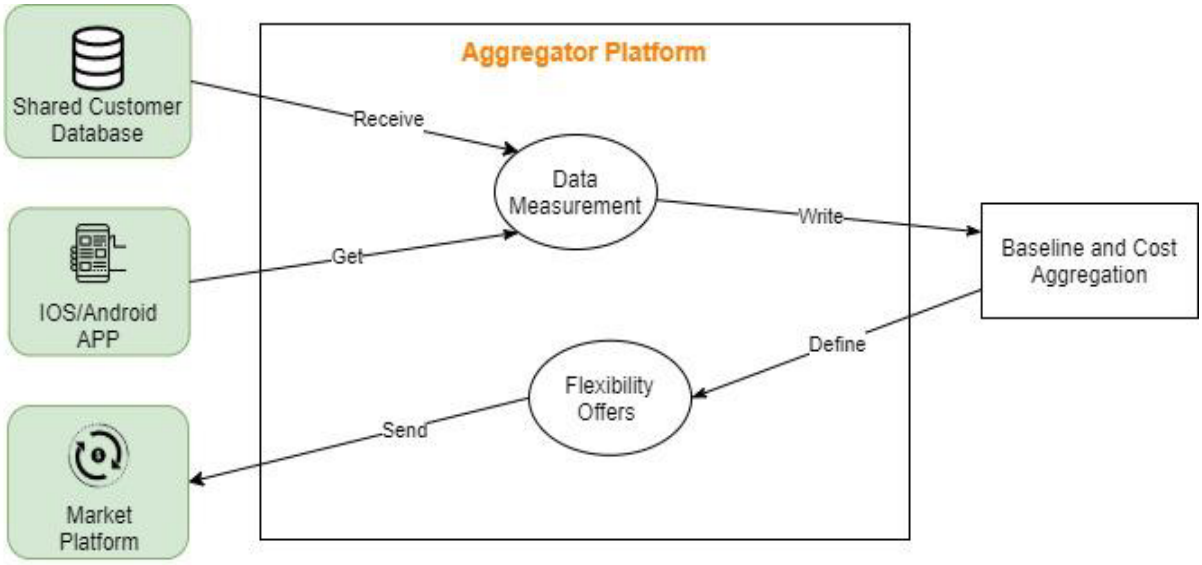


Figure 26: Market Offers Definition UC Diagram

There are two types of flexibility offer that the Aggregator can present to the market. The first one is a **single offer**, in which the aggregator determines a specific flexibility offer for a specific MTU; the second type is a **Flexible Block offer**, in which the aggregator defines a specific flexibility offer but it does not define the specific MTU of the offer.

This complex product is built to better exploit the flexibility potential of the small-scale resources. Often, the available flexibility is only bounded by an energy constraint (the amount of energy that a flexible resource can provide) and not by a pre-defined time constraint. Introducing a more “flexible” product makes the market more liquid and increase the percentage of matched requests from the DSO.

The main information flow of this use case is the offer presentation by the Aggregator to the MP. The structure of the data includes a first part (Message ID) which is independent from the type of offer, then the structure changes depending whether the offer is single or flexible block type, specifying the necessary attributes.

Based on the described actions and information flows, key-functional requirements for the Market Offers Definition Use Case have been identified and described in Table 9.

Table 9: Description of the functional requirements for the Market Offers Definition UC

Requirement ID	FR_AP_MI&O_1
Description	The AP is able to receive measurement data and to build a database of historical consumption/production of the flexible units
Implementation	1. The AP subscribe every 15 minutes the acquisition of measurement data published on Apache Kafka from SCD 2. The measurements are stored in AP database 3. The measurements are made available within the AP as input in a load/generation forecasting algorithm in order to define the baseline
First Release	Yes

Requirement ID	FR_AP_MI&O_2
Description	The AP is able to elaborate and send flexibility offers to the Market Platform
Implementation	1. The AP operator has a reporting page with all the PoDs enabled to participate in the flexibility market 2. Furthermore, the AP operator can choice flagging/unflagging which PoD must be sent to Marketplace to represent the Aggregator's offer 3. The AP on the scheduled time, post all enabled flexibility offers to Market Platform via REST API 4. The AP operator as supervisor, has always the possibility to manually post all enabled flexibility offers to Market Platform via REST API
First Release	Yes

Requirement ID	FR_AP_MI&O_3
Description	The AP needs to make available measurement data to the Customer App
Implementation	1. AP exposes a REST API to get data from PoDs memorized in the database 2. The mobile Application can get via REST API from AP all measurement data related to a customer/PoD specifying the period
First Release	No

Activation

A fundamental step in the Italian Demo architecture is the sending of the set-points to the flexible units, i.e. the activation of the flexibility. The AP is in charge of this task but the set-point is not sent directly to the flexible unit, it is sent to the DSO Technical Platform which then forwards the right set-point to each Light Node.

Figure 27 depicts the basic communications flows among MP, AP, SCD and DSOTP. As depicted, the SCD is also informed of the activation command.

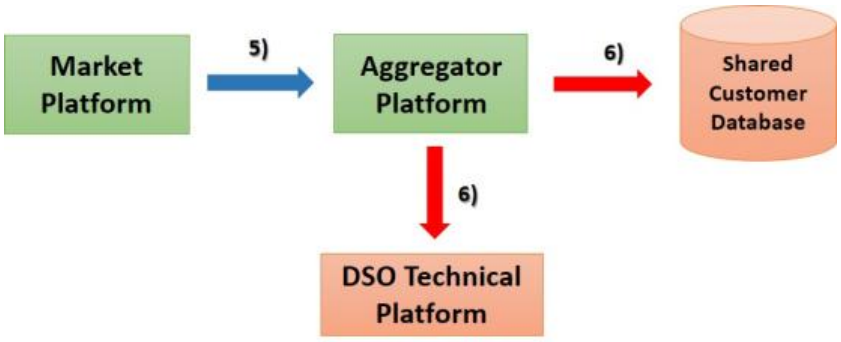


Figure 27: Activation workflow

In Figure 28, the tasks of the functional blocks are detailed. In this case, the Dispatching Management is responsible for elaborating the market outputs received from the MP, and for defining set-points. This set-point definition depends on many other constraints: the flexibility constraints, the accepted offers, the baseline and the technical constraints of each unit. The set-point command is then sent to the DSOTP, which directly forwards the set-points to the Light Nodes of the flexible PoDs, and it is sent to the SCD for keeping track of the activation command sent by the Aggregator.

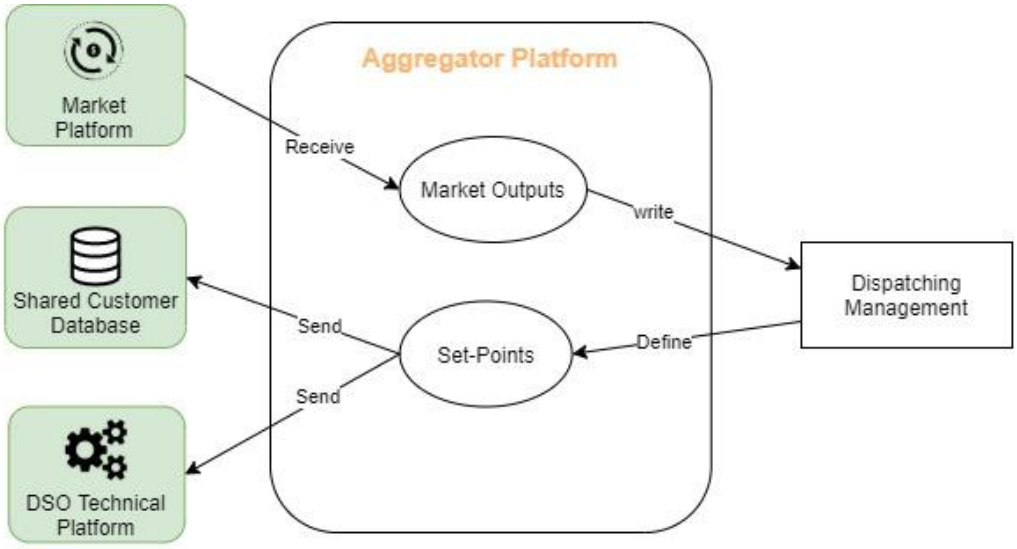


Figure 28: Activation UC diagram

Based on the described actions and information flows, key-functional requirements for the Activation Use Case have been identified and described in Table 10.

Table 10: Activation functional requirements

Requirement ID	FR_AP_A_1
Description	The Aggregator Platform is able to receive market outcome from the market
Implementation	1. Market outcomes are published on Apache Kafka from Market Platform 2. AP subscribe the acquisition of market outcomes topics from Apache Kafka 3. The market outcomes containing accepted/rejected offers are stored in the AP database 4. AP shows market outcome within a specific report 5. The AP operator can compare previous PoD offered with the outcome received from the Market platform
First Release	Yes

Requirement ID	FR_AP_A_2
Description	The Aggregator Platform is able to elaborate on the received market outputs and correctly define the set-point for each energy unit taking into account all the necessary inputs.
Implementation	1. The market outcomes acquired by AP from Market Platform are used, in addition to the technical and economic constraints of each PoD to define the set-points to be sent.
First Release	Yes

Requirement ID	FR_AP_A_3
Description	The Aggregator Platform is able to send the activation command to the DSOTP and to the SCD
Implementation	1. The AP at specific predefined instant time is able to send activation command with the correct set-point for each PoD that must be managed 2. The AP posts the list of PoDs/set-points value to DSOTP via REST API 3. The AP posts the list of PoDs/set-points value to SCD via REST API 4. In both cases (day ahead activation and real time activation), AP is able to send the set-points related to the next four hours, 15 minutes before the time slot window
First Release	Yes

Settlement and Remuneration

The last use case concerns the economic settlement of the flexibility market, in which the aggregator receives payments for the activated flexibility and it distributes to the flexibility owner's the correct remuneration/penalty according to their actions.

As explained in the Market Platform chapter, in the Blockchain Service Layer (BSL) there are the information needed in order to remunerate the PoD. When signing a new flexibility contract with the aggregator, the end-user agrees on certain economic condition for the remuneration of his/her flexibility, i.e. the flexibility reward. These conditions are then, certified in the BSL of the Market Platform as a guarantee for the final user that the market remunerates its flexibility according to the contractual conditions.

Figure 29 represents the data flow between MP, AP and the Customer App.

Figure 29: Settlement and Remuneration workflow

In this use case (depicted in Figure 30), the AP receives the validated market outputs from the MP, which contains the economic reward/penalty for the aggregator and for each customer. On the other hand, the AP receives also the quarter-hourly measures of its PoDs from the SCD, including the set-point command previously sent. These two information sets allow to the Settlement and Remuneration functional block to perform all the necessary economic calculations and to verify all the market outputs. The economic outputs are then sent to the customer app to notify the end-user.

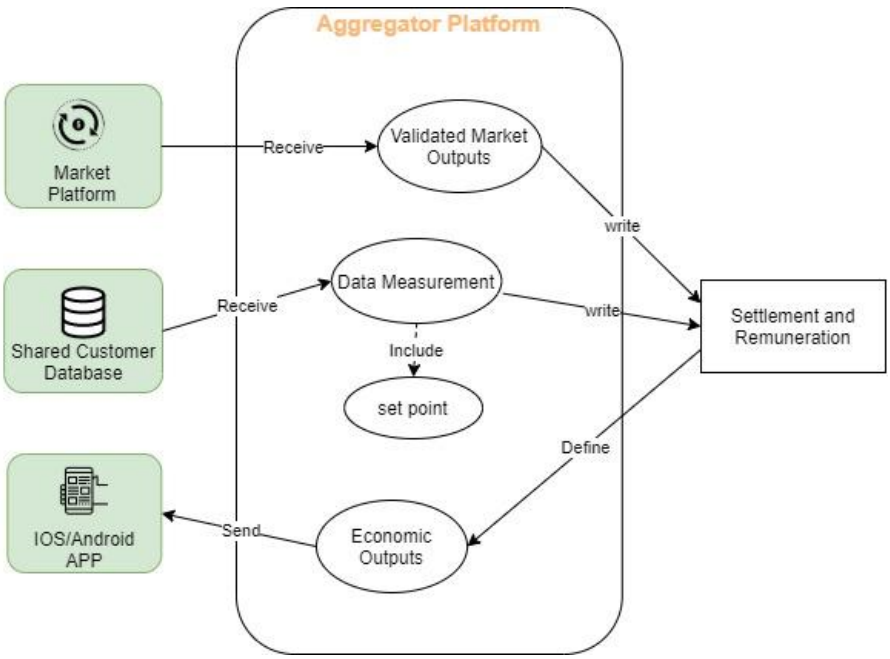


Figure 30: Settlement and Remuneration UC Diagram

Based on the described actions and information flows, key-functional requirements for the Settlement and Remuneration Use Case have been identified and described in Table 11.

Table 11: Settlement and Remuneration functional requirements

Requirement ID	FR_AP_SR_1
Description	The Aggregator Platform is able to receive Validated Market outputs from the Market Platform
Implementation	To be Defined
First Release	No

Requirement ID	FR_AP_SR_2
Description	The aggregator Platform is able to double check customer's economic outputs received from Market Platform by comparing it with the data measurement received from the SCD
Implementation	To be Defined
First Release	No

Requirement ID	FR_AP_SR_3
Description	The Aggregator Platform is able to perform all the needed economic calculations and it notifies the economic outputs through the customer app
Implementation	To be Defined
First Release	No

A.3 DSO Technical Platform

A.3.1 Overview

DSO Technical Platform (DSOTP) is an innovative platform, strictly connected with DSO's SCADA and GIS, that is able to provide the following services:

- Performing Grid State estimation;
- Sending flexibility requests to the Market Platform;
- Performing technical validation of flexibility offers;
- Sending set-points to flexible resources.

DSOTP receives as input data coming from the DSO monitoring and control system (DSO Operational Systems) such as voltage and current measurements acquired by field devices and historical data of customers' meters. The software application, running on the DSOTP is able to estimate the grid status and perform simulations to identify possible power grid congestion and voltage violations.

These simulations are carried out in two different timeframes located in correspondence with the "day ahead" and "real time" markets, as described in paragraph A.3.3.2 (*Setpoint carrying out*).

DSOTP is able to predict congestion or voltage violations that may arise in following day or in the next 4 hours, through its algorithms and shows them on its local interface.

In case that congestions or voltage violations are forecasted, DSOTP provide an alert to the Operator showing:

- issue type (voltage violation or congestion);
- issue value (e.g. Overload 100A);
- asset involved (e.g. Secondary Substation Transformer);
- flexible resources that can contribute to fix the issue (e.g. tot. -150kW).

The system is technologically set up to give to the Operator the choice, to fix the issue by DSO technologies (e.g. grid reconfiguration) or forward the Flexibility Request to the Market Platform. In the Platone Italian Demo, DSOTP integrates the alarms management and the automatic requests for the Market Platform.

In the next step the Market Platform matches the Flexibility Request with the Flexibility Offers provided by aggregators in the Market. The DSO Technical Platform receives from the Market Place the flexibility offers properly processed from a commercial/economic point of view and analyses them in order to return a technical validation. The results are sent back to the Market Platform.

A.3.2 Architecture

The DSOTP consists of a three-layer architecture:

- **UI Layer** includes a web dashboard that allows a DSO operator to insert computation parameters, evaluate computed requirements and evaluate required services.
- **Services Layer** provides the business logic, including the Power Flow Analysis, the Flexibility Requests function and the Flexibility Assessment
- **Data Layer** provides the management of the DSOTP data

The **communication layer** allows the integration of external components and internal communication among the different layers within DSO Technical Platform. It provides both synchronous communication interfaces (REST APIs) and asynchronous communication interfaces (Message Broker).

The DSO Technical Platform is shown in Figure 31.

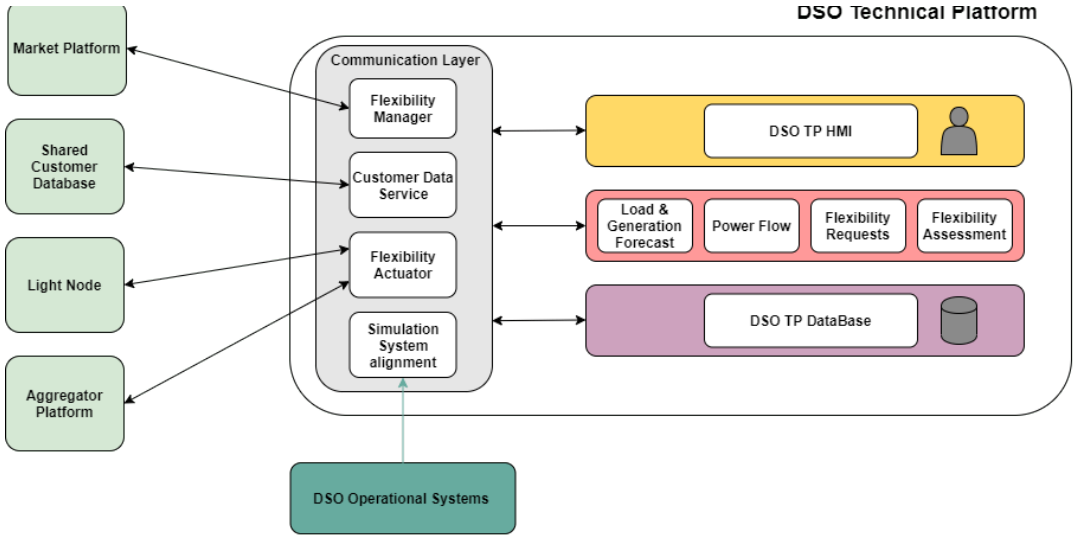


Figure 31: DSO Technical Platform Architecture

To estimate the grid status, the DSOTP uses data coming from the distributor's Information Systems, including the following platforms:

- SAP (ISU/MDM): used to handle the users' data such as PoDs code, the nominal power, the type of user and Smart meters;
- Metering Information System IdSpecto: is the system dedicated to the computerized management of measurements and curves (non-hourly and with hourly treatment) coming from the Smart Meter - Electric Measurement Groups (GME);
- DSO Shared Servers;

Furthermore, DSO Technical Platform receives the following data from GIS and SCADA:

- Network topology;
- Network configuration;
- Network electrical model;
- MV and LV field measurements (busbar voltage and current module) coming from transducers;

In addition, DSOTP receives Weather Forecast data to be used to perform generation forecast.

To update the calculation algorithms, the DSOTP uses the quartorary curve of the users that participate in flexibility provided by the Shared Customer Database, as described in the next paragraph.

The DSO Technical Platform is therefore a complex system of several cooperating modules, bound to two different network management systems owning the real time snapshot of MV and LV network. This complexity, involving several dedicated service hosts, is hidden to other *Platone (Italian Demo)* systems as DSOTP shows a set of API endpoints (dedicated to REST client of *Platone*) and an MQTT broker for message oriented protocols, especially dedicated to Light-Node communication.

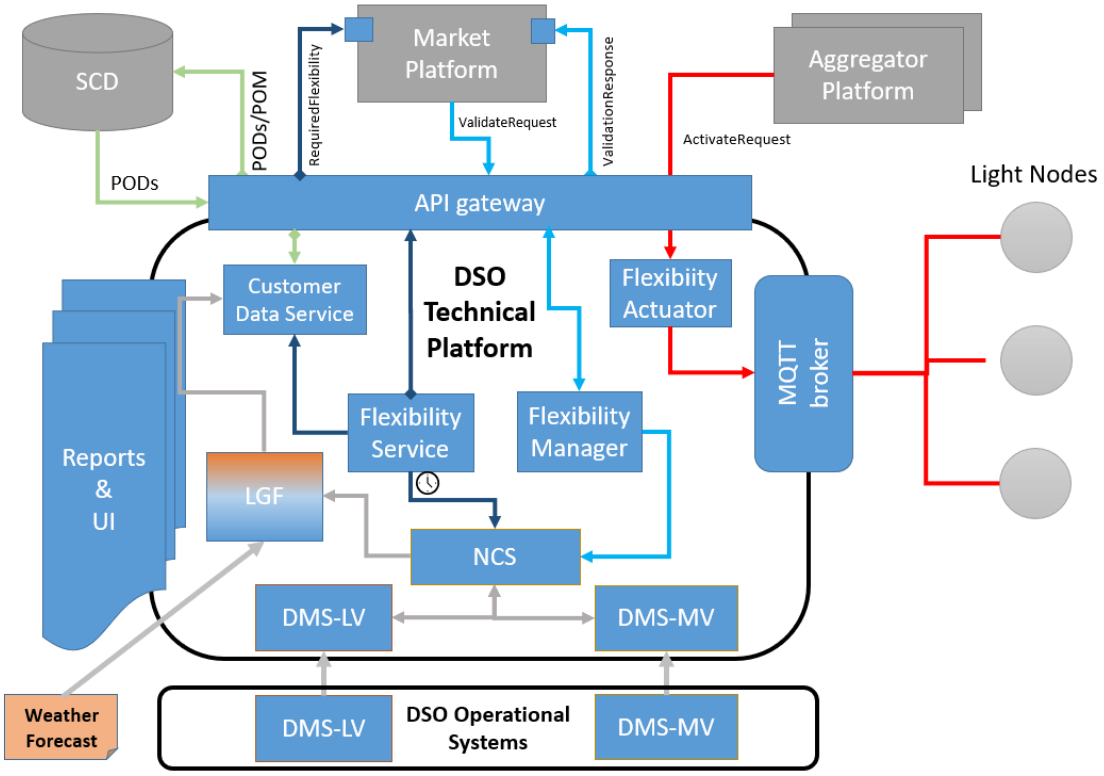


Figure 32: Components and boundaries of DSOTP

Figure 32 shows boundaries of DSOTP respect to all components involved in data defined by use cases, grouping them by colours. Green arrows are PoDs lifetime related flows, blue and cyan arrows are about flexibility requests and validations, red arrows stand for setpoints actuations while grey arrows are DSOTP internal flows requirements or alignment processes with the on-line DSO Operational Systems.

It also offers a picture of some DSOTP internal components (whose structure is out of the scope of this document) in order to put evidence onto complexity of the system itself and uniquely naming some component that could be referenced in this and following documents. It is also clear that DSOTP involves a direct communication channel with DSO Operational Systems (DMS-LV and DMS-MV) to be continuously synchronized with real time network situation; in addition, the connection of DSOTP (i.e. “Load & Generation Forecast” tool) to Weather Forecast data is shown.

The NCS block (Network Calculation System) includes, both for LV and MV network, uses the following algorithms:

- Power Flow
- Flexibility Requests function
- Flexibility Assessment function,

as described in paragraph A.3.2.2.

A.3.2.1 Data Layer

The Data Layer manages all the data necessary for the implementation of DSO Technical Platform services and it includes a relational database (PosgreSQL/Oracle) for the storage of the data.

A.3.2.2 Service Layer

The Service Layer is the core of the DSOTP and it includes all the services that implement the functionalities offered by the platform. It is based on Java Spring Boot framework.

The Services implemented are the following:

Power Flow Analysis

All the algorithms dealing with Flexibility are based on an initial Power Flow run that, for the MV network, contemplates a symmetrical regime; the single MV plants (loads, generators) are considered according to a "PQ model" and the "Slack node" for each single computation coincides with the HV busbar at Primary Substation level.

The algorithm chosen to solve the Power Flow problem is the well know Newton Raphson method that uses the information about the first derivatives of the Power Flow equations.

The outputs provided by the Power Flow function are:

- voltage for each network bus
- current for each network branch
- active and reactive power flows for each branch
- active and reactive power flows for each transformer
- active and reactive network losses for each branch
- active and reactive losses for each transformer
- current congestions for each branch (including lines, transformers etc.) and voltage violations for each bus

Flexibility Requests function

This function finds the optimal customers' flexibility activation necessary to provide network services to the DSO and to guarantee a safe network operation. This evaluation considers congestion management and voltage profiles; the optimal dispatching of the flexibility is performed with the objective of minimizing the costs connected to the procurement and use of the flexibility resources.

In the *Platone (Italian Demo)*, DSO flexibility requests include:

- the lists of PoDs able to provide the requested services,
- the amount (e.g. kW in the related time-slot) to be provided.

Flexibility Assessment function

This function verifies all the customers' flexibility services (accepted by the Market Platform) considering the potential negative effect that they can bring on the electrical network and, therefore, validates/excludes them defining the final permitted flexibility service use. This evaluation is performed with the objective of maximizing the use of the flexibility services (up or down) not exceeding the operative distribution network constraints.

In the *Platone (Italian Demo)*, the single customers' flexibilities are characterized by different priorities that are treated as "penalty factors" in the function.

Flexibility functions approach

For both functions (Flexibility Requests and Assessment), the customers' flexibility options are represented by active and reactive power bands that are potentially available at PoD level (i.e. connection point between the user plant and the distribution network) deviating from the baseline profile. Moreover, considering the structure of the offered flexibility services, they are processed like a combination of "continuous services" (potential continuous increasing or decreasing of the exchanged power with the network) and "discrete services" (on/off flexibility activation).

For the MV network, a small degree of imbalance and a radial network configuration is considered so the functions are developed basing on sequential calculations of linear optimal power flow models and sensitivity analysis to achieve the expected objectives. These algorithms consider both the issues connected to congestion management or the flexibility services maximization (active power dispatching) while avoiding voltage problems (i.e. assuring the necessary reactive power dispatching).

A.3.2.3UI Layer

The DSOTP UI Layer includes different Web applications based on cutting-edge SPA (Single Page Application Standards) and built using HMTL5, CSS3, AngularJS, ReactJS framework; the integrated DMS-MV HMI is based on QT framework.

In addition, the DSOTP UI Layer provides specific Grafana Dashboards to track all the necessary logs and metrics of the whole workflow about flexibility services management (i.e. data exchange with Aggregator Platform, Market Platform etc.).

A.3.2.4Communication Layer

The DSOTP is equipped with interfaces to communicate with the other components and actors of the system. It uses two communication approaches to provide its services to other platforms: client / server and subscriber / publisher. These two modes successfully meet the needs of synchronous and asynchronous communication with the other elements of the system and ensure a high degree of scalability. In particular, the synchronous communication is necessary for the time-bounded communications that are requested when DSOTP processing is an input for the receiving platforms' processing: this is the case of the communication with the Market Platform, the Aggregator Platform and the SCD.

In the communication between the DSOTP and all the Light Nodes participating in the Platone Italian Demo the subscriber / publisher technology chosen guarantees extremely light message management, useful for limited devices, low bandwidth and high latency networks.

Furthermore, a reduced transport overhead and a mechanism for notifying interested parties of an abnormal disconnect, ensures a minimized data exchange that allows the reduction of network traffic, decreasing the impact on the end users.

DSOTP, as stated before, offers two main interfaces to accomplish the achievements of *Platone (Italian Demo)* and, moreover, one interface dedicated to human interaction with it:

1. **API gateway**: its aim is to expose all REST API DSOTP offers to other components and, internally, to offer a single endpoint for all REST calls that will be dispatched to external components API.
2. **MQTT broker**: dedicated to asynchronous communications, should primarily transmit setpoints from DSOTP to Light Nodes.
3. **Reports and UI**: aimed to report DSOTP computation status, flexibility request and insert parameters influencing computations aligned with DSO requirements. It also offers UI taken from DMS-LV and DMS-MV, as a clone of these components are part of the DSOTP itself.

Orthogonally to this interfaces, DSOTP and other *Platone (Italian Demo)* components should agree onto a security layer improving authentication and authorization.

A.3.3 Requirements and Technical Specifications

A.3.3.1 Actors

The DSO Technical Platform foresees the participation of many different actors, both persons and external systems.

Persons

- DSOTP Administrator, is the administrator of the DSP Technical Platform. He/she can:
  - Insert computation parameters.
  - Evaluate computed requirements.
  - Evaluate required services.

External Systems

- Market Platform, it is the system in charge of market clearing operations using flexibility requests and flexibility offers.
- Aggregator Platform, it is the system in charge of the creation of the flexibility offers.
- Shared Customer Database, it is the system that provides information about the creation/update of the PoDs and field measurements.
- The Light Node is a device, installed at DERs' premises that receives Setpoint from DSO Technical Platform and makes it available to Customer's Activation Systems (such EMS, smart appliance etc.) to activate flexibility.

A.3.3.2 Use Cases

To take an overall view of the different ways that a user/system might interact with the platform, you can see the following diagram:

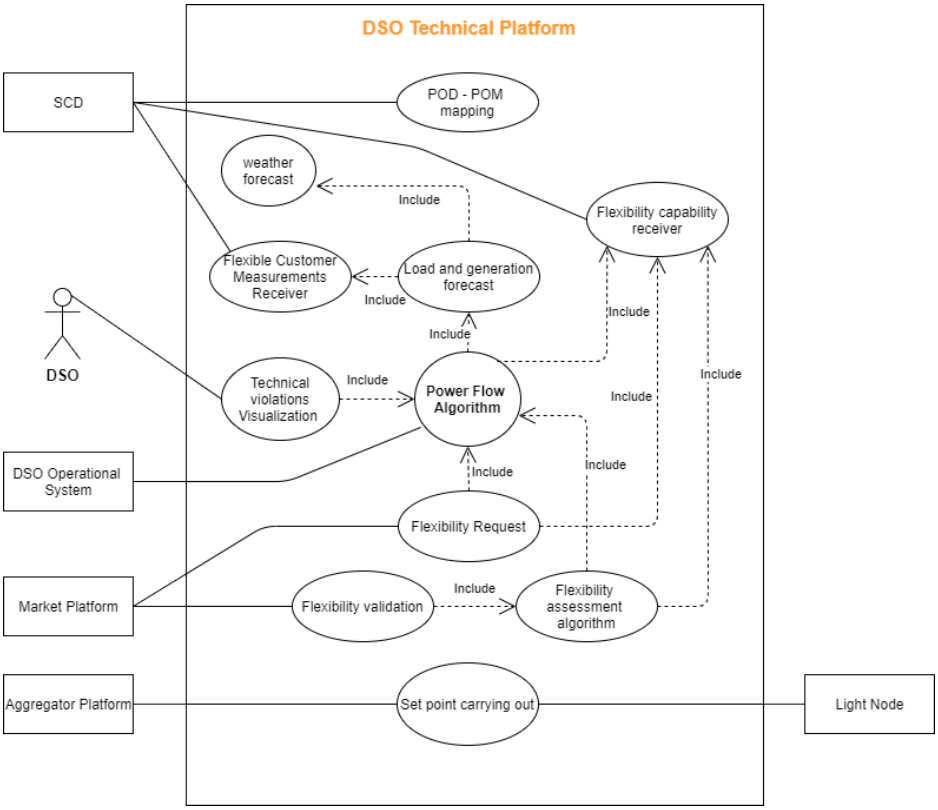


Figure 33: DSOTP UC Diagram

In the Italian Demo, the DSOTP has several tasks and we individuated four main use-cases:

- Power Flows Analysis
- Request Of Flexibility
- Assessment And Technical Validation Of Flexibility Offers
- Setpoint Carrying Out

Power Flows Analysis

The DSO Technical Platform includes all the basic components needed to perform a set of Power Flow runs providing an estimation of all the relevant electrical quantities (voltages, currents, active/reactive power flows, and losses) along the MV and LV distribution network involved in the Platone Italian Demo.

Starting from the Power Flow results and basing on configurable thresholds, the DSO Technical Platform detects (for each future time slot) the technical issues on the distribution network such as voltage violations on grid nodes and current overloads on branches (including lines, transformers etc.).

The DSO Technical Platform Power Flows are performed on:

- the LV network (starting from the LV busbar of each Secondary Substation transformer) that has at least one active LV customer involved in the Platone Italian Demo;
- the MV network (starting from the HV busbar of each Primary Substation) that includes at least one active customer (LV or MV) involved in the Platone Italian Demo.

All the MV/LV Secondary Substation transformers that do not include any LV customers involved in the Platone Italian Demo are modelled considering an aggregated approach (by means transformers suppling the relevant LV lumped load).

Part of the results provided by the LV Power Flows (active and reactive power flows on the LV side of the MV/LV transformer) are used as an input for the MV Power Flows run at the upper hierarchical level.

The DSO Technical Platform receives from the on-line SCADA systems the topology of the network, all the electrical data and the necessary dynamic data to set up the reference network configuration that is used for the different Power Flow simulation time slots.

Forecasting tool for productions and consumptions

The DSO Technical Platform includes specific tools that, both for the MV and LV customers, perform a load and generation forecast.

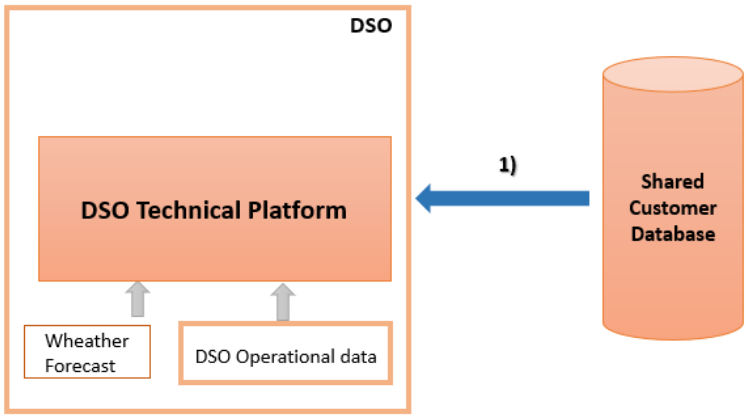


Figure 34: Input for the Forecasting tool

The generation forecast considers all the relevant technical data for each generation plant and dynamic data like weather forecast for renewable resources (PV, wind) and historical data processing for all the other plants.

The load forecast tool produces a set of “standard” typical load profiles for each MV and LV customer (for the parts of the network that don’t include any LV customers involved in the Platone Italian Demo, the LV level is aggregated under the MV/LV transformer). The general approach considers three typical profiles (weekday, Saturday, Sunday/holiday) for each month of the year.

All these data are reprocessed by the forecast tools (for example once a month) considering the new data coming from the field devices (i.e. by means Shared Customer Database and SCADA systems).

All the generation and load data produced by these forecasting tools represent one of the most significant inputs for the DSO Technical Platform Power Flow simulations; the reference time slot is 15 minutes.

In Figure 35, a high-level Use Case diagram that represents the DSOTP and the functional requirements related to Power Flow services mechanisms.

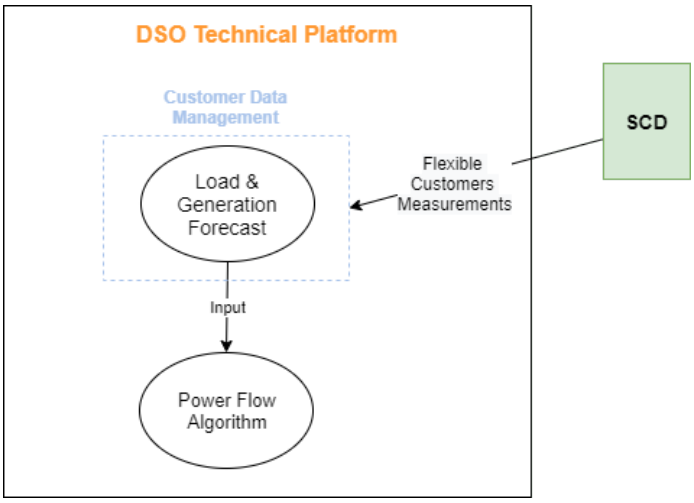


Figure 35: Power Flow UC Diagram

Table 12: Power Flow functional requirements

Requirement Id	**FR_DTP_PFA_1**
Description	DSOTP is able to receive measurement of the flexible customer coming from the SCD and Operational System to refine the load and generation forecast
Implementation	1. DSOTP uses a Shared Customer Database REST API to request the measurements of the flexible customer
First Release	No

Requirement Id	**FR_DTP_PFA_2**
Description	DSOTP is able to receive information coming from the DSO Operational System
Implementation	1. Loading network configuration; 2. Loading network electrical model; 3. Loading network topography;

First Release	Yes

Request Of Flexibility

The DSO Technical Platform implements a “flexibility request” algorithm that is triggered only if some technical violations (voltage and/or current) are detected on the distribution network while running the set of Power Flows on the reference time window. It’s important to consider that the Power Flows for the “day-ahead” are using baseline profiles for customers involved in the Platone Italian Demo and load & generation forecast for others customers; in the “real-time” Power Flows, the flexibility services already accepted in the “day-ahead” replace the baseline profiles for customers involved in the Platone Italian Demo.

Starting from the described basic network scenarios, the “flexibility request” algorithm applies a specific optimization approach able to find, among the MV and LV customers that are actively involved in the project (i.e. available to provide flexibility services), those that can more effectively solve the DSO technical issues.

The final result of the algorithm is a set of aggregated MV and LV customers (identified with different PoD lists) including, for each timeslot, the requested power profile; this data is the content of the “flexibility requests” that the DSO will put into the Market Place (**Arrow 2c** –Figure 36).

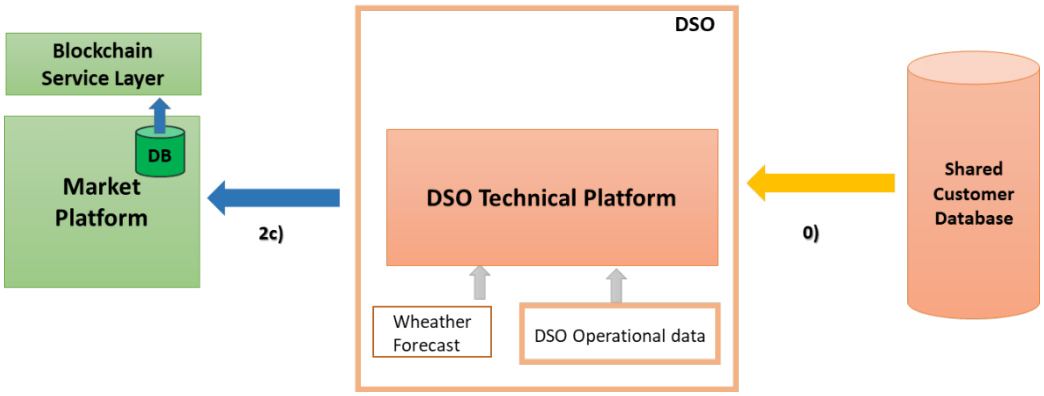


Figure 36: Request of Flexibility workflow

Detailed inputs regarding the flexibility services and the baseline profiles that the LV and MV customers involved in the Platone Italian Demo can provide are made available to DSO Technical Platform through the Shared Customer Database (**Arrow 0** –Figure 36).

In Figure 37, a high-level Use Case diagram that represents the DSOTP and the functional requirements related to Request of Flexibility services mechanisms.

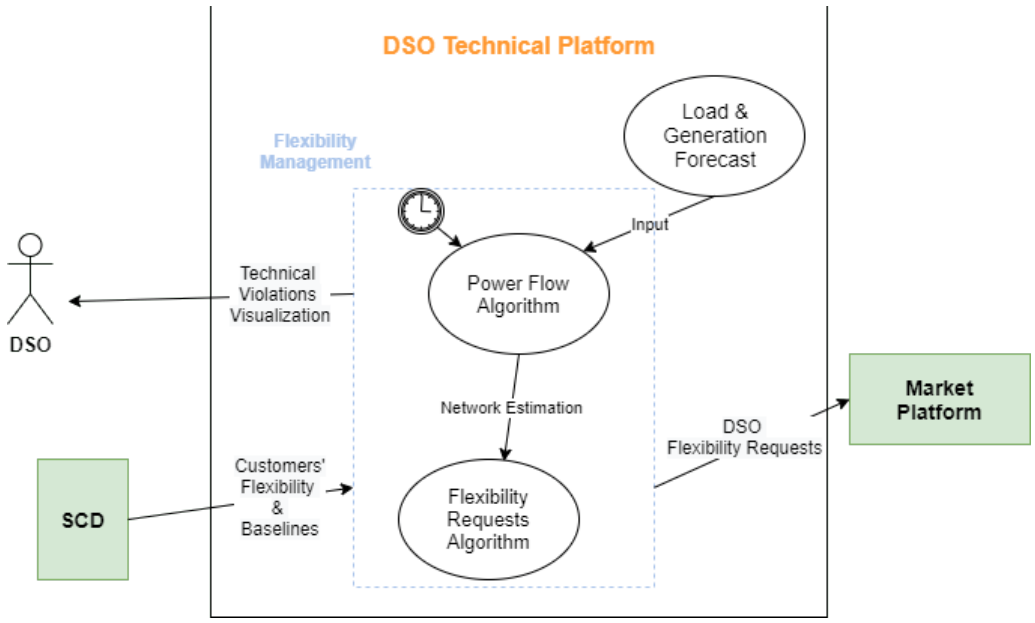


Figure 37: Request of Flexibility UC Diagram

Table 13: Request of Flexibility functional requirements

Requirement Id	FR_DTP_ROF_1
Description	DSOTP is able to receive information about PoDs entering or exiting the flexibility market and manage their persistence at DSOTP side.
Implementation	1. DSOTP starts with an empty shared flexible PoDs archive 2. DSOTP implements a REST API allowing SCD to send data about PoDs lifecycle changes
First Release	Yes

Requirement Id	FR_DTP_ROF_2
Description	DSOTP is able to offer mapping between PoDs and PoM (Point of Measure is the connection point between TSO and DSO where the service requested by TSO must be delivered).
Implementation	1. DSOTP starts with an empty PoDs-PoM mapping 2. DSOTP map each new PoD arriving with flow 0 to the right PoM 3. DSOTP uses a SCD REST-API to send PoDs-PoM mapping
First Release	Yes

Requirement Id	FR_DTP_ROF_3

Description	DSOTP is able to define a set of PoDs that DSO requires to solve its congestions or voltage limit violations and send them to Market Platform.
Implementation	1. DSOTP periodically checks its technical situation starting from the current network status 2. DSOTP evaluates which PoDs can solve problems eventually found 3. DSOTP uses a Market Platform REST API to send its flexibility requirement marking them with a request ID
First Release	Yes

Requirement Id	**FR_DTP_ROF_4**
Description	DSOTP is able to show to an Operator possible technical violation on the grid
Implementation	1. DSO implements an Human Machine Interface (HMI) to show the results of the power flow
First Release	Yes

Assessment And Technical Validation Of Flexibility Offers

The DSO Technical Platform implements a "flexibility assessment" algorithm that is triggered by the Market Platform after every "day-ahead" and "real-time" market session. It's important to consider that in this phase of the process the purpose of the flexibility services (i.e. fulfil DSO or TSO requests) is completely not relevant for the DSO Technical Platform.

The preliminary step also for this function is to run a set of Power Flows (on the reference time window) applying the selected flexibility services received from the Market Platform for the customers involved in the Platone Italian Demo.

Starting from the described basic network scenarios, the "flexibility assessment" algorithm applies a specific optimization approach able to exclude properly some of the flexibility services selected by the Market Place (**Arrow 3** –Figure 38) with the final goal of fixing potential critical situations on network constraints and restore safety operation on the DSO network. Performing the technical assessment, the algorithm considers the offers' "priority" order provided by Market Platform.

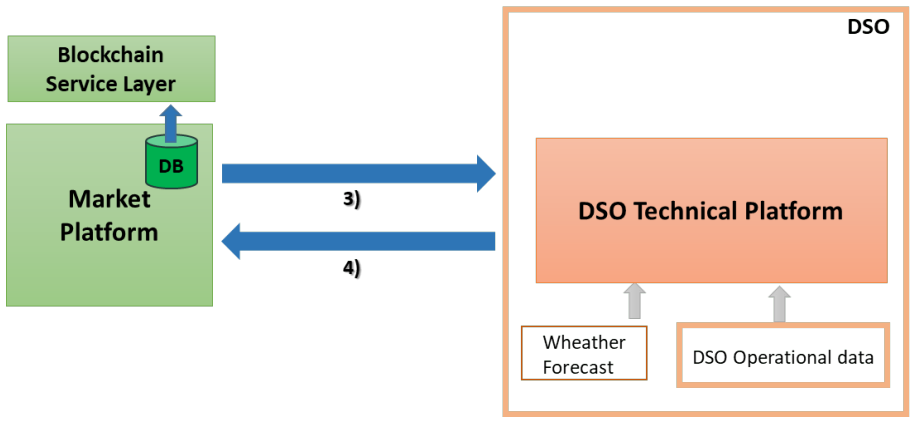


Figure 38: Assessment and technical validation workflow

The final result of the algorithm is a list that considers all the MV and LV customers pre-selected by the Market Place (identified with the PoD code) including, for each timeslot, the result of the technical assessment (i.e. KO or OK also with partial service acceptance; **Arrow 4** –Figure 38). If there are no flexibility services that bring to technical violations (voltage and/or current) on the network, all of them will be accepted by the DSO Technical Platform.

In Figure 39, a high-level Use Case diagram that represents the DSOTP and the functional requirements related to Assessment and Technical Validation services mechanisms.

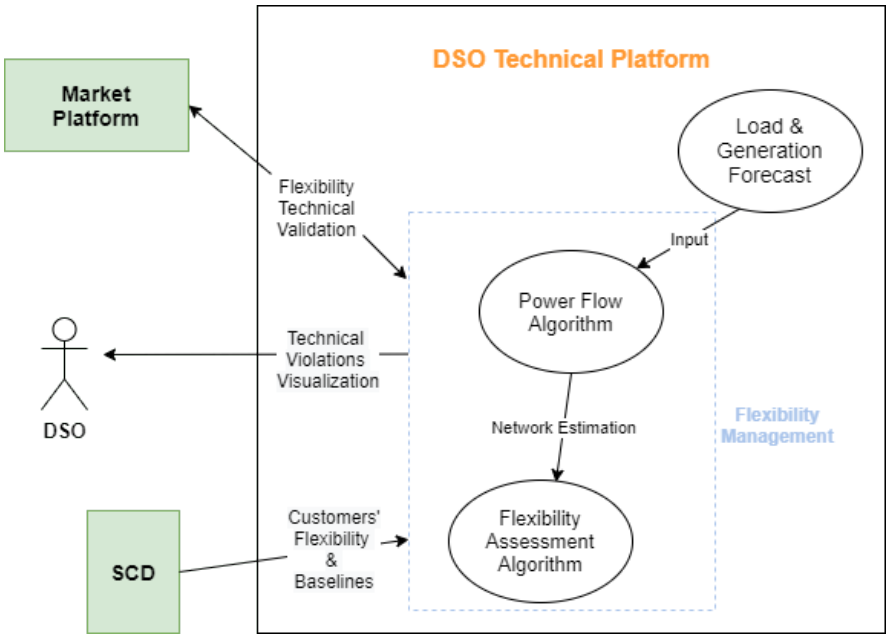


Figure 39: Assessment and Technical Validation UC Diagram

Table 14: Assessment and Technical Validation functional requirements

Requirement Id	**FR_DTP_ATV_1**
Description	DSOTP is able to receive Market Platform flexibility services outcomes
Implementation	1. DSOTP starts with a snapshot of the real time network status 2. DSOTP offers a REST API allowing Market Platform to send new flexibility validation requests for a given time interval marked by a Market Outcome ID.
First Release	Yes

Requirement Id	**FR_DTP_ATV_2**
Description	DSOTP is able to inform Market Platform about its flexibility services outcomes acceptance or refusal.
Implementation	1. DSOTP starts with Market Platform outcomes received in flow 3

	2. DSOTP validates them against network current status across the entire required time interval 3. DSOTP uses a Market Platform REST API to send outcomes technical acceptance or refusal, marked with the same outcomes ID used by Market Platform
First Release	Yes

Requirement Id	**FR_DTP_ATV_3**
Description	DSOTP is able to receive final Market Platform outcomes.
Implementation	1. Market Place offers to DSOTP (broker Kafka) the definitive outcomes for the next time slice. 2. To be defined
First Release	No

Setpoint Carrying Out

According to a pre-defined schedule, the DSO Technical Platform receives the overall activation for all the flexibility services (for DSO and TSO) from the Aggregator Platform (**Arrow 6** –Figure 40) and forwards the setpoints to the Light Nodes involved in the flexibility service activation (**Arrow 6**). This setpoint data is sent all together (one shot) immediately before the "activation" slot and it contains, for each time slot (15 minutes), the requested power profile at the point of common coupling of the customer, that is the PoD.

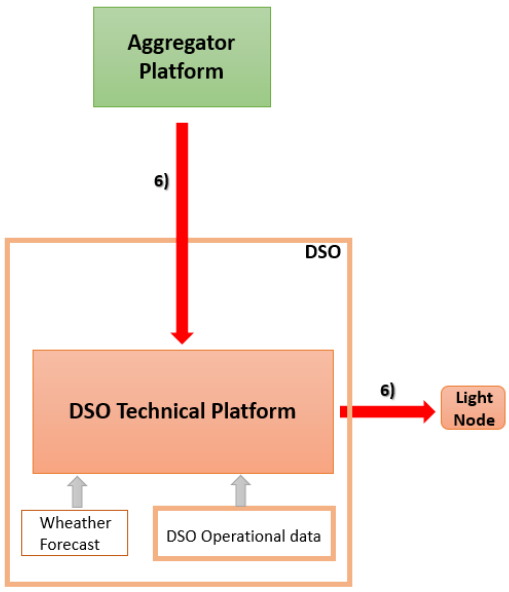


Figure 40: Setpoint Carrying Out workflow

In Figure 41, a high-level Use Case diagram that represents the DSOTP and the functional requirements related to Activation Request services mechanisms.

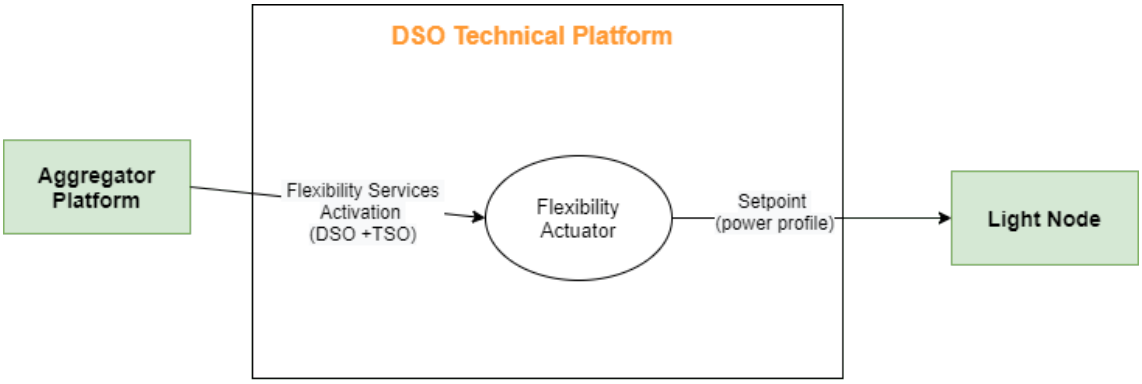


Figure 41: Setpoint Carrying Out UC Diagram

Table 15: Setpoint Carrying Out functional requirements

Requirement Id	**FR_DTP_SCO_1**
Description	DSOTP is able to receive accepted flexibility outcome as setpoints to be pushed toward Light Nodes
Implementation	1. DSOTP offers Aggregator Platforms a REST API to receive PoDs setpoints to be activated (marked by an Aggregator ID) 2. DSOTP manages Aggregator Platforms requests in order to send them to Light Nodes
First Release	Yes

Requirement Id	**FR_DTP_SCO_2**
Description	DSOTP manages a MQTT broker dedicated to DSOTP and Light Nodes communication about setpoints
Implementation	1. DSOTP setups and manages a MQTT broker 2. DSOTP publishes incoming PoDs setpoints onto each Light Node dedicated MQTT topics 3. DSOTP receives Light Node acknowledgment subscribing a dedicated MQTT topic.
First Release	Yes

A.3.3.1 User Interfaces

The MV-DMS HMI shows the topological view of the network.

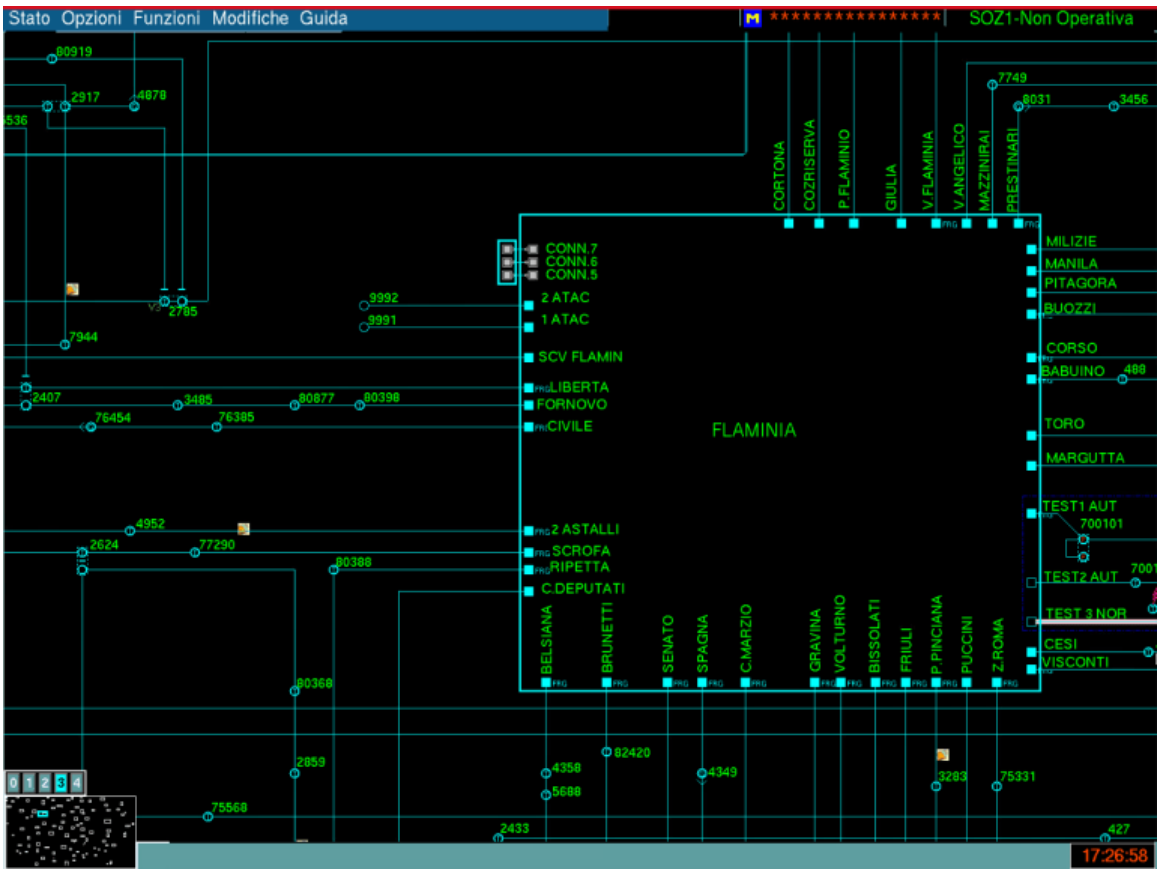


Figure 42: Network Topology View

The Web application “Schematica” shows the topological view of the network in a browser.

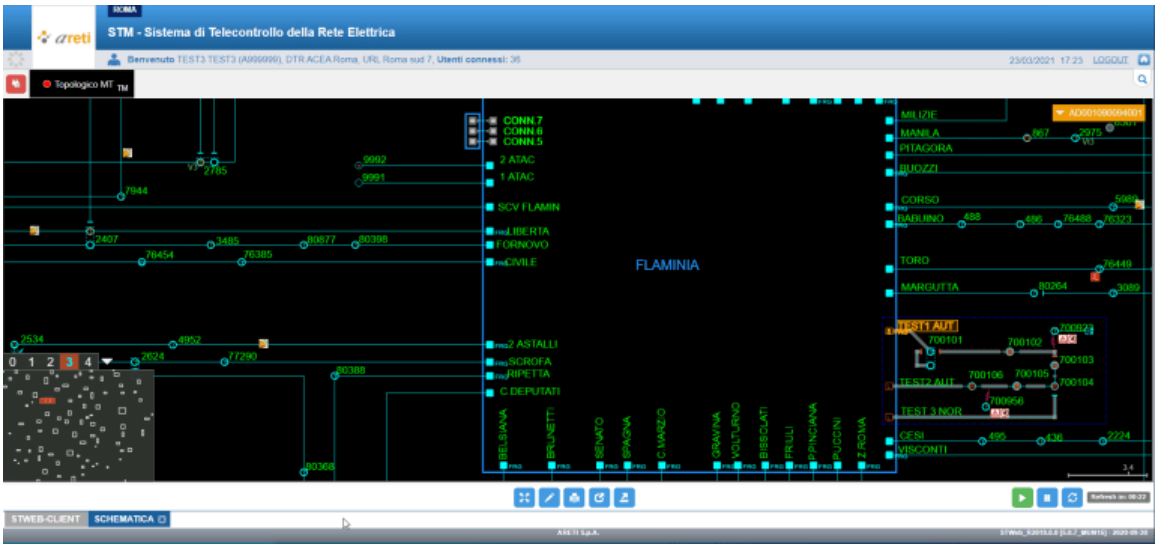


Figure 43: Schematica - Browser Network Topology View

The Web application “Load Profiles Estimator” shows all the data about the typical load profiles calculated for the MV-LV Transformers and MV Customers.

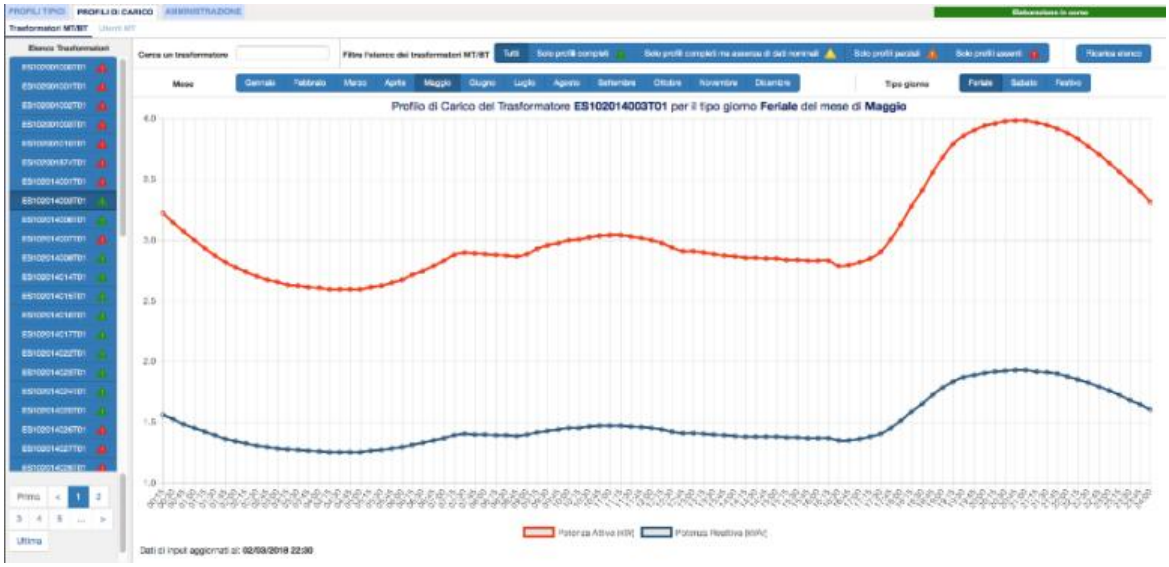


Figure 44: Load Profiles Estimator – MV/LV Transformer

Figure 45: Load Profiles Estimator – MV Customers

The Web application “Load & Generation Forecast” shows all the calculated data (also in aggregated form) for the MV-LV Transformers and MV Customers.

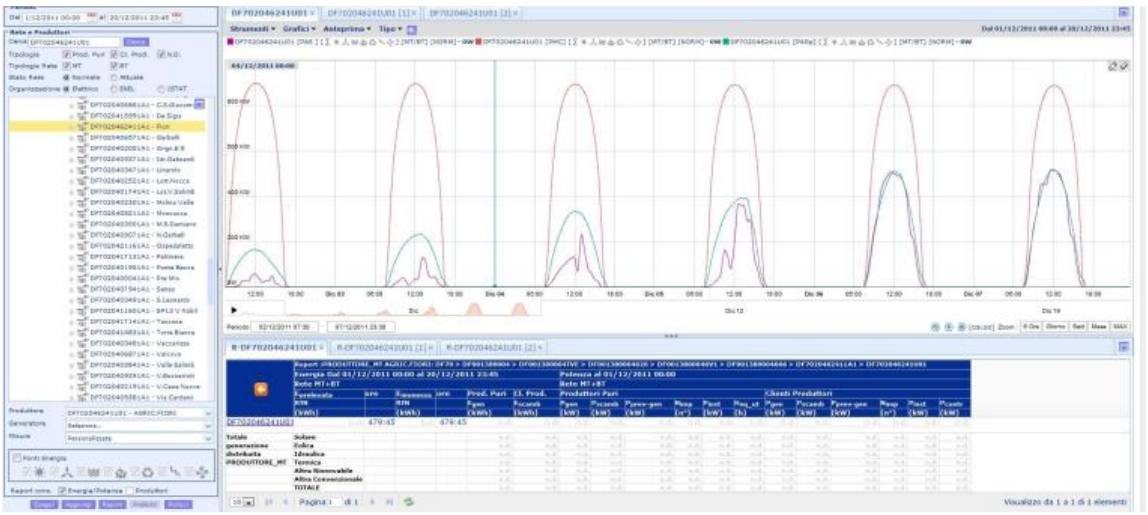
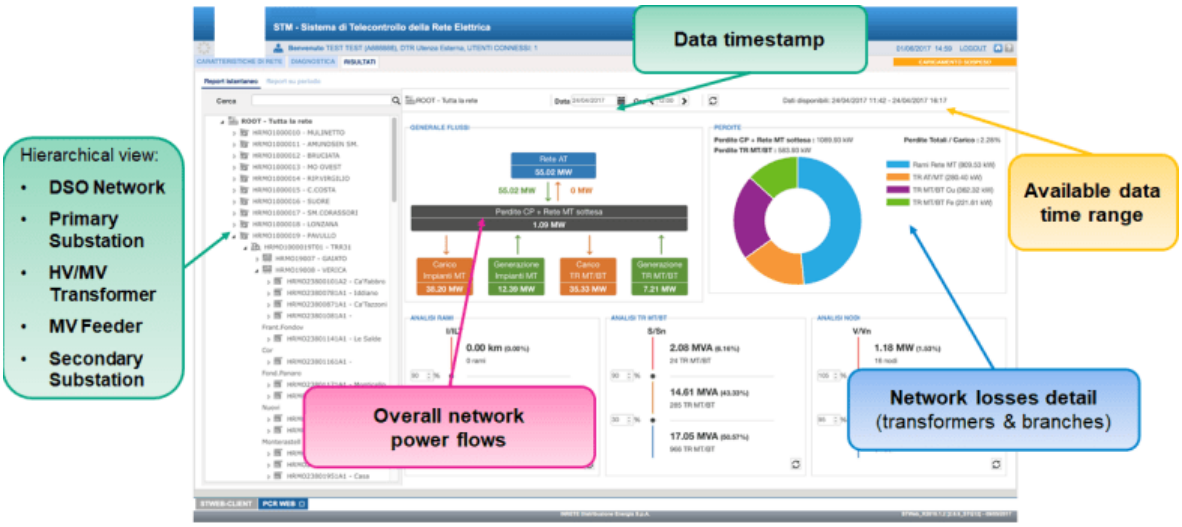


Figure 46: Load & Generation Forecast

The Web application “Network Calculation System HMI” shows the estimated network power flows, losses and some specific indexes about potential critical situations on technical constraints.



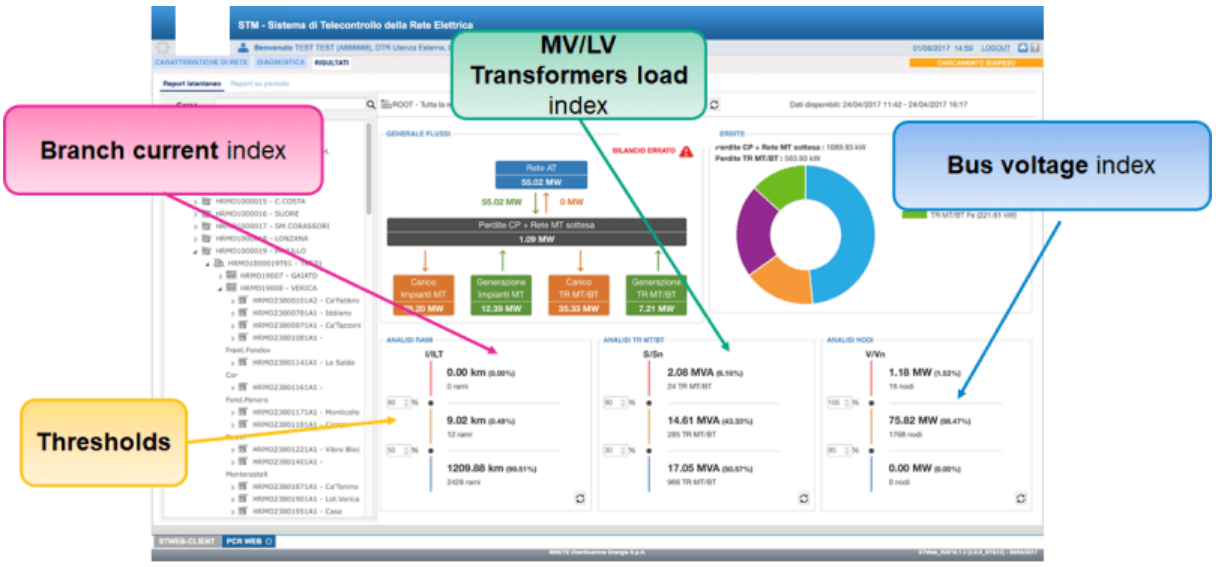


Figure 47: Network Calculation System HMI

Another Web application shows the list of alarms on the network elements where there are estimated violations of technical constraints.

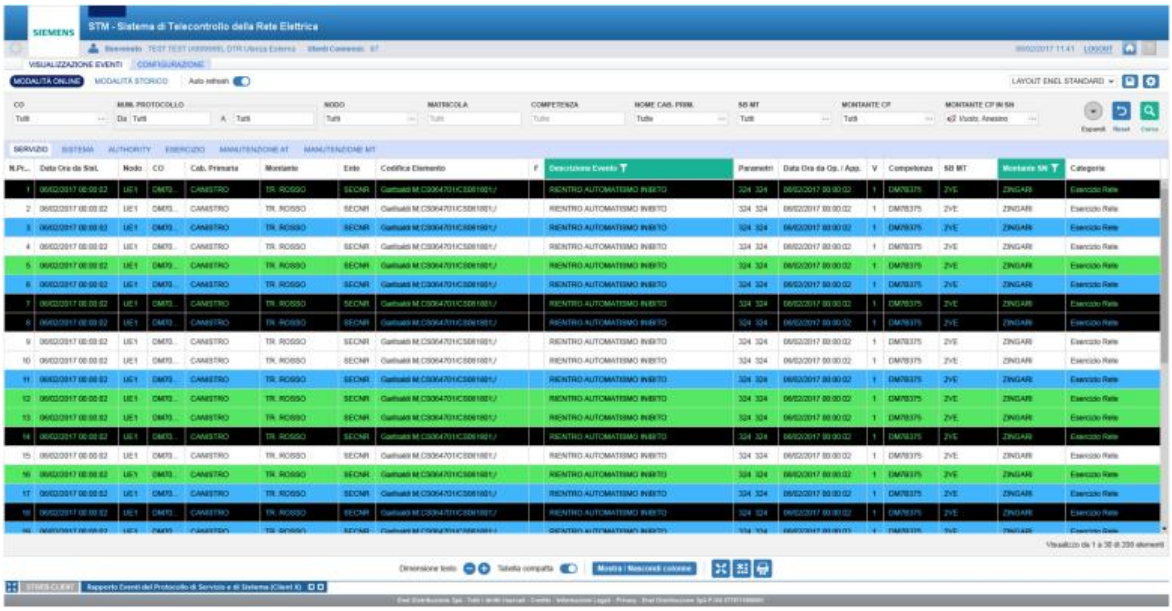


Figure 48: Network Elements List of Alarms

The following Grafana Dashboards show all the additional information about the processes *Flexibility Requests*, *Flexibility Services Validation* and *Flexibility Services Activation*. These are only as “example approach”, because the related functionalities are now in developing phase and will be release in during the next release.

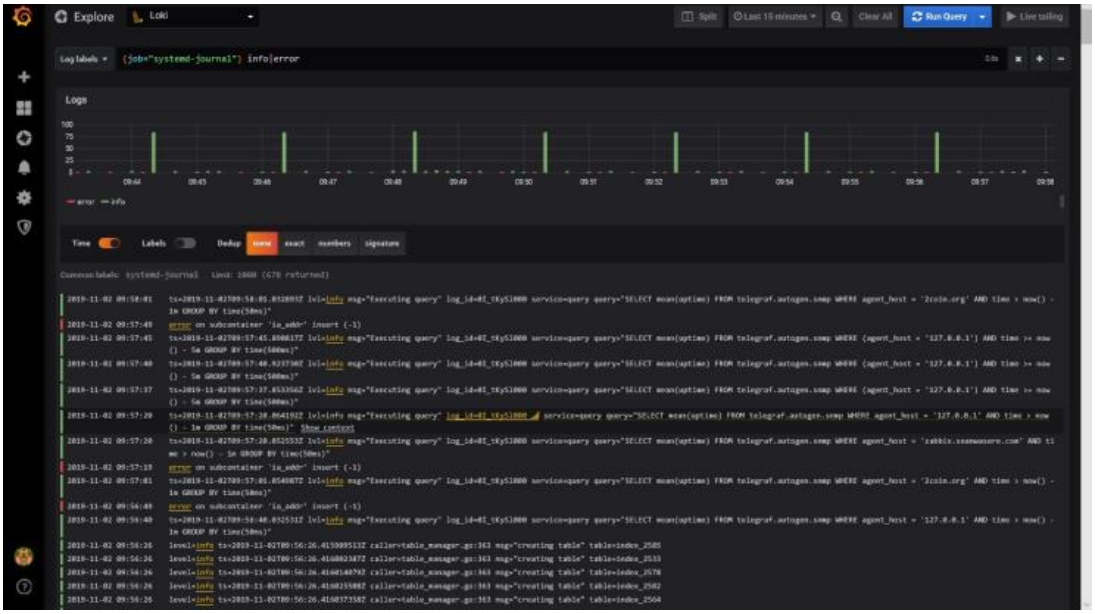


Figure 49: Example of Grafana Dashboards - Flexibility Requests and Flexibility services validation process

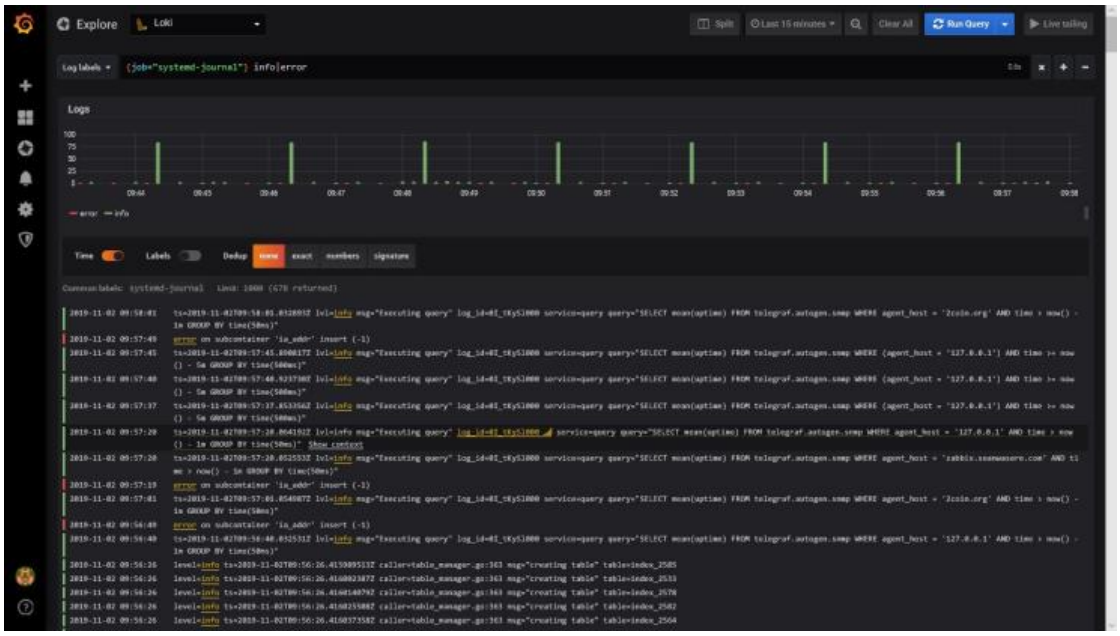


Figure 50: Example of Grafana Dashboards - Flexibility services activation process

A.4 Access Layer

A.4.1 Overview

The Blockchain Access Layer (BAL) and the Light Node (LN) are the two crucial components of Access Layer in the Italian Demo (WP3).

The Light Node is the contact point between Metering (LV/MV Meter) and Customer's Activation Systems (EMS). Moreover, it is an access point to the Blockchain Access Layer through which the Metering and Activation data can be exchanged.

The Blockchain Access Layer connects the Light Node to the Shared Customer Database ensuring, by means of timestamping features, the immutability of data along the whole path.

In particular, Light Node and Blockchain Access Layer allow the Italian Demo to:

- Take the *Metering Data* from *Electric Meter*;
- Receive Set-Point that comes from the DSO T.P and make this available to Customer's EMS;
- Add Timestamping to Metering and Set-Point data;
- Send Data and Timestamping to the Shared Customer Database;
- Detect Communication and other Anomalies (Light Node Issues, EMS Issues, Blockchain Access Layer Issues).

A.4.2 Architecture

The Blockchain Access Layer consists of a five-layer architecture:

- **UI Layer** includes an easy-to-use web dashboard that allows all the stakeholders to explore Blockchain Transactions and DSOs to monitor the Light Node's status;
- **Services Layer** provides the business logic, including the Shared Customer Database communication, Timestamping services and Smart Contract Services;
- **Data Layer** provides the management of the Blockchain Access Layer and Light Node data and the registration of Timestamping Information of Light Node (Metering and Set-Point).
- **MQTT BROKER** provides bi-directional communication channel with the connected Light Node;
- **Blockchain Layer** provides the Distributed Ledger Technology (DLT) features, in Blockchain Infrastructure transactions are arranged in blocks, and placed in a P2P network.

The Light Node is an edge device that consists of two layers and two interfaces:

- ***MQTT Client*** provides connection to the DSOTP and the Blockchain Access Layer;
- ***Identity Layer*** provides a digital identity (public and a private keys) for the Light Node to signs and sends data packet to Blockchain Access Layer;
- ***EMS Interface*** interacts with several Energy Management Systems (for example Battery Management Systems, Smart Homes Devices, Power Plant Management Systems);
- ***Meter Interface*** interacts with several Meters technologies (for example Low Voltage and Medium Voltage Meters).

The Access Layer complete architecture is shown in Figure 51:

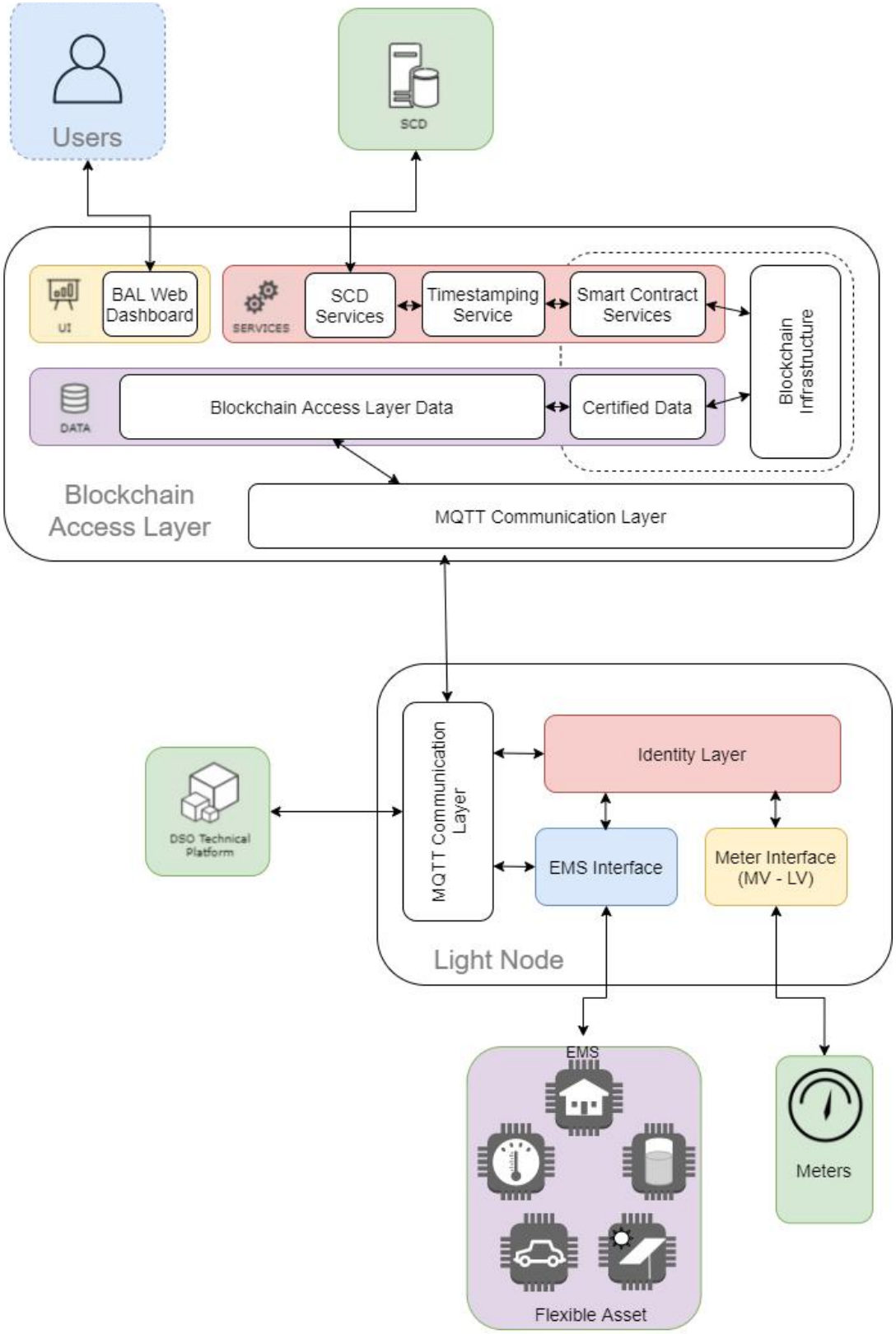


Figure 51: Access Layer Architecture

Additional information concerning Blockchain Access Layer and Light Node architecture and components are available in report D3.2 [11].

A.4.3 Requirements and Technical Specifications

A.4.3.1 Actors

The Access Layer foresees the participation of different actors, both persons and external systems.

Persons

- DSO, (s)he has access to the web dashboard and (s)he is able to view all the Transactions and Light Nodes status in the UI
- Market Authority, (s)he has access to the web dashboard and (s)he is able to view all the Transactions in the UI

External Systems

- DSO Technical Platform, it is the system in charge of sending set-point to the Light Nodes connected;
- Shared Customer Database, it is the system that receives the certified information and anomalies of Light Nodes.

A.4.3.2Use Cases

In the Italian Demo, the Access Layer has several tasks and we identified four main use-cases:

- Light Node - Retrieve metering data
- Light Node - Set-Point Management
- Blockchain Access Layer – Timestamp and send to SCD
- Blockchain Access Layer – Anomalies Detection

Light Node - Retrieve metering data

The Light Node communicates with the Electric Meter in three different ways that can be activated in the configuration phase of device.

Communication channel depends on electric meter capabilities:

- ***Medium Voltage meters*** integration through an Industrial Protocol (Modbus TCP or Modbus RTU);
- ***Low Voltage Smart Meters*** integration through powerline interface (PLC-C as known as Chain 2);
- ***Low Voltage Meters (not smart)*** integration through additional meters (smart devices capable to retrieve the necessary electrical parameters).

In Figure 52 a high-level Use Case diagram and the functional requirements of the metering data sending mechanism.

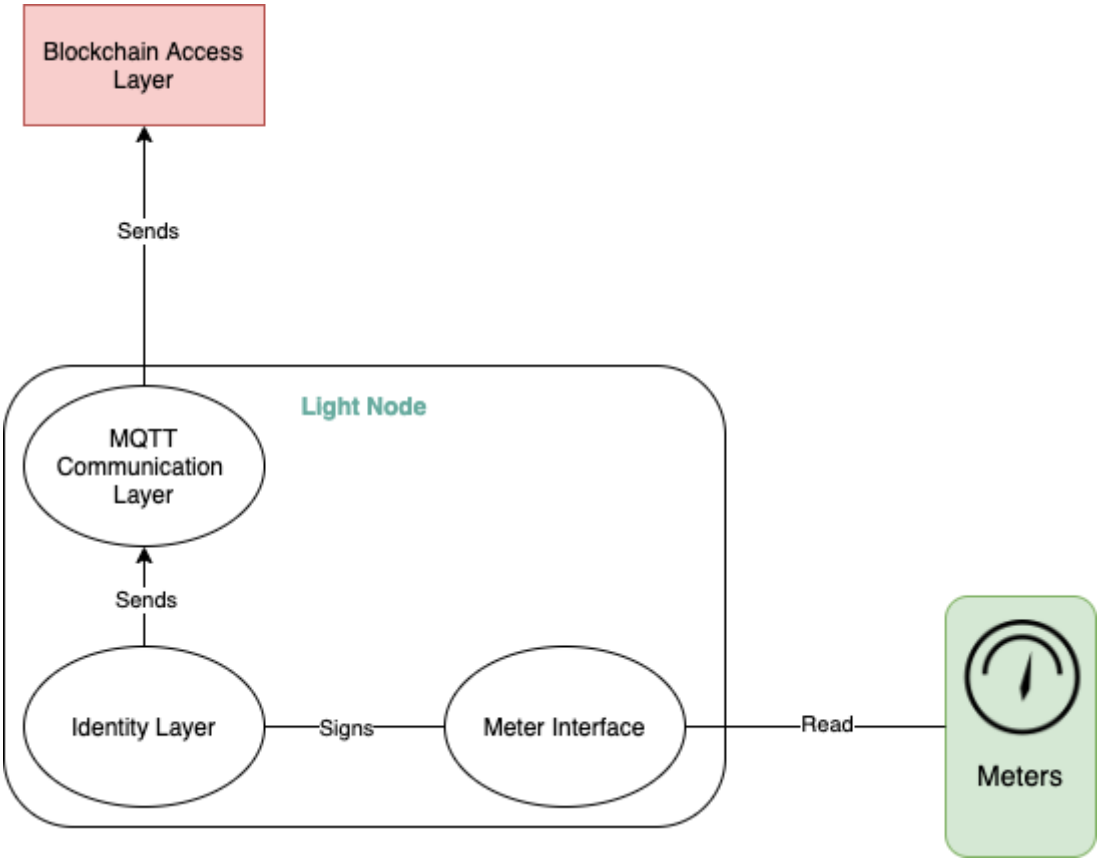


Figure 52: Light Node UC Diagram – Retrieve Metering Data

Requirements to perform Retrieve meter data services are listed in Table 16.

Table 16: Light Node Retrieve Metering Data Technical Requirements

Requirement Id	FR_LN_RMD_1
Description	Light Node retrieves metering data from Meters (LV/MV)
Implementation	1. The Light Node retrieves from the configuration a list of physical interfaces used to communicate with Meters. 2. The Light Node initiates the communication to each connected Meter by sending the appropriate payload. 3. The Light Node receives responses from each meter. 4. The Light Node translate data received from each meter, applying the appropriate encoding.
First Release	Yes

Requirement Id	FR_LN_RMD_2
Description	Light Node signs with Identity the metering data (Hash / Signs)
Implementation	1. Light Node signs every reading received from Meters with an appropriate hash function and by providing its own Identity.

First Release	Yes

Requirement Id	FR_LN_RMD_3
Description	Light Node sends through MQTT communication layer the signed packet data
Implementation	1. Light Node is connected to the Blockchain Access Layer through MQTT. 2. Light Node sends each signed measurement to the Blockchain Access Layer through MQTT.
First Release	Yes

Light Node - Set-Point Management

The DSOTP communicates with Light Node through MQTT protocol. In Figure 53 is shown a high-level Use Case diagram and the functional requirements of Light Node related to set-point management mechanism.

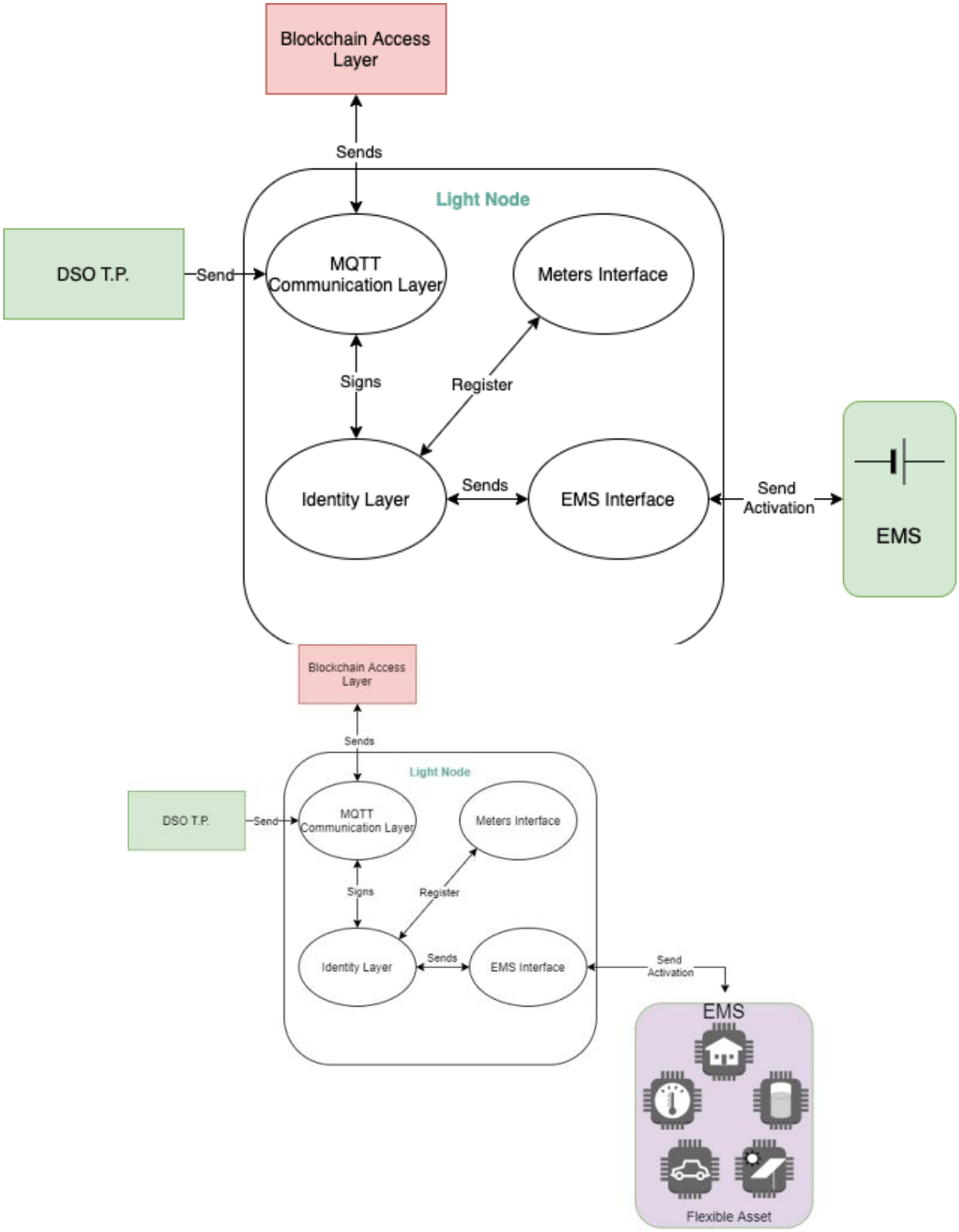


Figure 53: Light Node UC diagram - Set Point Management

Requirements to perform Set Point Management services are listed in Table 17.

Table 17: Light Node Set Point Management Technical Requirements

Requirement Id	FR_LN_SM_1
Description	Light Node receives Set-Point from DSOTP through MQTT protocol
Implementation	1. Each Light Node is connected to the DSOTP through MQTT and it is SUBSCRIBED to a topic which is unique for its PoD. 2. Each Light Node receives Set-Point data by listening for messages on the unique topic.
First Release	Yes

Requirement Id	FR_LN_SM_2
Description	Light Node signs with Identity Layer the Set-Point received
Implementation	1. When the Light Node receives a set-point from the DSOTP, it signs the Set-Point with its own Identity by calling an appropriate hash function.
First Release	Yes

Requirement Id	FR_LN_SM_3
Description	Light Node sends Set-Point to the Meters Interface
Implementation	1. The Light Node retrieves from the configuration a list of physical interfaces used to communicate with Meters. 2. The Light Node initiates the communication to each connected Meter by sending the appropriate serial command with Set-Point data.
First Release	Yes

Requirement Id	FR_LN_SM_4
Description	Light Node sends Set-Point to the Customer's EMS and registers its response (where applicable)
Implementation	1. The Light Node retrieves from the configuration a list of physical interfaces used to communicate with EMSs. 2. The Light Node sends Set-Point data to the EMS. 3. The Light Node receives the EMS response
First Release	Yes

Requirement Id	FR_LN_SM_5
Description	Light Node sends to Blockchain Access Layer the whole data packet composed by Set-Point and EMS Response (it contains also hash and sign).
Implementation	1. The Light Node signs a data structure containing Set-Point data and EMS Response. 2. The Light Node sends the signed data structure to the Blockchain Access Layer by publishing it on the appropriate MQTT topic.
First Release	Yes

In particular, *the DSOTP sends the Activation Service to the Light Node*. The output of the DSOTP contains the following parameters:

Table 18: Activation Service

Field	Type	Description
PoD	String	PoD Identifier
ActivationId	String	Activation Identifier
Set-Point	Array	An array of 16 elements composed of: - active and reactive power - activation quarter of an hour
Timestamp	Date	Date and Time of the Status Message

The *MQTT Communication Layer* then signs the Activation Service Data Packet through the Identity Layer. The Activation Service Data Packet:

- Registers the *Set-point* on *Meter Interface* to send the correct data packet (meter and set-point) during the *Activation Service*;
- Sends the *Set-Point* to the *EMS Interface.*

The *EMS Interface* then sends the *Set-Point* to the *Customer's EMS*. The communication protocol used depends on the EMS installed at customer side:

- Industrial Use-Case: In this environment, the communication protocol is Modbus RTU or Modbus TCP;
- Energy Community Use-Case: In this environment, the communication protocol is REST API or MQTT;
- Electric Vehicle Charger Use-Case: the communication protocol is REST-API or Modbus RTU or Modbus TCP.

Based on EMS's communication protocol, the EMS Interface read EMS Response. Then the EMS Interface, through MQTT Communication Layer, sends the Activation Data-Set to the Blockchain Access Layer signed by the Identity Layer. The output of the MQTT Communication Layer to the Blockchain Access Layer contains the following parameters:

Table 19: Activation Data-Set

Field	Type	Description
PoD	String	PoD Identifier
Hash	String	Hash of the Input Data Field
SignedHash	String	Signature of the Hash Field made through ECDSA algorithm
PublicKey	String	Public Key linked to the private key used to sign the hash
InputData	Object	Metering and Setpoint packet data

The input data object is composed by:

Field	Type	Description
ActivationId	String	Activation Identifier
Set-Point	Array	An array of 16 elements composed by active and reactive power set-point
Status	Array	An Array of three elements showing respectively timestamps of follow events; - DSOTP send Set-Point; - Light Node receives Set-Point; - Customer's EMS receives Set-Point.

Blockchain Access Layer – Timestamp and send to SCD

The Light Node exchange Measurements and Setpoint data with Blockchain Access Layer using MQTT communication protocol. In Figure 54 is represented a high-level Use Case diagram and the functional requirements of the Blockchain Access Layer related to Timestamp and Send to SCD mechanism.

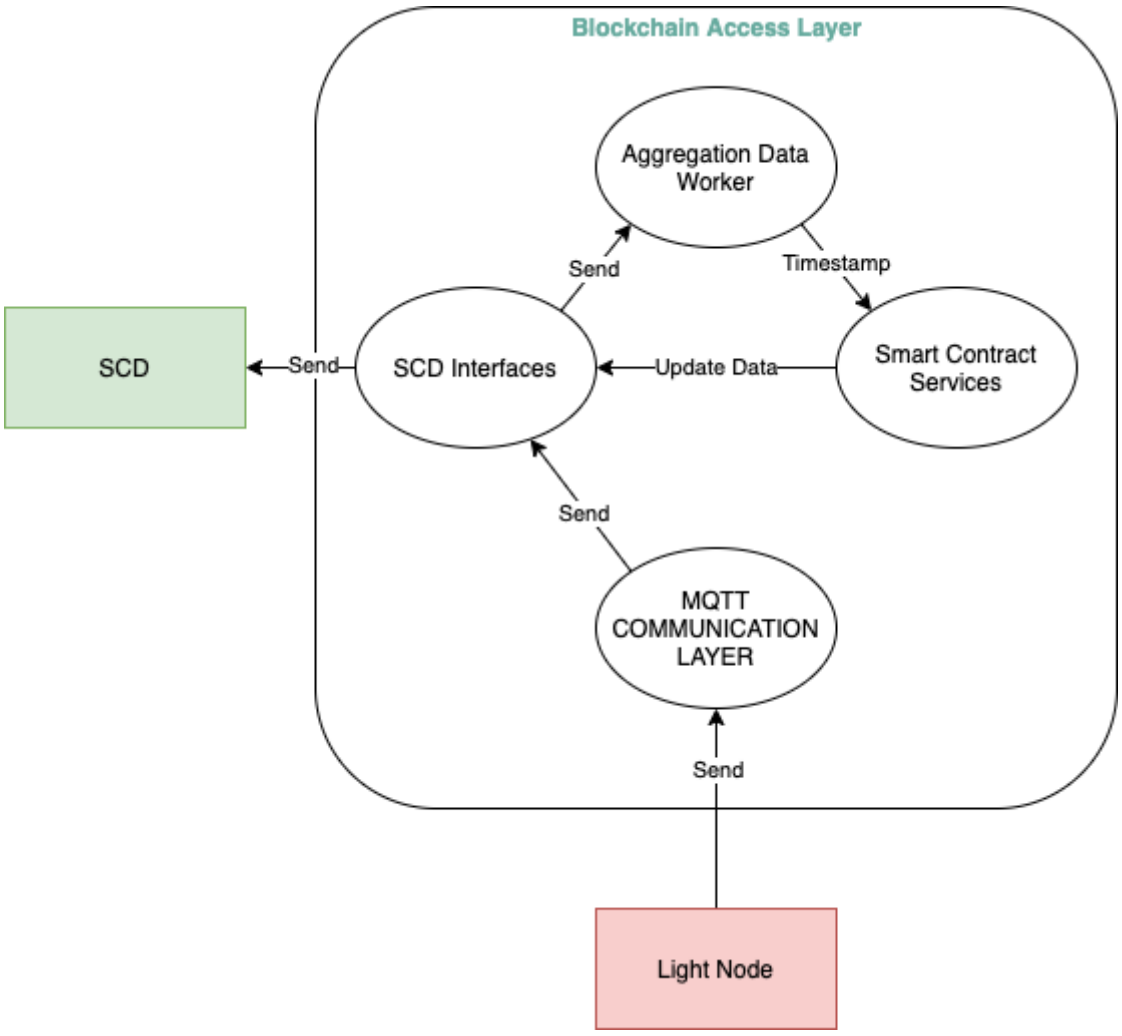


Figure 54: Blockchain Access Layer UC diagram - Timestamp and Send to SCD

Requirements to perform Timestamp and sent to SCD services are listed in Table 20.

Table 20: Blockchain Access Layer Timestamp and Send to SCD Technical Requirements

Requirement Id	FR_BAL_TS_1
Description	The Blockchain Access Layer receives data from Light Node through MQTT connection.
Implementation	1. The Blockchain Access Layer exposes an MQTT broker to all Light Nodes. 2. Light Nodes can authenticate to connect to the Broker. 3. Light Nodes publish Set-Point and Meter Data to the Blockchain Access Layer through appropriate MQTT topics. 4. The Blockchain Access Layer stores data sent by Light Nodes.
First Release	Yes

Requirement Id	FR_BAL_TS_2
Description	The Blockchain Access Layer uses the Aggregation Data Worker to timestamp the data.
Implementation	1. An Aggregation Worker is a batch worker which constantly looks for non-timestamped data stored by the Blockchain Access Layer and sent by Light Nodes. 2. Whenever the Aggregation Worker finds a non-timestamped message, the worker invokes the appropriate function to apply a provable timestamp to the message. 3. The Blockchain Access Layer stores the now timestamped messages.
First Release	Yes

Requirement Id	FR_BAL_TS_3
Description	The Blockchain Access Layer sends data to the Shared Customer Database
Implementation	1. The Shared Customer Database exposes a Kafka topic to which the Blockchain Access Layer can write messages. 2. The Blockchain Access Layer writes timestamped messages to the Kafka. Topic exposed by the Shared Customer Database.
First Release	Yes

The Light Node sends the following data packet through MQTT Communication Layer to the SCD Interfaces:

Table 21: Metering and Set-point Data

Field	Type	Description
PoD	String	PoD Identifier
Hash	String	Hash of the Input Data Field
SignedHash	String	Signature of the Hash Field made through ECDSA algorithm
PublicKey	String	Public Key linked to the private key used to sign the hash
InputData	Object	Metering or Setpoint packet data

The SCD Interfaces send the packet directly to the SCD through a REST-API. The SCD responds with a Unique ID, so the SCD Interfaces add the Unique ID to the Data Packet and send it to the Aggregation Data Worker.

Aggregation Data Worker receives the following packet:

Table 22: Aggregation Data Worker Data Packet

Field	Type	Description
PoD	String	PoD Identifier
Hash	String	Hash of the Input Data Field
SignedHash	String	Signature of the Hash Field made through ECDSA (Elliptic Curve Digital Signature Algorithm) algorithm
PublicKey	String	Public Key linked to the private key used to sign the hash
InputData	Object	Metering or Setpoint packet data
UniqueID	String	The Unique ID of the Data Packet received from the Shared Customer Database

The Aggregation Data Worker then, through a Merkle Tree Aggregation Algorithm and a Calendar Microservice, aggregates several data packets as one and timestamps it through the Smart Contract Service.

Then the Smart Contract Service updates the data packet as represented in the following table:

Table 23: Updated Data Packet

Field	Type	Description
PoD	String	PoD Identifier
Hash	String	Hash of the Input Data Field
SignedHash	String	Signature of the Hash Field made through ECDSA algorithm
PublicKey	String	Public Key linked to the private key used to sign the hash
InputData	Object	Metering or Setpoint packet data
UniqueID	String	The Unique ID of the Data Packet received from the Shared Customer Database
TransactionID	Hash	The transaction identifier of the Merkle Tree root
MerkleTreeStructure	Array	An Array of Object that starting from the Hash of the Data Packet let users recognize the transaction id

Blockchain Access Layer – Anomalies Detection

The Blockchain Access Layer receives data from Light Node and monitors functionalities of the Light Node. When an anomaly is detected the blockchain access layer sends an anomaly code to the Shared Customer Database.

The anomalies detected by the Blockchain Access Layer are the follow:

- Internet connections problems of Light Node;
- Connection issues with Meters;
- Connection issues with DSOTP;
- Connection issues with EMS;
- Connection issues with others metering devices.

Below is shown a high-level Use Case diagram and the functional requirements related to anomalies detection and anomalies communication.

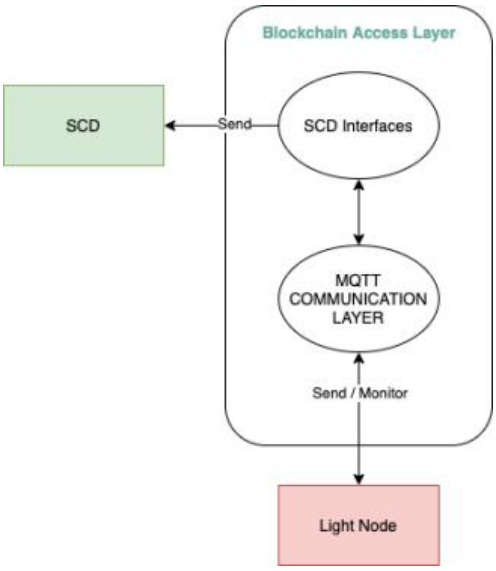


Figure 55: Blockchain Access Layer UC diagram - Anomalies Detection

Requirements to perform Anomalies Detection services are listed in Table 24.

Table 24: Blockchain Access Layer UC diagram - Anomalies Detection Technical Requirements

Requirement Id	FR_BALLN_AD_1
Description	The Blockchain Access Layer monitors the connection's status of the Light Node and also anomaly's duration
Implementation	1. Each Light Node is connected to the Blockchain Access Layer through a persistent MQTT connection. 2. The Blockchain Access Layer listens for Connection and Disconnection events on each Light Node. 3. Each connection and disconnection event is stored with a timestamp.
First Release	No

Requirement Id	FR_BALLN_AD_2
Description	The Light Node communicates the status of the connection and anomaly's duration with Electric Meter, DSOTP and Customer's EMS
Implementation	1. The Blockchain Access Layer exposes appropriate MQTT topics for receiving Anomalies detected by the Light Node.

	2. The Light Node periodically probes the connection with Electric Meters, EMSs and the DSOTP. 3. The Light Node send detected anomalies to the Blockchain Access Layer by publishing data to an appropriate MQTT topic.
First Release	No

Requirement Id	FR_BALLN_AD_3
Description	The Blockchain Access Layer sends to the SCD the Anomalies Data
Implementation	1. The Shared Customer Database exposes an appropriate Kafka topic to the Blockchain Access Layer. 2. The Blockchain Access Layer periodically queries its storage for anomaly data which was not yet sent to the Shared Customer Database. 3. The Blockchain Access Layer writes anomaly data to the given Kafka topic.
First Release	No

The Light Node sends the following data packet through MQTT Communication Layer to the SCD Interfaces:

Table 25: Anomaly Data Packet

Field	Type	Description
PoD	String	PoD Identifier
Hash	String	Hash of the Input Data Field
SignedHash	String	Signature of the Hash Field made through ECDSA algorithm
PublicKey	String	Public Key linked to the private key used to sign the hash
InputData	Object	Anomaly Data Packet composed by the anomaly code and a description of the anomaly

The *SCD Interfaces send the packet directly to the SCD through a REST-API.* The SCD responds with a Unique ID, so the SCD Interfaces can update the anomaly when solved.

A.4.3.3User Interfaces

Login

The login interface allows administrators and operators to authenticate with the Blockchain Access Layer. This is a required step in order to access other interfaces.

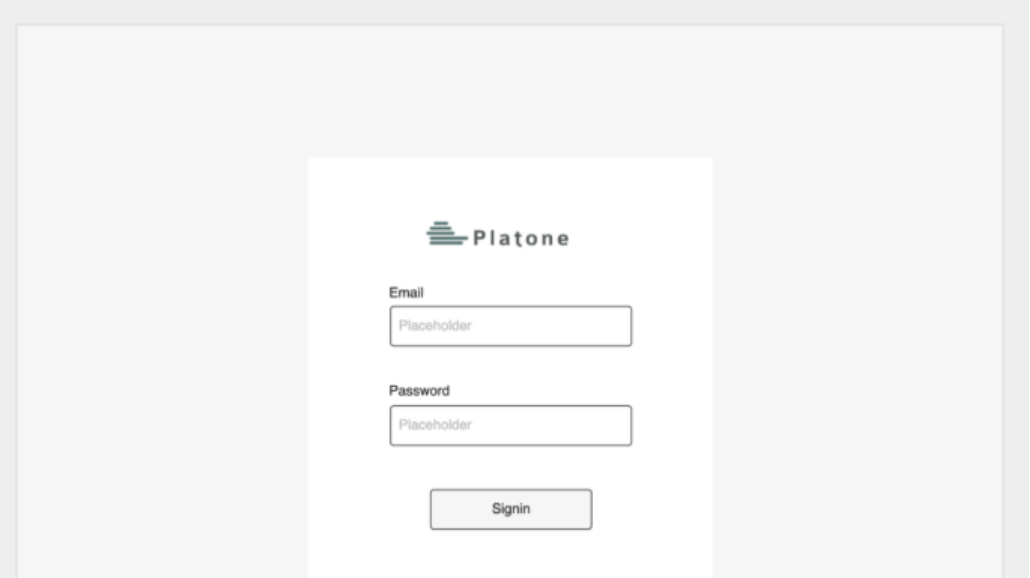


Figure 56: Login Interface

Dashboard

Light nodes management

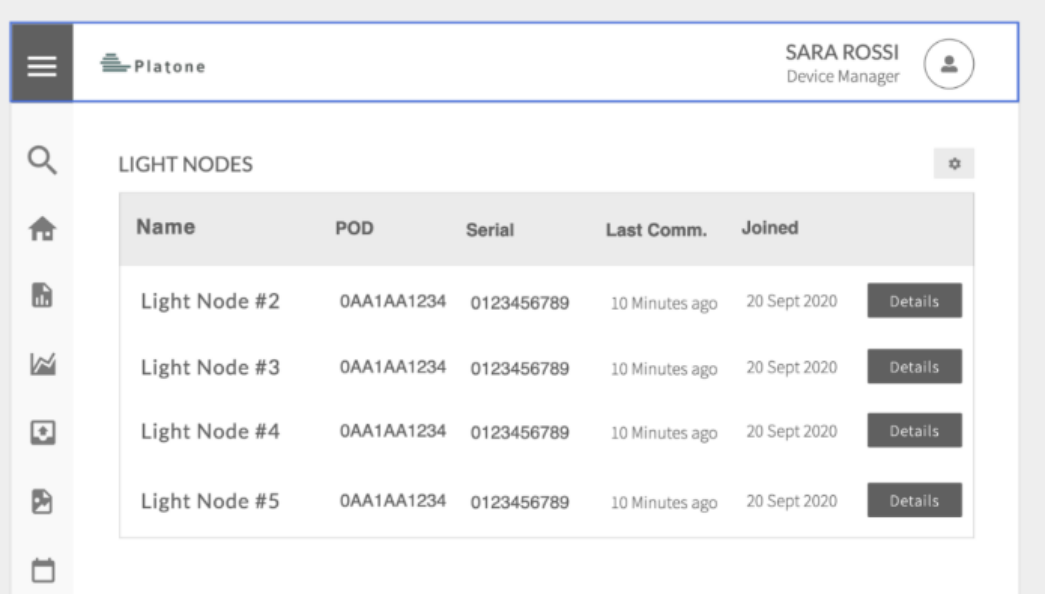


Figure 57: Light Node Management Interface

One of the main roles of the dashboard is to easily communicate the connection status of the deployed light nodes along with basic information such as the PoD and Serial Number of the meter.

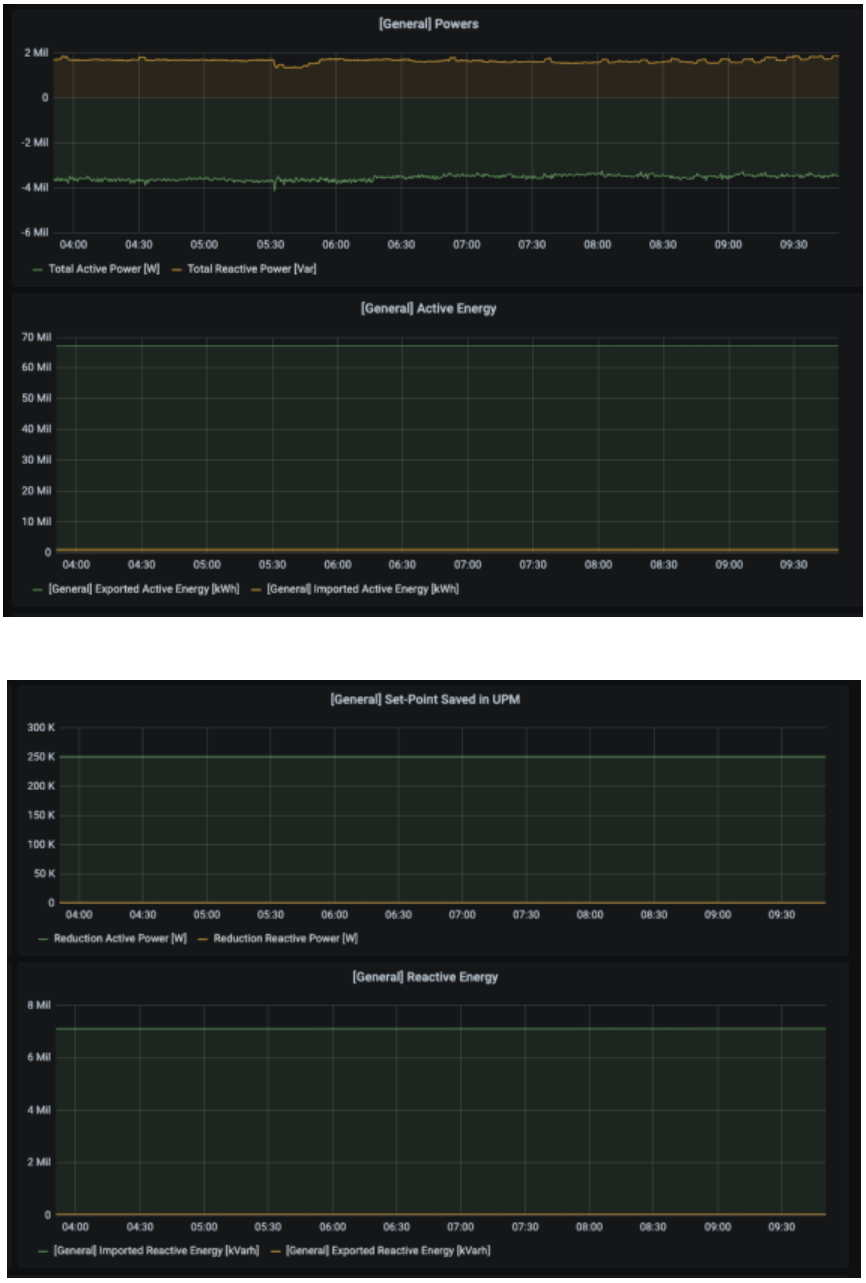


Figure 58: Light Node Data Monitoring

A.5 Shared Customer Database

A.5.1 Overview

The Shared Customer Database (SCD) is a collector of data made available to all the actors involved in the Italian Demo. It gathers and stores personal, technical and measurement data of the resources participating in the flexibility market.

The communication modalities between the Shared Customer Database and the other components and platforms are characterized by a huge amount of high frequency data exchange.

A.5.2 Architecture

The Shared Customer Database consists of a four-layer architecture visualized in Figure 59 below:

- **Communication layer**, the layer used by external actors to read and write within the Shared Customer Database;
- **Streaming layer** for the processing of data from the field. In the trial use cases it will be used mainly to move the data received by the ingestion component, the tool used for transferring the processed data to the persistence layer for archiving purposes;
- **Persistence layer** for data storage. It is characterized by a non-relational database and by a database with strong data search and aggregation skills;
- **Data Reporting** for the exposure of data processed in a ductile way to the ones who wish to monitor the trend of data flexibility.

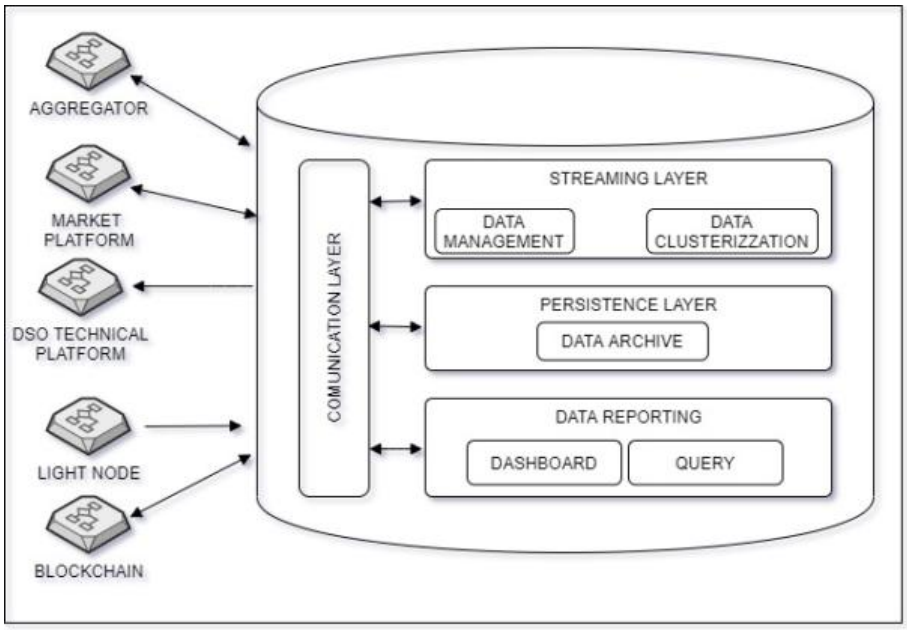


Figure 59: Shared Customer Database Architecture

Additional information concerning Shared Customer Database architecture and components are available in report D3.2 [11].

A.5.3 Requirements and Technical Specifications

A.5.3.1 Actors

The Shared Customer Database communicates with different actors and platforms in order to share data belonging to users that participate to the flexibility market.

Personas:

- Aggregator: the SCD establishes a bidirectional relation of information with it. From the Aggregator the SCD receives the personal and contractual data of the subjects available to participate in the flexibility market and the list of PoDs participating in a specific market session. Towards the aggregator, the SCD sends the measurement data and the implementation outcomes of the flexibility for the PoDs that participated in the market sessions;
- TSOs: the SCD sends to it the correlations between the available PoDs and the points of exchange between the TSO/DSO network, in order to allow the definition of requests localised according to their network criticalities;
- Market: the SCD sends to it the personal data of creation/updating of the PoDs available used for the clearing of market and the report of the data implementation to allow it to perform the clearance phase resulting from the contractual agreements.

External Systems

- The SCD adopts a type of two-way communication with several phase with the DSOTP. In a first phase, the SCD sends the list of PoDs showing an interest in active participation in flexibility. These PoDs will be considered by the platform in case of any network issues to be resolved. In a second phase, DSOTP returns the reference to which trading point between the TSO/DSO network is associated for each PoD previously received;
- With the same platform, the SCD provides measurement data and setpoints of PoDs present at DB to update the data of the applicant and improve the identification of the scope of resolution of criticalities;
- With the Blockchain Access Layer, the SCD receives all the certified measurement data, recorded by the devices in the field (Light Node).

A.5.3.2 Use Cases

In the Italian Demo, the Shared Customer Database has several tasks and we individuated three main use cases:

- Census of Resources Qualified to Provide Flexibility Services;
- Data on the implementation of flexibility services;
- Publication of data

Census of Resources Qualified to Provide Flexibility Services

One of the primary functions of the SCD is to collect and make available to the relevant stakeholders the personal data of the resources enabled to provide flexibility services.

These data are characterized by a series of identifiers and values (Table 26) associated with each resource enabled to provide flexibility services identified by the relevant PoD code.

Figure 60 below shows the flows involved in the implementation of this feature.

The data stream associated with each resource originates from the Aggregator Platform (Flow 0), as shown in Figure 60.

The information is made available to the DSO Technical Platform once obtained and recorded within the SCD, then the DSOTP returns for each PoD received, the related Point of Measure - POM (Flow 0A). The POM expresses the association between the TSO balancing nodes and the respective underlying PoDs. The POM, obtained from the DSO Technical Platform, accompanied by the personal information (referred to in Flow 0) is sent by the SCD to the TSO and the Market Platform (Flow 0B). The following is a high-level Use Case that depicts the relational flows notified between the different stakeholders aimed at surveying the availability of PoDs between flexibility services.

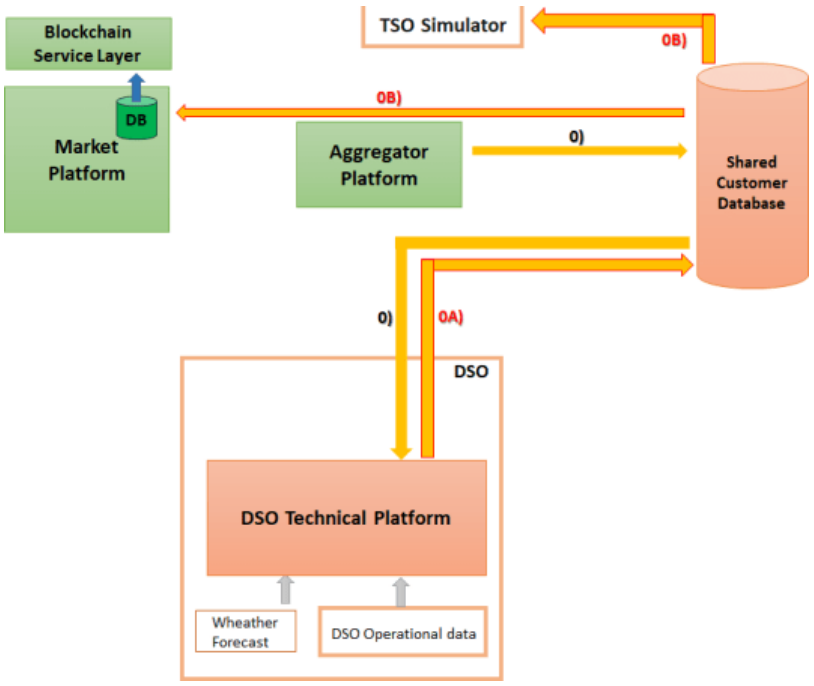


Figure 60: Census of Resources Qualified to Provide Flexibility Services

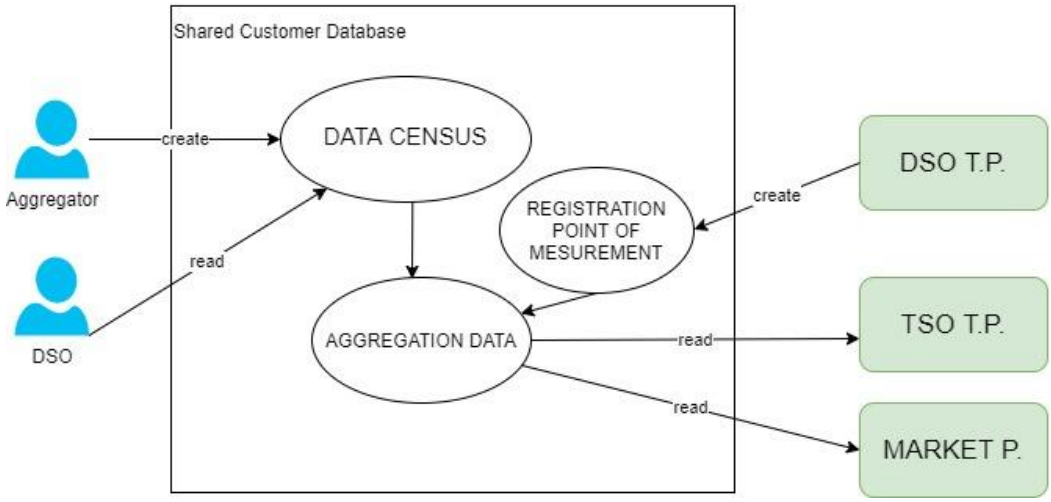


Figure 61: Census Data UC Diagram

In order to achieve the relational flows described, the following functional requirements for the commercial census of PoDs shall be developed:

Table 26: Census Data Functional Requirements

Requirement Id	FR_SCD_CA_1
Description	The SCD allows the aggregator to census the PoDs at the first entry to the market of flexibility and allows the subsequent modifications and cessations
Implementation	1. The SCD displays a REST service through which the aggregator sends the PoD data **(FLOW 0 AGGREGATOR→SCD)** 2. The SCD inserts/updates these data in the database

First Release	Yes

Requirement Id	FR_SCD_CA_2
Description	The SCD allows the transmission of census data to the DSO Platform
Implementation	1. The SCD, after having saved the data received by the aggregator, invokes a REST service exposed by the DSO through which it sends the data of the PoD **(FLOW 0 SCD→DSO)**
First Release	Yes

Requirement Id	FR_SCD_CA_3
Description	Receives Registry Completion Data from DSO Platform
Implementation	1. The SCD shall display a REST service through which the DSO sends data related to the association between the individual PoD and the POM on which the TSO requests the services **(FLOW 0A)**
First Release	Yes

Requirement Id	FR_SCD_CA_4
Description	Returns the full data values to the Market Platform
Implementation	1. The SCD updates the database of personal data by entering the PoD of the POM 2. The SCD invokes a REST service exposed by the Market Platform by sending all the data of the PoD, including the POM **(FLOW 0B)**
First Release	Yes

Requirement Id	FR_SCD_CA_5
Description	Returns the values of the complete data to the TSO
Implementation	1. The SCD shall invoke a REST service exposed by the TSO by sending all PoD data, including the POM **(FLOW 0B)**
First Release	Yes

Data on the implementation of flexibility services

In order to activate the agreed flexibility service, the Aggregator Platform defines the setpoints to be sent to the PoDs that will provide the related service. These data are also received by the SCD (Flow 6) that will store them.

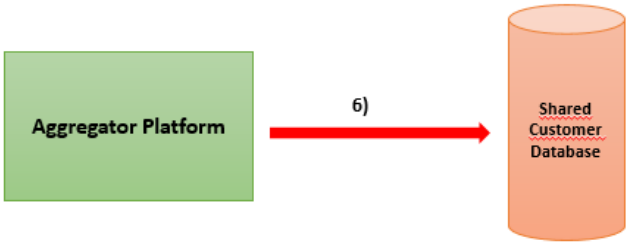


Figure 62: Flexibility Services Activation Data workflow

In the figure below a Use Case describing the request for the implementation service generated by TSOs and DSOs, through the Aggregator Platform is shown:

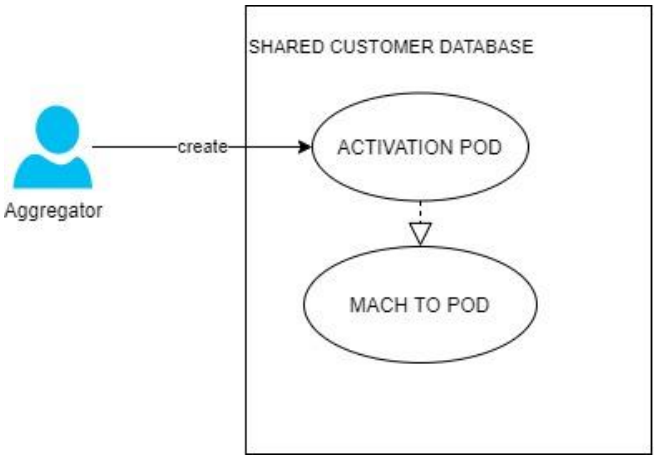


Figure 63: Service Activation UC Diagram

The following table lists requirements where this functionality is broken down:

Table 27: Service Activation Technical Requirements

Requirement Id	FR_SCD_AF_1
Description	Allows the reception of set points of implementation by the market
Implementation	1. The SCD shall display a REST service through which the aggregator sends the implementation data **(FLOW 6 AGGREGATOR→SCD)**
First Release	Yes

Requirement Id	FR_SCD_AF_2
Description	Attribution of data received to related PoDs
Implementation	1. The SCD inserts/updates the data in the database
First Release	Yes

Publication of data

The set points and measures from the PoDs that participate in the provision of flexibility services are collected by the Light Node and sent to the SCD through the Blockchain Access Layer.
The data received will be aggregated and published specifically to the following platforms: Aggregator Platform, Market Platform and DSO Technical Platform.
The PoD measurement data may also be made available to the TSO.

Publication of survey

The SCD will provide power values and set points related to PoDs for which a flexibility contract has been activated to all stakeholders.

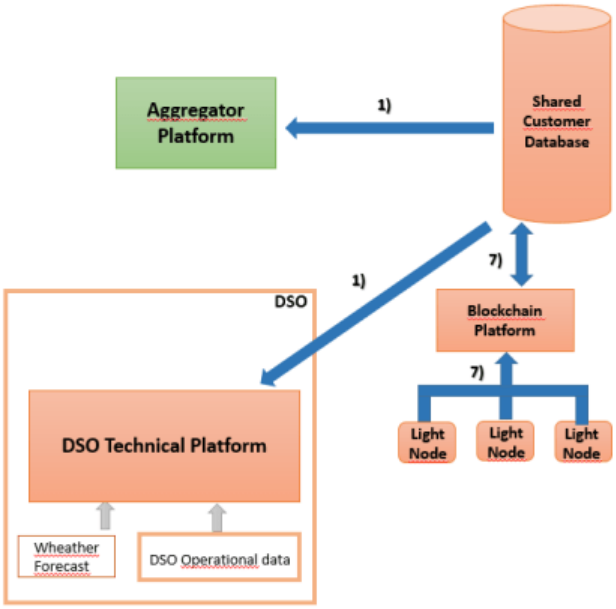


Figure 64: PoD Data workflow

The data to be published to the Aggregator will be sent according to a frequency of 15 minutes.

The same data will be provided according to an on-demand mode towards the DSO. For each PoD object of the instance it will be possible to recall the measurement data in possession of the SCD for defined temporal arcs within the month, up to a maximum depth of the previous solar year.

Figure 65 shows a use case that represents the publication relations among the SCD, Aggregator and DSO:

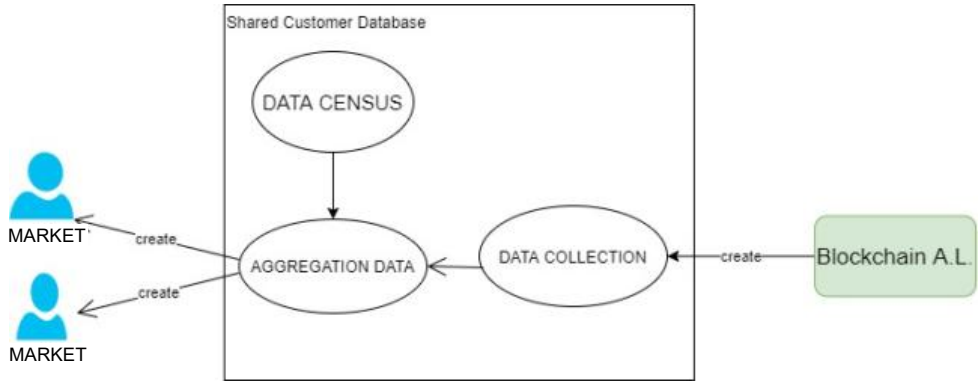


Figure 65: PoD Data workflow

The following table lists the requirements in which this functionality is broken down:

Table 28: PoD Data Technical Requirements

Requirement Id	FR_SCD_PD_1
Description	Enables receipt of certified measurement data from the Blockchain Access Layer
Implementation	1. The SCD subscribes to kafka topics on which the Blockchain Access Layer will publish the certified data coming from the Light Node 2. The SCD saves the measurements data coming from its DB
First Release	Yes

Requirement Id	FR_SCD_PD_2
Description	The SCD reports detection and/or operating errors when detected by field
Implementation	See point 2 of the implementations of the Requisite FR_SCD_PD_3
First Release	Yes

Requirement Id	FR_SCD_PD_3
Description	It publishes the measurement data and the implementation set point to the Aggregator every 15 minutes
Implementation	1. The SCD takes from its DB any data of the real-time flows necessary to send the data packet to the Aggregator 2. The SCD publishes on a Kafka topic the data to be communicated to the Aggregator with operating errors or anomalies 3. Even if for 15 minutes no data comes from the Light Node, the SCD will make available a data package for that arc of time
First Release	Yes

Requirement Id	FR_SCD_PD_4
Description	Publication of measurement data to the DSOTP in on-demand modality
Implementation	1. The SCD exposes to the DSO a REST service through which the DSO requests the measurement data 2. Upon arrival of the request the SCD also retrieves any required data that have been historicized in a separate portion of the DB, thus responding to that request with a higher latency than data relating to data corresponding to the two months preceding the request.
First Release	Yes

Publication Results of Implementation

For all those PoDs reported by the Aggregator subject to the SCD with Flow 6, through the attribution of a specific implementation code (marketOutcomeID), the SCD will subsequently send to the Market Platform the data physically collected and the set points associated with the PoDs.

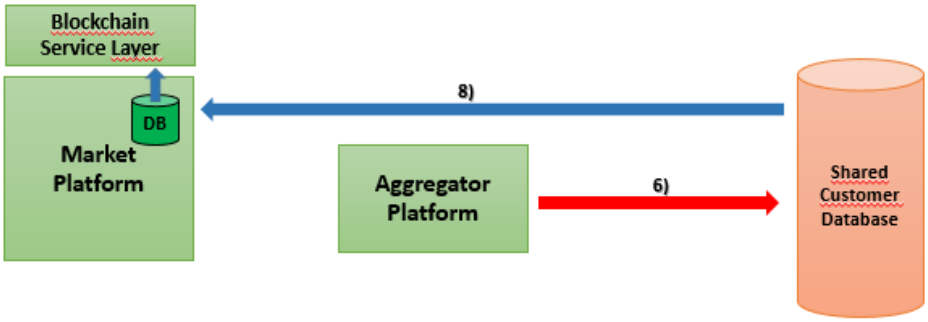


Figure 66: Publication Service Activation workflow

The publication to the Market platform will be carried out daily in aggregate way.

In Figure 67 is represented a Use Case that shows the publishing relations between the Shared Customer Database and the Market Platform:

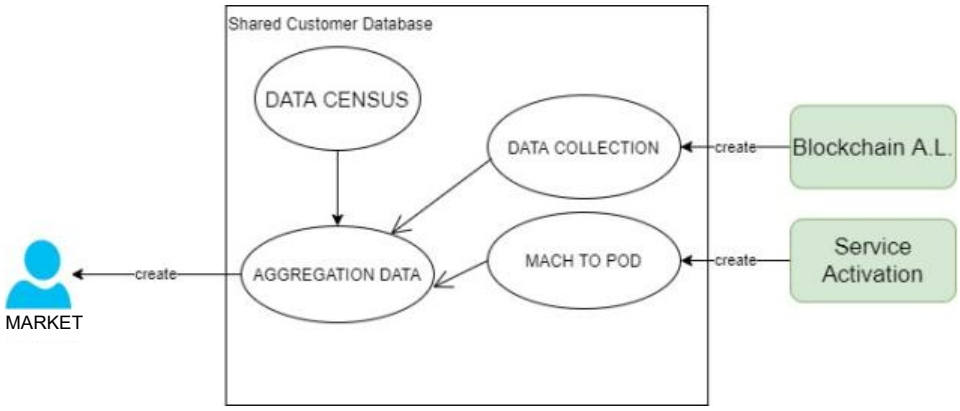


Figure 67: Publication Service Activation UC Diagram

The following table lists the requirements in which this functionality is broken down:

Table 29: Publication Service Activation Technical Requirements

Requirement Id	FR_SCD_PDA_1
Description	Aggregation of data with a Market outcome ID
Implementation	1. The SCD searches in its archive all the measures arrived on the same day for the PoDs that participated in the flexibility
First Release	Yes

Requirement Id	FR_SCD_PDA_2
Description	Publication of data to the Market Platform

Implementation	1. The SCD writes the data, once a day, in a topic Kafka that will be subscribed by the Market Platform **(FLOW 8 SCD→Market Platform)**
First Release	Yes

Publication Measures for network observability

The measurement data of all PoDs contained in the SCD and received from the Blockchain platform may be subject to specific consultation (communication) by the TSO.

The TSO may, for example, obtain measurement data from PoDs at a frequency appropriate for network observability purposes.

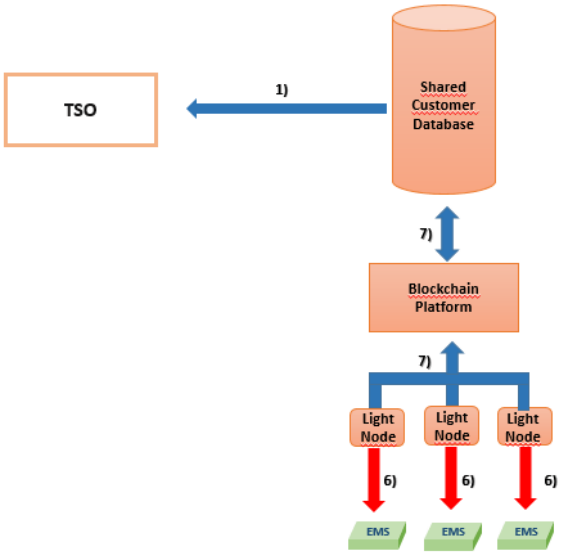


Figure 68: Publication PoD Data to TSO for Observability workflow

Figure 69 is the minimum publication data structure to the TSO entity:

Table 30: Publication model of measurement data

Field	Type	Description
Pod	String	POD ID for which implementation is requested
ID Aggregator	Number	ID Reference Aggregator
Timestamp	Data	Reference to the quarter of hour of data collection
Validation data	String	Certification values for data transited
Power	Number	Power values implemented in Flexibility
POM	Number	Point Of Measurement

Implementation SetPoint	Number	Power values request in Flexibility
Anomaly code	Number	Id Identification of the anomaly found and/or of the non-collection data.

In Figure 69 is represented a high-level Use case that describes the high-frequency communication between SCD and TSO:

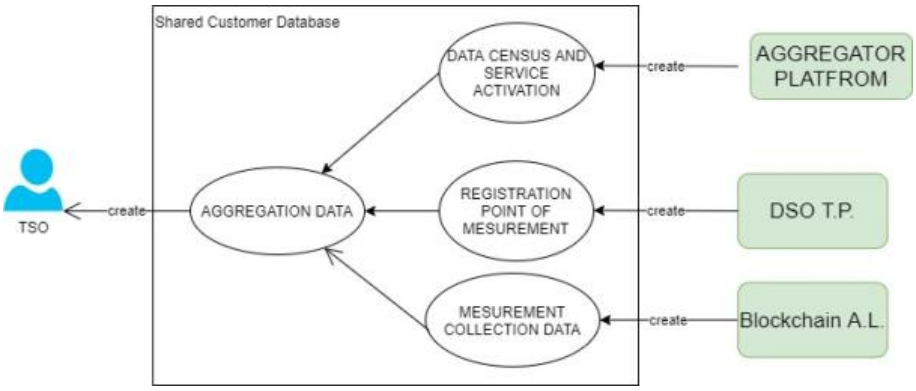


Figure 69: Publication PoD Data to TSO for Observability UC Diagram

In order to publish measurement data for network observability, the Shared Customer Database will implement the following functional requirements:

Table 31: Publication PoD Data to TSO for Observability Technical Requirements

Requirement Id	FR_SCD_PDO_1
Description	Enables receipt of certified measurement data from the Blockchain Access Layer
Implementation	
First Release	Yes

Requirement Id	FR_SCD_PDO_2
Description	The SCD reports detection and/or operating errors when detected by field
Implementation	
First Release	Yes

Requirement Id	FR_SCD_PDO_3
Description	The SCD reports detection and/or operating errors when detected by field

Implementation	Publish measurement data and implementation set points to the TSO at a frequency of seconds
First Release	Yes

A.5.3.3 User Interfaces

Figure 70 is a list of screenshots of the user interface where it is possible to see the measurement in the SCD coming from the Light Node:

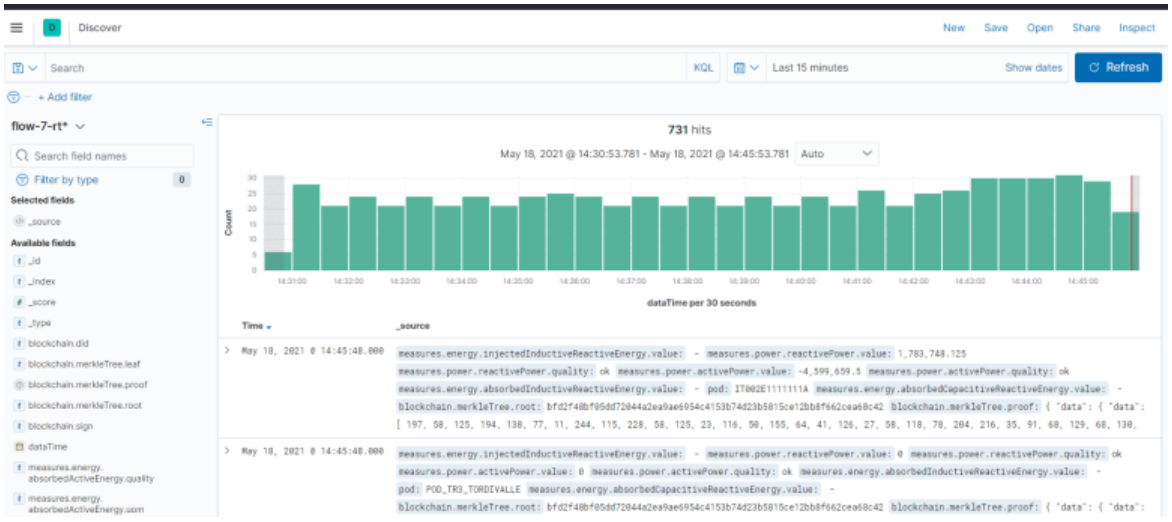


Figure 70: Real time flow measurement example

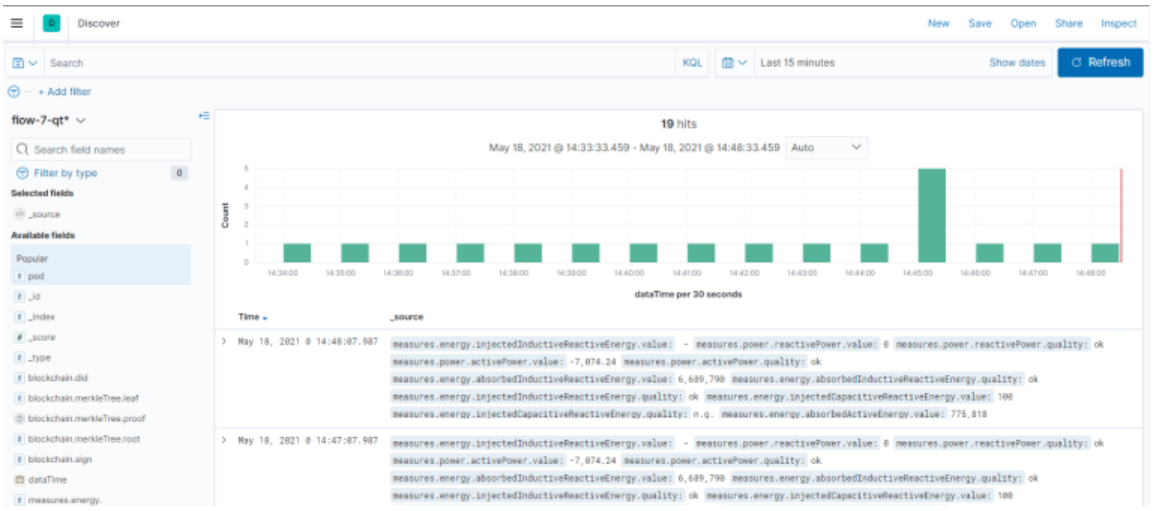


Figure 71: Quarter hour measurement flow example

Figure 72: Example with highlighted values

Figure 73 shows some screenshots of the user interface where it is possible to see the registry of the PoDs containing the data received by the SCD from the Aggregator Platform and the DSO Technical Platform

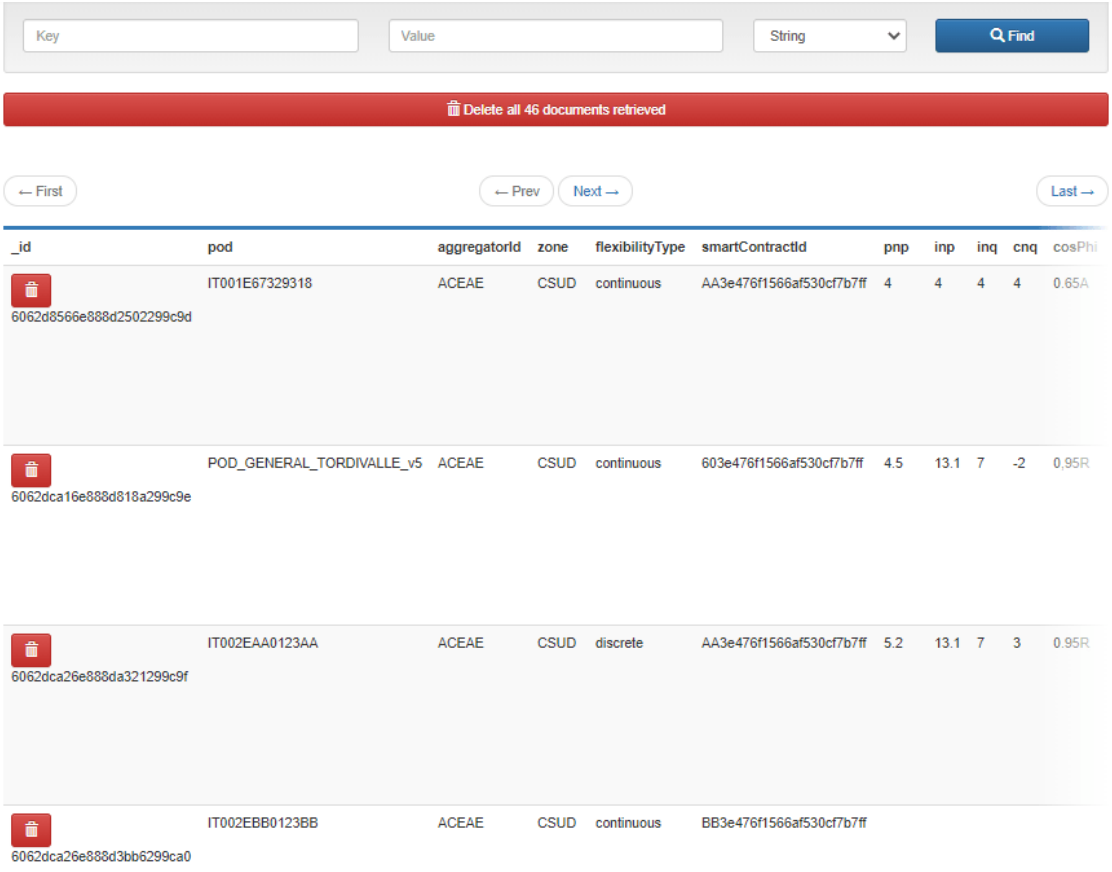


Figure 73: Tabular view of PoD registry

```
{
    _id: ObjectId('609d1dc1bc535f4e6fc27c62'),
    pod: 'IT002E1111111A',
    aggregatorId: 'ACEAE',
    zone: 'CSUD',
    flexibilityType: 'continuous',
    smartContractId: 'AA3e476f1566af530cf7b7ff',
    pnp: 1,
    inp: 2,
    inq: 0.3,
    cnq: 0.2,
    cosPhi: '0.95R',
    maxFlexibility: {
        upperP: 24,
        downP: 0,
        upperQ: 0,
        downQ: -24
    },
    powerBaselineCurves: {
        workday: [
            {
                timeSlotIndex: 0,
                p: 10.7,
                q: 5.35
            },
            {
                timeSlotIndex: 1,
                p: 9.999,
                q: 4.9995
            },
            {
                timeSlotIndex: 2,
                p: 9.414,
                q: 4.707
            },
            {
                timeSlotIndex: 3,
                p: 8.926,
                q: 4.463
            },
            {
                timeSlotIndex: 4,
                p: 8.507,
                q: 4.2535
            },
            {
```


Figure 74: Registry of the PoD in details

Annex B Light Node

The Light Node permits the acquiring and the certification of the data coming from the smart meter (power, energy, voltage, …), and provides these information to authorized stakeholders. Moreover, the Light Node receives the orders sent by third part operator (as DSO) and makes this order available to the Energy Management Systems (EMS) in customer property.

In detail, the main functionalities implemented on the device are:

- Real time acquiring, through the Power Line Communication protocol, of the data measured by the new Italian Smart Meter (named, Smart Meter 2G);
- Real time acquiring, through the Modbus protocol, of the data measured by the Peripheral Unit Monitoring (PMU);
- Blockchain certification and sending of the data to a database;
- Acquiring of set-points sent by DSO
- Data exchange with the EMS in customer premises

Figure 75 shows the Light Node.

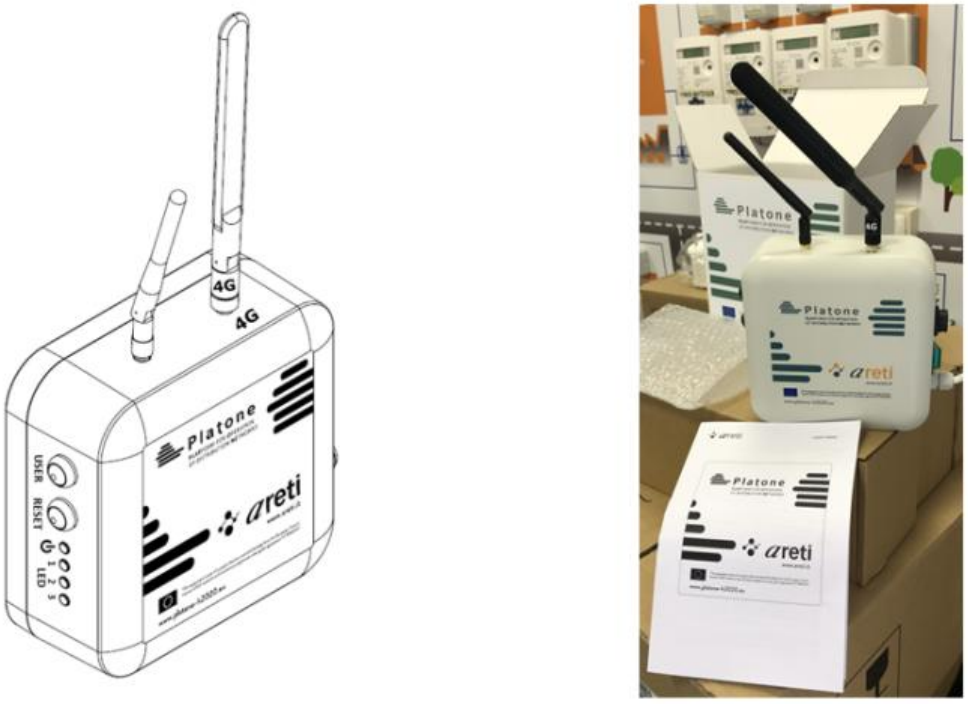


Figure 75: Light Node

Figure 76 shows the main data (Real time Active Power and Quarterly Active Energy) acquired by Light Node.

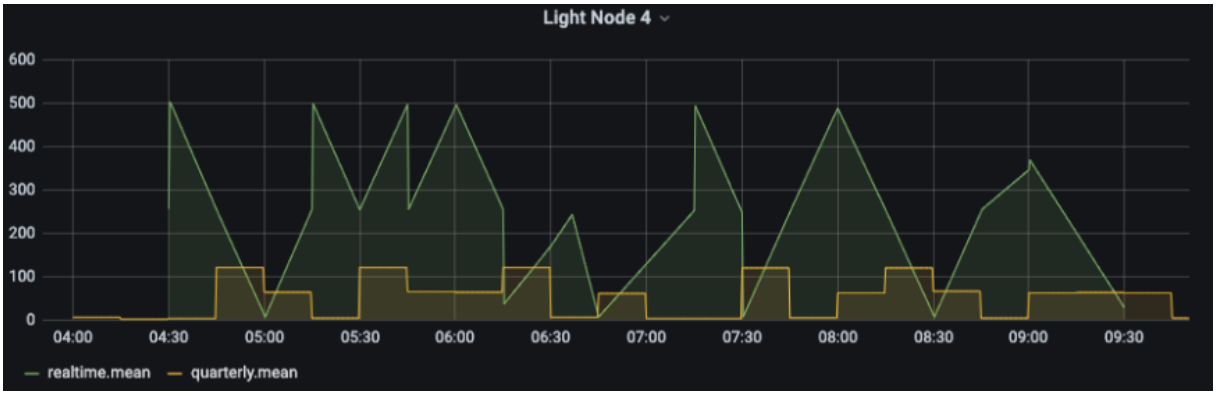


Figure 76: Data acquired by Light Node

Here follow is the Light Node hardware specification.

Technical specification:

- **Dimensions (L, H, T):** 160 x 160 x 70 mm
- **Weight**: 993 g
- **IP degree:** IP44
- **Case Material:** ABS
- **Flammability degree**: UL94 HB

Operating Conditions:

- **Indoor**
- **Operating Temperature:** -15° ÷ +45°C
- **Storage Temperature:** -15° ÷ +55°C
- **Humidity:** 5% ÷ 95%
- **Altitude:** <= 2000 m
- **Overvoltage class protection:** II
- **Pollution degree:** 2
- **Isolation:** II

Supply

- **Connection:** cable with plug CE 7/16 typo C
- **Nominal Voltage:** 230Vac
- **Voltage Range:** 185-264Vac.
- **Frequency**: 50 Hz
- **Consumption**: 100 mA max

Certification

Directive: RED 2014/53/UE
Standards:
EN 61010-1:2010/A1: 2010
EN 61000-3-2, EN 61000-3-3, EN 61326, ETSI EN 301 489-1, ETSI EN 301 489-17

WI-FI and BLUETOOTH

Standards IEEE 802.11b, IEEE 802.11g, IEEE 802.11n, IEEE 802.11d, IEEE 802.11e, IEEE 802.11h, IEEE 802.11i, V2.1+EDR/BT, v3.x, v4.x.

Data Rate 802.11b: 11, 5.5, 2, 1 Mbps; 802.11g: 54, 48, 36, 24, 18, 12, 9, 6; Mbps 802.11n: up to 150Mbps 1 Mbps for Basic Rate 2,3 Mbps for Enhanced Data Rate 6,9,12,18,24,36,48,54 Mbps for High Speed

Modulation 802.11b: CCK, QPSK, DBPSK, 802.11g/n: OFDM GFSK, □/4 DQPSK, 8DPSK

Channels: 11: (Ch. 1-11) –United States;13: (Ch. 1-13) – Europe13: (Ch. 1-14) –Japan Ch. 0 ~78

Frequency: 2.400GHz ~ 2.4835 GHz

Security: WPA, WPA-PSK, WPA2, WPA2-PSK, WEP 64bit & 128bit, IEEE 802.11x, IEEE 802.11i Simple pairing

Ethernet

- Bitrate: 10/100 Mbps until 1000Mbs (in compliance with IEEE 802.3 e IEEE 802.3u).
- Protocols: (TCP/IP/IPV4/IPV6/Multi-PDP/FTP/FTPS /HTTP/HTTPS/SMTP/SMTPS/DNS).
- Security levels: SSL3.0/TLS1.0/TLS1.2.

Phone Communication

- Standard: 4G/3G/2G/GSM/GPRS/GNSS HAT, support LTE CAT4 up to 150 Mbp
- SIM card slot: 1.8V/3V.
- Frequency bands:

LTE-TDD: B34/B38/B39/B40/B41;

LTE-FDD: B1/B2/B3/B4/B5/B7/B8/B12/B13/B18/B19/B20/B25/B26/B28/B66;

3G: UMTS/ HSDPA/HSPA+;

3G: B1/B2/B4/B5/B6/B8/B19;

2G: GSM/GPRS/EDGE; 850/900/1800/1900MHz;

Power Line Communication

- Modem ST75MM: C-Band, B-PSK Modulation.
- Application: DLMS/COSEM IEC (IEC 62056-5-3).
- data model: COSEM Data Model (IEC 62056-6-1, IEC 62056-6-2).
- Voltage PLC : 230 V; 185-264Vac range.

485 Serial Communication

- RS-485 (2 cables, half duplex, con porta DB-9).
- Baud Rates from 300 to 115200.
- Data Bits: 8.

- Stop Bits: 1.
- Parity: None, Even, Odd.
- Flow: None, Xon/Xoff.
- Protocol: MODBUS RTU MASTER (RS-485).
- Galvanic isolation 5.7 kV rms.

Annex C KPIs

C.1 KPI-PR-01 – Participant Recruitment

BASIC KPI INFORMATION			
KPI Name	Participant Recruitment	**KPI ID**	KPI_PR_01
Project's Objective	To improve customer engagement and facilitate their fair participation to market		
DEMO where KPI applies	☒IT		
Owner	Italian demo: areti/ACEA Energia		
KPI Description	This indicator calculates the percentage of customers that accepted their participation in the demo in relation with the total amount of customers contacted to participate in the demo. This indicator can be used to evaluate customer engagement.		
KPI Formula	$$R = \frac{N_{accept}}{N_{total}} \cdot 100$$ Where: N_{accept}: number of customers that accepted to participate in the demo. N_{total}: number of customers contacted to participate in the demo.		
Unit of measurement	%		
Target / Thresholds	Italian demo: 10% Considering that the Italian Demo tests an innovative solution involving active customers' cooperation in grid operation, it is assumed that participation is fulfilled by few "early adopters". The maximum number of customers involved depends on number of Light Nodes available.		
Measurement Process	Italian demo: Quantity of customers that accepted to participate to the project and quantity of customers involved in engagement are gathered during each customer engagement process. The KPI is calculated whenever a customer engagement process is complete.		
Reporting Period	Italian demo: yearly		
Reporting Audience and Access Rights	☐Public ☒Platone ☐Demo ☐Other		

KPI CALCULATION METHODOLOGY		
Italian demo		
KPI Step Methodology ID [KPI ID #]	**Step**	**Responsible**

KPI_PR_01_IT_1	Detecting the list of customers located in the demo's areas, through the Operational Systems (in detail the Customer Relation Management will be used)	areti
KPI_PR_01_IT_2	Evaluating the number of customers contacted (several solutions can be used: calls, letters, meetings) to participate in the demo	areti
KPI_PR_01_IT_3	Evaluating the number of customers that accepted to participate in the demo	areti
KPI_PR_01_IT_4	KPI calculation	areti

KPI DATA COLLECTION						
Italian demo						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools /Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Number of customers contacted to participate in the demo	N_{total}	List of customers contacted to participate in the demo	Datasheet of customer extracted from Operational System	Shared Customer Database	Once (update on event), up to end of project	areti
Number of customers that accepted to participate in the demo	$N_{accepted}$	List of customers that accepted to participate in the demo	Datasheet of customer involved in the demo	Shared Customer Database	Once (update on event), up to end of project	areti

C.2 KPI-PR-02 – Active Participants

BASIC KPI INFORMATION			
KPI Name	Active Participants	**KPI ID**	KPI_PR_02
Project's Objective	To improve customers' engagement and facilitate their fair participation to market		
DEMO where KPI applies	☒IT		
Owner	Italian demo: areti/ACEA Energia		
KPI Description	This indicator measures the percentage of customers actively participating in the Platone demo with respect to the total customers that accepted the participation. This indicator can be used to evaluate customer engagement and their participation to provide flexibility services.		
KPI Formula	$$R = \frac{N_{active}}{N_{accept}} \cdot 100$$ Where: N_{accept}: number of customers that accepted to participate in the demo N_{active}: number of customers actively participating in the demo* * definition of active customers will be determined by demo leaders		
Unit of measurement	%		
Target / Thresholds	Italian demo: 100%		
Measurement Process	Italian demo: Quantity of customer that actively provide flexibility services are extracted from the report provided by the Market Platform. Quantity of customer that accepted to participate in the project are gathered during each customer engagement process. A further analysis of the Market Platform report will allow to extract more details for example quantity of active customers divided for connected power or voltage level.		
Reporting Period	Italian demo: yearly		
Reporting Audience and Access Rights	☐Public ☒Platone ☐Demo ☐Other		

KPI CALCULATION METHODOLOGY		
Italian demo		
KPI Step Methodology ID [KPI ID #]	**Step**	**Responsible**
KPI_PR_02_IT_1	Evaluate number of customers that accepted to participate in the demo	areti
KPI_PR_02_IT_2	Evaluate number of customers actively participating in the demo	areti

KPI_PR_02_IT_3	KPI calculation	areti

KPI DATA COLLECTION						
Italian demo						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Number of customers contacted to participate in the demo	N_{total}	List of customers that accepted to participate in the demo	Datasheet of customer involved in the demo	Shared Customer Database	Once (update on even), up to end of project	areti
Number of customers providing offers actively	N_{active}	Analysis of offers list issued in Market Platform	Market Platform	-	Daily, Up to end of projects	areti

KPI BASELINE			
Italian demo			
Source of Baseline Condition	LITERATURE VALUES ☐	COMPANY HISTORICAL VALUES ☐	VALUES MEASURED AT START OF PROJECT ☐
Details of Baseline	N.A.		
Responsible (Name, Company) for Baseline	N.A.		

C.3 KPI-PR-03 – Flexibility Availability

BASIC KPI INFORMATION			
KPI Name	Flexibility Availability	**KPI ID**	KPI_PR_03
Project's Objective	To unlock flexibility to address local congestion and voltage stability issues. To improve customers' engagement and facilitate their fair participation to market.		
DEMO where KPI applies	☒IT		
Owner	Italian demo: areti / Engineering		
KPI Description	This KPI aims to measure the potential amount of flexibility that is available to the grid by flexible resources.		
KPI Formula	Italian demo: $$Flexibility\ Availability\ Up = \frac{1}{T}\sum_{t=1}^{T}\frac{\sum_{i=1}^{N}\lvert Available\_Flexibility\_Up_{i,t}\rvert}{\sum_{i=1}^{N}\lvert Baseline_{i,t}\rvert}\cdot 100$$ $$Flexibility\ Availability\ Down = -\frac{1}{T}\sum_{t=1}^{T}\frac{\sum_{i=1}^{N}\lvert Available\_Flexibility\_Down_{i,t}\rvert}{\sum_{i=1}^{N}\lvert Baseline_{i,t}\rvert}\cdot 100$$ Where: *Available_Flexibility_Up*$_{i,t}$: amount (kW, kVAr, etc.) of flexibility to increase generation/ decrease demand made available from *i*-th flexible resource in the period *t* *Available_Flexibility_Down*$_{i,t}$: amount (kW, kVAr, etc.) of flexibility to decrease generation/ increase demand made available from *i*-th flexible resource in the period *t* *Baseline*$_{i,t}$: baseline of flexible resource in the period *t* *N*: set of flexible resources that made flexibility available *T*: examined period For each flexibility service (congestion solving, voltage regulation), the separate value of this KPI will be calculated.		
Unit of measurement	%		
Target / Thresholds	Italian demo: 20% Taking into account that the Italian Demo tests an innovative solution involving active customers' cooperation in grid operation, it is guessed that amount of available flexibility approximately of 20% could be reasonable offered by customers.		
Measurement Process	Italian demo: Available flexibilities are data included in the offers. These data are then extracted from the report provided by the Market Platform. The *Baselines* are data stored in the Shared Customer Database and gathered by the Market Platform. The platform, at the end of the day, provides a report and automatically calculates the KPI.		

	A further analysis of the Market Platform report will allow to extract more details for example quantity of available flexibility divided by customer categories, connected power or voltage level.
Reporting Period	Italian demo: yearly
Reporting Audience and Access Rights	☐Public ☒Platone ☐Demo ☐Other

KPI CALCULATION METHODOLOGY		
Italian demo		
KPI Step Methodology ID [KPI ID #]	**Step**	**Responsible**
KPI_PR_03_IT_1	Extract flexible resources' offers from Market Platform	areti
KPI_PR_03_IT_2	Extract baselines of resources offering flexibilities services from Market Platform	areti
KPI_PR_03_IT_3	KPI calculation	areti

KPI DATA COLLECTION						
Italian demo						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Amount of flexibility offered in the Market Platform	*Available_Flexibility_Up*$_{i,t}$ *Available_Flexibility_Down*$_{i,t}$	Values included in offers issued by Aggregator in Market Platform	Market Platform	-	Daily, Up to end of project	areti
Baselines of resources offering flexibilities services	*Baseline*$_{i,t}$	Values inserted in Shared Customer Database by BRP and gathered by Market Platform	Share Customer Database	-	Daily, Up to end of project	areti

KPI BASELINE			
Italian demo			
Source of Baseline Condition	LITERATURE VALUES ☐	COMPANY HISTORICAL VALUES ☐	VALUES MEASURED AT START OF PROJECT ☐
Details of Baseline	Baseline is estimated by forecasting tool. For every customer involved in the flexibility market, the BRP (simulated in the demo by Aggregator) calculates the baseline for the day after and uploads it in the Shared Customer Database.		
Responsible (Name, Company) for Baseline	Acea Energia		

C.4 KPI-PR-04 – Flexibility Effectiveness

BASIC KPI INFORMATION			
KPI Name	Flexibility Effectiveness	**KPI ID**	KPI_PR_04
Project's Objective	To unlock flexibility to address local congestion and voltage stability issues.		
DEMO where KPI applies	☒IT		
Owner	Italian demo: areti		
KPI Description	This KPI aims to measure the effectiveness of flexibility provision. The KPI measures the sum of successfully provided flexibility in relation to the requested demand for flexibility.		
KPI Formula	Italian demo: $$Flexibility\ Effectiveness = \frac{1}{T}\sum_{t=1}^{T}\frac{1}{N}\sum_{i=1}^{N}\frac{\lvert Quantity\_provided_{i,t}\rvert}{\lvert Setpoint_{i,t}\rvert}\cdot 100$$ where: *Quantity_provided*$_{i,t}$: amount of quantity (kW, kVAr, etc.) exchange with the grid by *i*-th flexible resource in the period *t* *Setpoint*$_{i,t}$*:* amount (kW, kVAr, etc.) of *i*-th request of flexibility in the period *t* *N*: set of flexible resources that made flexibility available *T*: examined period For each flexibility service (congestion solving, voltage regulation), the separate value of this KPI will be calculated.		
Unit of measurement	%		
Target / Thresholds	Italian demo:70% This percentage is used by Italian TSO to penalize the DERs involved in the pilot project, descripted in the regulation 300/2017/R/ee (reported in the D 6.2). In detail, in the relevant period (daily) for any resources the energy provided in respect to the setpoint is verified, if the ratio is over ± 30% out of the reference value, TSO apply the penalty.		
Measurement Process	Italian demo: Quantity_provided is measured by smart meters, gathered by Light-Nodes and stored in the Shared Customer Database. Setpoints are stored in the Shared Customer Database. A further analysis of the collected data will allow to extract more details, for example customers' reliability.		
Reporting Period	Italian demo: yearly		
Reporting Audience and Access Rights	☐Public ☒Platone ☐Demo ☐Other		

KPI CALCULATION METHODOLOGY		
Italian demo		
KPI Step Methodology ID [KPI ID #]	**Step**	**Responsible**
KPI_PR_04_IT_1	Extract amount of measured quantities from Shared Customer Database	areti
KPI_PR_04_IT_2	Extract Setpoints from Shared Customer Database	areti
KPI_PR_04_IT_3	KPI calculation	areti

KPI DATA COLLECTION						
Italian demo						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
amount of quantity (kW, kVAr, etc.) exchange with the grid	*Quantity_provided*$_{i,t}$:	PoD's electrical data measured by Smart-Meters, gathered by Light-Node and sent to Shared Customer Database	Shared Customer Database	-	Daily, Up to end of project	areti
Setpoint	$Setpoint_{i,t}$	Values defined during Market phase and stored in Shared Customer Database	Shared Customer Database	-	Daily, Up to end of project	areti

KPI BASELINE
Italian demo

Source of Baseline Condition	LITERATURE VALUES ☐	COMPANY HISTORICAL VALUES ☐	VALUES MEASURED AT START OF PROJECT ☐
Details of Baseline	N.A.		
Responsible (Name, Company) for Baseline	N.A.		

C.5 KPI-IT-01 – Market Liquidity

BASIC KPI INFORMATION			
KPI Name	Market Liquidity	**KPI ID**	KPI_IT_01
Project's Objective	To unlock flexibility to address local congestion and voltage stability issues. To improve customer engagement and facilitate their fair participation to market. To support cooperation with the TSO.		
DEMO where KPI applies	☒IT		
Owner	areti / Engineering		
KPI Description	This KPI aims to measure the market liquidity. The ratio of the sum of flexibility offered to the requested demand for flexibility is measured.		
KPI Formula	$$Market\ Liquidity\ Up = \frac{1}{T}\sum_{t=1}^{T}\frac{\sum_{i=1}^{N}\lvert Flexibility\_offered\_up_{i,t}\rvert}{\sum_{j=1}^{R}\lvert Flexibility\_requested\_up_{j,t}\rvert}\cdot 100$$ $$Market\ Liquidity\ Down = \frac{1}{T}\sum_{t=1}^{T}\frac{\sum_{i=1}^{N}\lvert Flexibility\_offered\_down_{i,t}\rvert}{\sum_{j=1}^{R}\lvert Flexibility\_requested\_down_{j,t}\rvert}\cdot 100$$ where: Flexibility_offered_up$_{i,t}$: amount (kW, kVAr, etc.) of flexibility to increase generation/decrease demand offered from *i*-th flexible resource in the period *t* Flexibility_offered_down$_{i,t}$: amount (kW, kVAr, etc.) of flexibility to decrease generation/increase demand offered from *i*-th flexible resource in the period *t* Flexibility_requested_up$_{j,t}$: amount (kW, kVAr, etc.) of *j*-th request of flexibility to increase generation/decrease demand in the period *t* Flexibility_requested_down$_{j,t}$: amount (kW, kVAr, etc.) of *j*-th request of flexibility to decrease generation/increase demand in the period *t* N: set of flexible resources that made flexibility available R: number of SOs flexibility requests T: examined period For each flexibility service (congestion solving, voltage regulation), the separate value of this KPI will be calculated		
Unit of measurement	%		
Target / Thresholds	>150% To guarantee market liquidity this value should be as great as possible. A preliminary indicative value is assumed 150%. To be noted that liquidity of market should take into account also quantity of offers vs quantity of requests.		

Measurement Process	Offers and Requests are collected daily by Market Platform. The platform, at the end of day, provides a report and automatically calculates the KPI. A further analysis in the Deliverables D3.4 [12] and D3.5 [13] will allow to extract more details for example quantity of resources that provide offers divided by connected power or voltage level.
Reporting Period	yearly
Reporting Audience and Access Rights	☐Public ☒Platone ☐Demo ☐Other

KPI CALCULATION METHODOLOGY		
KPI Step Methodology ID [KPI ID #]	**Step**	**Responsible**
KPI_IT_01_1	Extract amount of requested flexibility from Market Platform	areti
KPI_IT_01_ 2	Extract amount of flexibility offered from Market Platform	areti
KPI_IT_01_ 3	KPI calculation	areti

KPI DATA COLLECTION						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Amount of flexibility requested	Flexibility_requested_up$_{j,t}$ Flexibility_requested_down$_{j,t}$	Values included in requests issued by SOs in Market Platform	Market Platform	-	Daily, Up to end of projects	areti
Amount of flexibility offered by resources	Flexibility_offered_up$_{i,t}$ Flexibility_offered_down$_{i,t}$	Values included in offers issued by Aggregator in Market Platform	Market Platform	-	Daily, Up to end of projects	areti

KPI BASELINE			
Source of Baseline Condition	LITERATURE VALUES ¨	COMPANY HISTORICAL VALUES ☐	VALUES MEASURED AT START OF PROJECT ¨
Details of Baseline	N.A.		
Responsible (Name, Company) for Baseline	N.A.		

C.6 KPI-IT-02 – Forecast Reliability – Customer profile

BASIC KPI INFORMATION			
KPI Name	Forecast reliability – Customer Profile	**KPI ID**	KPI_IT_02
Project's Objective	To ensure reliable and secure power supply in the context of increasing DER penetration.		
DEMO where KPI applies	☒IT		
Owner	areti / Siemens		
KPI Description	This KPI evaluates the reliability of the tool performing forecasting of power flow exchanged by each Resource with the grid. The indicator is calculated for forecasted time range (next 24h or next 4h).		
KPI Formula	$$FC_{Next24h}(\ or\ FC_{Next4h}) = \frac{1}{T}\sum_{t=1}^{T}\frac{1}{N_t}\sum_{i=1}^{N_t}\left\lvert\frac{RL\_profile_{i,t} - FC\_profile_{i,t}}{RL\_profile_{i,t}}\right\rvert \cdot 100$$ where: $RL\_profile_{i,t}$: real profile [kW or kVAr] of *i*-th customer in the period *t*; $FC\_profile_{i,t}$: forecasted profile [kW or kVAr] of *i*-th customer for the period *t*; N_t : number of customers in the period *t*; T : examined period		
Unit of measurement	%		
Target / Thresholds	25% It is assumed that 25% is a realistic value. This KPI is strongly linked to the data availability and granularity.		
Measurement Process	*RL_profile* data is measured by smart meters and stored in the Shared Customer Database. *FC_profile* data is calculated by and stored in DSO Technical Platform.		
Reporting Period	yearly		
Reporting Audience and Access Rights	☐Public ☒Platone ☐Demo ☐Other		

KPI CALCULATION METHODOLOGY
Italian demo

KPI Step Methodology ID [KPI ID #]	Step	Responsible
KPI_IT_02_1	Execute Forecasting Tool	areti
KPI_IT_02_ 2	Extract Smart-Meter's measures stored in Shared Customer Database relevant to the forecasted period	areti
KPI_IT_02_ 3	KPI calculation	areti

KPI DATA COLLECTION						
Italian demo						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Forecasted Power Demand and Generation for next 24h/4h	*FC_profile$_{i,t}$*	Generated by forecasting tool	DSO Technical Platform	-	Yearly, Up to end of project	areti
Ex post Power Demand and Generation	*RL profile$_{i,t}$*	PoD's electrical data measured by Smart-Meters and stored in DSO Operational Systems	Smart-Meters, DSO Operational Systems	-	Yearly, Up to end of project	areti

KPI BASELINE			
Italian demo			
Source of Baseline Condition	LITERATURE VALUES ☐	COMPANY HISTORICAL VALUES ☐	VALUES MEASURED AT START OF PROJECT ☐
Details of Baseline	N.A.		

Responsible (Name, Company) for Baseline	N.A.

C.7 KPI-IT-03 – Forecast Reliability – Grid Profile

BASIC KPI INFORMATION			
KPI Name	Forecast reliability – Grid Profile	**KPI ID**	KPI_IT_03
Project's Objective	To ensure reliable and secure power supply in the context of increasing DER penetration.		
DEMO where KPI applies	☒IT		
Owner	areti / Siemens		
KPI Description	This KPI evaluates the reliability of the tool performing forecasting of power flow in significant assets of the grid. The indicator is calculated for forecasting time range (next 24h or next 4h).		
KPI Formula	$Power\_Flow\_FC\_Next24h\ (or\ Power\_Flow\_FC\_Next4h) =$ $= \frac{1}{T}\sum_{t=1}^{T}\frac{1}{N_t}\sum_{i=1}^{N_t}\left\lvert\frac{RL\_Power\_Flow_{i,t} - FC\_Power\_Flow_{i,t}}{RL\_Power\_Flow_{i,t}}\right\rvert \cdot 100$ where: $RL\_Power\_Flow_{i,t}$: real power flow [kW or kVA] of *i*-th asset in the period *t* $FC\_Power\_Flow_{i,t}$: power flow forecasted [kW or kVA] of *i*-th asset for the period *t* N_t: number of assets of same category (e.g. Primary Substation nodes, Secondary Substation nodes etc.) in the period *t* T: examined period		
Unit of measurement	%		
Target / Thresholds	30% It assumed that 30% is a realistic value that could be fulfilled. This KPI is strongly linked to the data availability, reliability of network topology and accuracy of electrical model.		
Measurement Process	*RL_Power_Flow* are measured by DSO's sensors and stored in the Operational Systems. *FC_Power_Flow* are calculated by and stored in DSO Technical Platform. The DSO Technical Platform will calculate the KPI.		
Reporting Period	yearly		
Reporting Audience and Access Rights	☐Public ☒Platone ☐Demo ☐Other		

KPI CALCULATION METHODOLOGY
Italian demo

KPI Step Methodology ID [KPI ID #]	Step	Responsible
KPI_IT_03_1	Execute Forecasting Tool	areti
KPI_IT_03_ 2	Extract asset measures from SCADA relevant to the forecasted period	areti
KPI_IT_03_ 3	KPI calculation	areti

KPI DATA COLLECTION						
Italian demo						
Data	**Data ID**	**Methodology for data collection**	**Source/Tools/Instruments for Data collection**	**Location of Data collection**	**Frequency of data collection**	**Data collection responsible**
Forecasted Power Flows for next 24h/4h	*FC_Power_Flow*$_{i,t}$	Generated by forecasting tool	DSO Technical Platform	-	Yearly, Up to end of project	areti
Ex post Power Flows	*RL_Power_Flow*$_{i,t}$	Assets' electrical data measured by Field Sensors, gathered by SCADA	Field sensors, Operational Systems (SCADA)	-	Yearly, Up to end of project	areti

KPI BASELINE			
Italian demo			
Source of Baseline Condition	LITERATURE VALUES ☐	COMPANY HISTORICAL VALUES ☐	VALUES MEASURED AT START OF PROJECT ☐
Details of Baseline	N.A.		
Responsible (Name, Company) for Baseline	N.A.		