Platone

PLATFORM FOR OPERATION OF DISTRIBUTION NETWORKS

Platone

PLATform for Operation of distribution NEtworks

D3.6

Report on first integration activity in the field

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Abstract

The goal of the Platone Italian Demo is to develop a complete "end-to-end local flexibility market" assuring a proper TSO/DSO coordination.

This document aims to describe the relevant integration activities and data setup that followed the first "Delivering of technology" of all the Italian Demo Platforms including the Market Platform, the Aggregator Platform, the DSO Technical Platform and the Access Layer (composition of Light Node, Blockchain Access Layer and Shared Customer Database).

The Deliverable mentions some relevant integration activities between the DSO Technical Platform and the DSO Operational Systems, important ongoing installation activities on the customers' side as well as the development of a mobile App for the customer.

Furthermore, this work shows the scenario defined with real network data that was used to validate the overall Italian Demo Platone process. The complete up-and-running system led to some first relevant results in terms of TSO/DSO coordination highlighting in a real test scenario the importance of each single phase implemented in the Platone Italian Demo process (especially the role of the "DSO Flexibility Validation") and confirming the adopted flexible approach.

Keyword list

Access Layer; Aggregator Platform; Blockchain Access Layer; DSO Technical Platform; Light Node; Market Platform; System Architecture; Shared Customer Database; System Integration; Field Test

Executive Summary

"Innovation for the customers, innovation for the grid" is the vision of project Platone - Platform for Operation of distribution Networks. Within the H2020 programme "A single, smart European electricity grid", Platone addresses the topic "Flexibility and retail market options for the distribution grid". Modern power grids are moving away from centralised, infrastructure-heavy transmission system operators (TSOs) towards distribution system operators (DSOs) that are flexible and more capable of managing diverse renewable energy sources. DSOs require new ways of managing the increased number of producers, end users and more volatile power distribution systems of the future. Platone is using blockchain technology to build the Platone Open Framework to meet the needs of modern DSO power systems, including data management. The Platone Open Framework aims to create an open, flexible and secure system that enables distribution grid flexibility/congestion management mechanisms, through innovative energy market models involving all the possible actors at many levels (DSOs, TSOs, customers, aggregators). It is an open source framework based on blockchain technology that enables a secure and shared data management system, allows standard and flexible integration of external solutions (e.g. legacy solutions), and is open to integration of external services through standardized open application program interfaces (APIs). It is built with existing regulations in mind and will allow small power producers to be easily certified so that they can sell excess energy back to the grid. The Platone Open Framework will also incorporate an open-market system to link with traditional TSOs. The Platone Open Framework will be tested in three European field trials and within the Canadian Distributed Energy Management Initiative (DEMI).

The goal of the Platone Italian Demo is to develop a complete "end-to-end local flexibility market" assuring a proper TSO/DSO coordination.

This document aims to describe the relevant integration activities and data setup that followed the first "Delivery of technology" of all the Italian Demo Platforms providing a first overview on the adopted methodology (that will be used also in the next Project phases) and then focusing on the test architecture and on the single components. These tasks considered all the fundamental Platforms of the Italian Demo (Market Platform, Aggregator Platform, DSO Technical Platform and Access Layer), putting a solid basis in place for the first real deployment of the system in the field and also for the new functions that can be easily integrated. The test architecture was setup considering already the following steps of the project, enabling a simple evolution in terms of data flows and Platforms distribution

The Deliverable mentions some relevant integration activities between the DSO Technical Platform and the DSO Operational Systems focusing both on the real time interaction and on the historical measurements acquisition; this kind of integration added an important value to the Italian Demo in terms of alignment with the real electrical network scenario, setting up a strong link between the new Platone Platforms and the already existing DSO Operational Systems.

On the other side, some important ongoing activities on customers' side are listed like the installation of Electrical Storage Systems and the integration of Light Nodes with the local systems (i.e. EMS) as well as the development of a mobile App that will involve actively the customer in the whole process.

Furthermore, this work shows the technical/economic scenario defined with real network data that was used to validate the overall Italian Demo Platone process. The complete up and running system allowed to test all the necessary data flow and the internal algorithms behaviour leading to some first relevant results in terms of TSO/DSO coordination and confirming the flexible approach designed in the Platone Italian Demo. . In particular, the steps of the designed process (above all the "DSO Flexibility Validation") and the complete management of different relevant network points to be adopted for the DSO Flexibility Request and for the TSO Flexibility Requests contributed to mitigate the different structural approaches needed by the two System Operators (i.e. "large Flexibility Services" on large grid areas for the TSO vs "small Flexibility Services" on specific grid points for the DSO).

Authors and Reviewers

Main responsible		
Partner	**Name**	**E-mail**
SIEMENS		
	Carlo Adriano Arrigoni Brunella Conte	carlo.arrigoni@siemens.com brunella.conte@siemens.com
Author(s)/contributor(s)		
Partner	**Name**	
areti		
	Angela Irlandese	angela.irlandese@areti.it
	Massimiliano Finzi	massimiliano.finzi@areti.it
	Antonio Vito Mantineo	antoniovito.mantineo@areti.it
	Gabriele Fedele	gabriele.fedele@areti.it
	Ercole De Luca	ercole.deluca@areti.it
Acea Energia		
	Gianluca Nori	gianluca.nori@aceaenergia.it
	Simone Minniti	simone.minniti@aceaenergia.it
Apio		
	Alessandro Chelli	alessandrochelli@apio.cc
	Mattia Alfieri	m.alfieri@apio.cc
Engineering		
	Ferdinando Bosco	ferdinando.bosco@eng.it
SIEMENS		
	Andrea Zocchi	andrea.zocchi@siemens.com
	Franco Corti	franco.corti@siemens.com
Reviewer(s)		
Partner	**Name**	
AVACON		
	Benjamin Petters	
HEDNO		
	Stavroula Tzioka	
Approver(s)		
Partner	**Name**	
RWTH		
	Padraic McKeever	

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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 acquisition system based on a two-layer Blockchain approach: an "Access Layer" to connect customers to the Distribution System Operator (DSO) and a "Service Layer" to link customers and DSO to the Flexibility Market environment (Market Place, Aggregators, …). The two layers are linked by a Shared Customer Database, containing all the data certified by Blockchain and made available to all the relevant stakeholders of the two layers. This Platone Open Framework architecture allows a greater stakeholder involvement and enables 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), Market, customers and Aggregators. In particular, the DSO will invest in a standard, open, non-discriminatory, blockchain-based, economic dispute solving settlement infrastructure, to give both to the customers and to the Aggregators the possibility to more easily become flexibility market players. This solution will allow the DSO to acquire a new role as a market enabler for end users and a smarter observer of the distribution network. By defining this innovative two-layer architecture, Platone strongly contributes to removing technical and economic 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 Open Framework will be tested in three European trials (Greece, 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 Italian Demo, led by the Italian DSO *a*reti, aims to realise a completely integrated system able to involve all the distributed energy resources (connected to the Medium and Low Voltage networks) in providing Flexibility Services according to specific market frameworks and including all the relevant stakeholders (TSOs, DSOs, customers, Aggregators).

All the partners involved in WP3 worked on the implementation of the first version of the System Architecture of the Italian Demo that led to specific integration activities and to a first field test setup (Milestone 8 Field test fully operational in Italy).

This field test setup is a very important step on the Italian Demo roadmap because it concretizes all the partners' efforts showing a complete, up and running system working with first examples of real data and electrical network scenarios.

1.1 Task 3.2, 3.3 and 3.4

This Deliverable reports on all the integration activities connected to the main development Tasks of WP3:

- Task 3.2: "Development of a standard Blockchain based infrastructure, implementing a Common Access Interface between all the market players"
- Task 3.3: "Implementation of a technical platform for grid state estimation and flexibility requests validation"
- Task 3.4: "Solutions to enable Aggregators to provide flexibility: Aggregator platform and customer involvement"

Starting from the overall design of the technical solution and delivering of technology [2], activities continued involving different integration steps between all the Italian Demo platforms and preparing proper data scenarios for a first field test.

1.2 Objectives of the Work Reported in this Deliverable

The objective of the work reported in this Deliverable is to describe the integration activities that follow the "Delivering of technology (v1)" released on month 21 [2] taking into account the general adopted approach, focusing on the single Italian Demo platforms and on the overall necessary integration architecture. Furthermore, the Deliverable contains the description of the economical/technical scenario setup to test the overall Platone Italian Demo process.

1.3 Outline of the Deliverable

The document has the following structure:

- Chapter 1 is about the general introduction of the reported work
- Chapter 2 describes the adopted methodology and the single integration steps for the Italian Demo architecture
- Chapter 3 is dedicated to the overall test architecture and to the integration activities for each Platform of the Italian Demo
- Chapter 4 explores the data used to build the first test scenario, the description of the test process and the final results
- Chapter 5 presents the general conclusions of the activities shown in the Deliverable

1.4 How to Read this Document

This Document can be read independently from other Platone's Deliverables. Though, it is connected to other Documents of the Platone project and especially to D3.3 "Delivering of technology (v1)". The following list summarizes all the linked Platone Deliverables:

- D3.1 "Internal operational plan and WP3 roadmap" [3] released by areti on Month 3 (November 2019) as confidential detailed work plan and roadmap of WP3. 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)" [4] 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" [5] 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)" [6] released by ENG on Month 18 (February 2021) as a public report that accompanies the software delivery of the Platone Market Platform with an architecture overview and explanation of a demonstration setup.
- D3.3 "Delivering of technology (v1)" [2] released by areti on Month 21 (May 2021) as a public report that accompanies the software delivery of all the Italian Demo Platforms with a System Architecture overview defining the functional and technical requirements, and the communication mechanisms.

2 Methodology

2.1 Integration approach

The Italian Demo is based on the architecture shown in Figure 1 where:

- the Blockchain Service Layer (including Market Platform) was developed in WP2 and adapted to the Italian requirements (as necessary)
- the Aggregator Platform and the DSO Technical Platform were developed by Siemens
- the Access Layer was developed by APIO

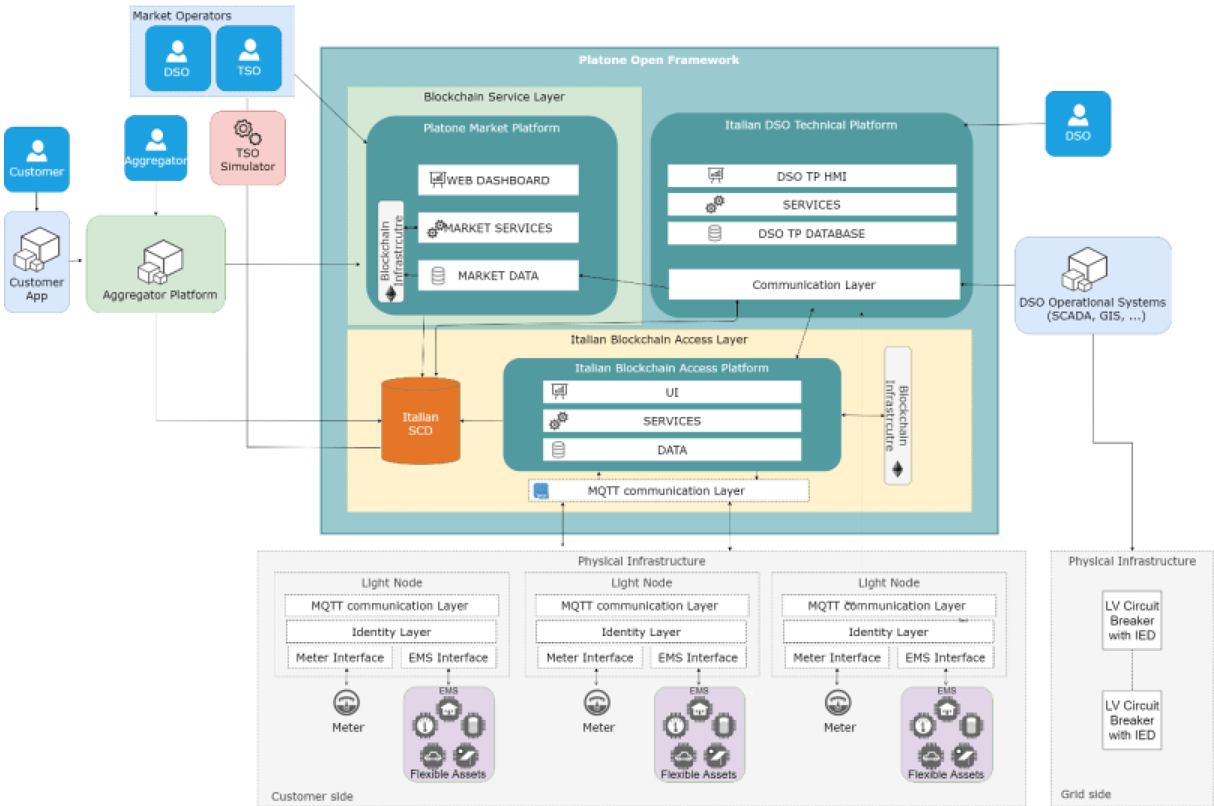


Figure 1: Italian Demo Architecture

After the Delivering of Technology (first release) [2] was done for each Italian Demo platform, different integration activities were performed to verify properly all the data flows between the different components of the system architecture.

All these integration activities were planned and organized keeping the already well-defined work streams of WP3 [2]. The main goal was to test this first Italian Demo release going into the complete functional process; this task was fulfilled still not implementing all data flows or specific features and performing the activities with different test boundaries (number of processed timeslots, number of considered flexible customers, electrical network scenario, combination of economic data).

Figure 2 shows the timeline of the whole Platone process defined in the Italian Demo. The first field tests described in this Deliverable considered all these phases in the "Day Ahead" market session:

- DSO/TSO flexibility requests
- Aggregators' flexibility offers
- Market Platform economical outcomes
- DSO flexibility validation
- services activation

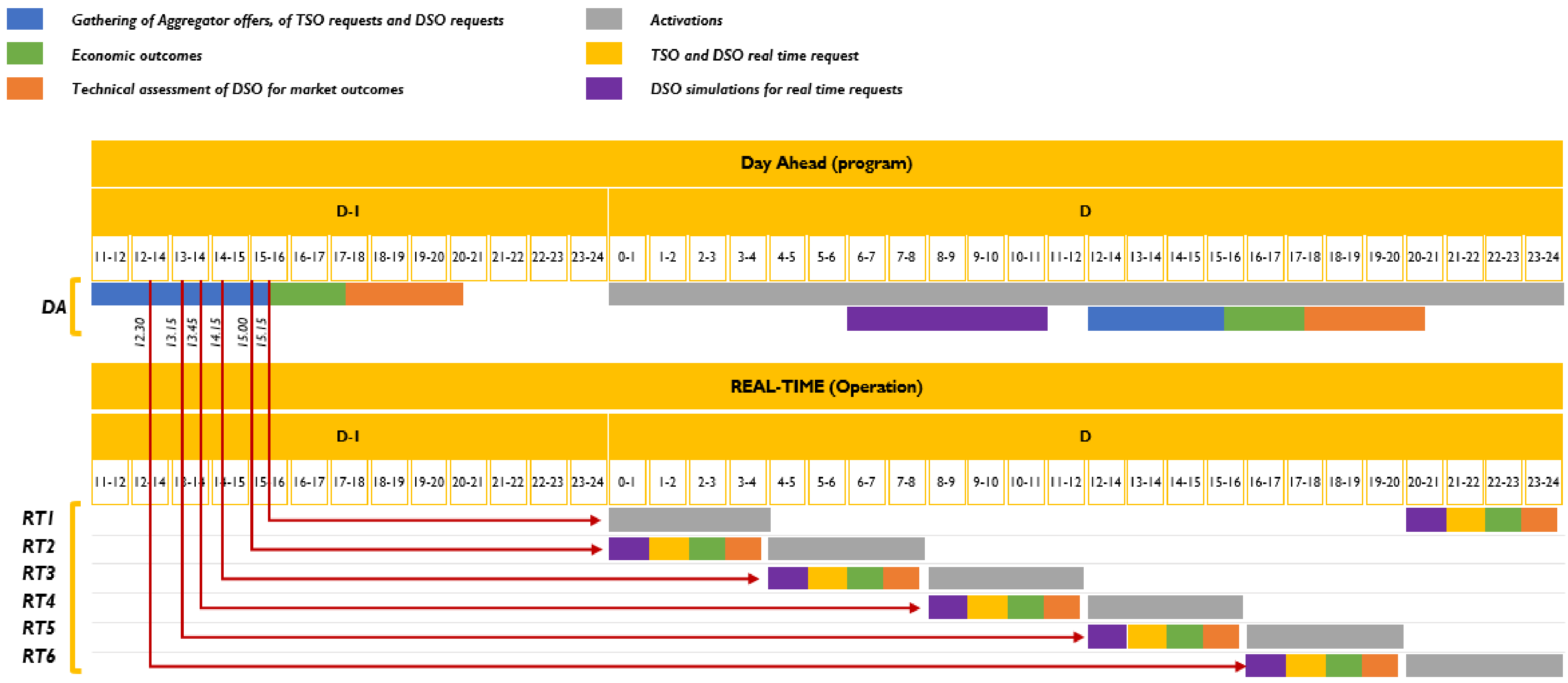


Figure 2: Timeline of the Platone Italian Demo process

2.2 Integration steps

To get to the first complete Italian Demo field test three main steps were followed:

- Unit Test: internal platforms integration (algorithms, services, interfaces, …)
- Integration Test: first platforms integration (using mock data and starting with "1-to-1" platform tests)
- End-to-End Test: using real data flows & full platforms operation (complete process consistency check)

More details about these integration steps, also involving some additional activities about the integration with physical devices, mobile apps and the DSO Operational Systems, will be reported in Chapter 3.

Figure 3 shows some more details about the data flow specified for the Italian Demo architecture that was all implemented besides Flow 1A between SCD and DSOTP, and Flow 5 between Market Platform and DSOTP. The content of each data flows is:

- Flow 0 (AP – SCD): Flexible PoD registration
- Flow 0 (SCD – DSOTP): Flexible PoD registration
- Flow 0A (DSOTP – SCD): Flexible PoD - PoM association
- Flow 0B (SCD – MP/TSO Simulator): Flexible PoD data
- Flow 1 (SCD – AP): Flexible PoD data (15min)
- Flow 1A (SCD – DSOTP): Flexible PoD data (more than 15min)
- Flow 2a (AP – MP): Flexibility offers
- Flow 2b (TSO Simulator – MP): TSO Flexibility requests
- Flow 2c (DSOTP – MP): DSO Flexibility requests
- Flow 3 (MP – DSOTP): Market outcomes for technical validation
- Flow 4 (DSOTP – MP): Validated market outcomes
- Flow 5 (MP – AP/DSOTP/TSO Simulator): Market results
- Flow 6 (AP – SCD/DSOTP): Setpoint
- Flow 6 (DSOTP – Light Node): Setpoint (to the field)
- Flow 6 (Light Node – EMS): Setpoint (customer's plant)
- Flow 7 (Light Node – Blockchain Platform): Measurement data & Setpoint
- Flow 7 (Blockchain Platform – SCD): Measurement data & Setpoint
- Flow 8 (SCD – MP): Measurement data & Setpoint

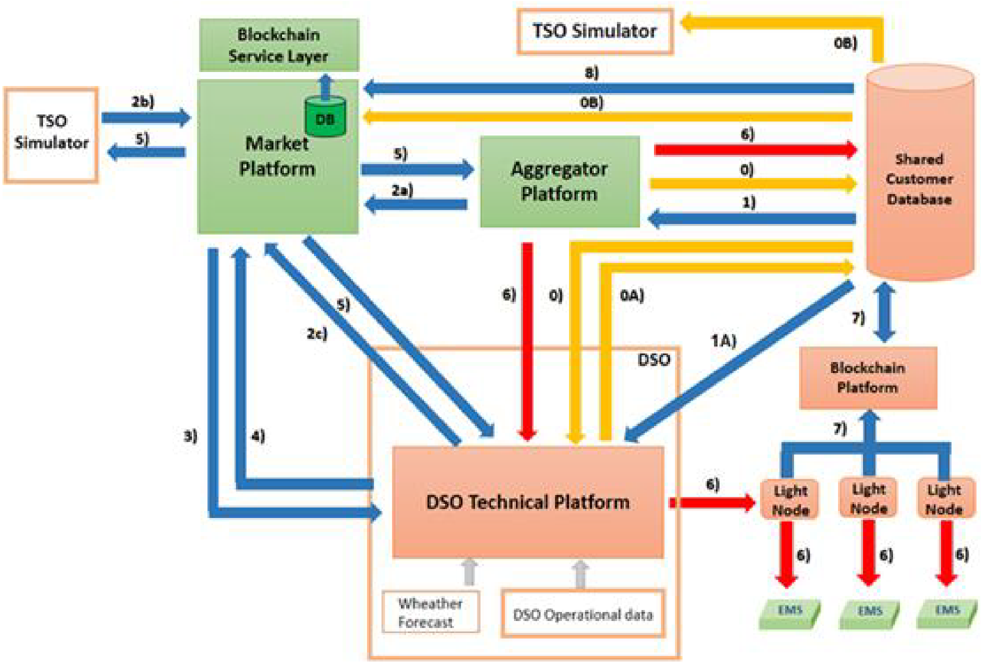


Figure 3: Data Flow for Italian Demo architecture

3 Test architecture and components integration

3.1 Overview

Chapter 3 shows the architecture that was setup to perform all the integration steps and also describes the activities related to the single components of the Italian Demo architecture.

The Unit Tests of the single platforms were performed without requiring any connection to the other components of the Italian Demo architecture; the next two steps (Integration Tests and End-to-End tests) required the test architecture shown in Figure 4.

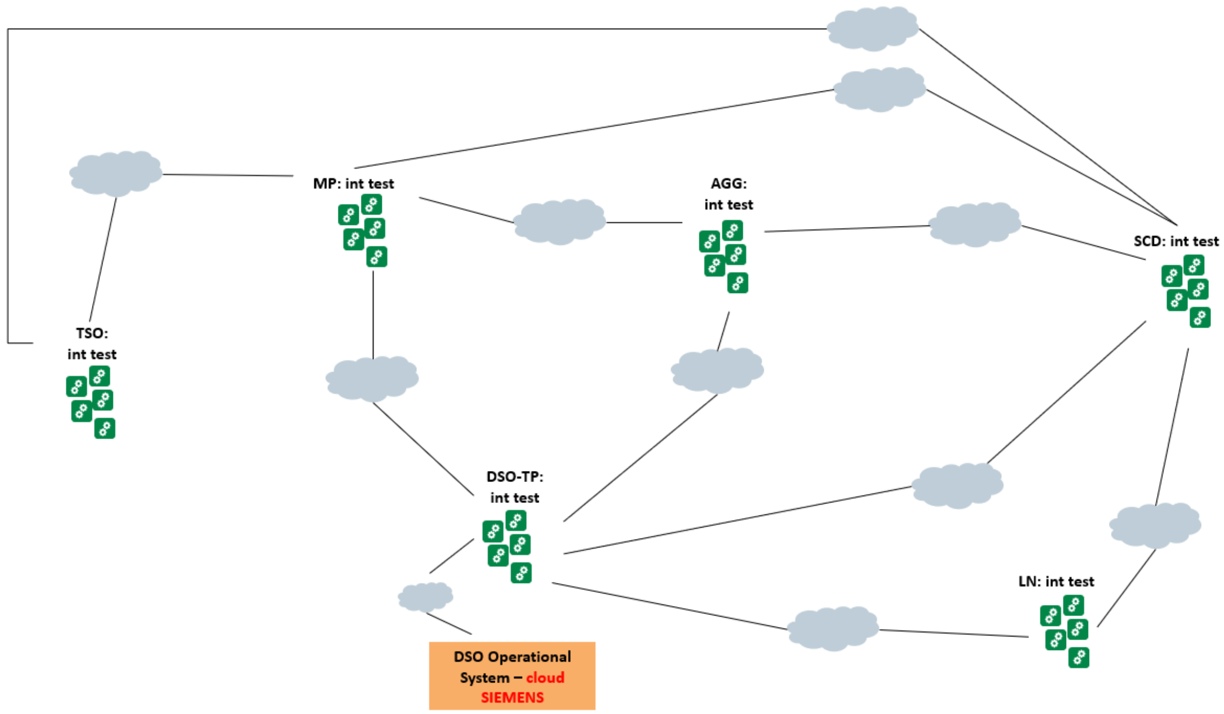


Figure 4: Test architecture

The different Platforms interact with each other in several ways:

- REST API (producer and consumer)
- MQTT (producer and consumer)
- Kafka (producer and consumer)

Attention was always put on security aspects using secure protocols:

- A certificate for https communications was generated and the public part distributed to the various actors;
- According to Oauth2, several credentials have been generated and used for authorization.

All inbound and outbound flows pass through an API gateway for the following reasons:

- Protect API from overuse and abuse using authentication service and rate limiting;
- Using a microservices architecture, a single request could require calls to dozens of distinct services.

3.2 Market Platform

The Platone Market platform is one of the core components of the Platone Open Framework (as described in D2.1 [4]). The Market Platform (MP) 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.

The first prototype of the Platone Market Platform was integrated in the Italian Demo Architecture and includes

- Only Day-Ahead Market Flexibility Services
- Clearing Market Tool based on price priority
- Settlement Outcomes and validation
- Blockchain and Smart Contract services for Settlement and Customer Incentivisation
- First prototype of the Web Dashboard for Market Participants.

For more detail about the first release of the Platone Market Platform, see D2.3 [6].

3.2.1 Integration with other platforms

In the context of the Italian Demo, the Platone Market Platform allows the integration of other platforms through a specific component: the communication layer.

As shown in the Figure 5 the communication layer is part of the overall Platone Market Platform architecture and 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).

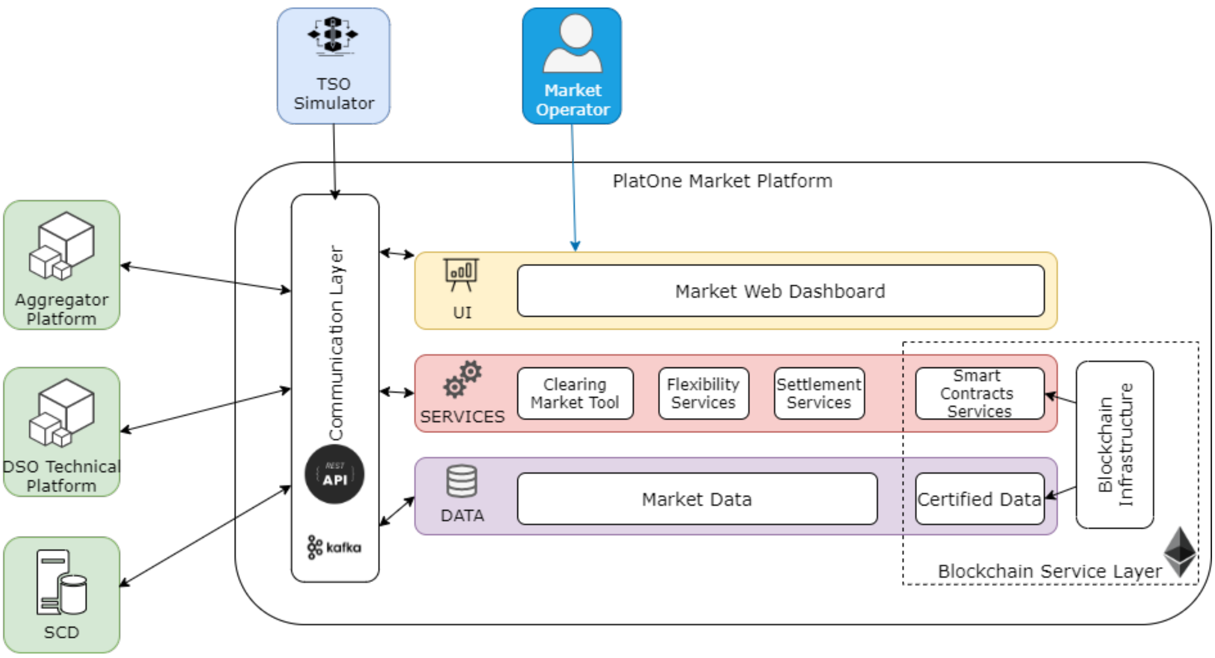


Figure 5: Market Platform Architecture

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

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 launched by the external systems.

The asynchronous communication is implemented in the Message Broker. It acts 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.

In the context of the Italian Demo both communication mechanisms were used based on the needs of the communication flow.

Figure 6 describes the integration flows between the Platone Market Platform and the other platforms.

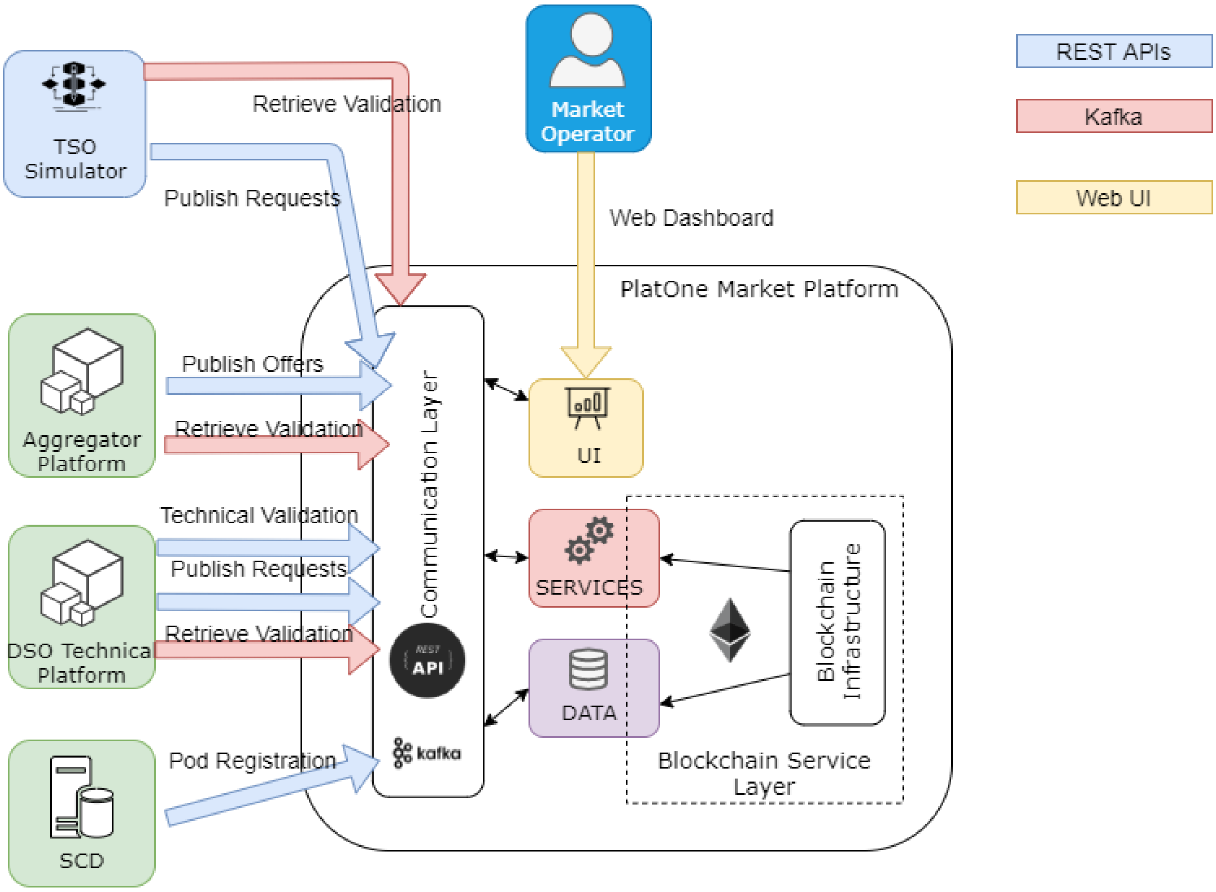


Figure 6: Integration with the Market Platform

All the REST APIs exposed by the Platone Market Platform implement an authentication mechanism based on Oauth2.0 over HTTPS connection and are documented as OpenAPI3.0 in the D3.3 [2].

In particular, three different APIs were used by the other platforms for the communication with the Market Platform. The APIs are briefly described in the Table 1.

Table 1: API used by other platforms

API	Actor(s)	Data Exchanged
/flexibilityService [POST]	TSO Simulator, DSOTP, Aggregator Platform	Flexibility Services
/technicalOutcome [POST]	DSOTP	Technical Outcome
/podRegistry [POST]	SCD	PoD

All the connections to the Message Broker are secured through a mutual authentication based on TLS.

In particular, the Validated Outcomes are published in the Message Broker. The Validated Outcomes are filtered for each Market Participant (DSO, TSO, and Aggregator(s)) and published in different Kafka Topics. Each consumer is authorized to read only in its own specific topic.

Table 2: Kafka Topics

Topic	Publisher	Subscriber	Message
DSOOutcome	Market Platform	DSO Technical Platform	Validated Outcome filtered by DSO
TSOOutcome	Market Platform	TSO Simulator	Validated Outcome filtered by TSO
AggOutcome(Id)	Market Platform	Aggregator(id)	Validated Outcome filtered by Aggregator (id)

3.2.2 Market Platform environment setup

The first prototype of the Platone Market Platform was released as Open Source and all the single components of the architecture are available as Dockers. The use of Dockers ensures not only an easy deployment process and total portability of the solution, but also a high level of scalability of the released applications.

The Figure 7 describes the deployment of the Platone Market Platform architecture, using Docker containers, in the ENG Cloud Infrastructure located at Pont-Saint-Martin (Italy).

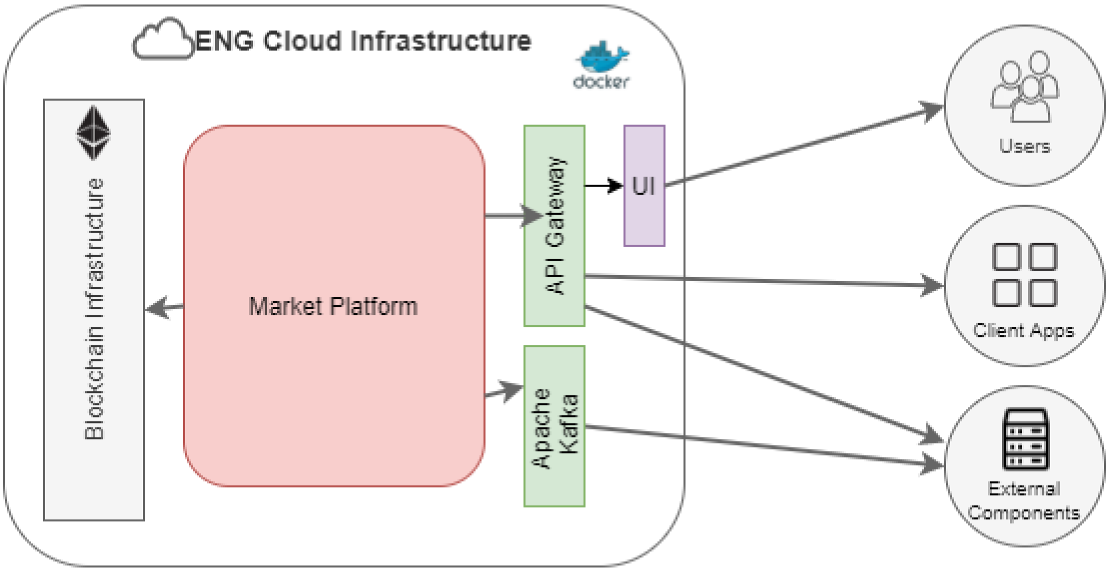


Figure 7: Deployment of the Platone Market Platform

The version deployed and configured in the ENG Cloud Infrastructure was used for the integration in the Italian Demo.

3.3 Aggregator Platform

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 (Point of Delivery) PoDs, and by providing optimal algorithms to optimize market strategy and flexibility offers. This platform is named DEOP (Distributed Energy Optimizer) and it is developed by Siemens. The functional and technical requirements of the AP are extensively described in Section A.2.3 of D3.3 [2] and a brief description is reported below for the sake of explanation.

In the Italian Demo, the AP has several tasks and four use-cases have been individuated which reflect four main functionalities:

1. Pod Registration and Baseline Definition. The AP is able to collect all information from the PoDs and must be able to register the data in the Shared Customer Database (SCD); furthermore, the AP is the platform in charge of generating for each Point of Delivery (PoD) the consumption/production baseline that is a fundamental element for the flexibility market and must be able to provide it to all market actors.
2. Market Offers Definition. The AP generates and sends to the market the flexibility offers, starting from the technical and economic constraints of each PoD; The AP is able to make measurements available to the Mobile App of the customers.
3. PoD Activation. The AP has also the fundamental role of sending the setpoint to the PoDs, consequently to the acceptance of a flexibility offer in the market phase.
4. Settlement and Remuneration. The AP must be able to take into account the economic outcome derived from the flexibility valorisation in the market and it needs to correctly attribute the right remuneration to the different users according to the BSP-final user contractual agreements.

Regarding the Aggregator Platform, at this stage of the project, two field integrations have been developed or are in the development phase: the integration of the AP with the mobile app of the customers participating in the pilot of the Italian Demo and the integration of the AP with the light node, which provided detailed information on some customers' devices such as the battery energy storage.

3.3.1 Integration with other platforms

In a similar manner to the other platforms for allowing inter-platform communication, the Aggregator Platform architecture includes a Communication Layer, a specific component that provides integration with other components of the architecture, using two different communication mechanisms, synchronous and asynchronous.

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

The Figure 8 represents the main data exchanges between the AP and the other Platforms highlighting also the type of communication in place for each data flow with different colours.

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.

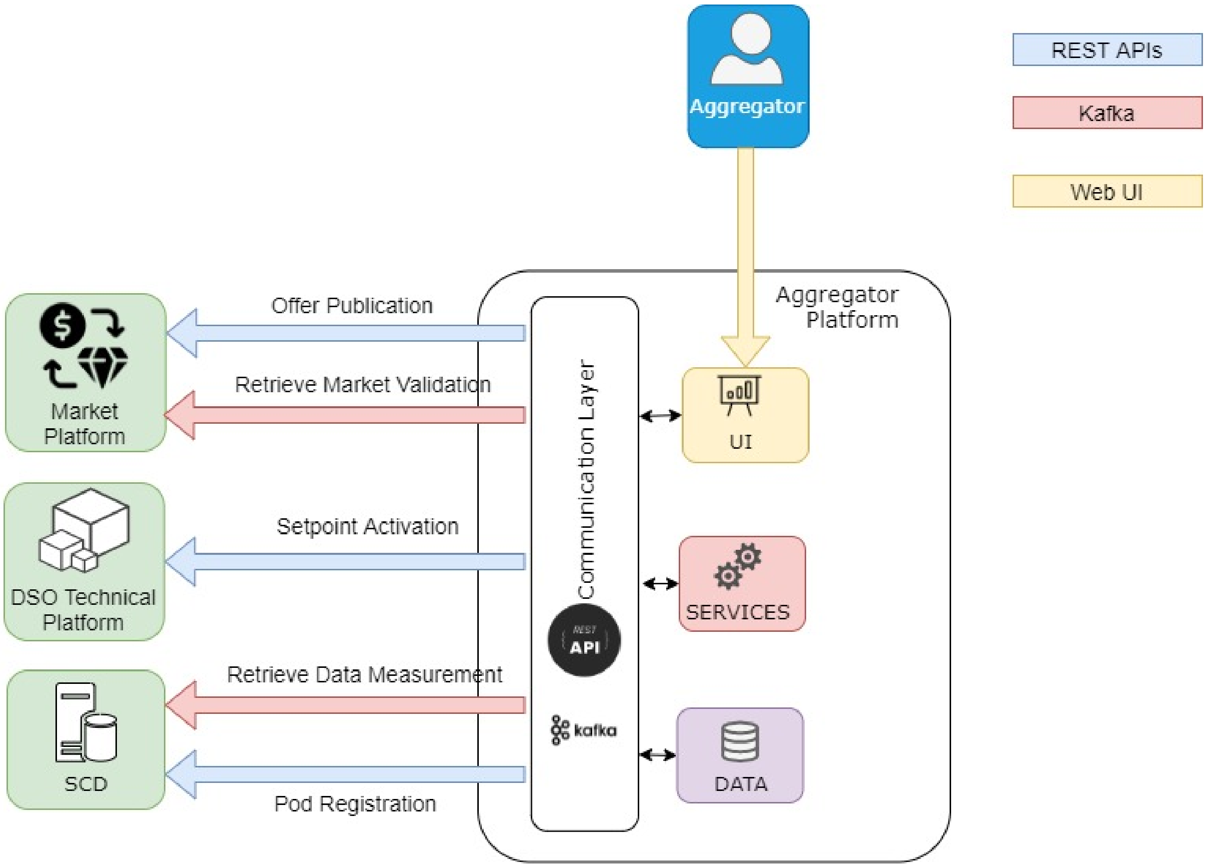


Figure 8: Data exchange between AP and other Platforms

3.3.2 App

The first integration in the field for the AP, which is being implemented and will be tested by August 2021, is the one with the mobile App for the Customers participating in the Italian pilot named ***Flessibili***. This integration is necessary to guarantee an active collaboration between Customers and the Aggregator, making customers more aware of their consumption and Aggregators informed about the customers' flexibility habits.

The main functionalities of the customer app are listed below:

- providing measurement data, giving visibility of consumption to the client (first release);
- performing easily a double-check of contractual details and configuring all the details concerning the flexibility preferences (the amount of flexibility which is available for the Aggregator) defined in the first place (first release);
- measurement data via notifying 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;
- giving the possibility to the end-user to make available/unavailable his/her flexibility for the next day;
- providing economic overview of how the flexibility is remunerated, by assigning tokens according to the contractual agreement in place between the customers and the user.

In particular, as shown below in Figure 9, at this stage of the project, the integration between the AP and the mobile application is needed to make clients accessible to their own consumption data. The data layer of the AP, which receives the measurements from the SCD, makes the data available also for the mobile application.

The measurements shown in the mobile app are acquired calling specific REST APIs made available from AP, in order to exchange consumption/production data. Those public REST APIs allow performing interrogation to the AP Database, which can be accessed through the API Gateway after obtaining the Auth-Token. This means that to access in a secure way the AP data, is used an authorization mechanism, based on apikey.

The Login request is the very first action that is needed from the mobile app in order to get the valid apikey used in all the next requests. The apikey value that goes with this request is the one that is necessary to be able to perform all the other requests. In case of apikey expiration, a Renew request is necessary to postpone the expiration date.

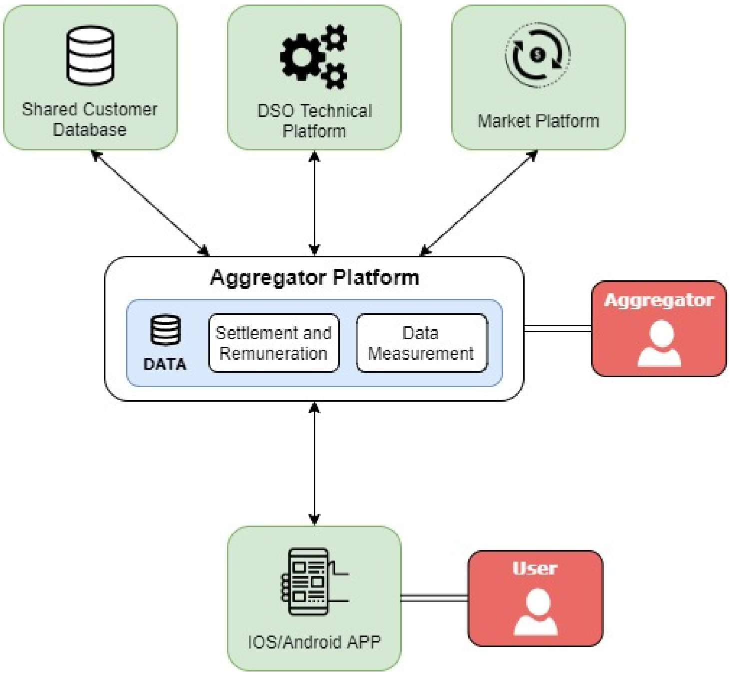


Figure 9: Integration between AP and mobile application

A mock-up of the consumption page can be seen below in Figure 10:

Figure 10: Consumption page

3.3.3 Light Node-Aggregator Platform integration

Within the pilot, most of the users will have battery storage and PV panels installed at their premises. These installations will make the users more active, thus increasing their flexibility potential. For this reason, an integration, which will be implemented by September 2021, is needed to get detailed information on energy flows and state of charge of the devices. The link between customers' devices and the AP is the Light Node, and this integration is necessary to provide the Aggregator with a wider set of data, in order to perform comprehensive analysis of the flexibility potential of each customer. The Light Node is able to read the information of customer's Energy Storage System (see Ch. 3.6) and pass them on to the AP. A scheme of the infrastructure is presented below, in Figure 11:

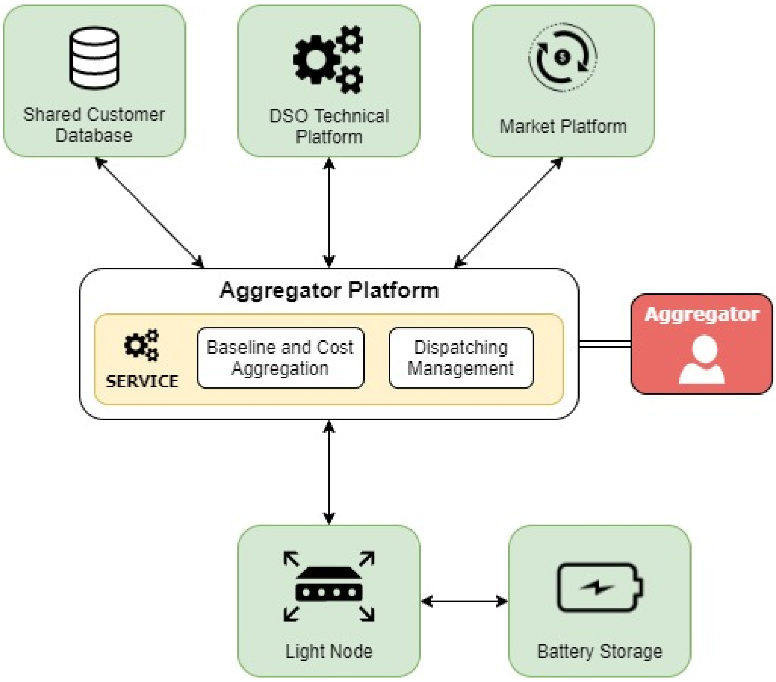


Figure 11: Infrastructure's scheme

With this integration, the AP has more information as input for its Service Layer, which is the layer in charge of defining baseline and flexibility offers for the market. This information includes for example, the state of charge (SOC) of the storage, the direction of the energy flows (also of the energy produced by PV), and based on that, the AP is able to build a bidding strategy compliant with the ability of the customer of responding properly. This information is also needed for building an energy baseline for each PoD which represents the best forecast for the day after.

The AP supports the integration of "field entities" using MQTT protocol (http://mqtt.org/) via an MQTT Broker that allows them:

- to send information (e.g. field data value) to the AP Platform: MQTT publish is required;
- to receive information (e.g. configuration data, commands) from the AP Platform: MQTT subscribe is required.

By taking advantage of this feature, Light nodes (that support MQTT protocol) can connect directly to AP platform to send battery storage information. This functionality has not been implemented yet, but it will be a fundamental addition for the next release.

The Light nodes in order to start communicating with AP via MQTT need:

- the URL of AP MQTT Broker
- the service provider <serviceProvider>
- the unique DeviceID <deviceId>
- the username and password

Furthermore, Light nodes implement MQTT over SSL (MQTTs) to guarantee security exchange of data. In order to succeed in connecting to the AP broker via SSL, the MQTT device (Light nodes) must have a private key and an SSL certificate provided by the AP provider.

3.3.4 Aggregator Platform environment setup

The AP is a cloud platform designed following the Internet of Things paradigm. It is composed by service packages deployed using docker images.

To set up the environment it is necessary to install:

- Docker and docker-compose;
- MongoDB;
- Docker containers with general microservices;
- Docker containers with specific microservices.

The following containers are independent, each one with its dedicated git repository and implemented features, developed expressly for Platone project:

- A specific gateway to communicate with SCD using a client Kafka. It allows the AP to receive quarterly hour measurement from SCD;
- A specific gateway to communicate with MP using a client Kafka. It allows the AP to receive validated offers from MP;
- A specific connector, to manage all the business logic:
    - to send general data to SCD;
    - to send offers to the MP;
    - to send setpoint to DSOTP.

3.4 DSO Technical Platform

3.4.1 Introduction

The DSO Technical Platform (DSOTP) is an innovative platform able to provide the following functions:

- Performing Power Flows
- Sending flexibility requests to the Market Platform
- Performing technical validation of flexibility offers
- Sending set-points to flexible resources

DSOTP receives different inputs coming from the DSO monitoring and control system (DSO Operational Systems) like MV distribution network consistency, its real status measurements acquired by field devices and historical data of customers' meters. The algorithms running on the DSOTP are able to estimate the future grid status and identify possible congestions or voltage violations; all these data are shown on the local DSOTP interface.

In case of congestions or voltage violations, the DSOTP identifies the flexible resources that could solve the issue and automatically sends the flexibility requests to the Market Platform.

On the other side, when the Market Platform performs the matching between Flexibility Requests and Flexibility Offers (provided by Aggregators), the DSOTP executes the final technical validation of the flexibility services that can really be activated on the DSO's network.

The DSO Technical Platform is shown in Figure 12.

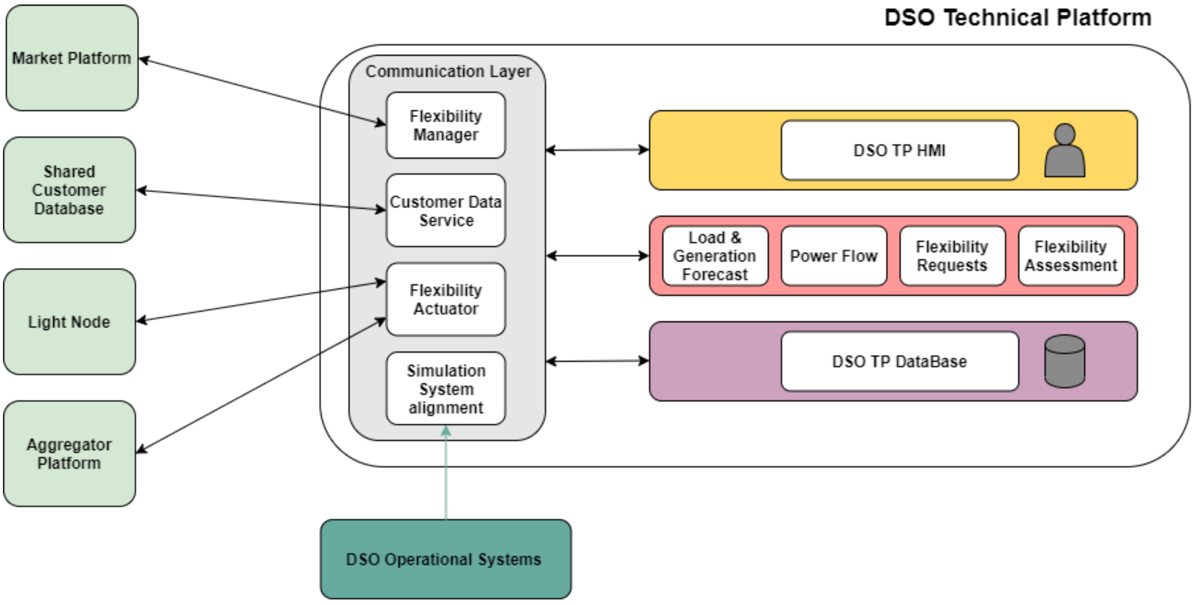


Figure 12: DSO Technical Platform

3.4.2 DSOTP internal integration

The Power Flow algorithm requires knowledge of network physical structures data, topological configuration and a time-fixed snapshot of each power contribution (active/reactive) related to loads and generations. The first integration effort was aimed to decouple the Power Flow and Flexibility Algorithms from the DSOTP interface services development (i.e. integration of external data flows).

This leads to two main advantages:

- parallelized development of computation components and DSOTP integration with Platone Italian Demo data flows;
- offers a high-performance computation platform easily available in both day-ahead and real time context.

The computational platform (Figure 13, internally called NCS - Network Calculation System) was implemented so that it can be instructed to replicate a given network structure and topological configuration identified by a specific model identifier. Using that model identifier, power flow computation can be carried out, related to specific timestamps, by other components of DSOTP that, basing on power flow results, can activate flexibility requests or validation on specific portions of the grid involving electrical violation or congestions. The reference timestamp is mandatory to allow NCS recover information about situation of powers inside the network, collecting them from available sources.

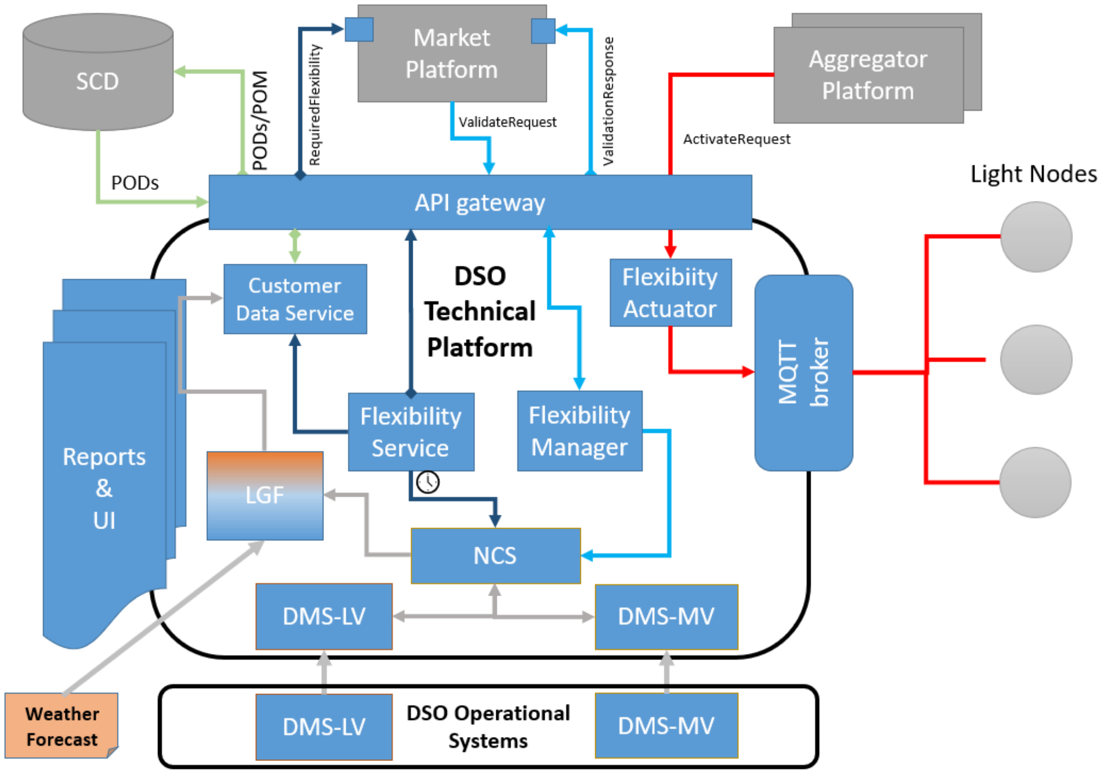


Figure 13: NCS - Network Calculation System

Once NCS was correctly configured and available to any client calls, the next integration went through data sources, giving computations more reliable data to work with. Network structure data, involving network physical components and their connections was extracted from DMS-MV and bound to electrical objects data (using well known defaults where lacking) giving a base network picture to use for test computation.

Considering the nodal power injections (active/reactive power), the “Load & Generation forecasting tool” (LGF) contribute to manage data required from computations creating a timeline indexed collection of profiles for each power entity in the network; another internal DSOTP component manages separately PoDs’ flexibilities related data. NCS can access power data basing on computation time reference or receive them directly by DSOTP internal components.

During the integration, for non-flexible PoD related powers (MV customers or MV/LV transformers) DSOTP first used less reliable data sources (based on default nominal power data) while the “Load & Generation forecasting tool” (LGF) was set up to produce more reliable power profiles for each network object. Thus, NCS could work with more reliable power data as time passed and new profiles were available, without need to stop service availability if some object lacks explicit profiles. A similar approach was used for the PoDs’ flexibilities data, until a complete set of services was able to receive data coming from outside the DSOTP (from the other Italian Demo Platone platforms) and use them in computation calls.

Implementing DSOTP was a continuous process of components parallelization and integration, basing everything onto a services architecture that can easily accommodate new services, test their communication process and hiding most of the underlying complexity behind simple interfaces.

3.4.3 Metering Information System data

As mentioned before, to run the Power Flow algorithms, the DSOTP uses data coming from the distributor's Information Systems; one of the integrations done in this framework is the acquisition of data from the “Metering Information System IdSpecto” to generate the MV customers’ load and generation profiles.

The purpose of the “Metering Information System IdSpecto” is the automatic management of measurements coming from the Smart Meters - Electric Measurement Groups (GME).

To acquire the data on DSOTP, these steps were performed:

- IdSpecto files acquisition (proprietary format)
- IdSpecto files conversion and data acquisition
- GME data consistency check
- GME data processing to obtain the MV customers load and generation curves

Data available in these files consider the measurements divided into registers connected to the MV customer behaviour:

- absorbed active energy
- generated active energy
- absorbed inductive reactive energy
- generated inductive reactive energy
- absorbed capacitive reactive energy
- generated capacitive reactive energy

The final processed MV customers load profiles are available on DSOTP on a monthly and “typical-day” base (workday, preholiday, holiday) and are calculated using the recorded measurements of the GME for the previous year.

The generation forecast for MV plants with “other” (i.e. non solar or wind) primary energy sources (for example hydro, biogas…) is calculated too, processing the measurements recorded by GME meters; this generation forecast is done daily for the current day and for the next two days.

3.4.4 DSO Operational System alignment

DSOTP needs to know the consistency of the MV distribution network and its real status, in order to perform all its basic functions. As mentioned before, this information is transmitted in real time by the DSO monitoring and control system (DSO Operational Systems). The first field test that will be described in the next sections considered a “static” screenshot of the network (without online measurements). This specific integration will be tested in detail in the next stage.

3.4.4.1 Initialization of the consistency and status of the DSOTP network

When the DSOTP is up and running, it transmits a connection request to DSO Operational Systems.

When the DSO Operational System receives a connection request from the DSOTP, it checks the version of its own Database and that one of the DSOTP.

If the two systems operate with the same version of the Database (i.e. with the same consistency of the network), the DSO Operational System enables the transmission to the DSOTP of all the events which notify the network status changes and the measurement values acquired from the field.

If the two systems have a different version of the Database, the DSO Operational System transmits its network Database to the DSOTP so that it can align the initial network status. The DSOTP then activates the received Database both to show the network topology on its Human-Machine Interface (HMI) and to initialize the Power Flow and Flexibility calculations.

3.4.4.2 Update of the consistency and status of the DSOTP network

The DSO Operational System has also the task of keeping updated the consistency and status of the DSOTP network.

To keep the consistency up-to-date, the DSO Operational System, during the Database update operation (requested by a DSO Control Room operator), transmits to the DSOTP the copy of the Database that is going to be updated and deactivates the communication channel to the DSOTP.

The DSOTP receiving this new version of the Database from the DSO Operational System, activates the procedures for updating its local Database and then requests the reconnection to the DSO Operational System.

To keep the status of the DSOTP network constantly updated, the DSO Operational System transmits to the DSOTP all the new events generated as a result of changes in the network connection status and the measurements acquired from the field. The DSOTP then processes in real time the events and measurements received from the DSO Operational System to update the status of the network in its Database and uses this information for all its internal elaborations.

3.4.5 DSOTP environment setup

For the whole development and integration phases, the DSOTP was based on "Docker" like on-premises solution (Figure 14). The only exceptions are:

- Database "Postgresql" where a native installation was used as recommended for data security and performance tuning
- DMS-MV where setup consisted of copying and configuring virtual machines

The system is composed of several microservices, mainly based on "Java" for the backend and "React" for the frontend, as well as some third-party tools like:

- Consul: Service Discovery
- WSO2-IS: Identity Sever
- Loki/Grafana/Promtail: log aggregation system
- Nginx: reverse proxy
- Spring Boot Gateway
- Harbor: Docker Registry

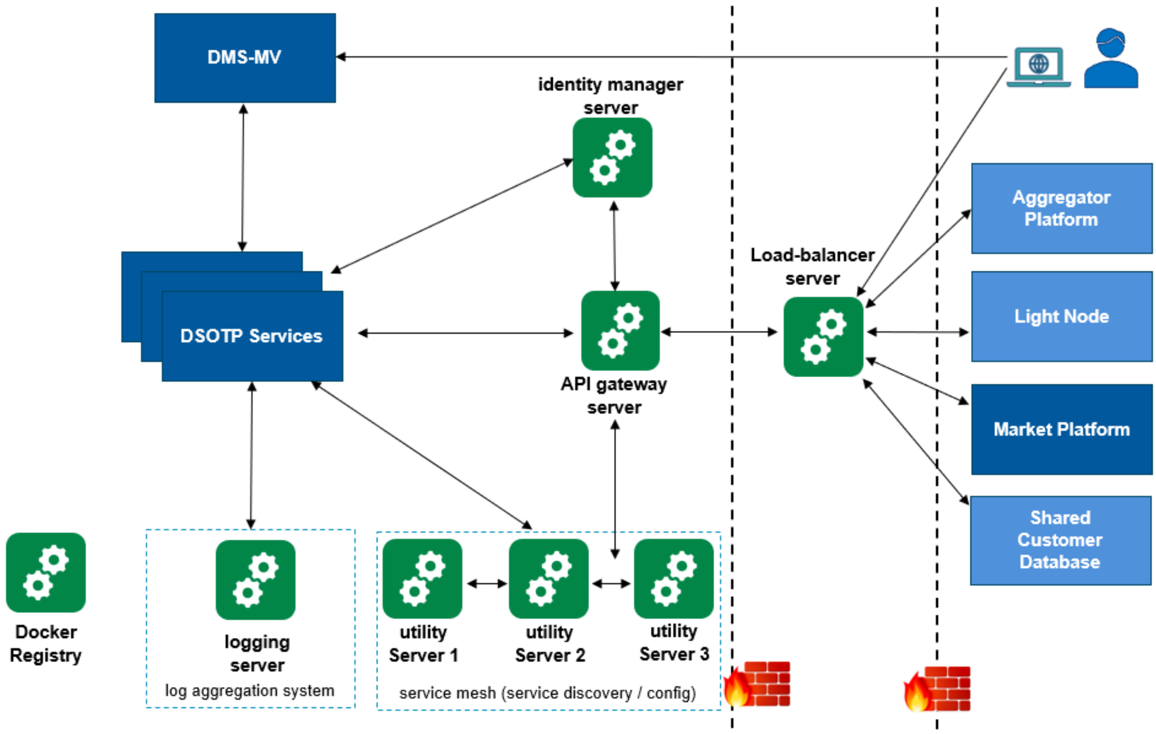


Figure 14: DSOTP environment setup

The Continuous Integration has been configured to automatically generate, test and push the docker images for each component of the system, optimized according to the language used.

In this way the developers can build and start the system in a similar way to what happens in production using a subset of the docker images (or all for a complete test), simply by starting docker-compose files.

A bench of Ansible scripts allows us to auto-magically deploy a full environment by performing the following actions:

- preparing the machines by installing the basic software (docker engine)
- Database installation
- generation and copying of the necessary files
- starting the services

Two environments were set up for the development/testing:

- dev: activity under development
- pre: activities ready for integration tests

3.5 Shared Customer Database

The Shared Customer Database (Figure 15) is a repository system where all Blockchain certified data related to flexible PoD are stored and made available to demo platforms and stakeholders, and represents the link between the two Blockchain Layers of the Platone architecture.

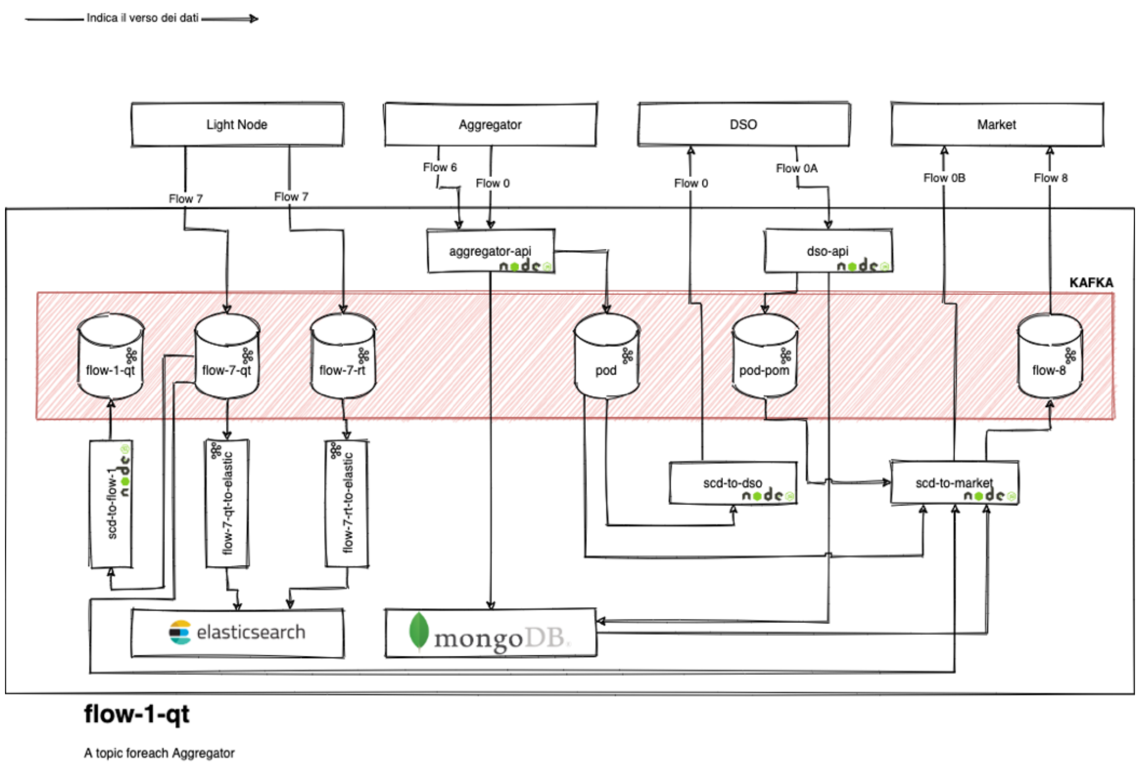


Figure 15: Shared Customer Database

It is important to underline that all the customer data flowing in the Platone Italian Demo System have been properly anonymized, in full compliance with GDPR provisions.

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.

3.5.1 Inbound Integration

To receive data SCD exposes REST API and Apache Kafka topics to the outside world:

- The Light Node send measurements using some Apache Kafka Topics using Mutual Authentication via TLS: in such way now one can *read* data or username or password. Data received in topics are stored to an Elasticsearch database using Apache Kafka Connect that guarantees data persistence and schema validation. In case of error, data is sent to a dead letter monitored by a Prometheus server installation that scrapes Kafka metrics via jmx.
- The Aggregator platform uses a Rest API through a Kong API gateway that acts as OAUth2 Authorization server; the Rest API stores data in a MongoDB database and in an internal Kafka topic for outbound integration.
- The DSO platform uses a Rest API through a Kong API gateway that acts as OAUth2 Authorization server; the Rest API stores data in a MongoDB database and in an internal Kafka topic for outbound integration

3.5.2 Outbound Integration

The SCD exposes data to the outside word in two different ways:

- Stores data in Kafka topics acting as producer;
- Calls external Rest API.

Aggregator Platform:

- Data send by the Light Node read in realtime using a µService that acts as a Kafka consumer and it is written in a Kafka topic after it is enriched with some other information: there are different topics for different Aggregator platforms.

DSOTP:

- Data sent by the Aggregator platform and stored in a specific topic, is read in realtime using a µService that acts as a Kafka consumer and it is sent to the DSO using DSO REST API.

Market Platform:

- Data sent by the DSO platform and stored in a specific topic, is read in realtime using a µService that acts as a Kafka consumer and it is sent to the Market using Market REST API;
- Data sent by the Light Node and stored in a specific topic in enriched used MongoDB data and published in a specific Kafka Topic.

3.5.3 SCD environment setup

For the whole development and integration test phases the SCD was based on Docker and Kubernetes.

The system is composed of many µServices based on NodeJS and some third-party tools like:

- Apache Kafka and Apache Kafka Connect
- Elastcsearch and Kibana
- MongoDB
- Kong API gateway

The Continuous Integration has been configured to automatically generate, test and push the docker images for each component of the system, optimized according to the language used.

Using docker and docker compose a developer can bring up an infrastructure similar to the production environment and can test his\her software.

A set of Ansible scripts allows us to deploy the complete infrastructure using the Infrastructure as Code patter:

- Deploy Kubernetes cluster
- Deploy Elasticsearch containers
- Deploy Apache Kafka and Kafka Connect containers
- Deploy MongoDB containers
- Deploy µServices

Two environments were set up for the development/testing:

- dev: activity under development
- pre: activities ready for integration tests

3.6 Access Layer

The Blockchain Access Layer and the Light Node form the Access Layer (Figure 16), a data exchange infrastructure among flexible DERs, platforms and stakeholders within demo architecture.

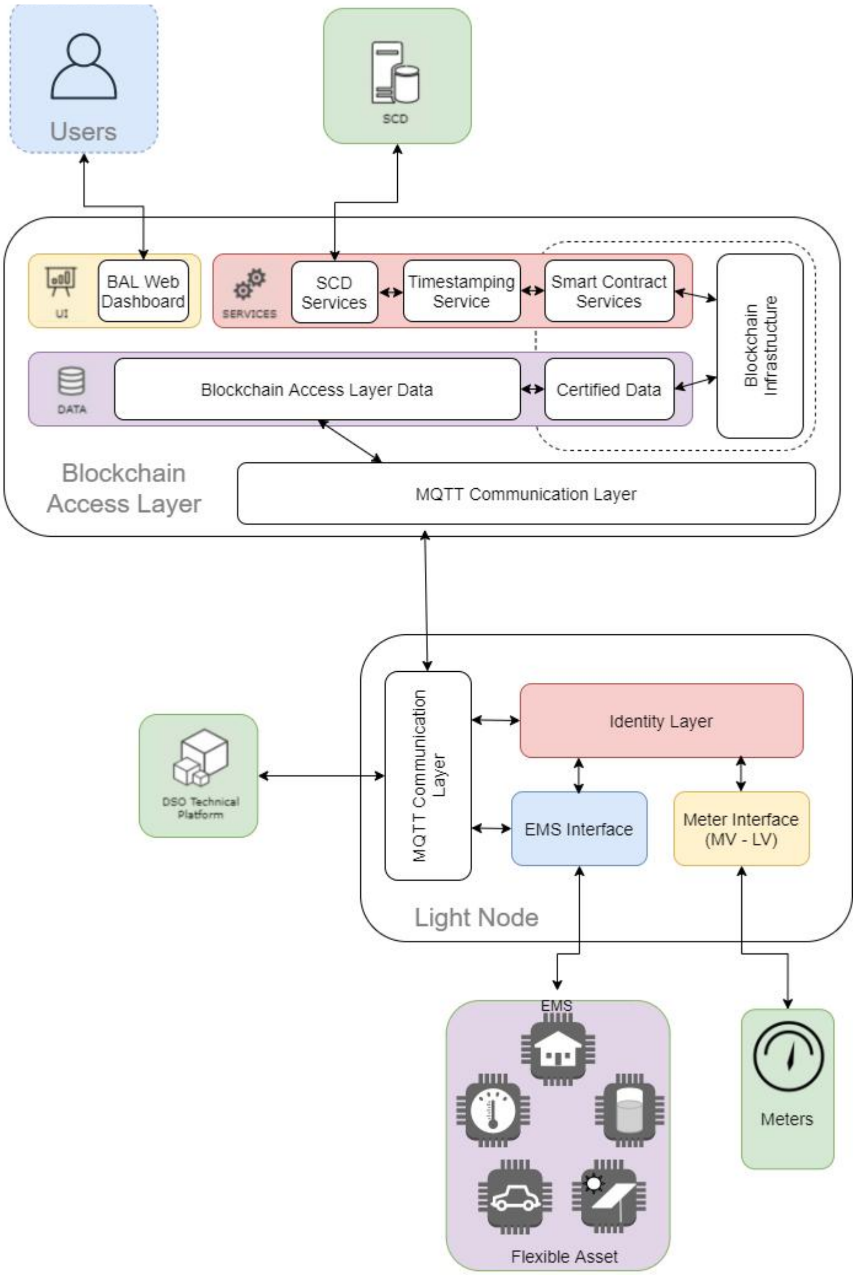


Figure 16: Access Layer

The Light Node is the touching point between DERs and the Platone Italian Demo Architecture, while the Blockchain Access Layer is the secure path connecting the Light Nodes to the Shared Customer Database. More details and functionalities are available in D3.3 [2].

In the following chapter additional information and peculiarities concerning such components, their development, integration and test within the demo and the customer's systems are listed.

3.6.1 Blockchain Access Layer

The Blockchain Access Layer connects the Light Node to the Shared Customer Database. The Blockchain Access Layer ensures, by means of timestamping features, the immutability of data along the whole path from Light Node to Shared Customer Database. The main difference from Blockchain Access Layer of the Italian Demo (WP3) and Blockchain Access Layer of the Platone Standard platform (used in the other Demos) is in the Internet of Things data stream integration. In fact, while the Standard Platform creates a timestamp data directly from the Shared Customer Database, the Blockchain Access Layer of the Italian Demo creates a timestamp of the data directly on the Light Node.

Concerning communication between Light Node and Blockchain Access Layer, a MQTT communication was implemented. In particular, Light Node signs the measurements and sends them through MQTT to the Blockchain Access Layer. The Blockchain Access Layer verifies and aggregates them through a merkle tree and then creates a timestamp on Blockchain. After that, it sends through Kafka to the Shared Customer Database.

3.6.1.1 Blockchain Access Layer setup

During the development and integration phases, the Blockchain Access Layer (BAL) was deployed on Debian Linux Virtual Machines running on Amazon Web Service's Elastic Cloud service (AWS EC2).

There are two environments:

- The production environment;
- The test environment.

Only the test environment was used during the integration tests with other platforms.

Production environment setup

Two Virtual Machines are dedicated to the Quorum Blockchain: two Quorum nodes, each deployed on a single virtual machine.

A third Virtual Machine is dedicated to Blockchain Access Layer services, such as Timestamping, SCD integration and Smart Contract invocation, as well as the MQTT Broker which allows the communication with Light Nodes.

A fourth Virtual Machine is dedicated to

- The timeseries database InfluxDB in which the system writes measurements provided by light nodes
- The timeseries database and monitoring system Prometheus for storing system metrics such as CPU usage and Storage usage
- The Visualization Web Application Grafana, use to graph data coming from both InfluxDB and Prometheus

Each virtual machine is provisioned in a Virtual Private Cloud, a dedicated and isolated network in the AWS Cloud Platform

Test environment setup

In the test environment we provisioned a total of 2 Virtual Machines on the AWS cloud platform. One machine is dedicated to a Quorum node instance, while the other machine contains each other software component described in the production environment setup: databases, monitoring and services.

Smart Contract Setup

For both Test and Production Environment two smart contracts were deployed on the Quorum Blockchain Network:

- Light Node Public Key Register: A public association Light Node IDENTIFIER shared with the whole infrastructure (SCD, Aggregator, Market and DSOTP) and the Light Node Public Key, used to sign metering and set-point data.
- Timestamping Smart Contract: A ChainProof contract that registers the merkle root of several data received in a time slot. In test environment aggregated data received from Light Nodes are timestamped every four seconds.

3.6.2 Light Node

The Light Node is an essential device of the Italian Demo of Platone. It has been developed, designed and built within the demo based on an existing technology (under patent of *a*reti, Apio, Indra) that makes available a small, economic and easy-to-install device that, by interfacing with existing field systems (such as smart meters and energy management systems), enables all customers to provide flexibility services to the grid.

The Light Node is able to acquire data coming from the smart meter (power, energy, voltage, etc.) to receive flexibility activation order (setpoint) from third party operator (as DSO), to certify all this information and make it available to the platforms within the demo and to the authorized stakeholders.

Moreover, the Light Node implements some interfaces to customer's devices, e.g. Energy Management Systems (EMS), Energy Storage System (ESS), etc., which manage locally the setpoint and deliver the required flexibility services to the grid.

In Figure 17 and Figure 18 communication interfaces and protocols between Light Node and external device and demo platforms are shown.

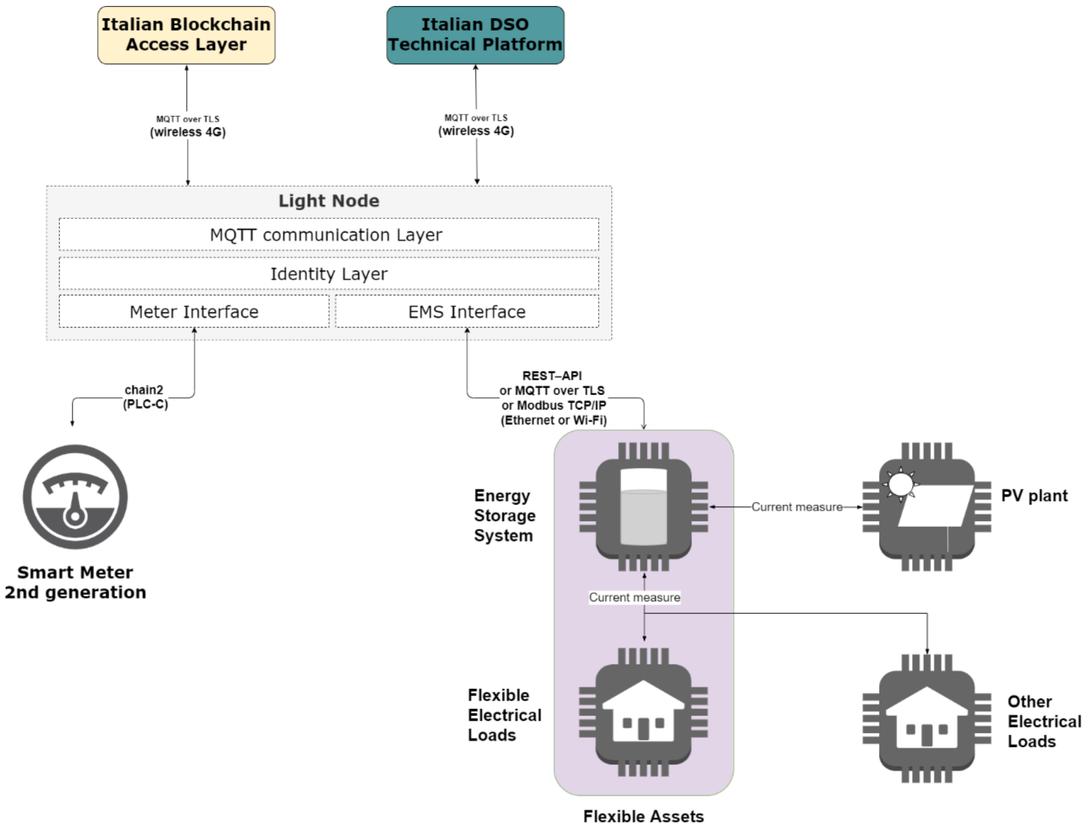


Figure 17: Residential user

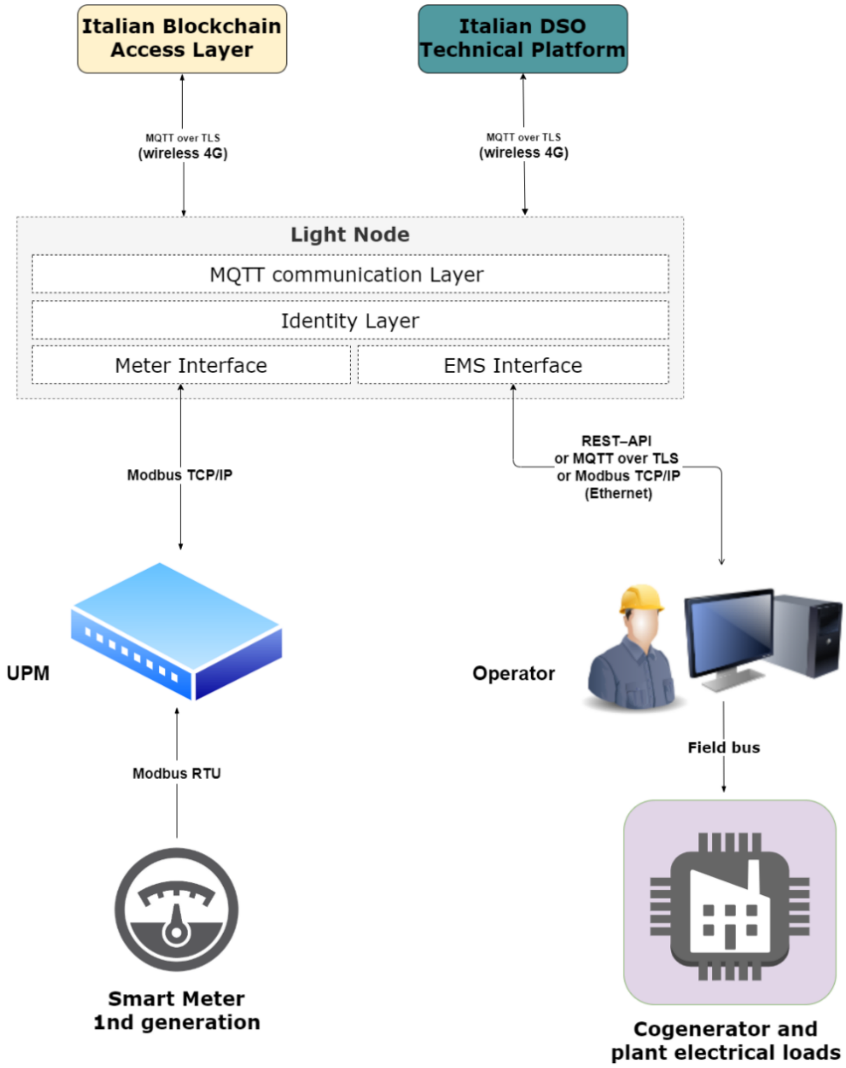


Figure 18: Industrial user (Tor di Valle)

Concerning communication between Light Node and Smart Meter, three different ways can be implemented depending from the type of smart meter installed at customer's premises:

a) by chain2, i.e. the PLC standardized by the Italian technical norm CEI 13-84[1] and developed to define one possible way of communication between Smart Meter 2G and Customer device,

b) by Modbus RTU, connecting RS485 port of Light Node to the one installed on some Smart Meters (the one typically installed for contractual power greater than 25kW),

c) by Modbus TCP/IP, connecting RJ45 Ethernet of Light Node to customer apparatus already connected to Smart Meter means RS485 by Modbus RTU.

Generally, it is assumed that:

- solution a) is the typical way adopted for small and residential customers;
- solution b) is the typical way that could be adopted for existing medium and large commercial/industrial customers;

[1] Electricity metering equipment - Communication with end-user devices – Part 3-1: PLC protocol stack in the frequency band 125 kHz - 140 kHz (C band)

- solution c) is the typical way adopted for medium and large commercial/industrial customers that are equipped with customer monitoring or controlling apparatus and/or equipped with other apparatus enabling them to provide service to the Italian TSO (i.e. UPM[2] or CCI[3]).

Concerning communication between Light Node and Customer Flexible Asset, several approaches can be implemented depending on the type of Customer Flexible Asset installed by the customer:

- On Local Network (LAN) those approaches can be used:
    - REST API, connecting Light Node through RJ45 Ethernet or through Wi-Fi to the Customer Local Network. The communication will be interfaced made through the standard HTTP API;
    - MQTT;
    - Modbus TCP/IP.

Using the Serial Communication connecting RS485 port of the Light Node, it is possible to communicate through Modbus RTU.

Regarding the communication between the Light Node and the Storage System, there is also a communication channel (MQTTs or REST-API) to Aggregator Platform that will be activated in the next release to provide the functionalities described in Ch. 3.3.2.

3.6.2.1 Light Node devices setup

The Light Node is an Internet of Things (IoT) Edge Device. In particular, it uses a Linux operating system with Debian distribution. The application software stack is built around several independent Node.js microservices:

- Client Light Node Smart Meter: Service that interacts with Chain 2 channel PLC-C, signs the measures and then sends through MQTT communication to Blockchain Access Layer;
- Client DSO Technical Platform: Service that receives set-point from DSOTP.
- Client EMS: Service that interacts with Flexible Asset installed by the customer.

Every Light Node is configured according to the customer configuration, in particular:

- Smart Meter: for Smart Meter 2G, the smart meter private key must be configured on the Light Node, and the Device Key must be uploaded on the smart meter.
- For Industrial Smart Meter, the exact communication protocol must be configured (Modbus RTU or TCP-IP).
- DSOTP: configuring the Light Node number and Unique ID shared with DSO Technical Platform, Aggregator, Market and Shared Customer Database;
- EMS: configuring the proper library according to the Customer Flexible Asset.

The setup of the Light Node device is made through Remote Access, synching microservices to the remote repository. The remote communication is made through Cellular Network, so it is independent from User Network.

After the microservices' configuration, the first time that the Light Node sends a transaction to Blockchain Access Layer creates the Light Node Public Key association, and then every time it signs data it uses the private key associated to the Public Key registered.

[2] Unità Periferica di Monitoraggio, i.e. a monitoring unit apparatus able to monitoring several electrical values of the customer plant.
[3] Controllore Centrale di Impianto, i.e. an UPM including also controlling features of the customer plant.

3.7 Components at customer side

3.7.1 Customer Flexible Assets

Up to now, the customer engagement activities have resulted in the involvement of 12 customers. Based on the customer category and the flexible asset available, these can be grouped as indicated in Table 3:

Table 3: Customer category and the flexible asset available

No. of customers	Category	PV plant	Energy Storage System	Cogeneration plant	Other (I.e. manual activation of flexible assets like dishwasher, HVAC, etc.)
1	Industrial	-	-	X	-
1	Residential	X (note 1)	-	-	X
1	Residential	-	X (note 1)	-	-
4	Residential	X	X (note 1)	-	-
5	Residential	X (note 1)	X (note 1)	-	-

Note 1: assets provided and installed by *areti*

Data of assets provided by *areti* is as follows:

PV plant

The customer has been provided a 250W PV system.

It consists in a photovoltaic panel and in an inverter installed at the back of the panel. The full system is therefore easy to install because it is enough to connect the inverter output, equipped by a simple electrical plug, to a dedicated circuit of customer plant (Figure 19).

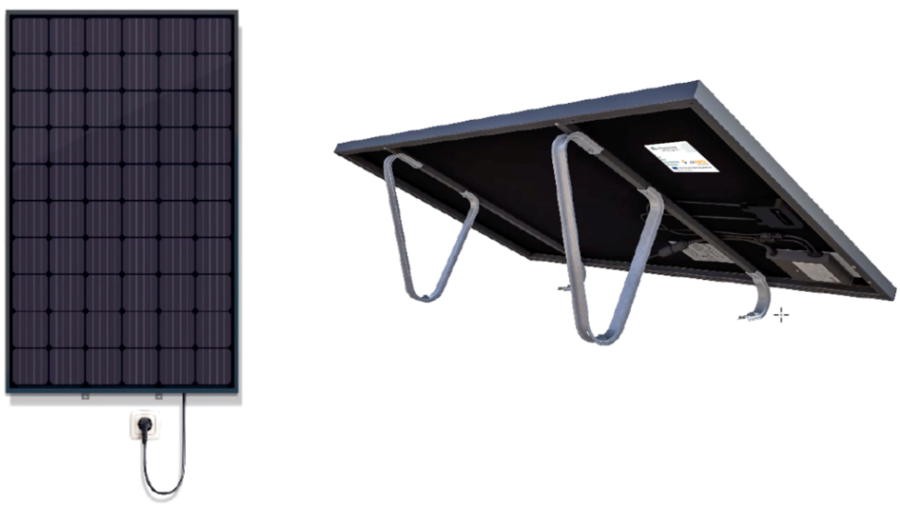


Figure 19: Circuit of customer PV plant

Apart from its ease of installation, this solution has been chosen taking into account the typical space available: residential customers of Rome, often live in flats located in condominiums, therefore the PV panel can just be installed on their balcony or in a terrace shared with all other residents of the condominium.

The panel dimensions (in mm) are shown in Figure 20:

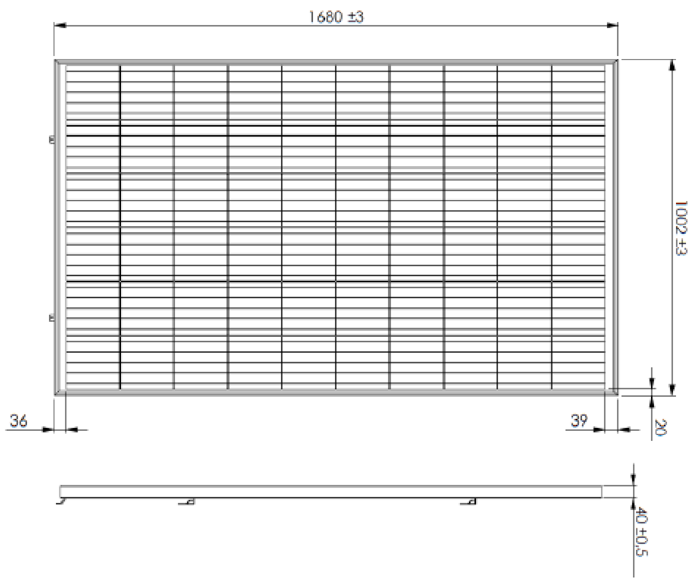


Figure 20: PV panel dimensions

Finally, it could be noted that it is possible to connect up to three such panels in parallel, simply by connecting the related inverters to each other using the dedicated cable provided by the manufacturer.

Energy Storage System

The customer has been provided with an Energy Storage System connected at AC side of his plant. This solution has been chosen because it works regardless whether a PV system is already connected (but of course, if the PV system exists, operation of the storage is anyway coordinated with this one).

Three types of Energy Storage System has been installed. The main technical data are resumed in Table 4 and shown in Figure 21.

Table 4: Energy storage system's technical data

Installation	**Power** [kVA]	**Power Factor** [p.u.]	**Capacity** [kWh]	**Supply**	**Dimensions WxDxH** [mm]	**Weight** [kg]
Floor-mounted	3 or 4.6	-0,8 to 0.8	2.4 or 4.8 or 9.6	1Ph+N 230Vac or 3Ph+N 230/400Vac	590x485x965	up to 104
Wall-mounted					600x250x1810	up to 98
Outdoor-mounted					800x500x2110	up to 197

Floor-mounted
a)

Wall-mounted
b)

Outdoor-mounted
c)

Figure 21: Types of Energy Storage System

All these systems are able to communicate with Light Node:

- providing storage data and other measurements acquired by the storage system (e.g. electrical quantities at grid/customer plant connection point and PV productions - acquired by dedicated sensors provided with the storage system itself);
- acquiring set-points from Light Node in order to deliver the flexible services to the grid.

3.7.2 Installation and integration activities

As described, the Italian Demo architecture foresees availability of particular devices installed at customer side. Some of these are owned by customers while others are owned by DSO (see Table 5).

Table 5: Device and Owner

Device	Functions	Already installed (regardless of the project)	Communication methods with Light Node	Owner
Smart Meter (SM)	• Measures electrical quantities at PoD	Yes[4]	• Chain2 • Modbus (see Ch. 3.6.2)	DSO
UPM/CCI	• Acquires measurements (UPC/CCI) and manages the electrical load of the plant (only CCI)	Yes[5]	• Modbus (see Ch. 3.6.2)	Customer

[4] Additional SMs could be needed to measure generation or storage quantities.
[5] Only for industrial customers already enabled to provide services to the TSO.

Light Node (LN)	• Acquires data from SM • Receives Set-point and forwards it to customer activation systems (e.g. ESS or EMS) • Acquires data from ESS	No	-	DSO (at least only for the pilot project)
PV plant	• Produces electrical energy for user consumptions	Yes/No (see Table 3 in Ch.3.7.1)	-	Customer
Energy Storage System (ESS)	• Stores electrical energy produced by PV or withdrawn by the grid • Modulates power flow at PoD to optimize user self-consumption • Acquires Set-point and manages itself to provide flexible service to the grid • Shares collected data to LN	No	• Ethernet	Customer
Operator or EMS of cogeneration plant	• Acquires Set-point and manages all connected customer systems to provides flexible service to the grid	Yes	• Ethernet	Customer
Other (Flexible) Electrical loads (I.e. dish washer, HVAC, etc.)	• Electrical loads that can be switched-on/off or modulated manually by the customer to modify power flows at PoD to provide flexible service to the grid	Yes	-	Customer

Concerning devices installed for project purpose, the following lists the activities performed on the customer side.

Light Node (residential customer)

1. Power supply of device from mains socket;
2. Set and activate communication data exchange between Smart Meter and Light Node (by chain2 for 2nd Generation SM or Modbus for the others);
3. Perform and set Ethernet connection between Light Node and Energy Storage System (where applicable).

Light Node (industrial customer)

1. Power supply of device from mains socket (or by a terminal strip connector);
2. Set communication data exchange between UPM[6] and Light Node (by Modbus TCP/IP);
3. Perform and set Ethernet connection between Light Node and Operator workstation.

[6] Refer to Figure 17. Data connection between UPM and Smart Meter 1G, as well as field data connection between Operator Workstation and cogeneration plant loads, already exist independently from Italian Demo of Platone project.

Figure 22: Light Node installation (residential user)

Figure 23: Light Node installation (industrial user)

PV plant

1. Adapt customer's electrical plant with additional connections dedicated to PV plant;
2. Install the PV panel and connect it to the dedicated plug;

Figure 24: 250W PV plant

Energy Storage System

1. Adapt customer's electrical plant with additional connections dedicated to storage;
2. Install the storage and connect to the dedicated circuit;
3. Install current sensor to measure current at PoD;
4. Install current sensor to measure PV generation;
5. Connect current sensors to the storage system;
6. Set Ethernet connection between Energy Storage System and Light Node;
7. Set ESS with customer plant data (contractual power, supply type and voltage, PV power, etc.).

Figure 25: Energy Storage System installation

4 First field test

4.1 Overview

As already mentioned in the previous chapters, the main goal of the first field test was to test the whole Italian Demo process involving all the platforms and actors.

In particular, the first field test addressed the topic "Congestion management in transmission and distribution systems" (UC-IT-2 described in D1.1 [5]) following the main phases designed in D3.3 [2] (Figure 26).

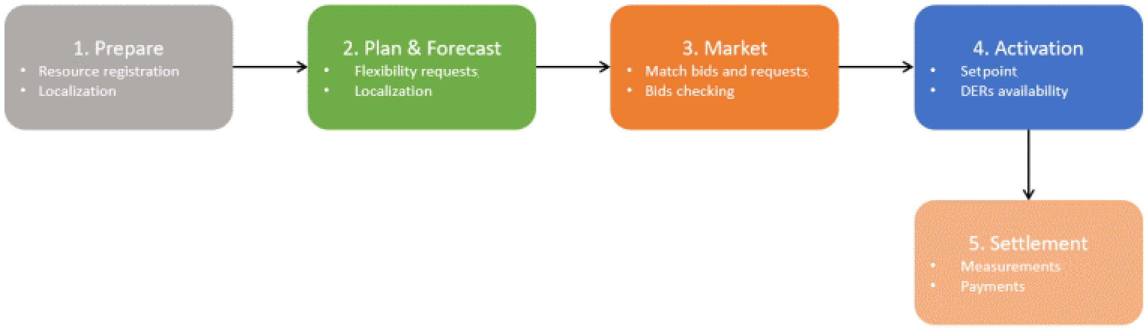


Figure 26: Field test phases

For the preparation of the first field test, an additional preliminary "Phase 0" has been foreseen involving the definition of the whole test scenario and input data needed to run a consistent technical/economical process along the whole Italian Demo Platone architecture; this preliminary activity will be described in Ch. 4.2.

During the field test, Phases from 1 to 3 were involved and checked in a complete way while Phase 4 (Activation) was partially simulated (Light Nodes); Phase 5 considered the necessary data flows between platforms but without automatic "Settlement" procedures. It is important to underline that the test was performed considering two different Aggregators offering Flexibility Services.

4.2 Test scenario and input data

The first field test considered the MV distribution network connected to the "Tor di Valle" Primary Substation focusing on five simulated Flexible Users connected to two different MV feeders ("Mostacciano" and "Nanchino"). Moreover, the whole process was tested considering the "Day Ahead" market on timeslot number 50 (that corresponds to 12:30 PM).

The following Table 6 shows the main data for the selected Flexible Customers.

Table 6: Main Data for selected Flexible Customers

MV Feeder	Substation	Abs.P [kW]	Gen.P [kW]	PoM	PoD	Aggregator
Mostacciano	81823	3000	400	CP-IRLANDESE	IT002E61899978	ACEAE
Mostacciano	80598	1900	0	CP-IRLANDESE	IT002E60976796	ACEAE_2
Mostacciano	80586	6000	0	CP-IRLANDESE	IT002E60974469	ACEAE
Nanchino	12150	250	0	CP-IRLANDESE	IT002E60499620	ACEAE_2
Nanchino	12157	625	0	CP-IRLANDESE	IT002E60550189	ACEAE

In Figure 27 the Primary Substation and all the connected MV Feeders can be seen; furthermore, the two abovementioned MV Feeders are shown.

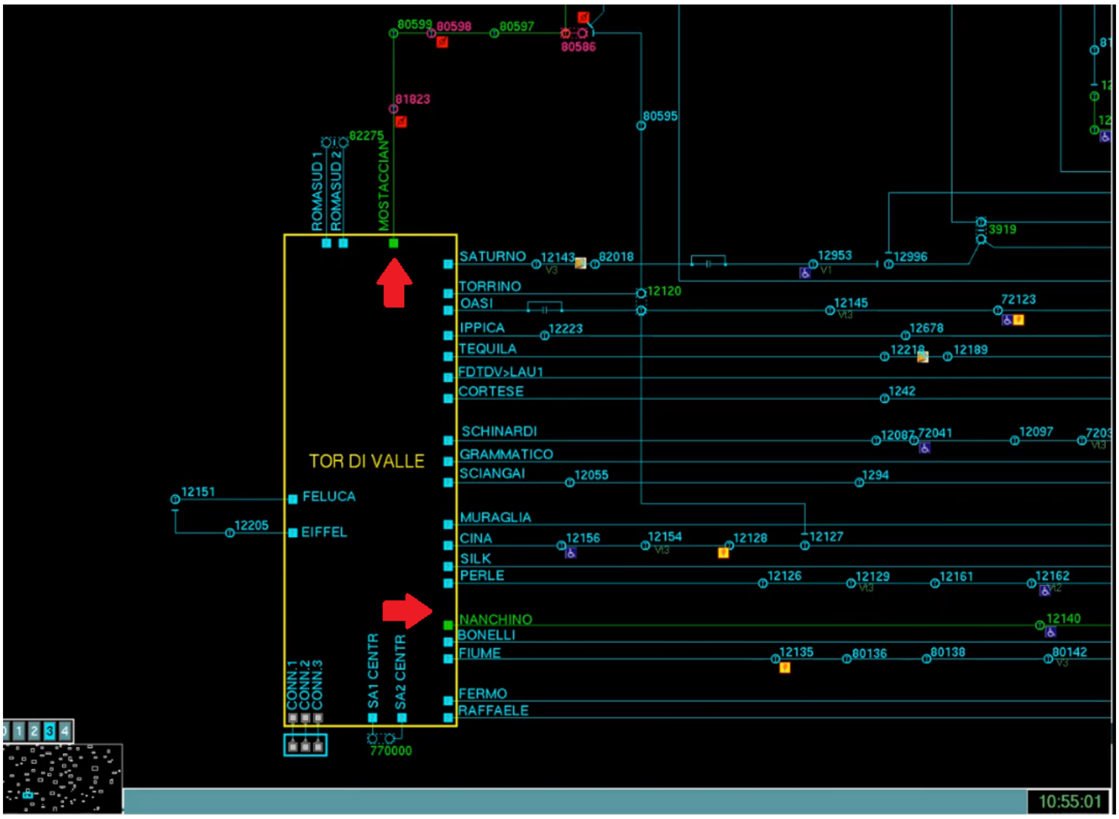


Figure 27: Primary Substation and MV Feeders

The next Figures (Figure 28 and Figure 29) display the detailed structure of the two MV Feeders and the position of the Flexible Customers.

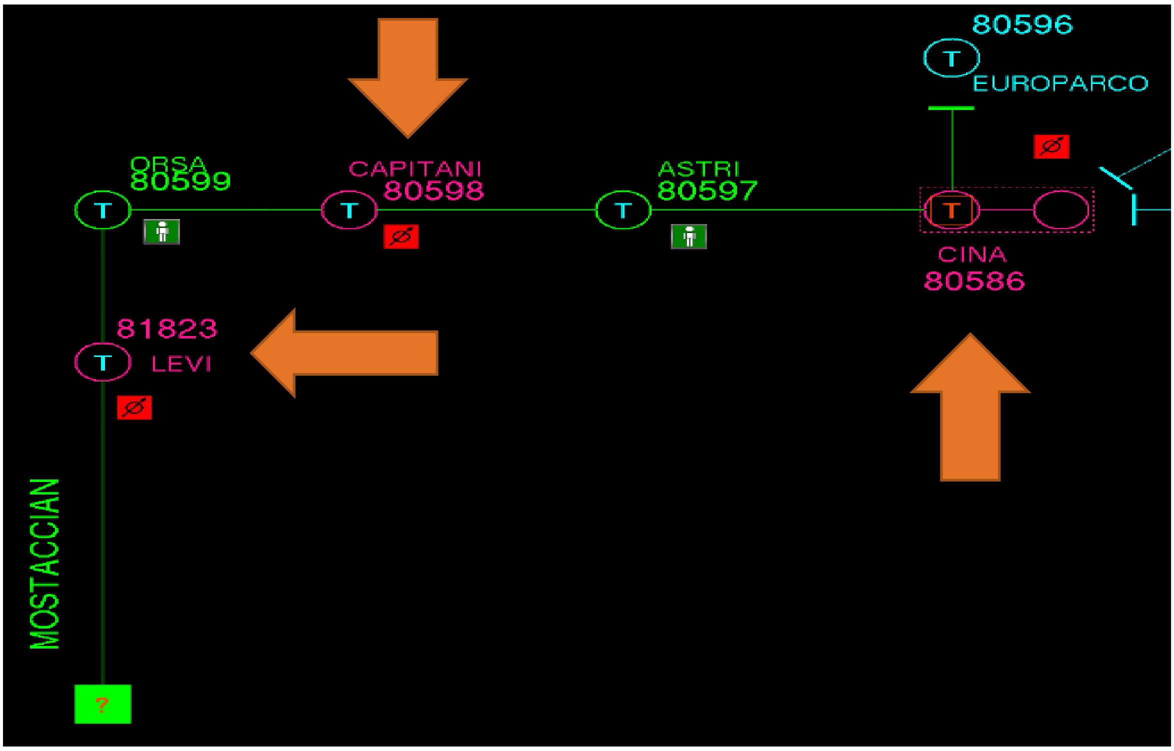


Figure 28: MV Feeder “Mostacciano”

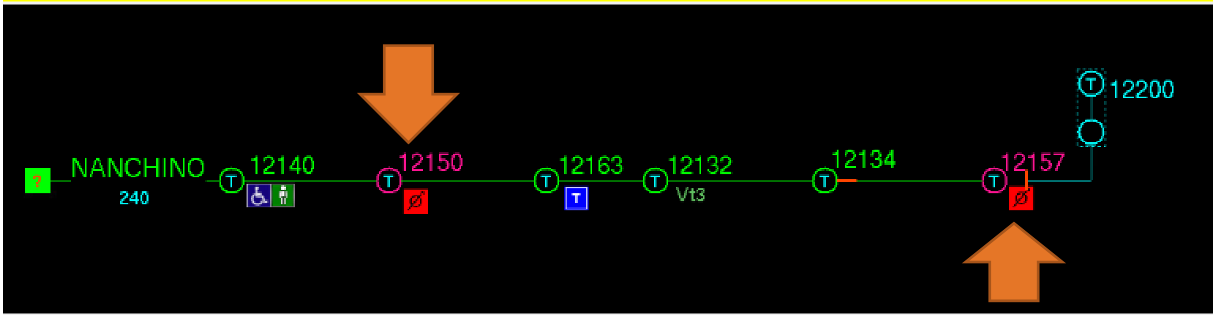


Figure 29: MV Feeder "Nanchino"

Table 7 shows some more detailed data chosen for the Flexible Users in the test scenario; the hypothesized flexibility services involved in this stage only the active power (no reactive power flexibility).

Table 7: Detailed data chosen for the Flexible Users

PoD	Max Flex P up [kW]	Max Flex P down [kW]	Baseline P [kW]	Offered Flex P [kW]	Total Flex Service [kW]	Price [€/kW]
IT002E61899978	0	2000	2278,545	-1000	1278,545	0,01
IT002E60976796	100	100	312,145	0	-	-
IT002E60974469	1000	2400	4557,09	-500	4057,09	0,03
IT002E60499620	200	0	10,092	0	-	-
IT002E60550189	500	0	70,38	500	570,38	0,07

4.3 Test process and results

The next sections will show the complete test process step by step.

4.3.1 PoD registration

In the first step, all the relevant data for the Flexible Customers (PoD) is registered in the Aggregator Platform (Figure 30). This information about the Flexible Customers is then sent from the Aggregator Platform to the Shared Customer Database that registers all the data (Figure 31).

Then the Shared Customer Database forwards these data also to the DSOTP and receives back the PoD-PoM association (Figure 32); this link will be important in the next steps because the TSO will require Flexibility on the PoM[7] level.

This data about the Flexible Customers is then transmitted by the Shared Customer Database to the Market Platform too (Figure 33), so all the Platforms are aligned.

[7] A PoM (Point of Measurement) is a connection point between Distribution grid and Transmission grid; generally, several PoMs exist between Transmission grid and Distribution grid. Since the TSO cannot know the current Distribution grid configuration, it does not know which PoDs or aggregates of PoDs can delivery Flexibility Services (through the Distribution grid) at a specific Transmission grid point. To solve this issue, Platone Italian Demo foresees that the DSOTP performs an association between PoD and PoM according to the Distribution grid configuration; this association is shared with all the related stakeholders in the Shared Customer Database.

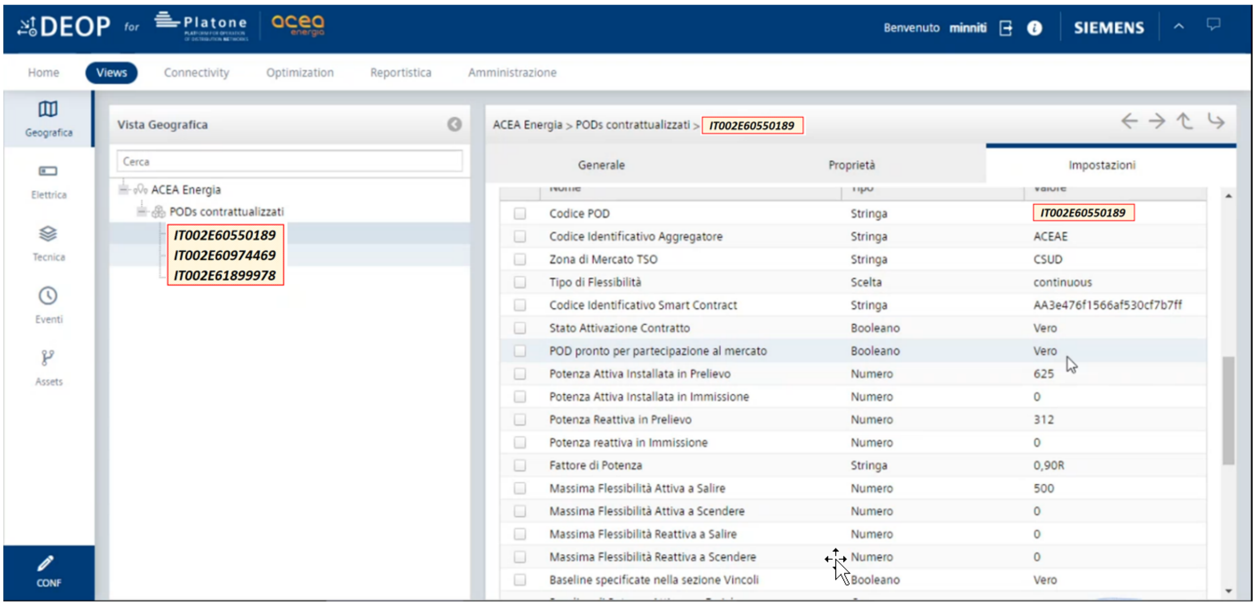


Figure 30: Platone Aggregator Platform

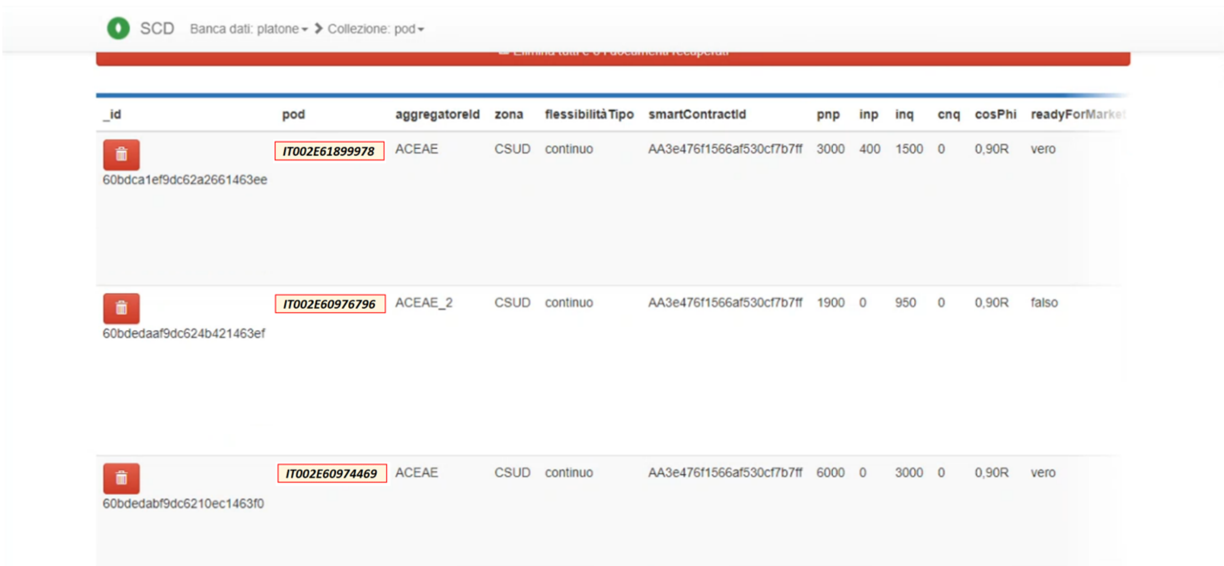


Figure 31: Shared Customer Database received data from Aggregator Platform

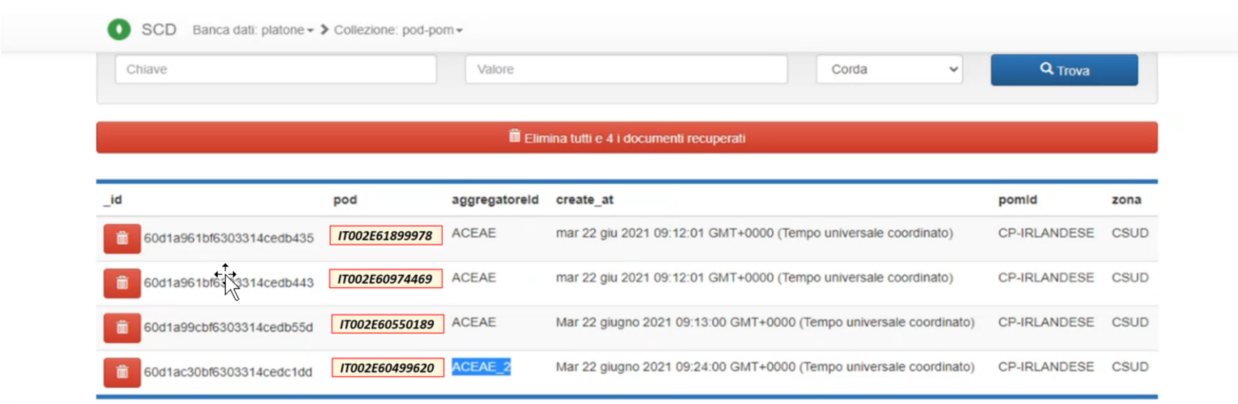
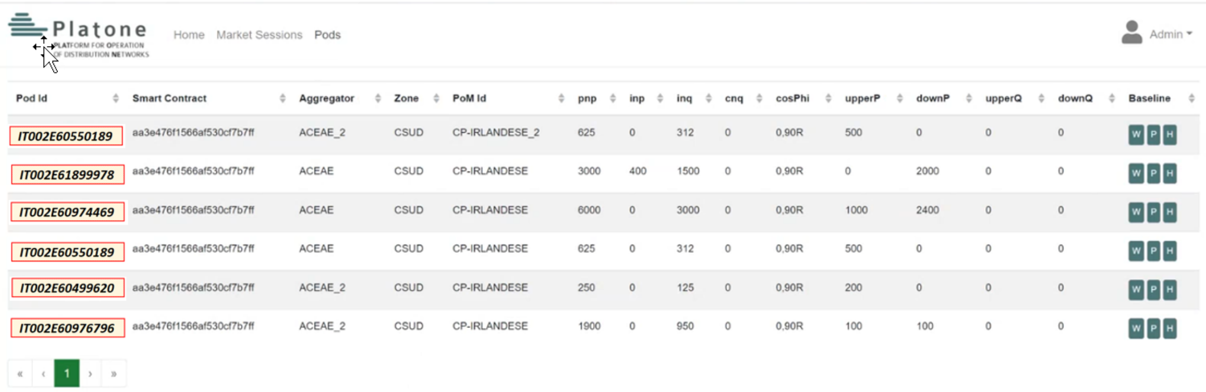


Figure 32: SCD PoD-PoM association



Pod Id	Smart Contract	Aggregator	Zone	PoM Id	pnp	inp	inq	cnq	cosPhi	upperP	downP	upperQ	downQ	Baseline
IT002E60550189	aa3e476f1566af530cf7b7ff	ACEAE_2	CSUD	CP-IRLANDESE_2	625	0	312	0	0,90R	500	0	0	0	W P H
IT002E61899978	aa3e476f1566af530cf7b7ff	ACEAE	CSUD	CP-IRLANDESE	3000	400	1500	0	0,90R	0	2000	0	0	W P H
IT002E60974469	aa3e476f1566af530cf7b7ff	ACEAE	CSUD	CP-IRLANDESE	6000	0	3000	0	0,90R	1000	2400	0	0	W P H
IT002E60550189	aa3e476f1566af530cf7b7ff	ACEAE	CSUD	CP-IRLANDESE	625	0	312	0	0,90R	500	0	0	0	W P H
IT002E60499620	aa3e476f1566af530cf7b7ff	ACEAE_2	CSUD	CP-IRLANDESE	250	0	125	0	0,90R	200	0	0	0	W P H
IT002E60976796	aa3e476f1566af530cf7b7ff	ACEAE_2	CSUD	CP-IRLANDESE	1900	0	950	0	0,90R	100	100	0	0	W P H

Figure 33: Alignment of the Aggregator Platform

4.3.2 Power Flow & DSO Flexibility Requests

As already mentioned before, to run the algorithms the DSOTP needs a proper set of load profiles for all the network elements; Figure 34 shows an example of a load profile set for a MV Customer (Web application "Load Profiles Estimator"); values have a fifteen-minute resolution and are represented according to the "load convention" (positive values mean consumption).

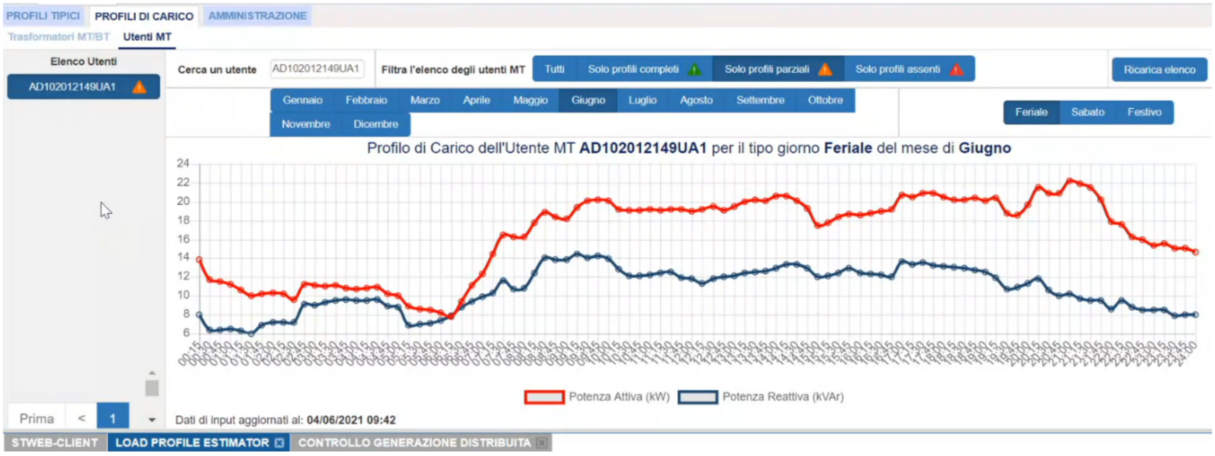


Figure 34: Load profile set for a MV Customer

And Figure 35 shows an example of a load profile set for a MV/LV Transformer (Web application "Load Profiles Estimator").

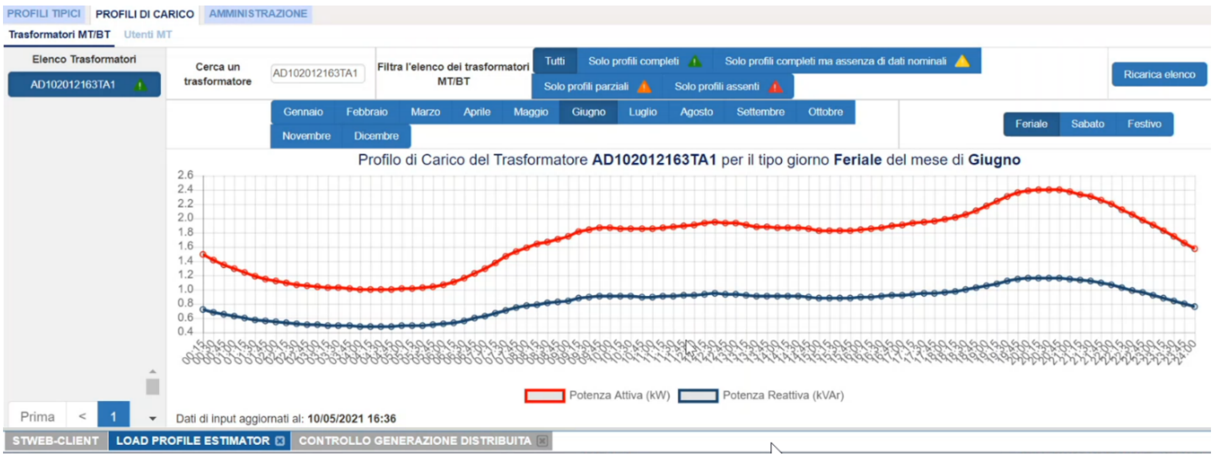


Figure 35: Load profile set for a MV/LV Transformer

Another important set of input for the DSOTP algorithms is the generation forecast for all the network elements; Figure 36 shows an example of generation forecast for a MV/LV Transformer (Web application "Load & Generation Forecast").

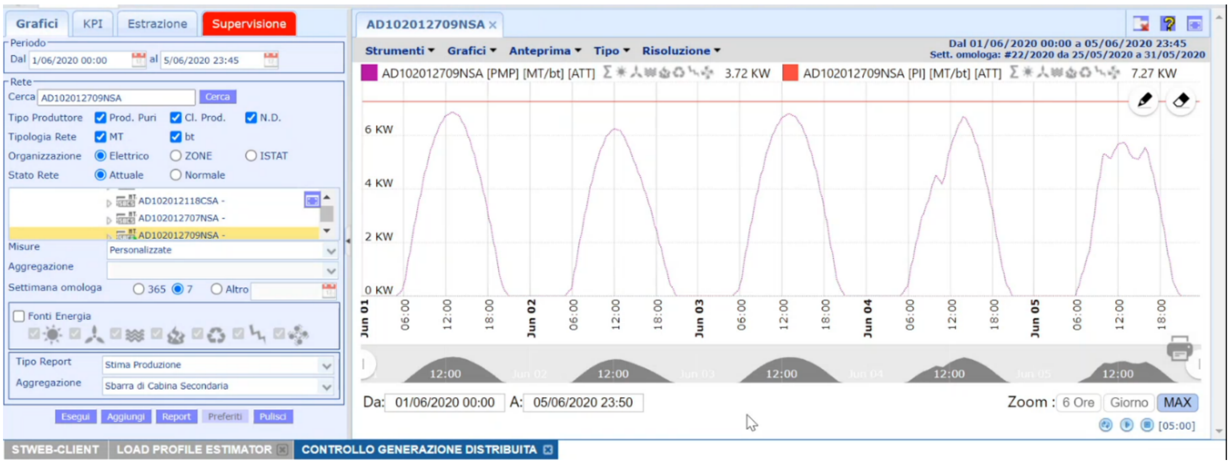


Figure 36: Generation forecast for a MV/LV Transformer

At this step of the process, the DSOTP runs a Power Flow on the whole MV network to detect some possible technical issues. Figure 37 and Figure 38 display an example of some results calculated for the MV Feeder "Mostacciano" (Web application "Network Calculation System HMI").

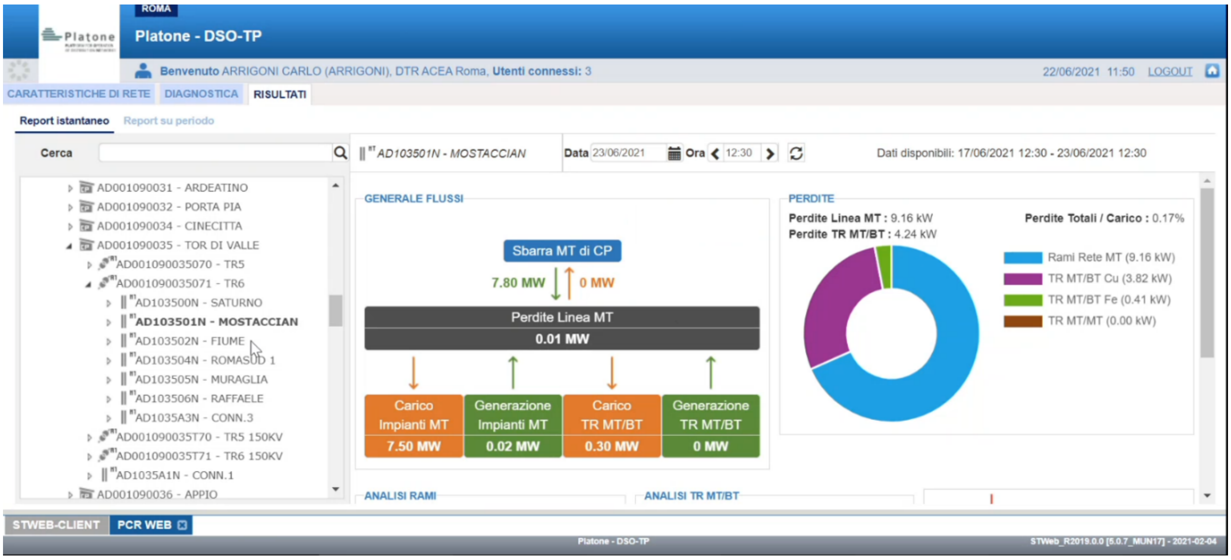


Figure 37: Results calculated for the MV Feeder "Mostacciano"

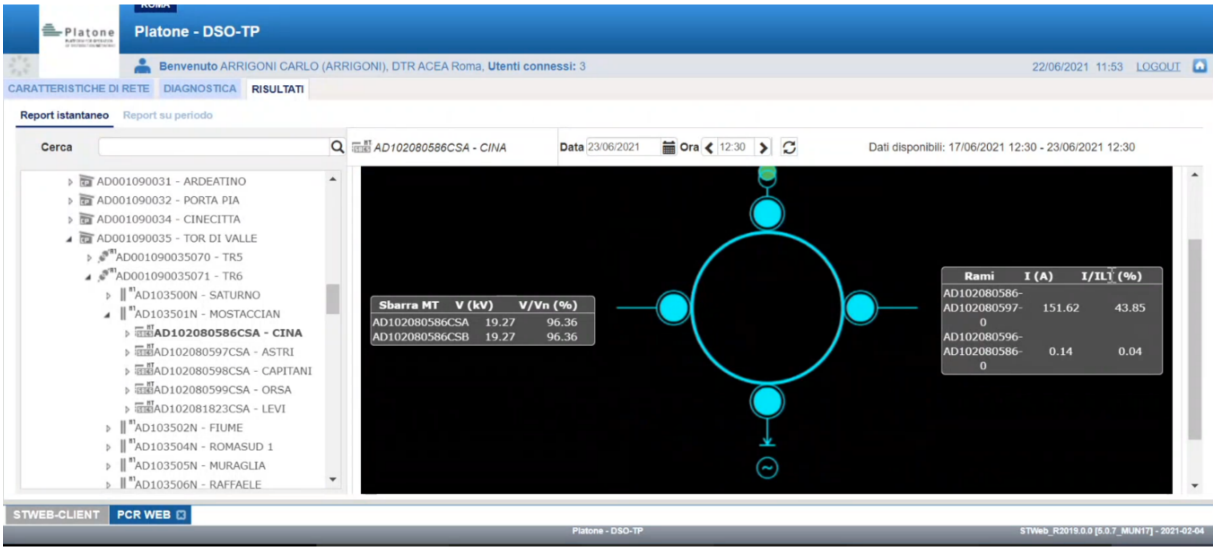


Figure 38: Other results calculated for the MV Feeder “Mostacciano”

And Figure 39 shows the alarm available on the DSOTP about a detected current overload on a branch of the MV Feeder “Mostacciano”; the max current is 212.80 A and the estimated one is 259.54 A.

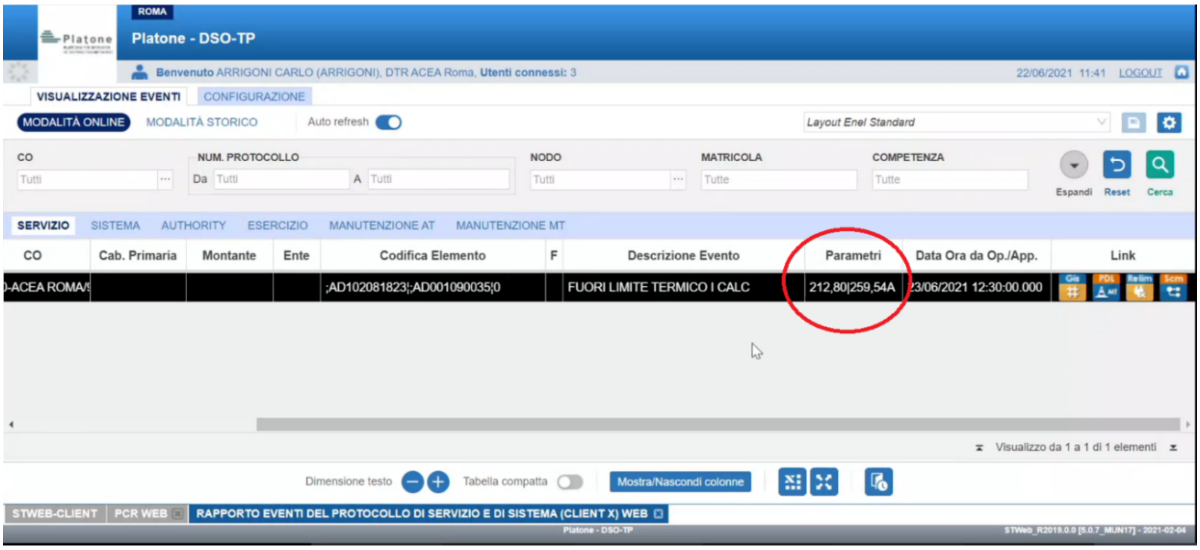


Figure 39: Alarm available on the DSO TP

Starting from this estimated network scenario, the DSOTP runs the Flexibility Request algorithm that is able to solve the current overload requiring proper Flexibility the MV Feeder “Mostacciano”. The following extract contains the real data flow sent form the DSOTP to the Market Platform. The DSO requires that on an aggregated base (the sum of the three available Flexible Customers on that Feeder), 5771.04 kW should be contributed to solve the technical issue.

{

"marketType":"dayAhead",

"duration":24,

"interval":15,

"playerId":"DSO",

"serviceType":"DSO_request",

```
  "playerServiceId":"DSO:::dayAhead:::2021-06-23T12:30:00.000Z",
  "flexibility":[
    {
      "pod":[
        " IT002E61899978",
        " IT002E60974469",
        " IT002E60976796"
      ],
      "power":[
        {
          "index":50,
          "p":5771.039299061133,
          "pPrice":0.1,
          "q":null,
          "qPrice":0.1
        }
      ]
    }
  ]
}
```


4.3.3 Aggregator Flexibility Offers

In the meanwhile, on the Aggregator Platform, the Flexibility Offers for the selected PoDs are put in place (Figure 40); all these data are sent to the Market Platform.

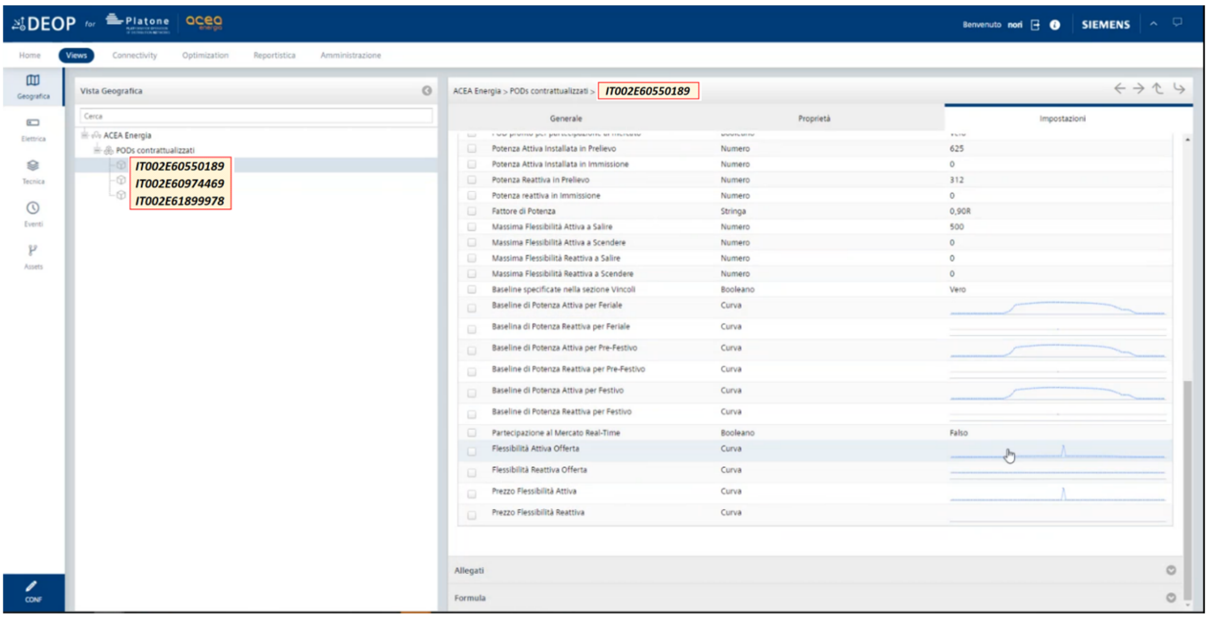


Figure 40: Flexibility Offer on Aggregator Platform

In the next Figure 41, an example about PoD IT002E60550189 is reported; this Flexible Customer is offering an overall Flexibility Service of 570.38 kW for the selected test timeslot (12:30 PM).

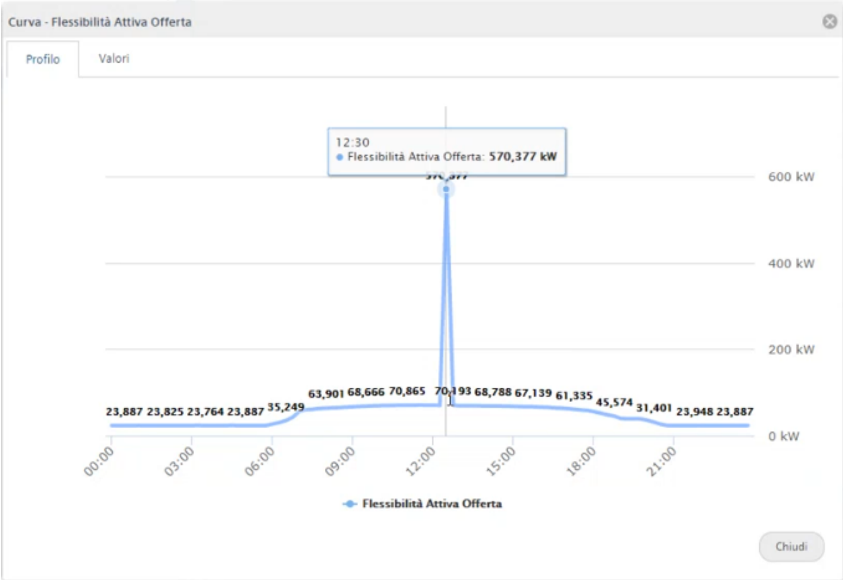


Figure 41: Offer of Flexibility Service from Flexible Customer

4.3.4 Market Platform economical outcomes

On the Market Platform, a “day-ahead” market session is properly setup (Figure 42) to collect all the Flexibility Offers coming for the Aggregator Platforms and the DSO Flexibility Requests coming from the DSOTP (as described in the previous chapters).

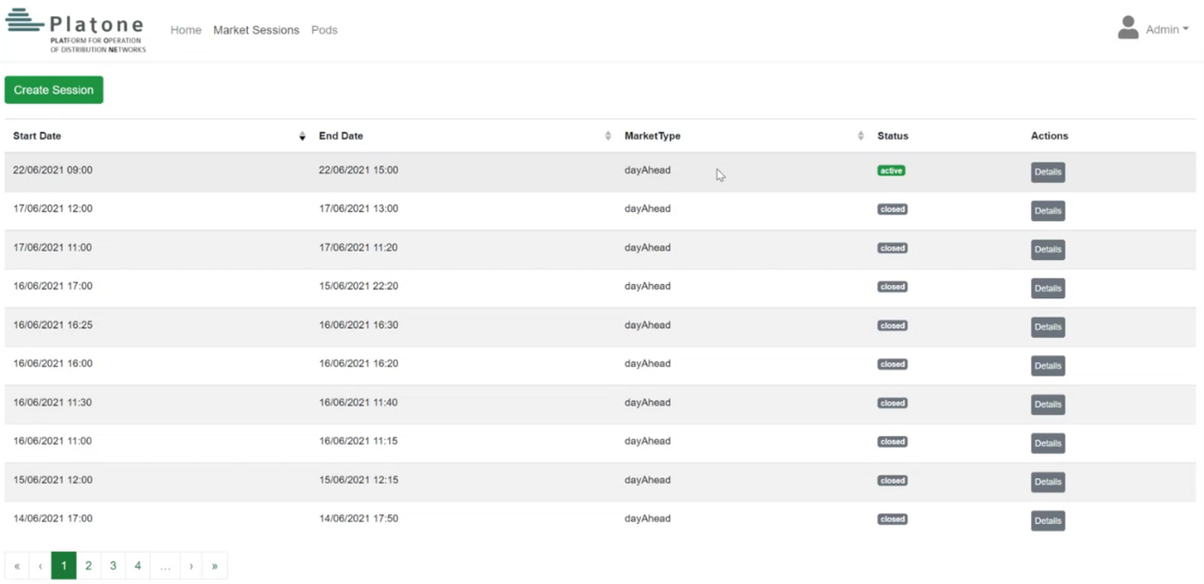


Figure 42: Market Platform’s “day-ahead” market session

Furthermore, a TSO Flexibility Request is simulated and registered into the “day-ahead” market session of the Market Platform (Figure 43). The TSO requires that on an aggregated base (on the PoM, i.e. on the sum of all the five available Flexible Customers) 7500 kW should be contributed to deal with his technical issues.

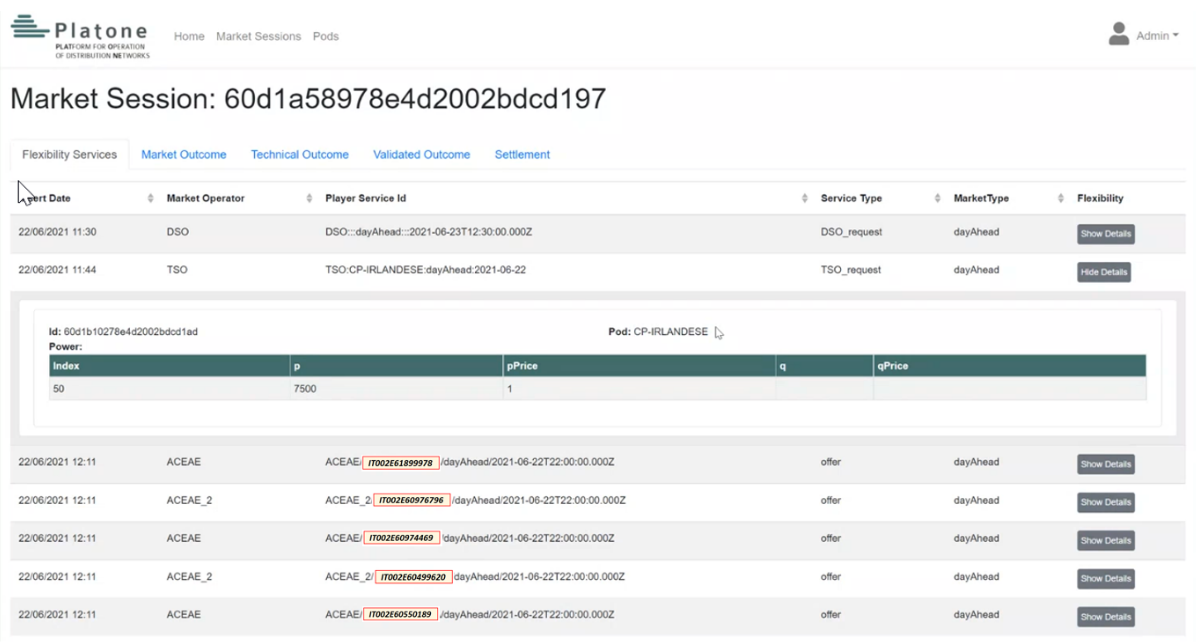


Figure 43: Simulation of a TSO Flexibility Request

At this stage, the "day-ahead" market session is closed and the Market Platform algorithm determines, on an economical base, the accepted Flexibility Services (Figure 44). The Flexible Customer IT002E61899978 is accepted for 1278.55 kW and IT002E60974469 for 4180.35 kW; to be noticed that the activation of these two Flexibility Services is connected to the DSO Flexibility Request. The Market Platform outcomes include also an acceptance for IT002E60550189 with a 342.13 kW contribution; this Flexible Customer is connected to the other MV Feeder "Nanchino" and the activation of this Flexibility Services is related to the TSO Flexibility Request (the DSO didn't request any Flexibility Service on that MV Feeder since no technical issue were detected).

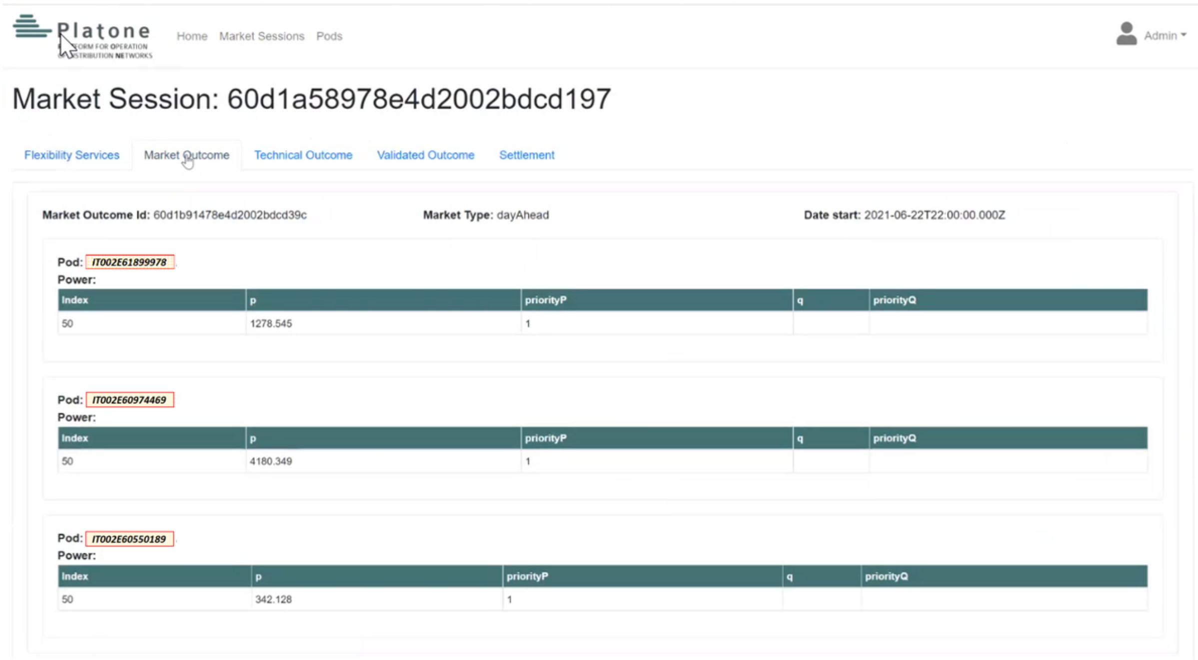


Figure 44: The Market Platform determines the accepted Flexibility Service

All these market outcomes are then sent from the Market Platform to the DSOTP for the final technical validation.

4.3.5 DSO Flexibility Validation

The DSOTP runs again a Power Flow analysis on the whole MV network applying the Flexibility Services received from the Market Platform; the goal is again to detect whether this new network scenario can lead to some technical issues.

Figure 45 shows the main result of this Power Flow run: the current overload previously detected on that branch of the MV Feeder “Mostacciano” is solved but a new alarm on the MV Feeder “Nanchino” occurs (the max current is 19.60 A and the estimated one is 30.07 A).

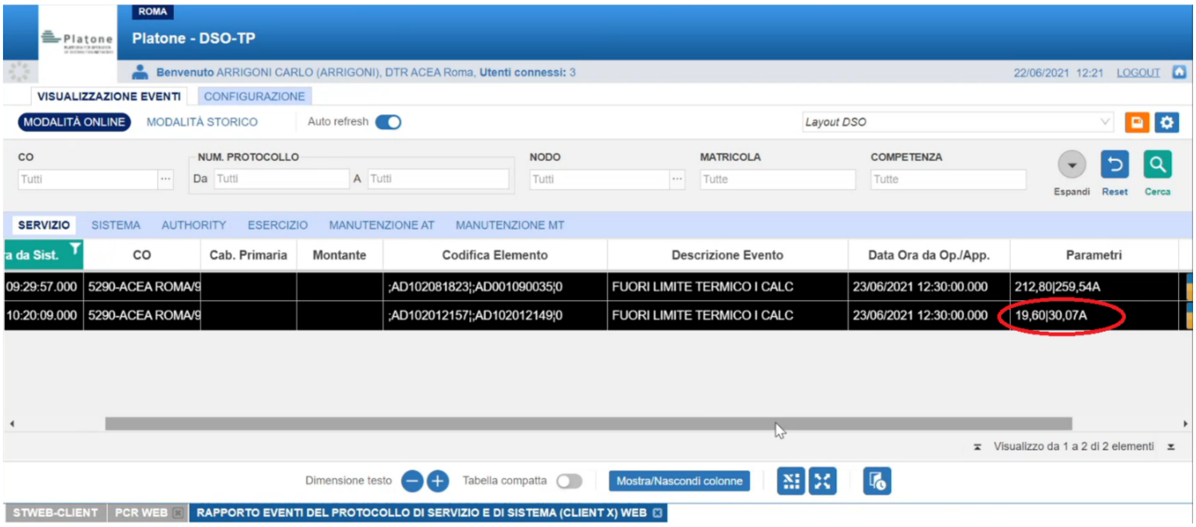


Figure 45: Result of Power flow run on DSO TP

Starting from this estimated network scenario, the DSOTP runs the Flexibility Validation algorithm that confirms the two Flexibility Services for IT002E61899978 and IT002E60974469 but, to solve the new current overload occurred on the MV Feeder “Nanchino”, accepts only a part of the Flexibility Service for IT002E60550189.

The following extract contains the real data flow sent form the DSOTP to the Market Platform; the DSO requires that for IT002E60550189 the activated Flexibility Services should be only 207.66 kW (instead of 342.13 kW).

{
"marketType":"dayAhead",
"duration":24,
"interval":15,
"startTime":"2021-06-22T22:00:00.000+00:00",
"marketOutcome":"60d1b91478e4d2002bdcd39c",
"flexibility":[
{
"pod":" IT002E61899978",
"power":[
{
"index":50,
"acceptedPValue":1278.545,
"acceptedP":"OK",

```
          "acceptedQValue":null,
          "acceptedQ":null
        }
      ]
    },
    {
      "pod":" IT002E60974469",
      "power":[
        {
          "index":50,
          "acceptedPValue":4180.349299061132,
          "acceptedP":"OK",
          "acceptedQValue":null,
          "acceptedQ":null
        }
      ]
    },
    {
      "pod":" IT002E60550189",
      "power":[
        {
          "index":50,
          "acceptedPValue":207.6620935799721,
          "acceptedP":"OK",
          "acceptedQValue":null,
          "acceptedQ":null
        }
      ]
    }
  ]
}
```


4.3.6 Final Market Platform outcomes

The technical outcomes received from the DSOTP are registered into the Market Platform that creates the final “validated” outcome (Figure 46) to be sent to the Aggregator Platform for the Service activation.

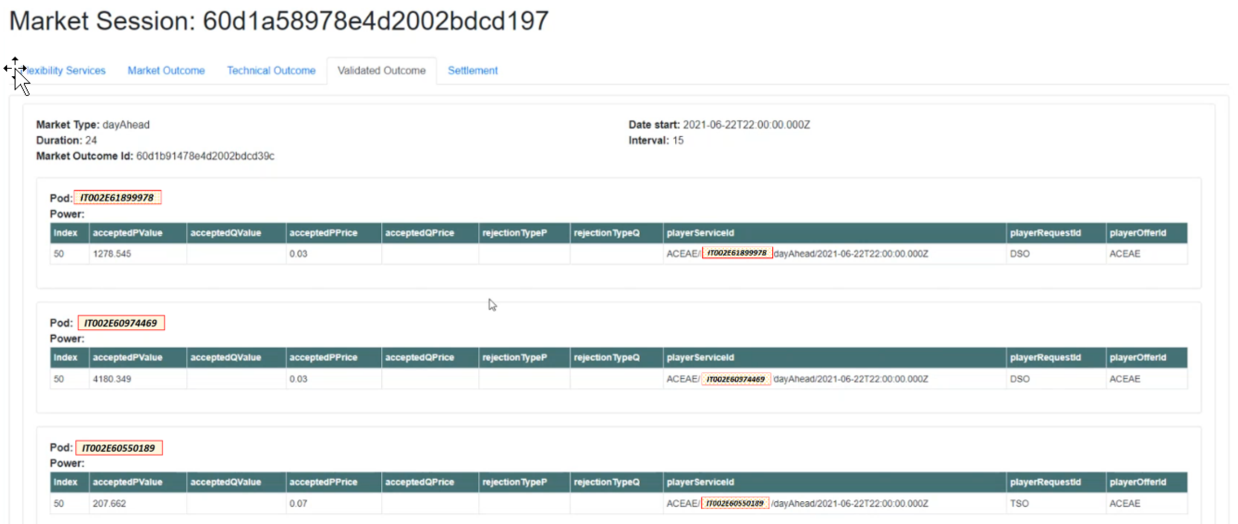


Figure 46: Final Validated outcome

4.3.7 Flexibility Service activation & measurements

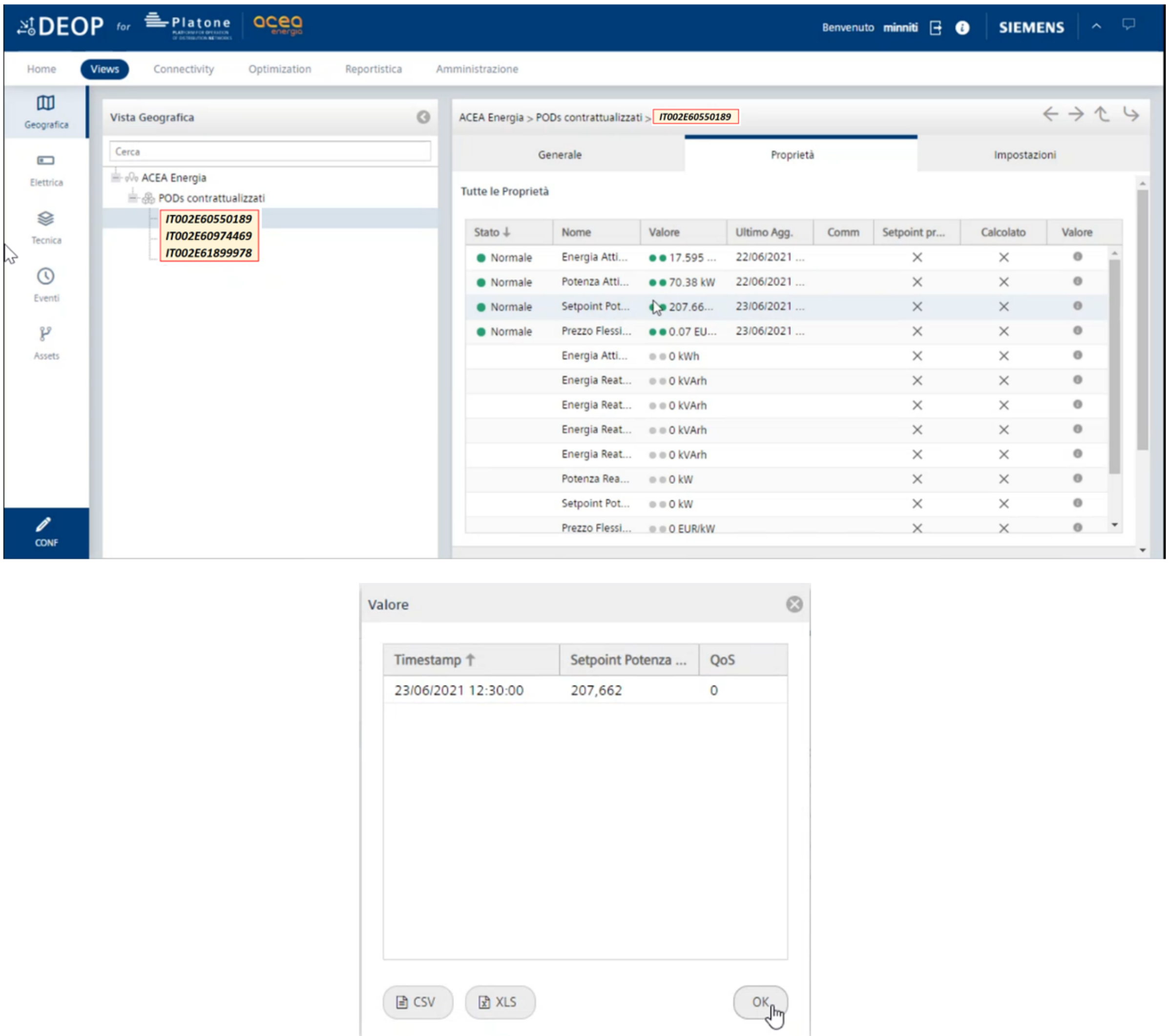


Figure 47: Aggregator Platform reaction to "validated" outcome

The “validated” outcome is acquired and managed by the Aggregator Platform (Figure 47) programming the activation of the Flexibility Service for the next day. Note that in the test scenario, purely for operational and timing reasons, the Flexibility Services were actually activated immediately and the data sent from the Aggregator Platform to the DSOTP; the last step brings the setpoints to be activated from the DSOTP to the Light Nodes (simulated devices).

Figure 48 displays an example of the data connected to the Access Layer where it’s possible to see the simulated measurements data flow coming from Light Nodes and the Flexibility Services activation (simulated setpoint).

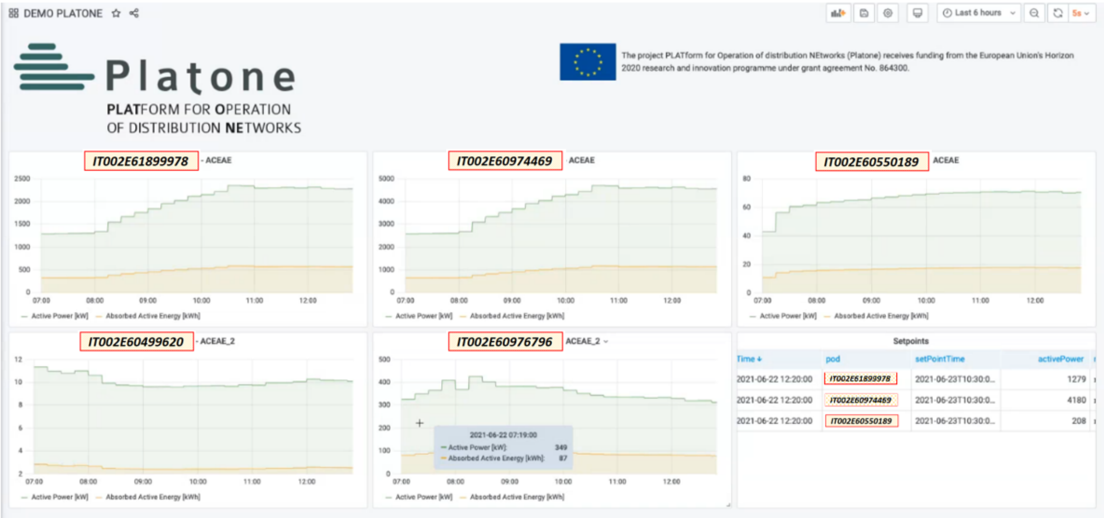


Figure 48: Data connected to the Access Layer

All the relevant data connected to the Customers behavior (measurement and setpoints) are registered in the Shared Customer Database (Figure 49).

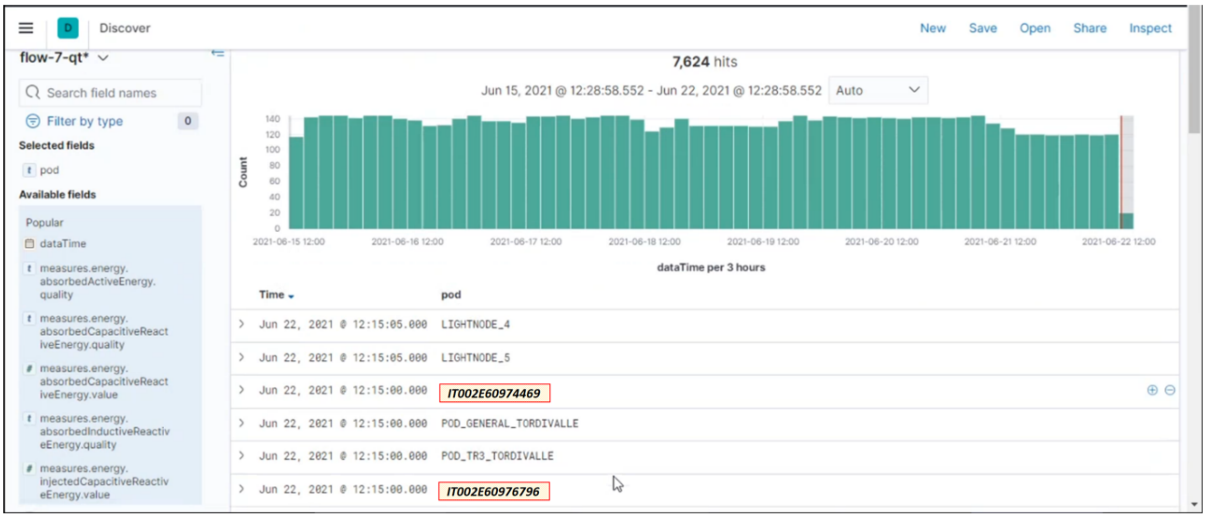


Figure 49: Shared Customer Database memorize data connected to the Customer behaviour

The measurements registered by the Shared Customer Database are finally sent to the Aggregator Platforms (Figure 50) and to the Market Platform for the settlement phase (Figure 51).

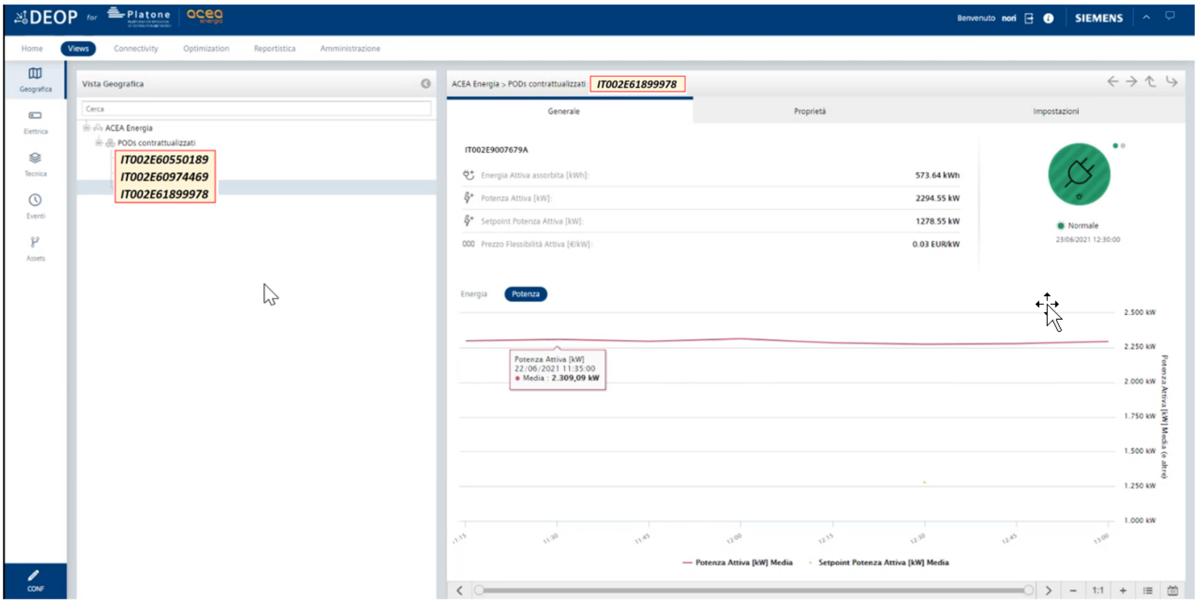


Figure 50: Aggregator Platform received measurement from SCD

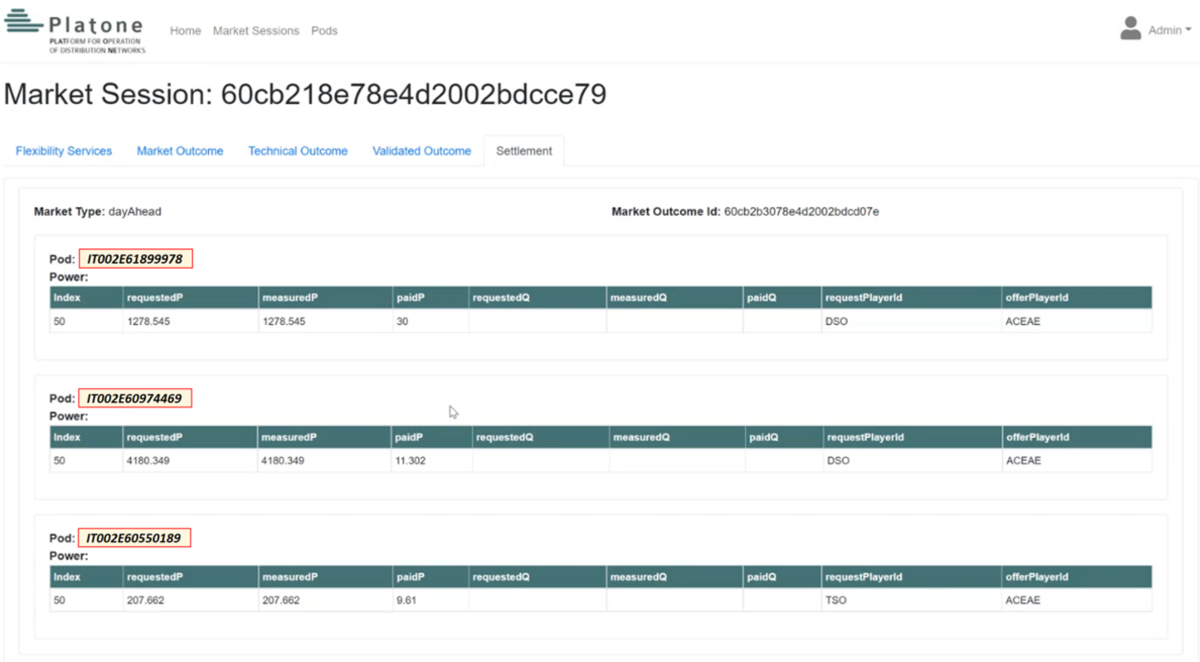


Figure 51: Market Platform received measurement from SCD

5 Conclusion

This first completely integrated field test involved all the Platforms of the Italian Demo demonstrating the correct interaction between them all, considering both the technical point of view (environment and platforms setup, communication channels) and the overall process data consistency.

In the analysed field setup, all the tested phases didn't show any specific issues and all the five platforms (Market Platform, Aggregator Platform, DSO Technical Platform, Shared Customer Database, Access Layer) were able to run properly and automatically all the necessary internal algorithms and data flows.

The considered scenario has already shown some interesting results, especially about the TSO/DSO coordination that will be deepened with other field tests and completed with the next Italian Demo Platforms' releases. Indeed, the flexibility services requests by TSO and DSO have different granularity, both in terms of volume (e.g. amount of kW) and in service delivery points (e.g. Primary Substation for TSO and Secondary Substations for DSO). It is managed by Platone Italian Demo thanks to algorithms that take into account interaction of each PoD with the connected Distribution grid.

Such a bottom-up approach allows to provide:

- the adequate low granularity needed by the TSO, i.e. high volume of Flexibility Service to be delivered at specific Distribution/Transmission grid connection points, regardless of who provides such a service;
- the high granularity needed by the DSO both to perform technical validation of economic market outcomes, as well as to request Flexibility Services localized in specific points of the Distribution grid that can change also dynamically with time and according to the environmental conditions.

In this regard, the test brings two notable results:

- The definition of PoMs (and the related PoD-PoM association performed by DSOTP) guarantees the needed granularity to the TSO;
- The "DSO Flexibility Validation" phase avoids that a possible activation of a service requested by the TSO (or less probably by the DSO) and selected only on economic criteria, instead of solving Transmission grid issues generates also undue troubles on Distribution grids (refer to Ch. 4.3.5: TSO request is only partially fulfilled).

The last result is probably the most significant. Regarding it, indeed, the Platone Italian Demo solution needs to be analysed more deeply because it is necessary to investigate how the SO (System Operator) that has not fulfilled the entire Flexible Request, can manage such an issue.

Regarding activities at customer premises, installations and tests are in progress but some preliminary results have been achieved. In detail, involvement of customer is essential, for example the installation of Electrical Storage System is the most time and space consuming. Dimensions and weights have significant impact when searching for the place of installation. Moreover, in case that the system is installed inside the flat, routing new cable needs to be done taking into account the aesthetical parameters of the flat.

Moreover, concerning inclusion and interaction of customer and Platone Italian Demo architecture, the development of Flessibili App has begun. This will request an active participation of the customer, who will be the tester.

Moreover, integration and test activities between Light Node and customer activation systems (such as EMS, Energy Storage System, etc.) has begun. Such activities, apart from customer cooperation, also needs involvement of the technology provider (such as the manufacturer of Energy Storage System) that will cooperate to guarantee data exchange and fulfil correct activation of setpoint.

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9 List of Abbreviations

Abbreviation	Term
AP	Aggregator Platform
BAL	Blockchain Access Layer
DER	Distributed Energy Resources
DEOP	Distributed Energy Optimizer
DSO	Distribution System Operators
DSOTP	DSO Technical Platform
EMS	Energy Management System
EV	Electric Vehicle
HV	High Voltage
MV	Medium Voltage
LV	Low Voltage
MP	Market Platform
NCS	Network Calculation System
PoD	Point of Delivery
PoM	Point of Measurement
SCD	Shared Customer Database
SO	System Operator
TSO	Transmission System Operator
WP	Work Package
LGF	Load & Generation Forecast