Flexible energy systems Leveraging the Optimal integration of EVs deployment Wave

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Deliverable D5.5

Platforms integration to effectively implement VGI via harmonised data/signal exchange

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List of Acronyms

Acronym	Meaning
AC	Alternate Current
API	Application Programming Interfaces
CPO	Charging Point Operator
DC	Direct Current
DER	Distributed Energy Resource
DSO	Distribution System Operator
EV	Electric Vehicle
FR	Flexibility Register
FSP	Flexibility Service Provider
IDS	International Data Space
IDSA	International Data Space Association
IT	Information Technology
M	Month
MQTT	Message Queuing Telemetry Transport
POD	Point of Delivery
TSO	Transmission System Operator
UVAM	Mixed Enabled Virtual Unit
V1G	Vehicle-1-Grid
V2G	Vehicle-to-Grid
VGI	Vehicle Grid Integration
WP	Work Package
VGIS	Vehicle Grid Integration Sector

Executive Summary

The increased shares of renewable energy combined with the rise of distributed sources are deeply impacting electricity markets and power system management.

The study of new business models as well as data integration analysis between different stakeholder's platforms represent crucial themes to optimize power system operations and grid data control.

Prosumers, energy aggregators, electric vehicle users, microgrids, parking and charging station operators, they all are developing advanced infrastructures in order to interact with utility companies and system operators.

This requires a re-thinking of the power sector to empower efficient levels of interoperability among different platforms enabling seamless communication and data exchange among energy stakeholders. This approach will ensure more efficient and coordinated bidirectional flows of energy and providing at the same time innovative network and business energy services.

Starting from the study of open data space and data governance framework for Vehicle Grid Integration Sector (VGIS), technologies and architectures for implementing a data-driven ecosystem for electromobility sector are discussed in the first part of the document.

Then a full description about the Crowd Balancing Platform is reported, with a focus on enabling FSPs to seamlessly participate with flexibility resources in electricity balancing TSO markets.

In this context, this document illustrates the analysis of connectors developed to purpose new functionalities for data/signal exchange and services between the CBP and EV market stakeholder to technically enable system-level VGI.

Finally, it's described a high-level additional service from the SOGNO framework integrated with the DSO technical platform to accomplish FLOW requirements.

1. Introduction

Data-driven technologies and platform integration among stakeholders in the electric vehicle energy market are the main pillars for a digital evolution in the driving energy sector, in order to fully exploit the potential of the evolving energy transition.

1.1. Purpose and Scope of T5.5

The main goal of FLOW task T5.5 is to foster VGI and advanced EV flexibility services, enabling harmonised data/signal exchange and service orchestration by designing and implementing new connectors and functionalities among the Crowd Balancing Platform (CBP) and existing energy market stakeholder platforms involved in EV charging and management chain (DSOs, TSOs, aggregators, BSPs, CPOs, etc.).

Moreover, in T5.5 will be implemented high level additional services from the SOGNO framework and other platforms (i.e. DSOTP) in order to accomplish FLOW requirements, supporting the integration in the FLOW demos, in particular in the Italian one (WP7).

1.2. Task 5.5

T5.5 aims to design and develop specific connectors for connecting the CBP and the platforms adopted by actors involved in EV charging and management chain (DSOs, TSOs, aggregators, BSPs, CPOs, etc.). The Orchestrator platform will be tested and evaluated in the Italian demo as a sandbox.

In the first reporting period of the project, ENG, as leader of the task 5.5, defined all activities and the time plan in collaboration with TERNA, RSE and NUIM, identified the specific requirements for improving the Crowd Balancing Platform (CBP) and deploying new VGI-related features connecting it with existing Platforms. In order to make this, in collaboration with WP3, a template for collecting technical specifications was shared with all the partners and technical workshops with the T5.5 partners (involving mainly the demo partners) were organized.

As a result of the analysis of outcomes collected in terms of requirements, use cases and scenarios, some possible use cases and scenarios involving CBP were identified during WP7 workshops:

- 1 macro-scenario: TSO flexibility market with EVs participation
- 2 processes: resource registration (implemented through CBP) and measurement collection from BSPs

In addition, an extension of the SOGNO Platform, including the EV routing service implemented in WP4 was provided, ensuring the improvement of the DSO technical platform with VGI innovative services. This service will be integrated and tested in the WP7 pilot (i.e., Italian demo) in collaboration with the Italian DSO (Areti).

1.3. Outline of the deliverable

Chapter 2 of the document analyses a data driven ecosystem, illustrating data sharing and service orchestration.

Chapter 3 describes the Crowd Balancing Platform, including the specific requirements for improving the CBP and deploying new VGI-related features connecting it with existing Platforms.

Chapter 4 takes into account the analysis, architecture and implementation of CBP connectors.

Chapter 5 analyses additional services of the SOGNO Platform.

Finally, Chapter 6 concludes this document.

2. Data-driven ecosystem: data sharing and service orchestration

2.1. Introduction

The concept of a data-driven systems and their application in the electromobility sector plays a key role in the evolution and transformation of energy systems: data sharing and availability represent reliable drivers for the implementation of innovative services based on V1G and V2G integration.

The analysis for the organization of distributed data in the EV market in specific use cases allows to make the information managed by data-driven applications such as Data Space even more reliable, enabling fair framework conditions for the sovereign exchange of data.

The value of the Data Space concept and the most relevant experimental initiatives have been deepened in WP3 in which have been identified specified components and technologies for the implementation of an architecture based on FLOW Data Space that can be exploited to be implemented in the EV ecosystem, facilitating interoperable cooperation data-driven and integration of EV stakeholders and their existing environment in a reliable and secure way.

2.2. Data and Service Orchestration

Given the proliferation of electric vehicles (EVs) in the recent market, the integration of EVs into the power grid infrastructure presents challenges [1]. Consequently, there is a requirement for a robust infrastructure that can control the charging process effectively and meet the requirements of their users. In this regard, data and service orchestration emerges as a critical framework for seamless coordination between vehicles, charging stations, and grid operators to enhance the reliability, efficiency, and sustainability of EV charging services [2]. To optimize the operation of EV charging infrastructure, the data and service orchestration leverages real-time data analytics and intelligent decision-making algorithms. Consequently, the data, their corresponding services, and communication are the core components of the data and service orchestration infrastructure to facilitate the power grid (TSO, DSO), utility and service providers (utility companies, energy aggregators, parking lot operators, CPOs, and MSPs), the EVs and their users' requirements. Following the FLOW Work Package 3, this section mainly focuses on the functional components of the data and service orchestration infrastructure and their utilization in the operation of EVs:

- The various components and their associated data highlighted in deliverable 3.4 of WP3 [3].
- The communication network protocols, and their corresponding security requirements discussed in deliverables 3.1 and 3.2 of WP3 [4, 5].
- The service orchestration architecture discussed in deliverable 3.3 of WP3 [6].

Based on these functional components, this section further discusses a blockchain based peer-to-peer energy trading service to facilitate secure transactions among the peers in the EV charging infrastructure.

2.2.1. Components and their associated data

The TSO, DSO, Utility Companies, EVs themselves, and their users are essential for achieving a well-functioning and responsive EV ecosystem.

1. **Transmission System Operators:** The TSOs are responsible for the high-voltage transmission of electricity over long distances [7] as well as for "dispatching", i.e., maintaining a balanced flow of electricity on the high voltage grid to ensure a constant equilibrium between supply and demand. They ensure grid reliability, manage system constraints, and coordinate with other TSOs for cross-border electricity exchange. They are responsible for grid development, by strengthening national grids and cross-border interconnections, for the security of the electricity grid and the continuity of supply, and also to increase the resilience of the transmission grid. TSOs record, collect and analyse data on electricity transmission, grid stability, and overall system conditions. This includes information on power flows, grid congestion, and interconnection with neighbouring systems.
2. **Distribution System Operators:** The DSOs manage the distribution of electricity to end-users within their designated areas. They maintain local grid stability, facilitate the connection of new distributed generation sources, and handle grid congestion issues [8]. DSOs gather data on electricity distribution within specific regions that are related to the local grid conditions, load profiles, and the integration of distributed energy resources (DERs).
3. **Utility Company:** The utility companies interact directly with consumers, providing energy services, billing, and customer support [9]. They also play a role in shaping market dynamics, offering various pricing plans, and promoting energy efficiency programs. They collect data on consumer energy usage, billing information, and market trends. This includes data on tariff structures, customer preferences, and demand patterns.
4. **Electric Vehicles and Their Users:** Electric vehicles and their users represent energy consumers who play a pivotal role in the energy system and participate in demand response programs to adopt energy-efficient practices, such as smart charging solutions [10]. The data associated with EVs includes the vehicle ID, battery capacity, state-of-charge (SoC), and required amount of energy. On the other hand, the users' data includes arrival time, departure time, and stay time. The objectives of EVs and their users are to meet the charging requirements of the EVs at a lower cost, considering their respective data.

2.2.2. Communication Protocols

Communication protocols play a crucial role in ensuring the seamless integration of EVs and power system infrastructure, including charging stations, energy management systems, parking lot operators, energy aggregators, DSOs, and TSOs. The FLOW deliverable 3.1 (D3.1) [4] presented a detailed discussion on the standardized communication protocols, including ISO 15118/IEC 61850, ChAdeMo, IEEE 2030.5, OpenADR, OCCP, OSCP, OCPI, OCHP, OICP, and eMIP, for integrating EVs into the power grid infrastructure. The deliverable discussed several charging scenarios broadly categorized into vertical and horizontal domains. The vertical scenarios include grid-to-vehicles (G2V) and vehicle-to-grid (V2G), while the horizontal scenarios include vehicle-to-vehicles (V2V), vehicle-to-building (V2B), and vehicle-to-load (V2L), detailing the charging process between the EV and charging stations. The

horizontal scenarios have the potential to support the power grid in reducing the charging load with lower charging through peer-to-peer charging.

2.2.3. Service Orchestration

In the domain of EVs, service orchestration refers to the management and coordination of various services and components involved in the charging process, such as EVs, charging stations, energy sources, and payment systems. Given the horizontal charging scenarios discussed in D3.1 [4] and the security mechanism discussed in D3.2 [5], peer-to-peer energy trading coupled with blockchain technology for secure payment is one of the most important service orchestrations that support the EVs charging requirements. It reduces the charging load while ensuring secure transactions among peers trading their surplus energy.

2.2.4. Peer-to-Peer Energy Trading

Peer-to-peer (P2P) energy trading within EVs has the potential to support the power grid by reducing the charging load, while also providing opportunities for sellers to save money through their excess energy and for buyers to purchase energy at a reasonable rate [11]. To manage the energy trading in a secure manner, the blockchain plays a critical role in supporting P2P transactions. There are different types of blockchains [12] that can support P2P energy trading for EVs.

1. **Public Blockchain:** The public blockchain is a fully decentralised platform that enables the EVs to automat energy trading and transactions through a smart contract that represents energy as tokens, thereby facilitating real-time pricing and grid management.
2. **Private Blockchain:** The private blockchain allows energy trading by validating the energy and transactions in the blockchain while monitoring the energy rates offered among the peers. This enables a more controlled and efficient energy trading system that can integrate EVs with microgrids and enable them to trade energy within the parking lot through the controlled entity infrastructure.
3. **Consortium Blockchain:** The consortium blockchain provides a semi-decentralized structure for allowing the energy stockholders, such as energy producers, consumers, utilities, and EV owners to trade energy and perform transactions over a single platform while maintaining a certain level of decentralization and control mechanism. The platform aligns with the private blockchain, however, the decision-making is distributed across multiple participants under the governance of a single entity like TSO/DSO, who is responsible for validating the energy rates and the transactions.

A cyber-physical view of the consortium blockchain architecture for P2P energy trading within electric vehicles is presented in Figure 1. The figure shows a physical view representing the physical connection between the EVs and the charging stations and showcases the physical infrastructure supporting bidirectional power flow to facilitate P2P energy trading. The cyber view shows the participating entities (the seller, buyer, and the infrastructure operators) and their interaction with the blockchain for transactions. The sellers and buyer make trading decisions independently, while the infrastructure operators are responsible for ensuring transparency in offer rates and validating the transactions. Each EV has a current state-of-charge (SoC), which represents the amount of stored energy in its battery.

This SoC is a function of the battery capacity and can be utilized to differentiate between the roles of seller and buyer by establishing a threshold-based criterion, as outlined in Equation (1).

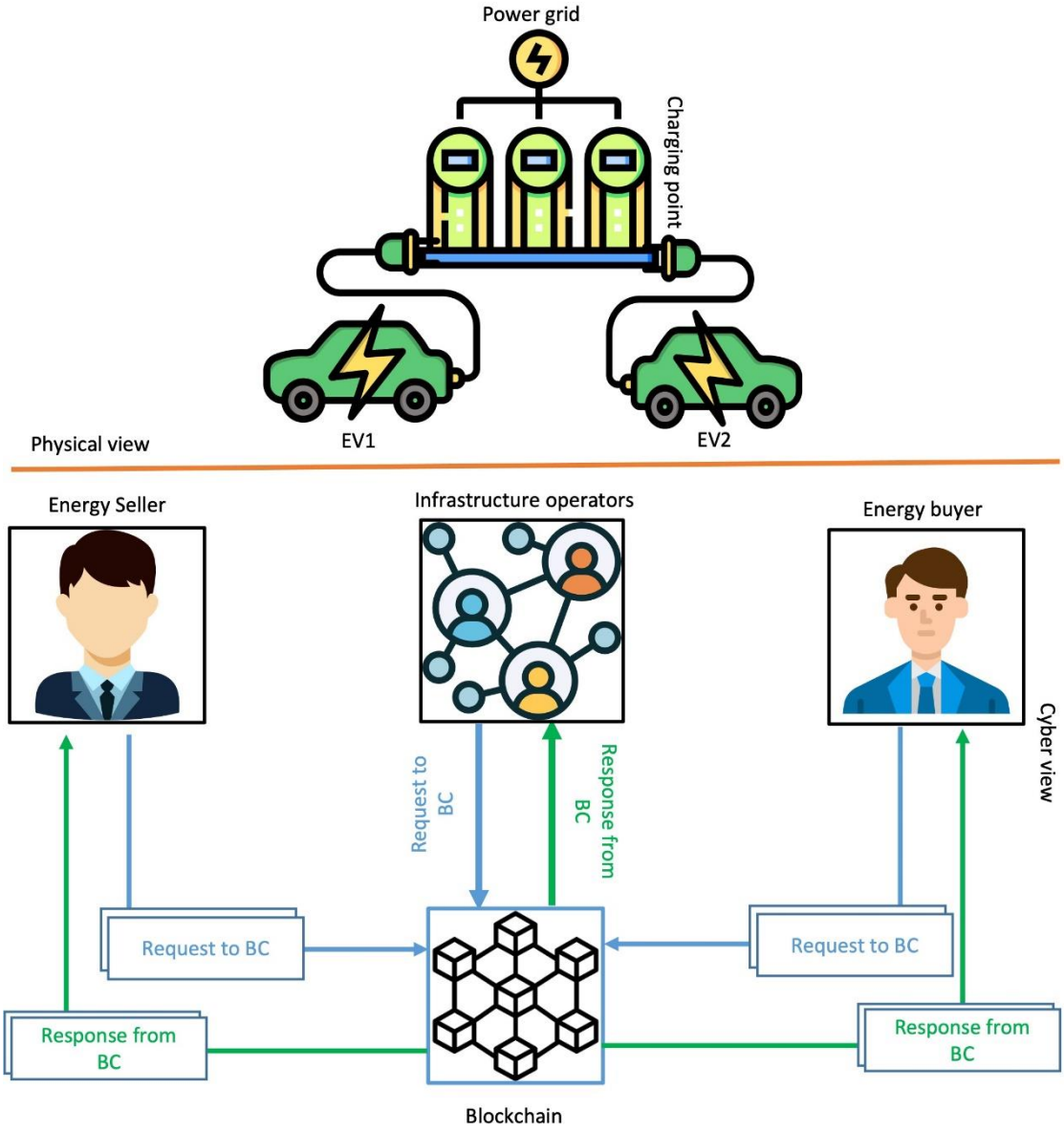

Figure 1. An illustration of a cyber-physical system with consortium blockchain enabled peer-to-peer energy trading, highlighting the data and service orchestration in the domain of EVs

The required energies for the buyer and the available energy for the seller are calculated using Equations (2) and (3), respectively. Once the sellers and buyers have determined their available and required energies, the trade amount and corresponding costs are computed according to Equations (4) and (5).

$$R_i = \begin{cases} B_i \ \ if\ (SoC_i \times BC_i) < T_b \\ S_i\ if\ (SoC_i \times BC_i) \geq T_s \\ N_i\ if\ T_b \leq (SoC_i \times B_i) \leq T_s \end{cases} \quad (1)$$

$$E_{required} = BC_{buyer} \times (SoC_{target} - SoC_{current}) \quad (2)$$

$$E_{available} = BC_{seller} \times (SoC_{current} - SoC_{threshhold}) \quad (3)$$

$$Trade\_Amount_{i,j} = \begin{cases} \min(E_{required}, E_{available})\ if\ E_{required} > 0\ \&\ E_{available} > 0 \\ 0\ \ Otherwise \end{cases} \quad (4)$$

$$Cost = Trade\_Amount_{i,j} \times P \quad (5)$$

Where R_i represents the role, B_i is the buyer, S_i is the seller, N_i is neutral, SoC_i is the state-of-charge, BC_i is the battery capacity, T_b and T_s are the thresholds set for determining buyers and sellers in the system and P represents the energy prices. The i, j are the indices of the buyer and seller. To highlight the importance of P2P energy trading and blockchain-based service orchestration, a case study is set up considering electric vehicles (EVs) with different battery capacities (40kWh, 60kWh, 80kWh, and 100kWh), state-of-charge (80% to 95% for sellers, and 30% to 60% for buyers), amount of required and available energies are computed based on the threshold criteria according to Equations (1)-(3). The simulation is performed, and the results are presented in Figure 2 and Figure 5.

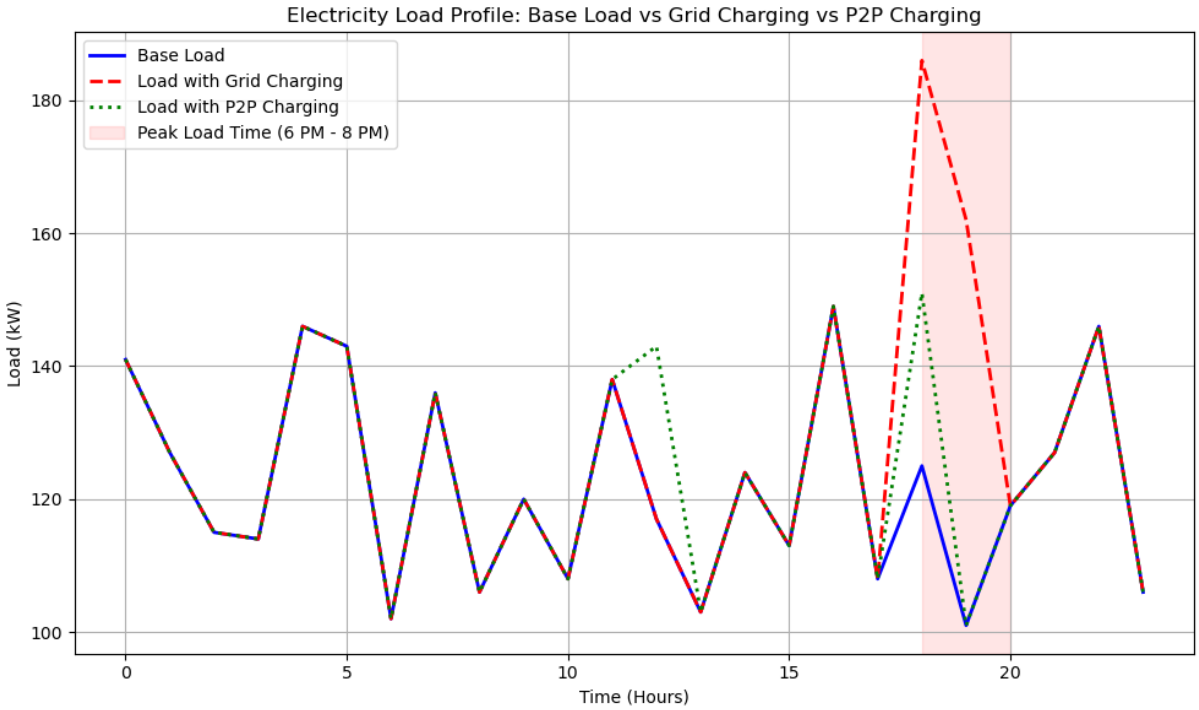

Figure 2. An illustration of the impact on the load profile considering the charging EVs from grid and with peer-to-peer charging

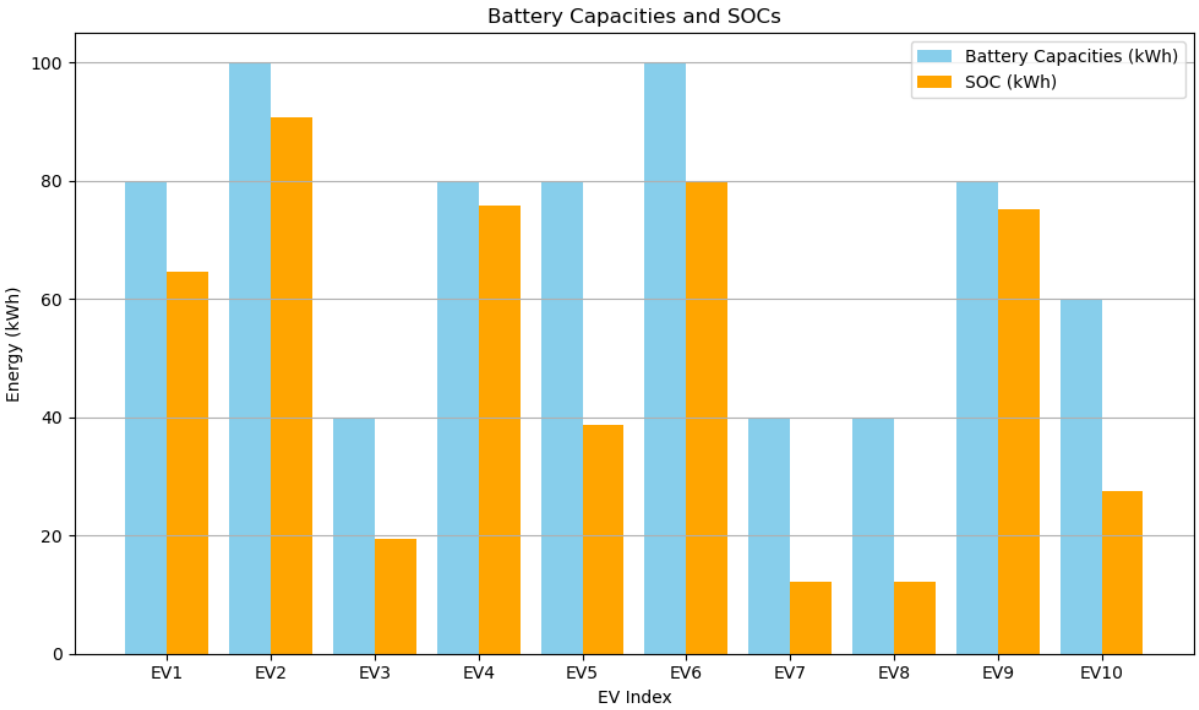

Figure 3. State-of-Charge of the EVs against their battery capacities

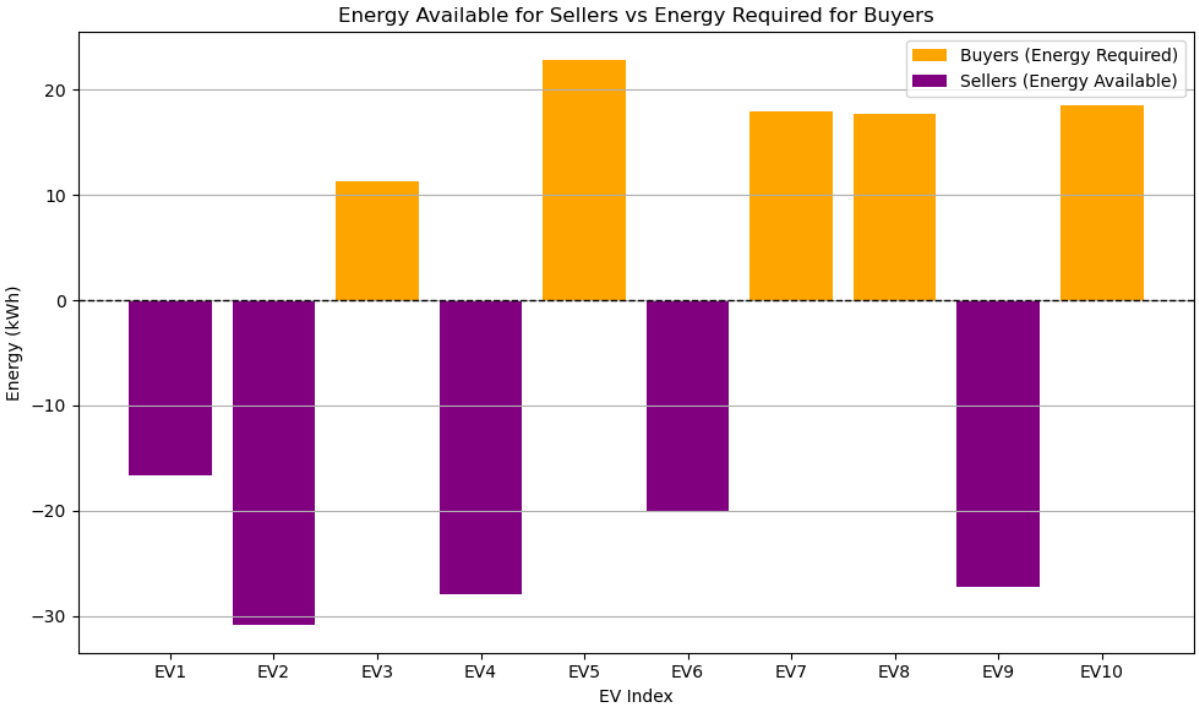

Figure 4. An illustration of the selling and buying amount of energies for each of the EVs

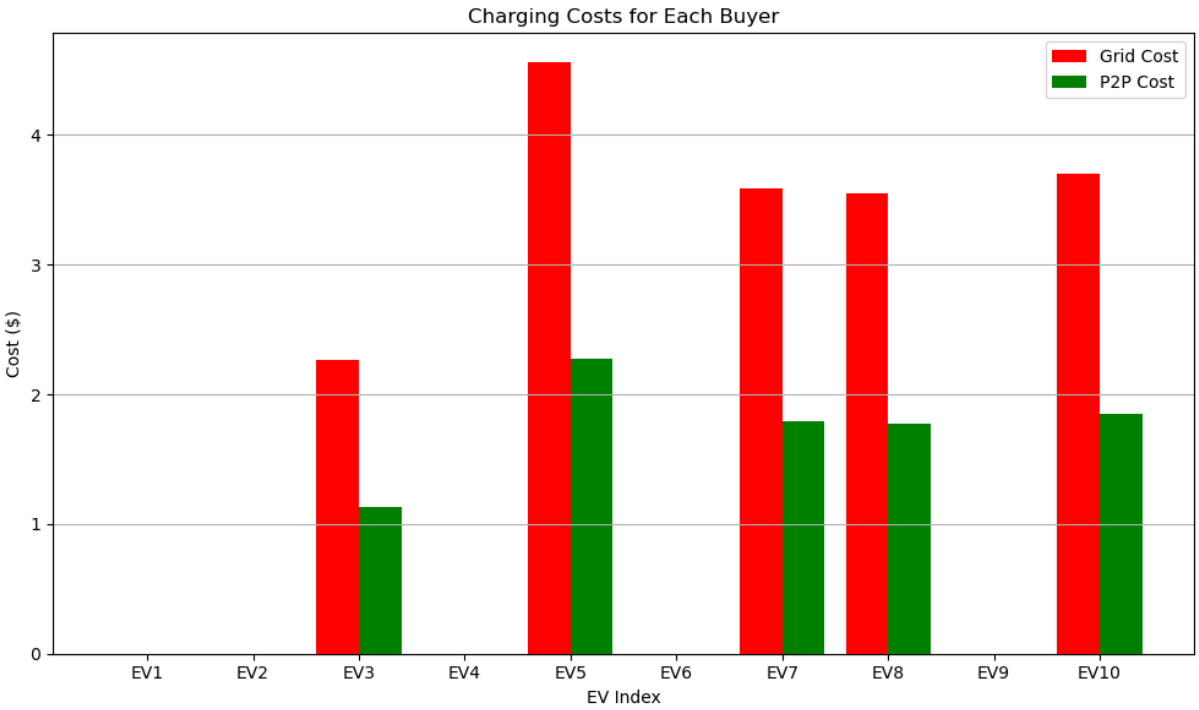

Figure 5. Comparison of the charging costs between charging from grid and charging with peer-to-peer energy trading

It is evident from Figures 2 and 5 that the peer-to-peer energy trading service supports both the power grid by reducing the charging load and EV users by satisfying their charging requirements at lower costs. The transaction process between peers using blockchain is illustrated in Figures 6 and 7. Figure 6 depicts the initiation of transactions by energy buyers to pay for their traded energy. Initially, these transactions are in a pending state and are stored in the blockchain once infrastructure operators confirm the traded energy amounts and associated costs, as shown in Figure 7.

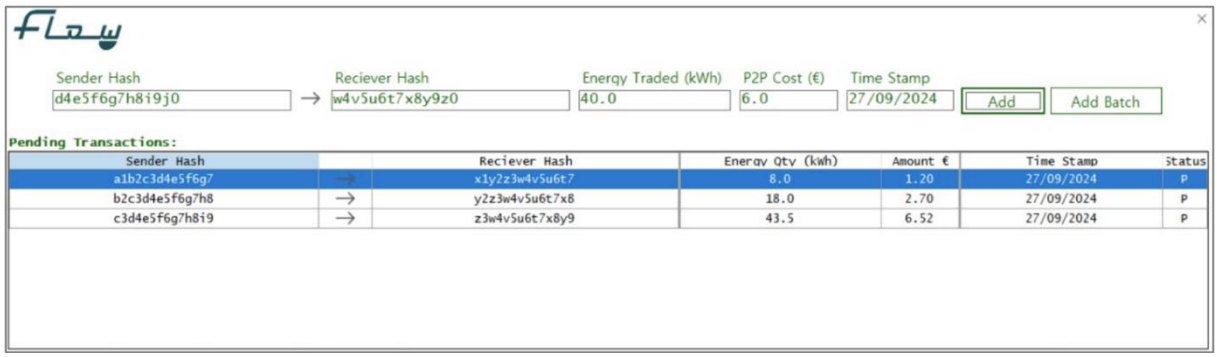

Figure 6. An illustration of the buyer transactions for their peer-to-peer traded energies

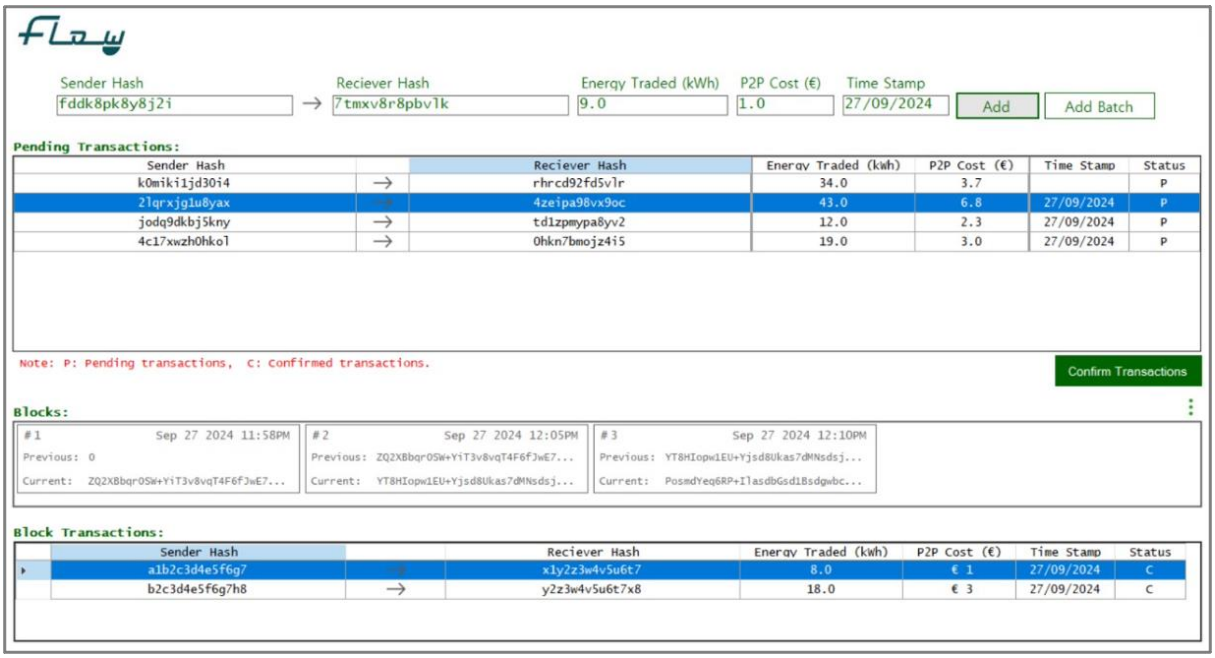

Figure 7. An illustration of the pending and confirmed transactions for the peer-to-peer energy trading between the sellers and the buyers

3. Crowd Balancing Platform (CBP)

3.1. Description and architecture

The CBP is built and managed as a distributed platform based on Hyperledger Fabric as the blockchain framework. The platform consists of two main components:

CBP Core – The core of the blockchain platform. It implements the "Core Platform" based on ENTSO-E and EBIX standards, as well as all functionalities related to security, monitoring, management, fraud detection, and external audit capabilities. It contains the platform's smart contracts, including the logic and transactions on blockchain assets. The smart contracts are deployed on blockchain because they also contain and maintain the World State database and the Blockchain Ledger.

CBP pps – The CBP apps enable the platform to be localized for each market and to operate within the specific laws, regulations, and use cases required. They include functionalities for a specific market implementation, including the logic to connect to the APIs of the market operators' systems with which the platform needs to integrate. The CBP apps implement the business logic for specific market processes and have a layer for integration with the Blockchain ledger.

The CBP platform, as detailed in the following sections, will be deployed in the cloud and operationally managed by Equigy. BSPs (Balancing Service Providers) are not required to install or configure any infrastructure components on their own systems, as all interactions with the platform will occur over the internet via API services, similarly to cloud SaaS service.

The CBP does not provide any user interface. All interactions and information exchanges must take place through the use of APIs defined in association with the identified processes.

It is understood that, if the BSP deems it appropriate or necessary for its operations, it has the option to independently define and implement graphical interfaces designed to call the CBP APIs, which can optimize the interaction between its IT perimeter and the CBP itself.

The platform can be managed in a distributed manner, where each participant can deploy an instance of the blockchain (peer). The platform supports multi-tenancy, which means that a single instance of a blockchain peer and the CBP apps can be used by multiple participants while maintaining privacy and security requirements through appropriate channels.

The solution defined for the Italian context, for the integration of the CBP platform with Terna, BSP, and DSO, is illustrated in the following image:

- Multi-Tenant Peer for BSP (FSP in the image)
- Multi-Tenant Peer for DSO
- Single-Tenant Peer for TSO (Terna), which will have the role of BNA (Business Network Administrator)

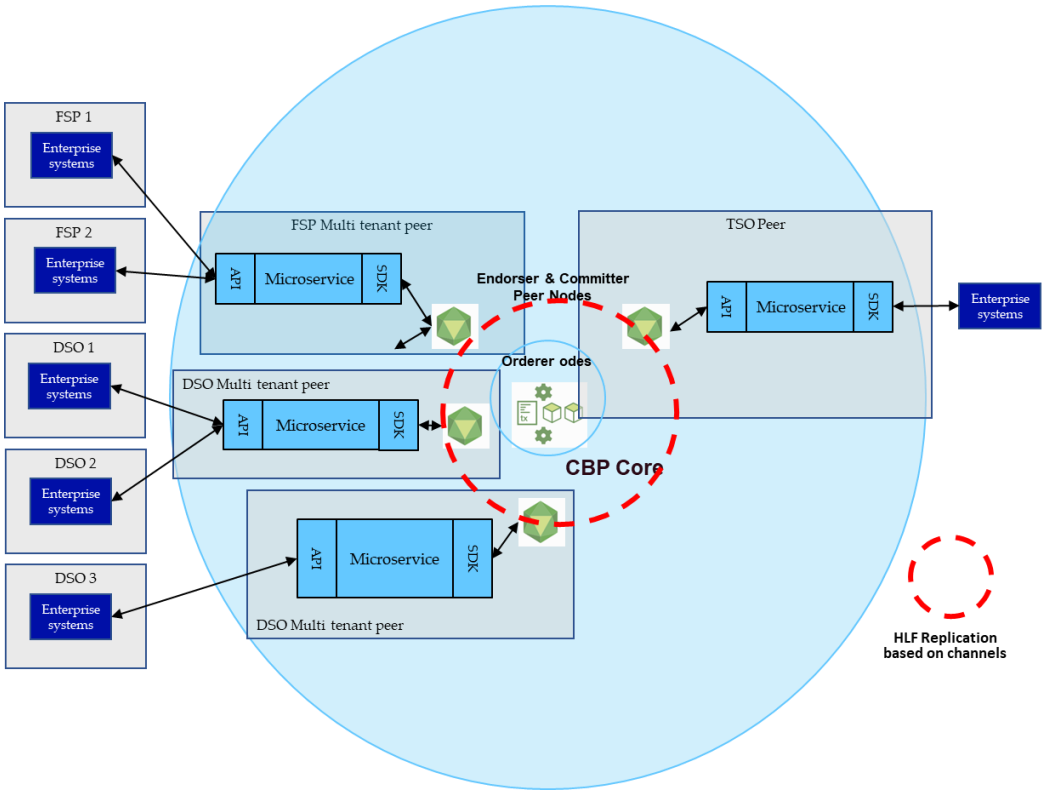

Figure 8. CBP General Architecture

Through the definition of dedicated private channels for communication between each actor within the defined deployment model, the necessary segregation of information is established to ensure data privacy within the multi-Tenant Peers.

3.2. Analysis of use cases, scenario and requirements

Adoption of the CBP will be done on the premise of the Rome demo of the FLOW project, in particular in the demo activities that will involve the transmission system operator and that will be dedicated to testing flexibility provision by e-mobility to support grid balancing.

The TSO use case deals with testing the capability of EV aggregates in providing flexibility to the grid in response to (slow) frequency regulation-like services, in particular services analogous to tertiary frequency reserve regulation.

The use case aims at assessing the EV resource behaviour in terms of availability and participation as well as the effects that a variation on parameters and requirements along the flexibility value chain can have on actual flexibility volumes and users' involvement.

The service requirements for the BSP will be those typically asked when participating in the ancillary services market, although, in the demo environment, some innovations will be introduced to test how they can facilitate the participation of EVs in flexibility provision.

One of the main innovations consists in the possibility for the BSP to adopt a behind-the-meter aggregation model, in which assets directly and not just connection points can take part in the aggregate while allowing for service verification thanks to the measurements provided by the assets' built-in measurement devices. Measurement frequency requirements will also be relaxed to take into account the peculiarities of these assets (e.g., 60 s measurements instead of 4 s measurements both for single assets and for aggregate). Moreover, some constraints will be relaxed to take into account for the limited size of the demo (e.g., an aggregate with size lower than 1 MW will be admitted) and for simplification purposes during development (e.g., no real time exchange of measurements), although a future real-environment implementation will have to envisage such features.

Four main phases are foreseen in the experimental user journey to be followed during the demo:

Registration. This phase is fundamental as it allows the creation of the resource by the BSP and to attach the associated POD. These resources can be managed by the BSP and updated in case their characteristics change. Once created they are used to form the aggregate, which is then the reference for service provisions. After resources and PODs have been registered, the competent DSO is in charge of validating the PODs. The functionalities regarding assets and aggregate registration will be developed and employed on the CBP during the demo and are described in the following chapter. These functionalities could also be potentially leveraged in the future by the BSP in light of the "Common Frontdoor" approach adopted by CBP and Equigy through which access can be provided to the BSP to multiple balancing and redispatch markets in multiple countries in an easy and standardized way.

Bidding: The BSP is asked to provide its availability in modifying the aggregate power absorption from the grid (as mostly V1G are expected) following various time patterns.

Activation: the TSO sends activation set points following the received availability and with a specific time advance.

Verification: the BSP shares b-t-m measurements regarding the activated assets as well as the DSO shares POD measurements to allow the TSO to make performance verification.

As previously remarked, since the demo testing will be led off-market in a sandbox environment, and also due to some of the demo characteristics, some simplifications will be applied in the various phases of the user journey of the experimentation. This allows the necessary elasticity to perform a wider variety of tests. On top of that, this also allows to implement and test innovative features that could eventually support market access of EV aggregates.

3.3. Specifications and implementation of new services

Asset Registration

The BSP registers on the CBP the flexibility resource (in this case a distributed flexibility resource, specifically the EVSE provided in the Rome demo) and its information (technical), considering the

interface of Grid Connection Point (POD) as a reference point and later specifying the characteristics of the underlying resource. The asset is registered (following a defined path based on the differentiation between consumption GCP, generation GCP, mixed GCP). The registration of a flexibility resource is to be considered a one-time event with the option for the BSP to always update the data regarding every GCP and in general accordingly to the status of the flexibility resource and based on the validation rules applied within the CBP and in the backend systems. The BSP will be able to aggregate flexibility resources into pools at a later stage, when in a "pre-validated" or "validated" status, along the process to bring the pool to prequalification.

The process implemented requires the BSP to invoke different services to enter all the information required for the correct storage of a POD on the platform:

- Register Flex Resource (Grid Connection Point) - for the creation and registration of a POD.
- Register Flex Resource (Flex Device) - for registering the generation or consumption units underlying the POD.
- Create Attachment - for entering attached documents required for saving the POD.
- Update Resource Status - to change the status of a POD.
- Update Resource Information - to update the data of a POD (operation only available on POD in 'open' status).

The registration flow followed by the BSP is detailed below:

1. The BSP invokes the Register Flex Resource service (Grid Connection Point) to register the POD data by passing as input the 'registered' status.
2. The BSP invokes the Register Flex Resource (Flex Device) service to register the technical entities underlying the POD by passing as input the status 'registered'.
3. The BSP invokes the Create Attachment service to create the attachments required to save the POD.
4. Once the attachment has been created on the CBP, the BSP shall call the Update Resource Information service to attach the attachment to the POD.
5. The process described in the previous steps brings the status of the POD to "Open". Once all the necessary information has been entered and the required services have been called, the BSP makes a call to the Update Resource Status service to confirm the information entered and request that the POD be switched to the "Under Review" status.
6. Once the PODs have been uploaded and sent for processing, the TSO verifies the information and, if successful, updates the POD status.
7. The DSO is notified of the operation and can perform the detailed analysis of the data, as well as express static constraints on each POD.
8. When feedback from the DSO is received if positive, the POD status becomes 'validated'.

Aggregate Registration

After the PODs are registered and validated on the CBP, the BSP can proceed to combine them together in pools of resources (where the number of resources is >=1) and register the resource group onto the CBP. The CBP will then store the resource groups and share the information with the TSO for its backend actions that starts the qualification process so that the asset can be qualified into the market. The following nomenclature refers to UVAM, as a reference for the aggregate of distributed resources (as per the Italian ancillary services market).

The process implemented requires the BSP to invoke different services:

- Register Resource Group - for registering the data of a resource group (UVAM).
- Register Resource in Resource Group - for selection and insertion of PODs in the created UVAM.
- Create attachment - for inserting attached documents required for saving the UVAM.
- Update Resource Group - for updating UVAM with the ids of attachments created via the 'create attachment' service.
- Register Connection - for entering details of connection parameters relating to the UVAM being registered.
- Update Status - for updating the status of a UVAM.
- Update Resource Group - for updating the data of a UVAM (only if in open status).

The registration flow followed by the BSP is detailed below:

1. The BSP invokes the Register Resource Group service to register the UVAM data by passing as input the status 'registered'.
2. The BSP invokes the Register Resource in Resource Group service in order to perform the pool creation step by indicating PODs, already registered and validated on CBP, to be entered in UVAM.
3. The BSP invokes the Create Attachment service to attach the documents required for its registration to UVAM.
4. The BSP invokes the Update Resource Group service to attach the documents necessary for its registration created in step 3 to the UVAM.
5. The BSP invokes the Register Connection service to define the UVAM's connection parameters.

The process described in the previous steps, brings the status of the UVAM to 'open'. Once all the necessary information has been entered and the required services have been called, the BSP makes a call to the Update Status service to confirm the information entered and request the UVAM to be passed 'under review'. UVAM information can only be updated if the UVAM itself is in an Open state (via the Update Resource Group service).

4. Data Space Connector for CBP integration

4.1. Analysis of requirements and specifications

The development of the CBP Connector was based on the analysis of the requirements from the FSP point of view to register the reference assets in the CBP as well as the study of the technical specifications for integration with the CBP.

In particular, the scenarios that the FSP will be able to manage in order to register its assets in the TSO/DSO platforms were explored in depth, thus enabling the subsequent testing phases of global flexibility in a scenario based on aggregator EVs.

For the Italian demo, the following use cases have been identified:

1. Data Dashboard
    - POD Dashboard
    - UVAM Dashboard

Figure 9 shows the use case diagram for the POD Dashboard and the UVAM Dashboard

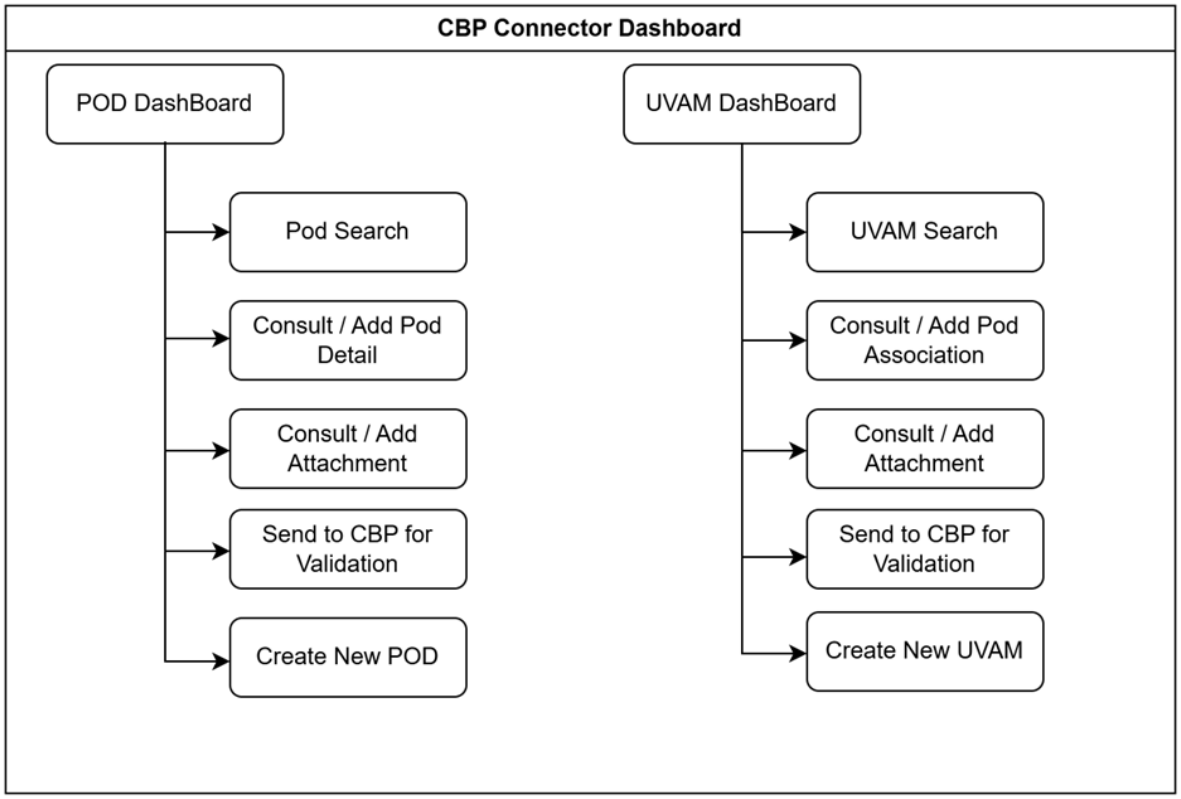

Figure 9. CBP Connector - Dashboard Use Case

Dashboards represent the user's access point to launch the different features designed to manage resources as

- Create new resource (POD / UVAM)
- List of resources
- Consult/Add resource details
- Consult/Add Attachment
- Start Validation Process

2. Asset Registration: the process of registering a new resource allows:
    - POD creation
    - Adding technical details of the resource
    - Sending data to the CBP
    - POD Validation

Figure 10 shows the use case diagram for the POD Registration process.

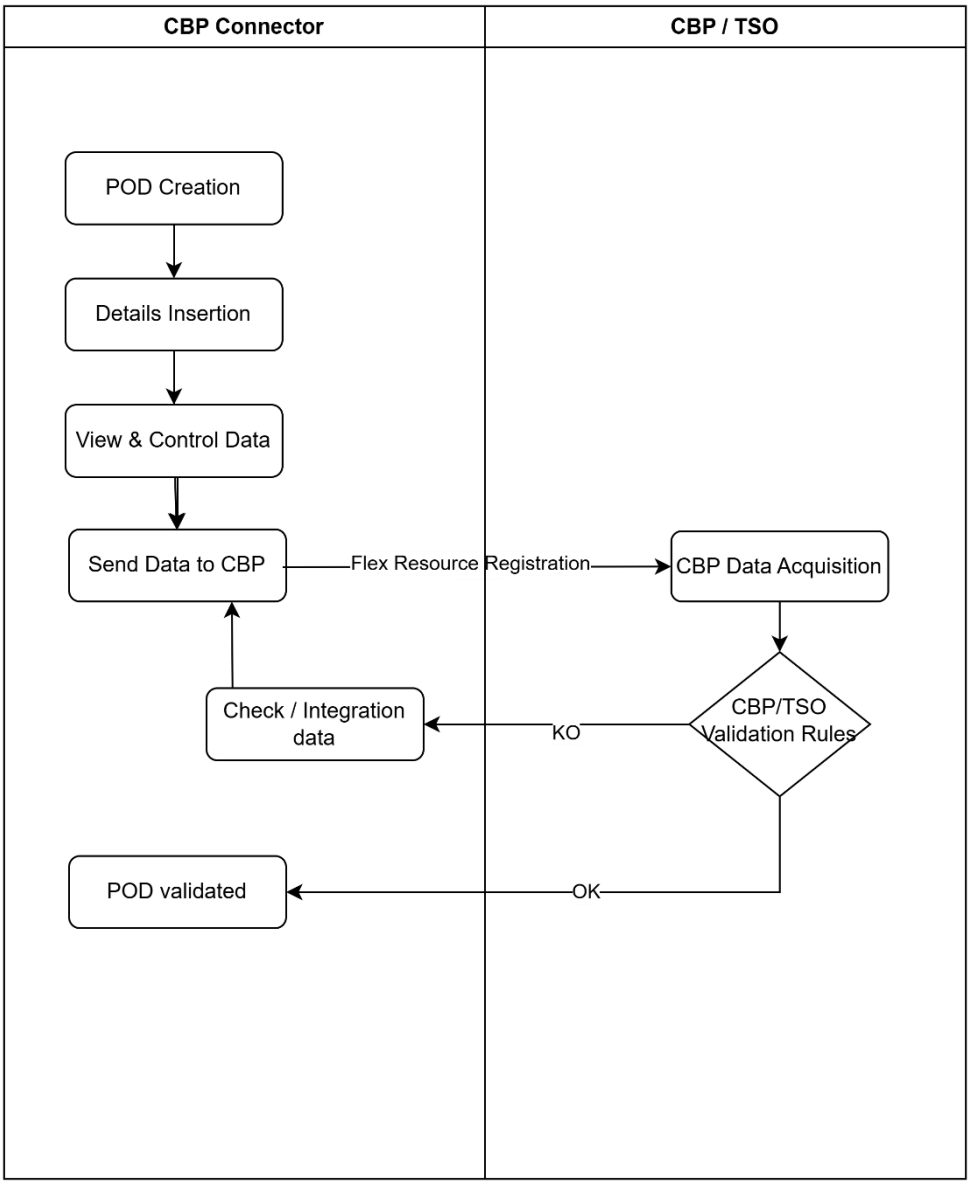

Figure 10. CBP Connector - POD Registration Use Case

3. The UVAM registration requirements include:
    - UVAM creation
    - POD selection for characterizing the aggregate resource
    - entering details of connection parameters relating to the UVAM
    - Sending data to the CBP
    - UVAM Validation

Figure 11 shows the use case diagram for the UVAM Registration process.

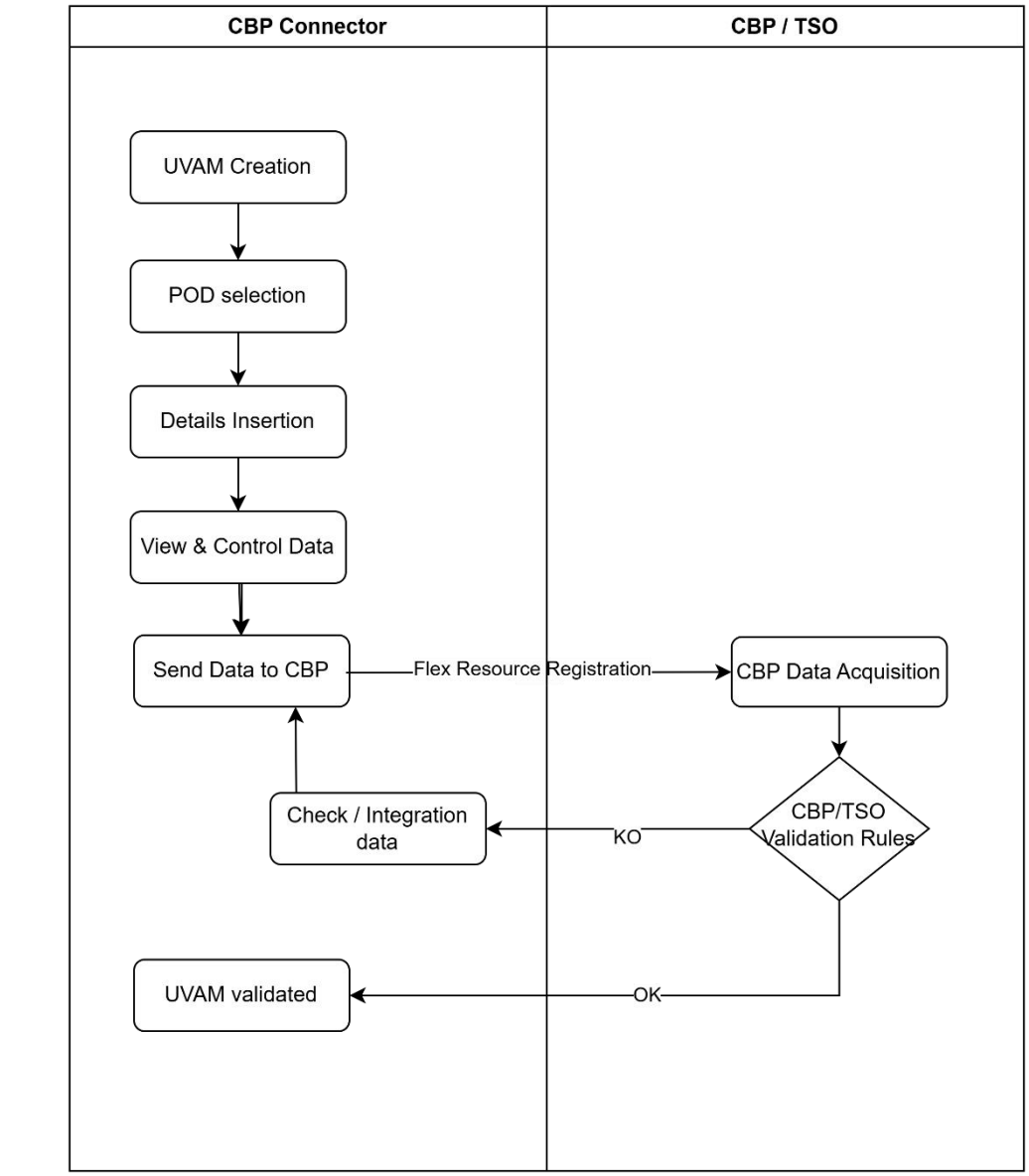

Figure 11. CBP Connector - UVAM Registration Use Case

Each expected use case will be managed by invoking API services exposed by the CBP as described in the following paragraphs. The CBP:

- performs data checks
- manages the dispatching of data flows with the stakeholders involved (TSO/DSO)
- validates the status of the resources in its registry
- updates the status of the BSP entities by invoking an ad hoc API service exposed by the CBP Connector.

All web services are executed in asynchronous communication mode to allow the processing of the different control and validation phases by the TSO/DSO systems connected to CBP.

The first release of the CBP connector provides the registration of single POD loading. In the next software release, a new feature will be provided to enable mass loading of PODs via upload from the GUI of a custom file, optimizing the user experience and integration by files.

4.2. Architecture

To implement CBP connectors to execute processes as per FSP requirements and specifications, a three-tier architecture was designed as shown in Figure 6:

1. **Graphical User Interface (GUI)** allows FSPs to initialize the process and load the necessary data according to the specifications required by CBP; this functionality can be designed for single or multiple loading.
2. **Service Layer** provides the business logic to process API requests and responses, enabling interaction between CBP and FSPs.
3. **Integration Layer** is dedicated to allows the seamless flow of data according to CBP standards of communication, providing asynchronous communication interfaces.
4. All data is saved in a dedicated DB according to access security and privacy control standards.

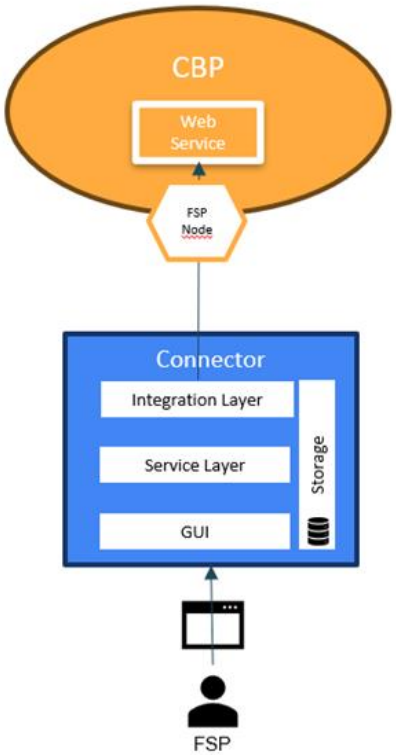

Figure 12. CBP Connector Architecture

4.3. Implementation, integration, and deployment

This section describes the details of the CBP Connector developed to handle FSP's resource registration using a web application integrated with Crowd Balancing Platform.

The CBP Connector has been designed to manage different potential processes of integration with CBP. In the context of the FLOW project, a connector has been implemented to perform the uploading of FSP resource master data on the CBP.

The connector's user interface is a web app that allows:

a. Guided data entry of the information needed to register the resource (POD / UVAM).

b. Consult recorded data from dashboard.

c. CBP interaction by calling web services with API according to the standards provided by the CBP.

The resource data registration process is structured by following functionalities:

- Registration of single POD and its flexible devices connected.
- Registration of resources aggregation, identified through the UVAM entity.
- Linking PODs and UVAM

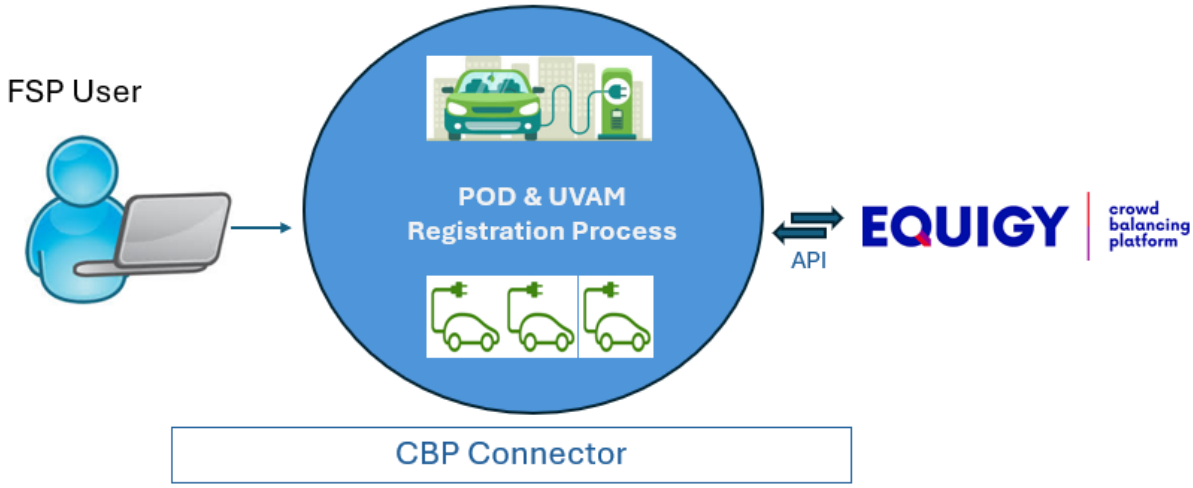

Figure 13. CBP Connector General Scheme

Each functionality mentioned above is realized by invoking different web services exposed by CBP to insert all the information needed to correctly save the technical information of the resources on the TSO/DSO platforms.

All web services are executed in asynchronous communication mode to allow the processing of the different control and validation phases by the TSO/DSO systems connected to the CBP.

The services managed by the connector to create a new Grid Connection Point (equivalent to a POD in this scenario) are summarized below:

API services for the registration of individual POD are summarized below:

- Register flex resource (Grid Connection Point): general data of the POD.
- Register flex resource (Flex Device): specific data of the production/consumption unit related to the POD.
- Create attachment: attachment required for the registration on the TSO platform
- Update resource status: task to update the resource status
- Update resource information: task to confirm the data registration

To optimize the process, the GUI guides the user in entering data, and once the checks relating to the mandatory information requested have been passed, receiving the results for each service invoked, the operator proceeds with the final request for validation of the resource always via the CBP connector.

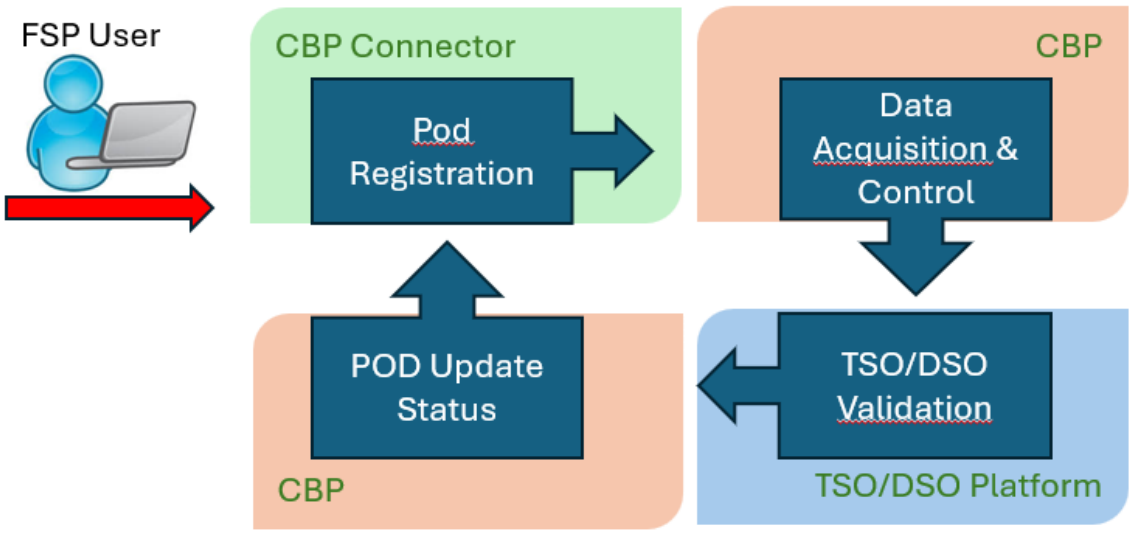

Figure 14. General Scheme of POD Registration Process

The UVAM registration functionality is separate from the POD registration functionality, being the process through which the BSP creates the virtual units of aggregated resources (UVAM): it can only occur after the POD registration has been validated by the TSO/DSO managers via the relevant platforms. To ensure alignment of POD status across platforms, the CBP connector exposes a service to the CBP to allow the POD workflow status to be updated following TSO/DSO resource validation, allowing for their selection during UVAM registration.

The logical process is similar at the *Registration POD*, here following the API services integrated by the CBP Connector:

- Register Resource Group: general Data of the UVAM
- Register Resource in Resource Group: selection of enabled PODs connected to the UVAM
- Create attachment: Attachment required for the registration on the TSO Platform

- Update Resource Group – UVAM update with IDattachment
- Register Connection – UVAM network connection parameters
- Update Status – task to update the resource status
- Update Resource Group – task to confirm the data registration details

At present, the connector has been developed as an on-premises application to be distributed in the FSP architecture.

4.3.1. API Services

Table 1 below resume the list of API services integrated with the CBP Connector, distinguished by functionality:

Table 1. API services.

Functionality	ID	SERVICE NAME	METHOD
POD Registration	1	Register Flex Resource	post
	2	Update Resource Information	patch
	3	Create Attachment	post
	4	Update Attachment	patch
	5	Update Resource Status	patch
UVAM Registration	6	Register Resource Group	post
	7	Update Resource Group	patch
	8	Register Resource in Resource Group	post
	9	Create Attachment	post
	10	Update Attachment	patch
	11	Register Connection	post
	12	Update Connection	patch
	13	Update Resource group Status	patch
	14	End Relation	patch

4.3.2. Languages, Technologies and External Tools

In Table 2, the languages, technologies and external tools used for the CBP connector are presented.

Table 2. Languages, Technologies and External Tools.

Layer/Component	Languages	Technologies/Framework	External Tools
GUI Layer	Javascript HTML5 CSS/SCSS	Docker Vue.js	Nginx

Service Layer	Javascript	Docker NodeJs ExpressJs	
Data Layer	Javascript	Docker NodeJs	MongoDB
Integration Layer	Javascript	Docker REST APIs NodeJs	Express Gateway

4.3.3. Data Models

The following section defines the interfaces of interest to the BSP, defined for the services in scope to the project and including the details of the relevant fields to be populated for each service of interest.

A) POD REGISTRATION

POD Registration – Register Flex Resource (Table 3)

Table 3. POD Registration – Register Flex Resource.

Field	Description	Data Type	Mandatory (yes/no)
registrationPeriod	Timestamp in unix version	Timestamp	Yes
receiverId	EIC Code of the service recipient	String	Yes
receiverCodingSchemeType	Call Recipient Type Code Schema	String	No
flexibilityServiceProviderId	BSP EIC Code	String	Yes
flexibilityServiceProviderCoding SchemeType	BSP Code Schema Type	String	No
accountingPointId	secondary POD	String	No
meteringPointId	POD	String	No
resourceType	resource Type	String	Yes
Status	POD status	String	No
locationId	Location ID	String	No
brpConsumptionCodingSchemeType	Dispatching Contract Schema Type	String	No
brpContractId	Dispatching Contract code	String	No
resourceName	resource name	String	No
resourceId	resource code	String	No
Direction	Type of POD	String	No
contractedPower	Contracted Power	Numeric	No

Field	Description	Data Type	Mandatory (yes/no)
contractedPowerSecondaryPOD	Contracted Power secondary POD	Numeric	No
maximumFlexUp	Maximum Flex Up	Numeric	No
maximumFlexDown	Maximum Flex Down	Numeric	No
gridVoltageLevel	Level of Voltage	String	No
distributionGridOperatorName	DSO EIC Code	String	No
parentResourceId	Id del POD del flex device	String	Yes
deviceType	Device Type	String	Yes
startDateTime	Start Date Time	Numeric	Yes
endDateTime	End Date Time	Numeric	No

POD Registration – Update Resource Information (Table 4)

Table 4. POD Registration – Update Resource Information.

Field	Description	Data Type	Mandatory (yes/no)
registrationPeriod	Timestamp in unix version	Timestamp	Yes
receiverId	EIC Code of the service recipient	String	Yes
receiverCodingSchemeType	Call Recipient Type Code Schema	String	Yes
technicalFlexibilityServiceProviderId	BSP EIC Code	String	Yes
flexibilityServiceProviderCoding SchemeType	BSP Code Schema Type	String	Yes
accountingPointId	secondary POD	String	Yes
meteringPointId	POD	String	Yes
resourceType	resource Type	String	Yes
Status	POD status	String	Yes
locationId	Location ID	String	Yes
period	period	String	Yes
startDateTime	Start Date Time	String	Yes
endDateTime	End Date Time	String	NO
brpConsumptionCodingSchemeType	Dispatching Contract Schema Type	String	Yes

Field	Description	Data Type	Mandatory (yes/no)
brpContractId	Dispatching Contract code	String	Yes
resourceName	resource name	String	Yes
resourceId	resource code	String	Yes
Direction	Type of POD	String	Yes
contractedPower	Contracted Power	Numeric	Yes
contractedPowerSecondaryPOD	Contracted Power secondary POD	Numeric	Yes
maximumFlexUp	Maximum Flex Up	Numeric	Yes
maximumFlexDown	Maximum Flex Down	Numeric	Yes
gridVoltageLevel	Level of Voltage	String	Yes
distributionGridOperatorName	DSO EIC Code	String	Yes
parentResourceId	Id del POD del flex device	String	Yes
deviceType	Device Type	String	Yes

POD Registration – Create Attachment (Table 5)

Table 5. POD Registration – Create Attachment.

Field	Description	Data Type	Mandatory (yes/no)
senderId	BSP EIC Code	String	Yes
senderCodingSchemeType	BSP Code Schema Type	String	Yes
receiverId	TSO EIC Code	String	Yes
receiverCodingSchemeType	TSO Code Schema Type	String	Yes
externalDocumentId	Type of document + extension	String	Yes
documentFile	Content in base64	String	Yes
Document Type	Document Type	String	Yes
mimeType	File extension	String	Yes

POD Registration – Update Attachment (Table 6)

Table 6. POD Registration – Update Attachment.

Field	Description	Data Type	Mandatory (yes/no)
receiverId	TSO EIC Code	String	Yes
externalDocumentId	Type of document + extension	String	Yes
documentFile	Content in base64	String	Yes
Document Type	Document Type	String	Yes
mimeType	File extension	String	Yes

POD Registration – Update Resource Status (Table 7)

Table 7. POD Registration – Update Resource Status.

Field	Description	Data Type	Mandatory (yes/no)
registrationPeriod	Timestamp in unix version	Timestamp	Yes
flexResourceId	POD ID	String	Yes
Status	POD status	String	Yes
FlexibilityServiceProviderId	BSP EIC Code	String	Yes
receiverId	TSO EIC Code	String	Yes

B) **UVAM REGISTRATION**

UVAM Registration - (Table 8)

Table 8. UVAM Registration - Register Resource Group.

Field	Description	Data Type	Mandatory (yes/no)
flexibilityServiceProviderId	BSP EIC Code	String	Yes
flexibilityServiceProviderCodingSchemeType	BSP Code Schema Type	String	Yes
technical FlexibilityServiceProviderId	SC Web Operator EIC Code	String	Yes
receiverId	EIC Code of the service recipient	String	Yes
receiverCodingSchemeType	Call Recipient Type Code Schema	String	Yes
Type	resource Type	String	Yes
name	resource name	String	Yes
Status	Aggregator status	String	Yes
perimeter	Location ID	String	Yes
maximumQualifiedPower	Maximum Flex Up	Numeric	Yes

Field	Description	Data Type	Mandatory (yes/no)
minimumQualifiedPower	Maximum Flex Down	Numeric	Yes
marketType	Market Type	String	Yes
period	period	String	Yes
startDateTime	Start Date Time	Numeric	Yes
endDateTime	End Date Time	Numeric	No

UVAM Registration - Update Resource Group (Table 9)

Table 9. UVAM Registration - Update Resource Group.

Field	Description	Data Type	Mandatory (yes/no)
flexibilityServiceProviderCoding SchemeType	BSP Code Schema Type	String	Yes
technical FlexibilityServiceProviderId	SC Web Operator EIC Code	String	Yes
receiverCodingSchemeType	Call Recipient Type Code Schema	String	Yes
technicalFlexibilityServiceProviderCodingSchemeType		String	Yes
name	resource name	String	Yes
Type	Resource Type	String	Yes
perimeter	Location ID	String	Yes
maximumQualifiedPower	Maximum Flex Up	Numeric	Yes
minimumQualifiedPower	Maximum Flex Down	Numeric	Yes
name		String	Yes
documentFile	document type	String	Yes
documentField	Id document to attach	String	Yes
receiverId	TSO EIC Code	String	Yes
flexibilityServiceProviderId	BSP EIC Code	String	Yes
marketType	Market Type	String	Yes
period	period	String	Yes
startDateTime	Start Date Time	Numeric	Yes
endDateTime	End Date Time	Numeric	No

UVAM Registration - Register Resource in Resource Group (Table 10)

Table 10. UVAM Registration - Register Resource in Resource Group.

Field	Description	Data Type	Mandatory (yes/no)
flexibilityServiceProviderId	BSP EIC Code	String	Yes
flexibilityServiceProviderCodingSchemeType	BSP Code Schema Type	String	Yes
receiverId	TSO EIC Code	String	Yes
receiverCodingSchemeType	Call Recipient Type Code Schema	String	Yes
resource	POD ID	String	Yes
resourceGroup	Aggregator ID	String	Yes

UVAM Registration - Create Attachment (Table 11)

Table 11. UVAM Registration - Create Attachment.

Field	Description	Data Type	Mandatory (yes/no)
senderId	BSP EIC Code	String	Yes
senderCodingSchemeType	BSP Code Schema Type	String	Yes
receiverId	TSO EIC Code	String	Yes
receiverCodingSchemeType	TSO Code Schema Type	String	Yes
externalDocumentId	Type of document + extension	String	Yes
documentFile	Content in base64	String	Yes
Document Type	Document Type	String	Yes
mimeType	File extension	String	Yes

UVAM Registration - Update Attachment (Table 12)

Table 12. UVAM Registration - Update Attachment.

Field	Description	Data Type	Mandatory (yes/no)
receiverId	TSO EIC Code	String	Yes
externalDocumentId	Type of document + extension	String	Yes
documentFile	Content in base64	String	Yes
Document Type	Document Type	String	Yes

Field	Description	Data Type	Mandatory (yes/no)
mimeType	File extension	String	Yes

UVAM Registration - Register Connection (Table 13)

Table 13. UVAM Registration - Register Connection.

Field	Description	Data Type	Mandatory (yes/no)
flexibilityServiceProviderId	BSP EIC Code	String	Yes
receiverId	TSO EIC Code	String	Yes
externalDocumentId	Type of document + extension	String	Yes
receiverCodingSchemeType	TSO Code Schema Type	String	Yes
ResourceGroupID	Resource Group ID	String	Yes
type	Type of document	String	Yes
manufacturer	“ABB”	String	Yes
ipAddress	Ip Address	String	Yes
fullScaleMin	Connection parameters	Numeric	Yes
fullScaleMax	Connection parameters	Numeric	Yes
documentFile	Content in base64	String	No

UVAM Registration - Update Connection (Table 14)

Table 14. UVAM Registration - Update Connection.

Field	Description	Data Type	Mandatory (yes/no)
flexibilityServiceProviderId	BSP EIC Code	String	Yes
receiverId	TSO EIC Code	String	Yes
externalDocumentId	Type of document + extension	String	Yes
receiverCodingSchemeType	TSO Code Schema Type	String	Yes
ResourceGroupID	Resource Group ID	String	Yes
type	Type of document	String	Yes

Field	Description	Data Type	Mandatory (yes/no)
manufacturer	"ABB"	String	Yes
ipAddress	Ip Address	String	Yes
fullScaleMin	Connection parameters	Numeric	Yes
fullScaleMax	Connection parameters	Numeric	Yes
documentFile	Content in base64	String	No

UVAM Registration - Update resource group Status (Table 15)

Table 15. UVAM Registration - Update resource group Status.

Field	Description	Data Type	Mandatory (yes/not)
ResourceGroupID	Resource Group ID	String	Yes
Status	Status of the aggragator	String	Yes
flexibilityServiceProviderId	BSP EIC Code	String	Yes

UVAM Registration - End relation (Table 16)

Table 16. UVAM Registration - End relation.

Field	Description	Data Type	Mandatory (yes/not)
id	unique id of the relationship between POD and UVAM returned by the nodeToLeaf invocation	String	Yes
receiverId	TSO EIC Code	String	Yes

4.3.4. CBP Connector Overview

This paragraph illustrates some of the main features developed on the CBP connector for the POD and UVAM registration processes.

Login page

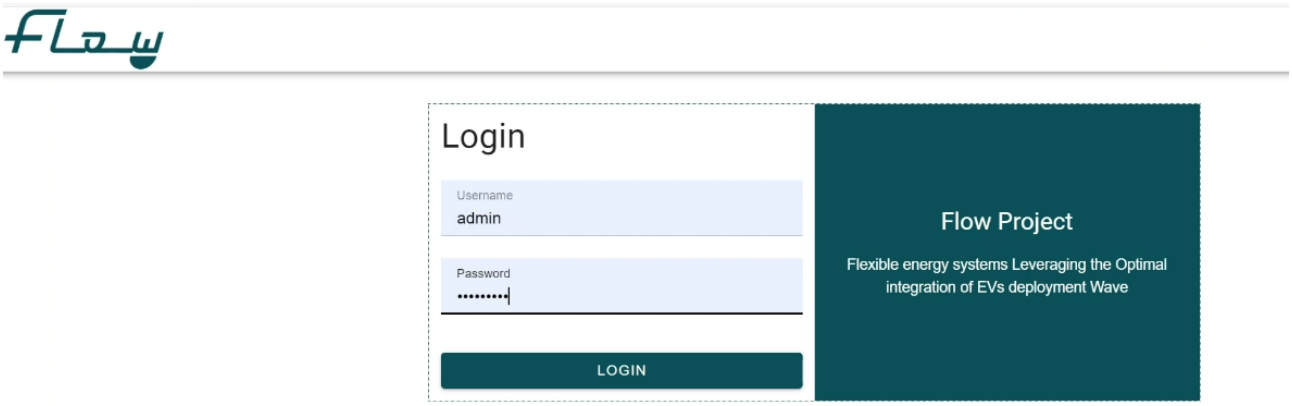

Figure 15. CBP Connector - Login

The authenticated user can choose the features available in the menu on the left side:

- Home
- Resources: create, read and update POD
- Resource Group: create, read and update UVAM

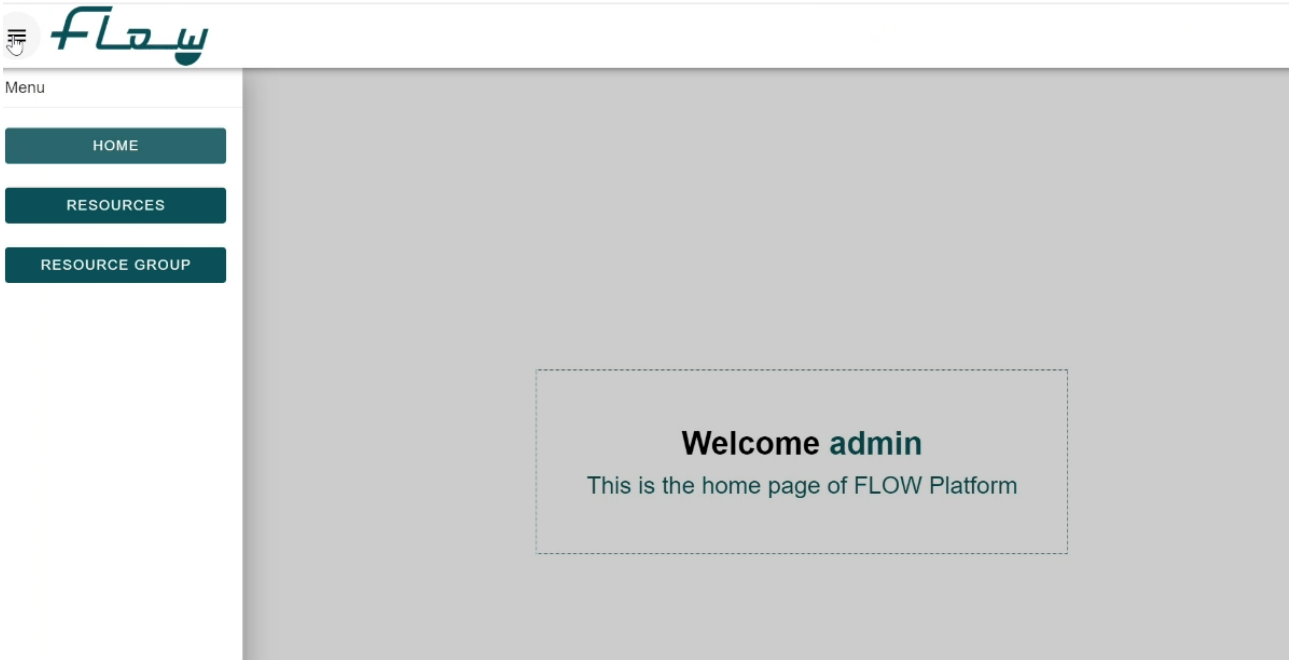

Figure 16. CBP Connector - Home Page

POD Registration Process

By clicking the "*create new POD*" button the user starts the process to register a new POD; once inserted data and saved, the POD is available on a list with their status, and it's possible to proceed with the other services using the reference buttons (see Figure 15):

- associate Flex Device to the POD
- view Flex Device associated with the POD
- create an attachment
- View attachments
- update POD status
- end process, waiting for validation

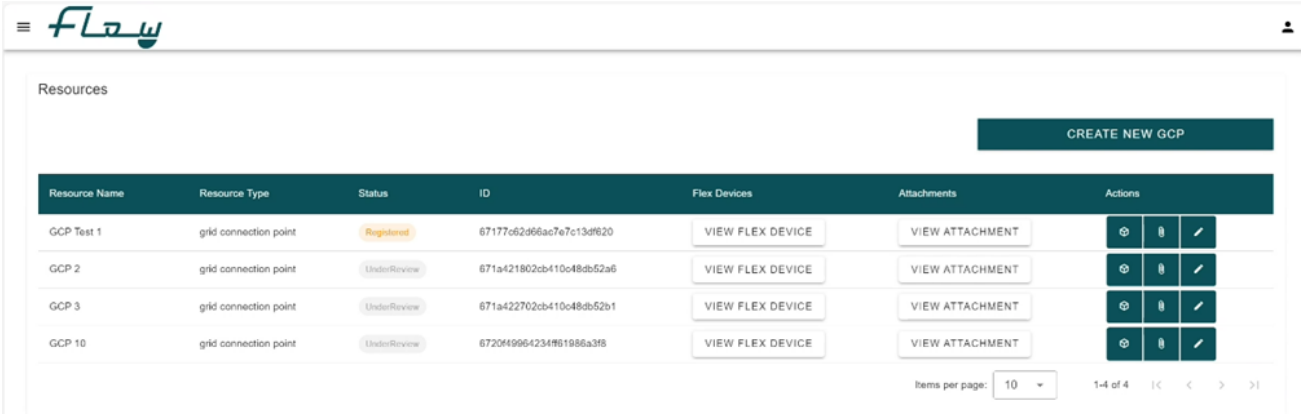

Figure 17. CBP Connector - Resources Dashboard

Here below Figure 16 shows an example of the information needed in the registration POD section

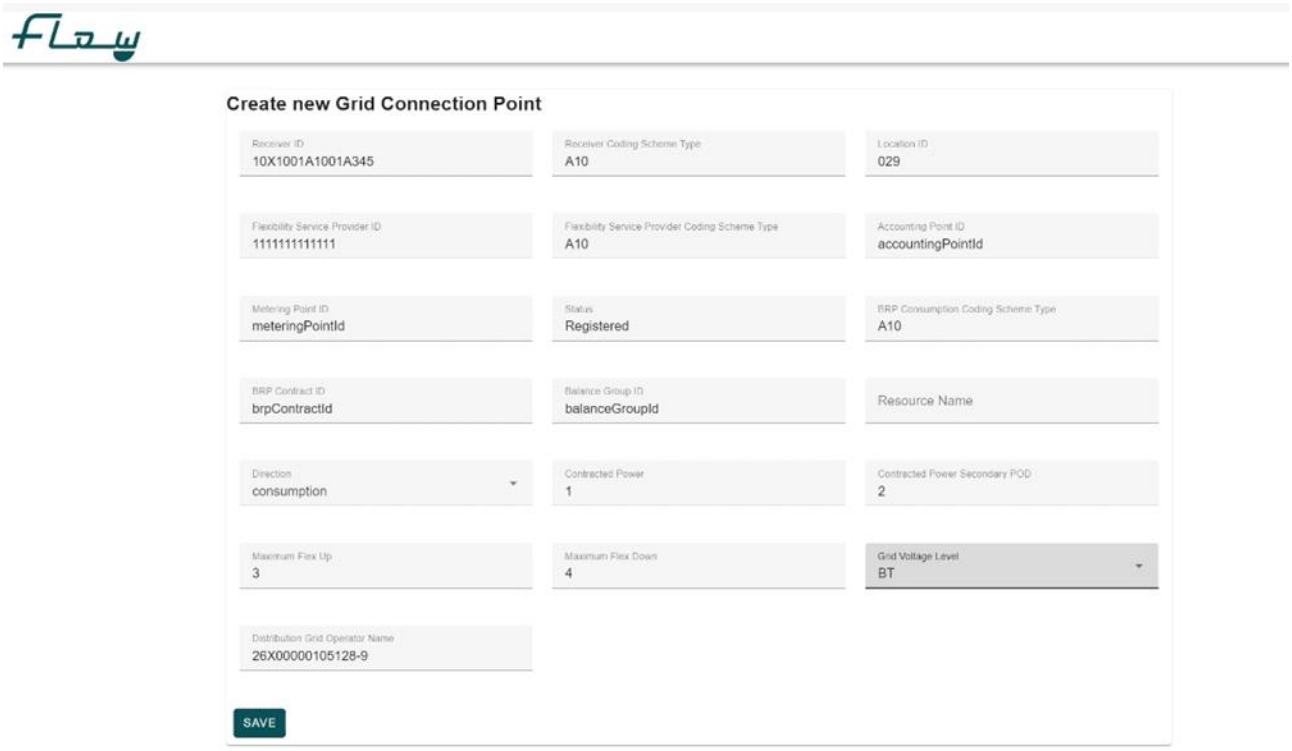

Figure 18. CBP Connector - Registration POD Module

Following an example of registration of a Flex Device and its view associated to the POD (Figures 17 and 18):

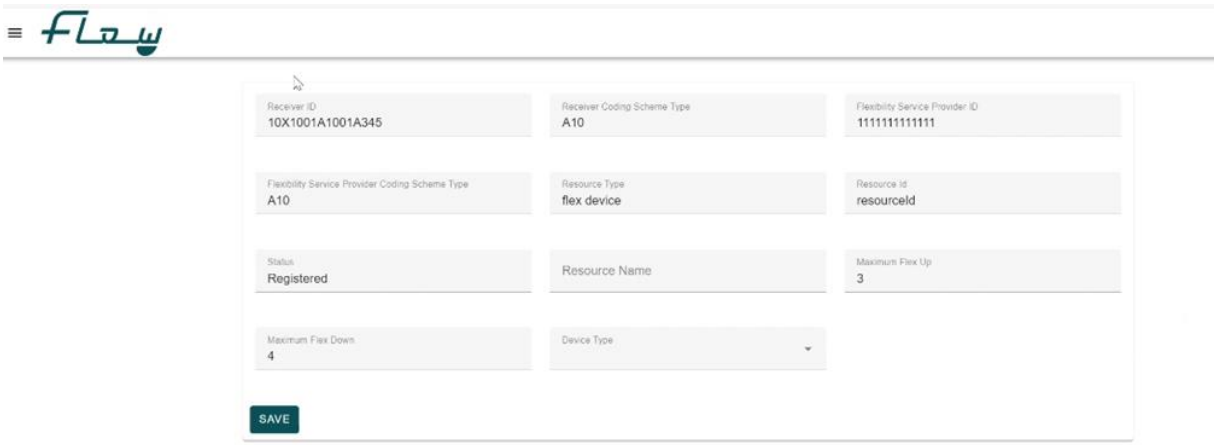

Figure 19. Flex Device Creation

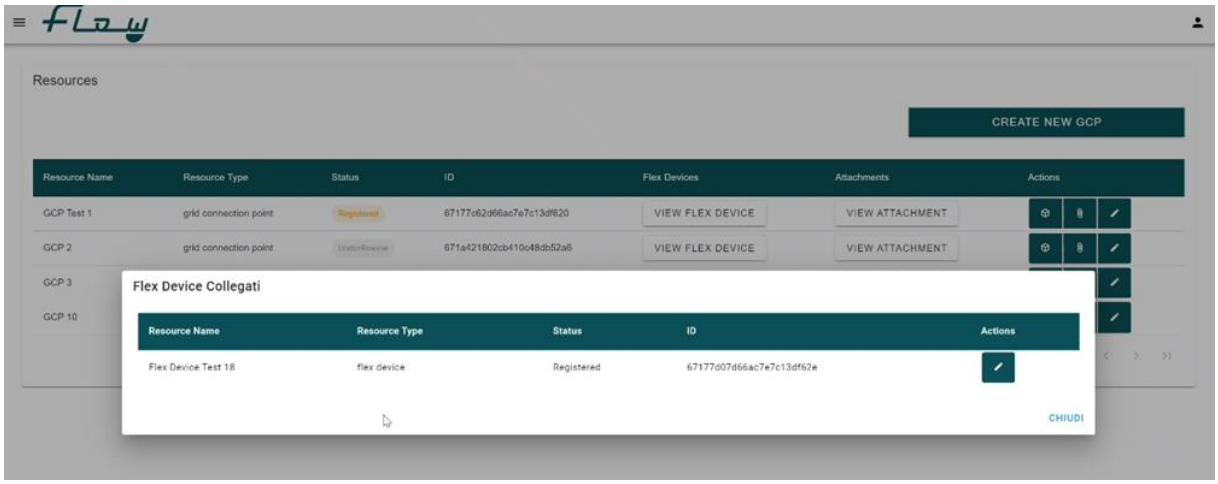

Figure 20. CBP Connector: Flex Device associated to the POD

For each POD on the list, it is possible to add a new attachment and view all the documents already linked to the resource. Figure ... presents detailed examples.

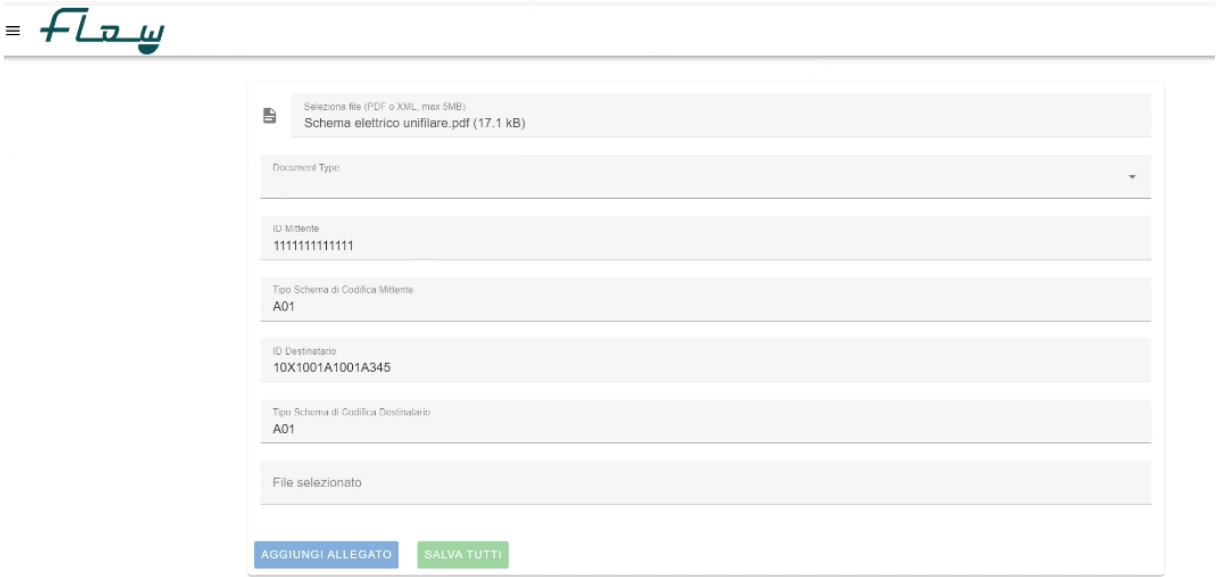

Figure 21. CBP Connector: Create Attachment

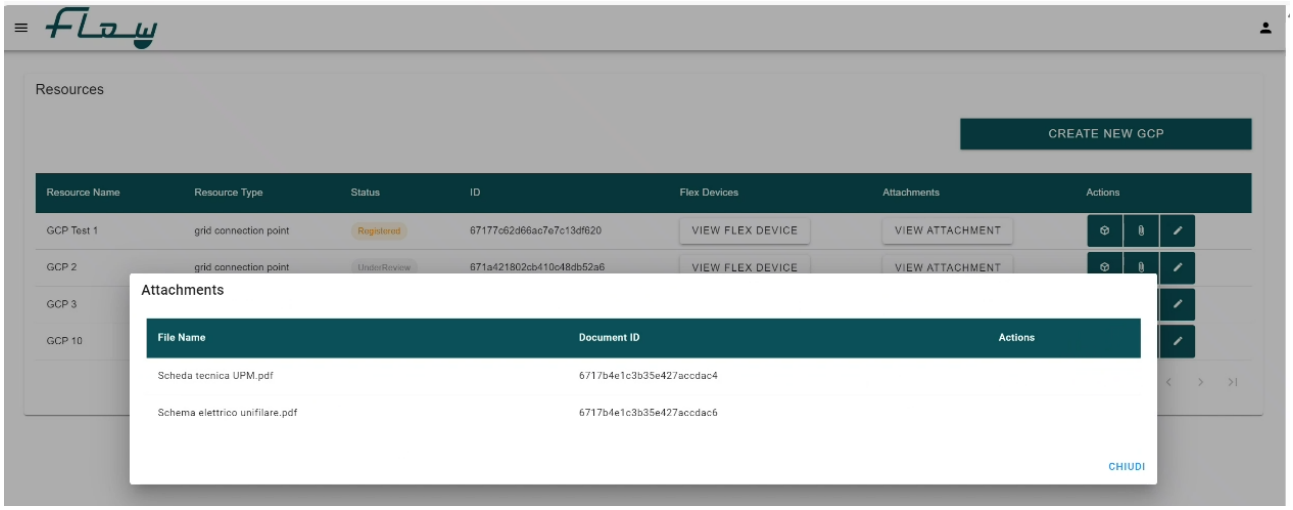

Figure 22. CBP Connector: List of attachment for single POD

UVAM Registration Process

The registration of aggregated resources is available from the main menu.

With an equivalent process logic of the POD registration, the registration of an aggregated resource involves several asynchronous API calls with the CBP to be able to insert UVAM details, attachments, create the Aggregate-PODs link and finally update the status.

By clicking on the “Create New UVAM” button, the user starts the procedure to register a new UVAM; once the data has been entered and saved, the UVAM is available and it is possible to associate the PODs and the other mandatory entities, concluding with the sending of a UVAM validation request to CBP. Features available for each UVAM are:

- View UVAM parameters, POD association, attachments
- Selection PODs for association to the UVAM
- Create attachments
- Create register connection

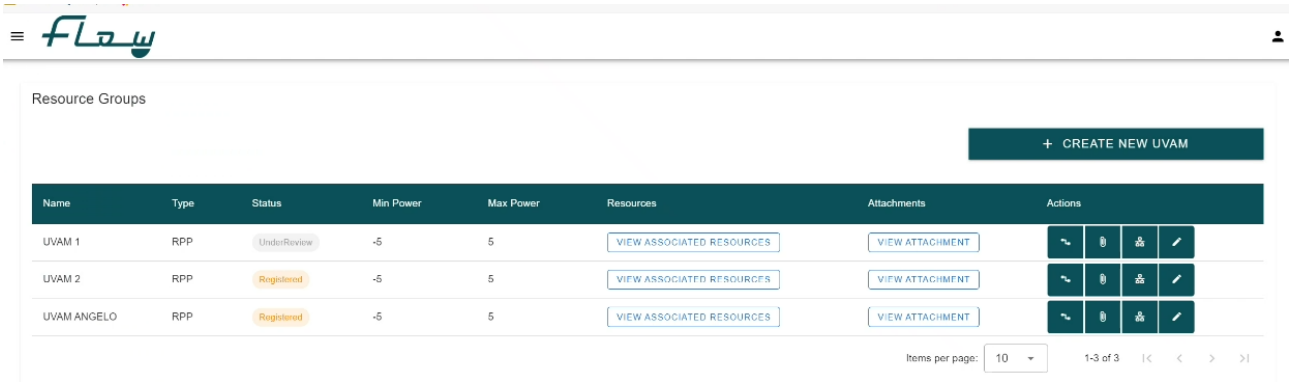

Figure 23. CBP Connector: UVAM Dashboard

In Figure 24 an example of UVAM data registration page is shown.

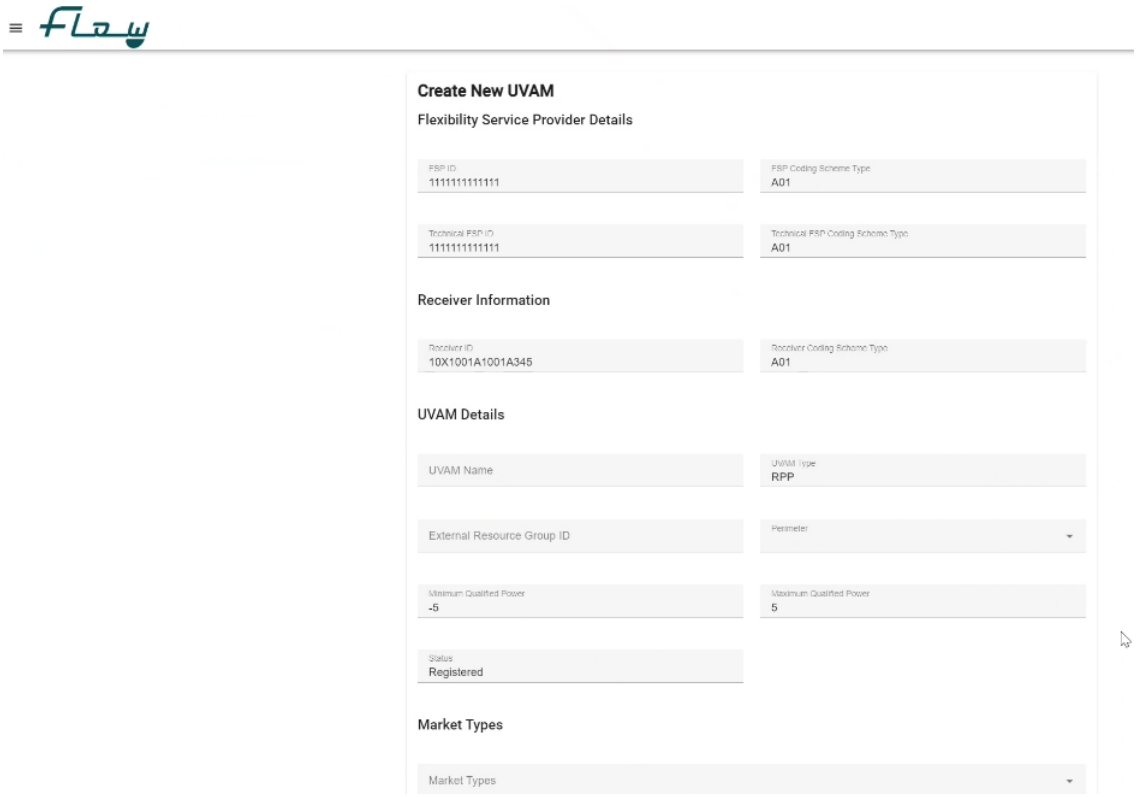

Figure 24. CBP Connector: UVAM Registration

Figure 23 shows an example to select enabled PODs and associate them to the UVAM

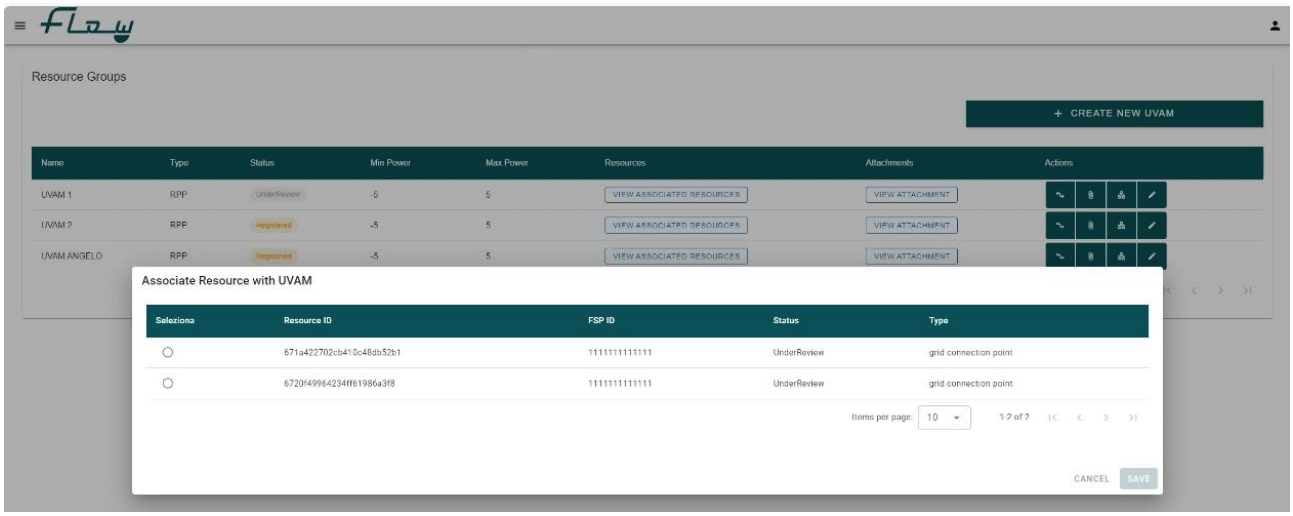

Figure 25. CBP Connector - PODs selection

The UVAM network connection parameters are realized by the service of register connection, as shown in Figure 24.

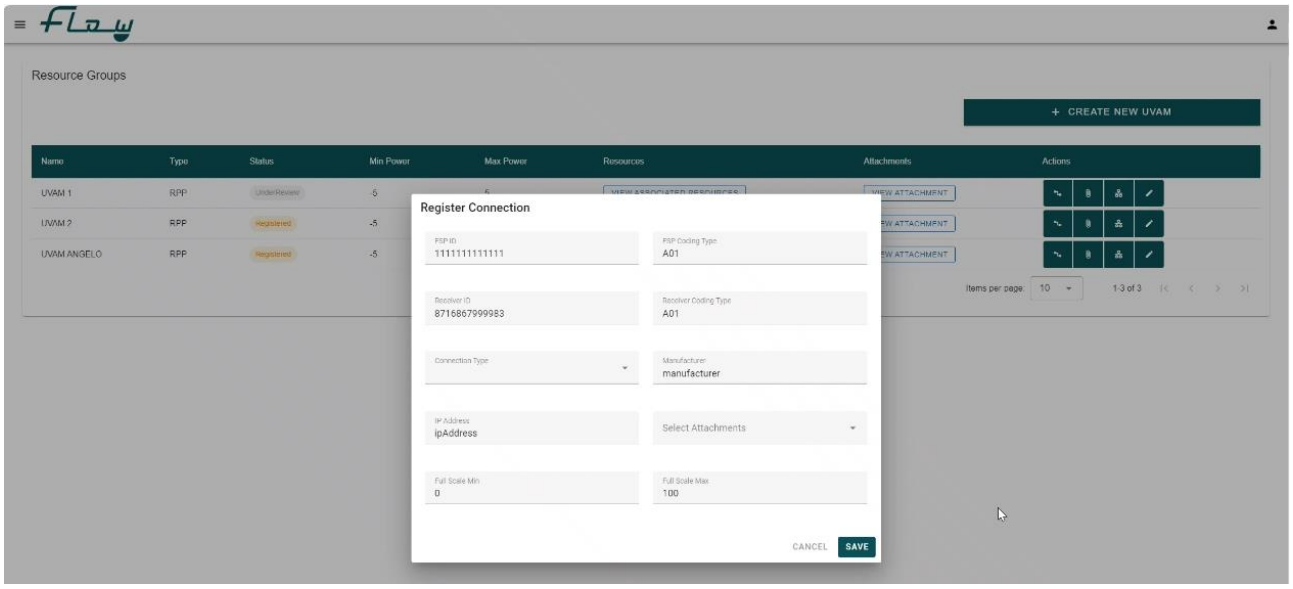

Figure 26. CBP Connector: Register Connection

A potential optimization of the registration processes is currently being designed, which includes the adaptation of the logic for the mass loading of data into the CBP connector through the use of custom tracks, facilitating the automation with the FSP systems that manage the resources.

5. Additional services and platforms for VGI enhancement

5.1. SOGNO platform and advanced services

SOGNO is the Service-based Open-source Grid Automation Platform for Network Operation, which is revolutionizing grid automation in electricity distribution. Its innovative, flexible design positions SOGNO as a key technology for the future of power grids by integrating open-source, microservice-based solutions. The platform's modular structure allows for flexible expansion of its automation architecture, supporting the seamless addition of components over time. Figure 27 provides an overview of the SOGNO architecture.

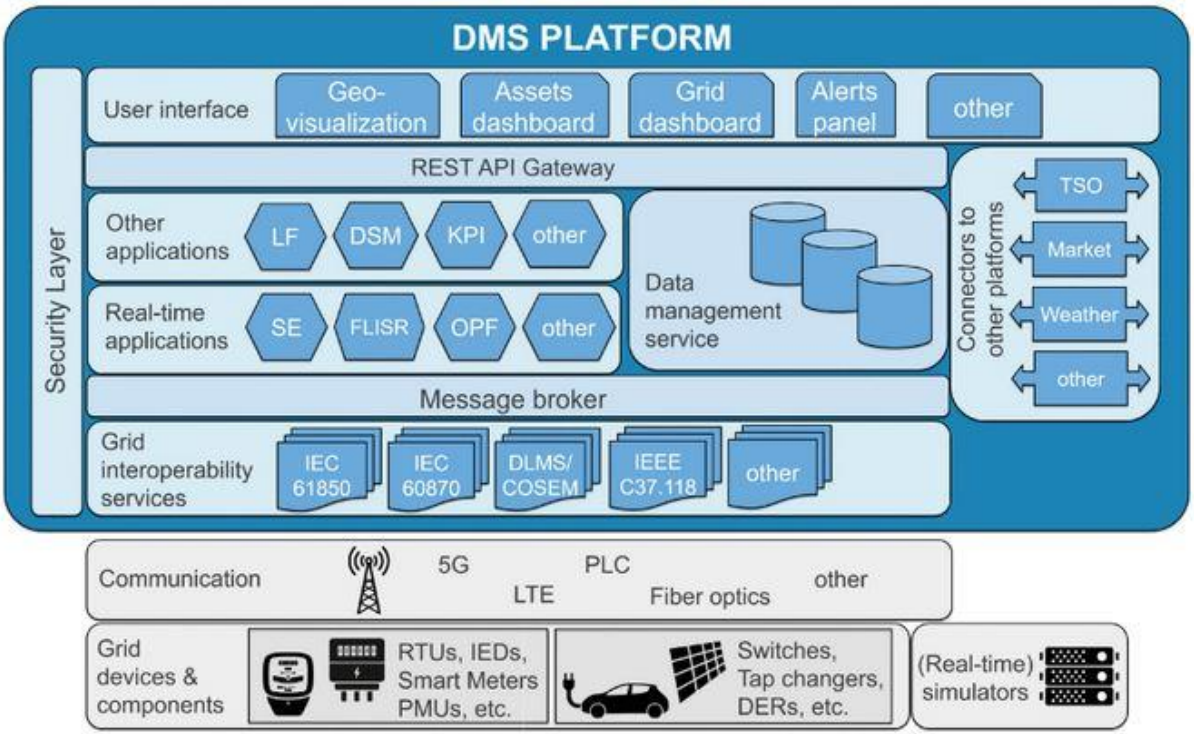

Figure 27. SOGNO architecture [13]

At the core of SOGNO's innovation are microservices, utilizing the architectural style that structures applications into small, independent services. These microservices enable autonomous operation through containerized, automated tasks, offering users the flexibility to select and configure services according to their specific requirements. The initial suite of services, including state estimation, load forecasting, and voltage management, is designed for seamless integration into Kubernetes environments, ensuring rapid deployment and scalability.

Communication within SOGNO is coordinated through MQTT (Message Queuing Telemetry Transport) or a comparable message broker. This choice of protocol enhances system scalability and responsiveness, as it facilitates efficient asynchronous communication between microservices. These services are accessed and managed through well-defined APIs (Application Programming Interfaces), enabling smooth interoperability and fostering a modular system architecture. The API-driven framework not only supports independent development and deployment of specific functionalities but also strengthens the system's agility, scalability, and maintainability. By leveraging these APIs, users can integrate and customize services, thereby increasing the adaptability and extensibility of the overall SOGNO platform.

As an open-source solution that provides APIs for the straightforward integration of new automation capabilities, while adhering to industry standards such as CIM IEC61970, SOGNO is ideally suited to meet the needs of a dynamic and flexible grid automation ecosystem. Its architecture enables more adaptive, efficient, and robust grid operations, positioning it as a critical enabler of future advancements in power distribution automation.

EVrich is a cloud-based service prototype integrated within the SOGNO platform, specifically developed to address the challenge of determining optimal charging locations within distribution grids, that feature multiple charging point operators (CPOs)[1]. This service offers an API through which electric vehicle (EV) drivers can input their charging preferences, including desired search area, target state of charge (SOC), and parking duration. In response, EVrich identifies available charging locations within the specified region, aggregated offers from CPOs and guides the EV driver to the most suitable option based on real-time conditions.

The service improves grid flexibility by smartly directing EVs to the best charging locations based on forecasted energy availability and grid load, utilizing the data, which could be provided by the Distribution System Operator (DSO). As illustrated in Figure 28, it starts by gathering user preferences, including the current location and SOC, estimated departure time, target SOC, and the preferred search radius for charging stations. In addition, the user shares with the service the V2G usage authorisation of his vehicle and how much energy this authorisation is limited to within the sojourn period.

EVrich then looks for available chargers within the defined area and checks the DSO's load data at each grid bus and/or LV/MV transformer to evaluate the effect of adding additional loads at each charging point. After gathering the data, the system runs an optimization algorithm that considers both grid capacity and user preferences. Currently, the optimization strategy employed by EVrich prioritizes minimizing charging costs for drivers. These costs are dynamically calculated with the smart bidding algorithm, in which the charging prices of charging points are being penalized in case of high load forecasts, introduced in [14]. This ensures the identification of the ideal charger based on factors like current grid congestion, real-time energy prices, and charger availability. The user is then provided with the best charging option, ensuring a tailored, budget-friendly, and efficient charging experience.

The service also utilizes a smart charging scheduler that adjusts the charging times. This scheduler optimizes the process by considering dynamic energy prices, grid demand, and excess energy production, ensuring that charging happens at the most economical times without straining the grid.

[1] GitHub link: https://github.com/sogno-platform/evrich

Furthermore, by incorporating Vehicle-to-Grid (V2G) technology, the system allows EVs to return energy to the grid when needed, acting as mobile energy storage units and generating revenue. This approach enhances grid sustainability and operational efficiency while reducing charging costs. By aligning with both user preferences and external factors, the service provides a personalized and smooth charging experience. This not only enhances user convenience but also contributes to grid stability and operational effectiveness, promoting a balanced and resilient energy network.

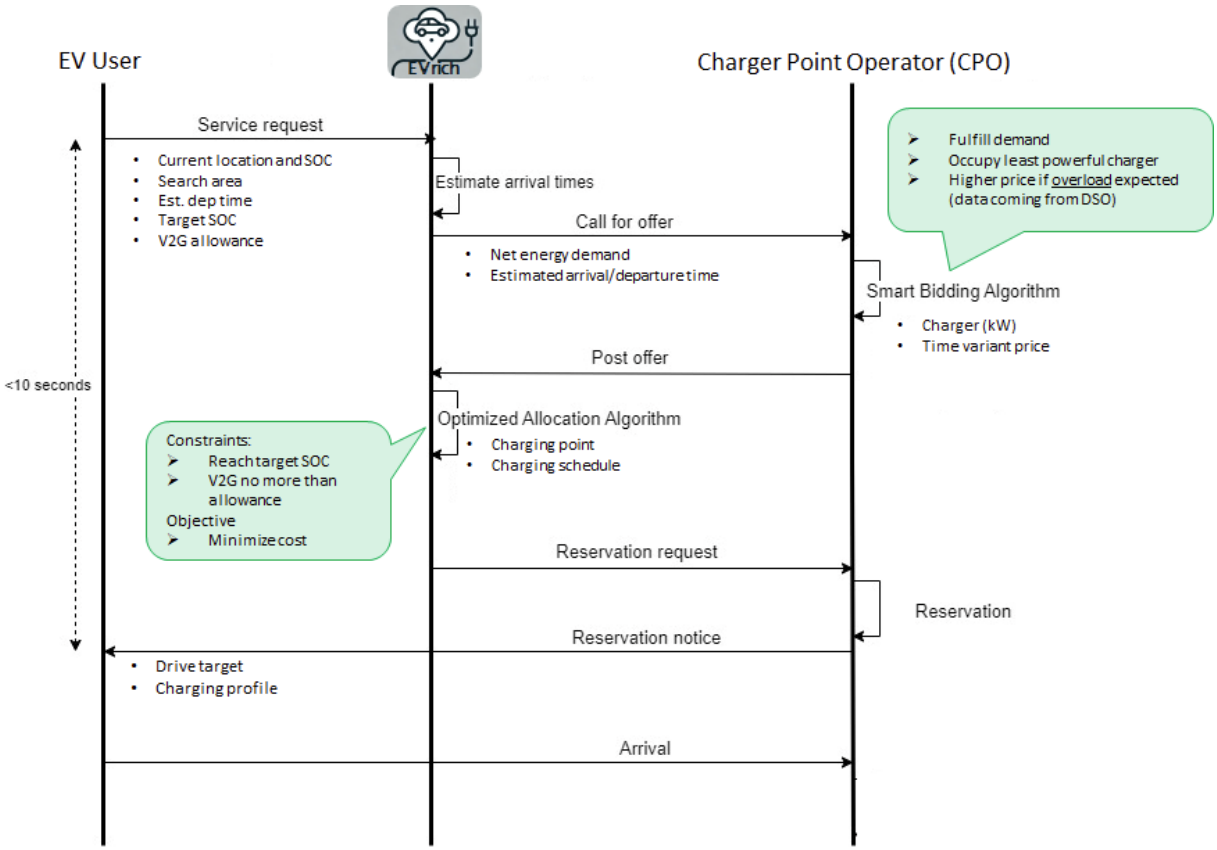

Figure 28. Operational mode of EVrich

Even though there is an optimization strategy employed by EVrich, its modular architecture allows for the seamless integration of alternative optimization strategies, providing flexibility to accommodate future advancements or user-specific preferences. This flexible structure of the service provides a good testing and analysis infrastructure for electromobility stakeholders.

Currently, the service's endpoints function as digital representations of real-world entities. However, the primary focus of future development is to transition these digital models into practical, real-life applications.

5.2. Pilot applications scenarios

5.2.1. Scenario

The energy transition policies request a huge decarbonisation of the urban contexts, to improve the air quality. Electric Vehicles (EVs) are a cornerstone of the strategy. In Rome, a great increase of the EVs will have to be coherent with the national energy scenario. To accommodate these assets new solutions, have to be found. The garages lacking in the centre and in historical neighbourhoods push the public charging requests in a specific point of the town.

The charging point concentration can cause grid issues, if the EVs feed the battery simultaneously. In detail, the public EVSEs connected to low voltage (LV) networks tend to be concentrated per transformer or BT line and typically overload the grid equipment due to the high nominal power ratings. Each charging infrastructure generally has two charging sockets, which may be of different or similar types, allowing for a maximum of two vehicles to be charged simultaneously. Regardless, the simultaneity coefficient of the sockets is often high, as even with low electric vehicle (EV) penetration, the likelihood of vehicles charging—either one or two at a time—is considerably high.

As a result, the probability of these infrastructures causing feeder overloads is significant. Due to the scattered distribution of charging points within the network, only a few feeders from each secondary substation are responsible for supplying an EVSE. Consequently, the transformer linked to these feeders has a lower simultaneity factor during peak charging times, reducing the likelihood of transformer overloads. In many cases, a transformer may only supply power to a single EVSE, which further minimizes the impact compared to the strain placed on LV lines.

5.2.2. Pilot system architecture

The Areti Distribution Management System (DMS) is already integrated with SOGNO Open Source Platform grid services. In task 5.5 ARETI will leverage the new service of the Sogno Platform EvRich for the EV grid management services. EvRich empowers EV users in finding the most optimal charging station for electric vehicles, considering factors like charging station locations, battery capacity, grid congestion and energy usage, to further limit the impact on low-voltage networks. Data is collected from several sources, such as line starts, substations, and SMUs along the lines; these readings are then fed to both forecast algorithms and the EvRich routing component, allowing the system to select the best CP given a holistic set of conditions.

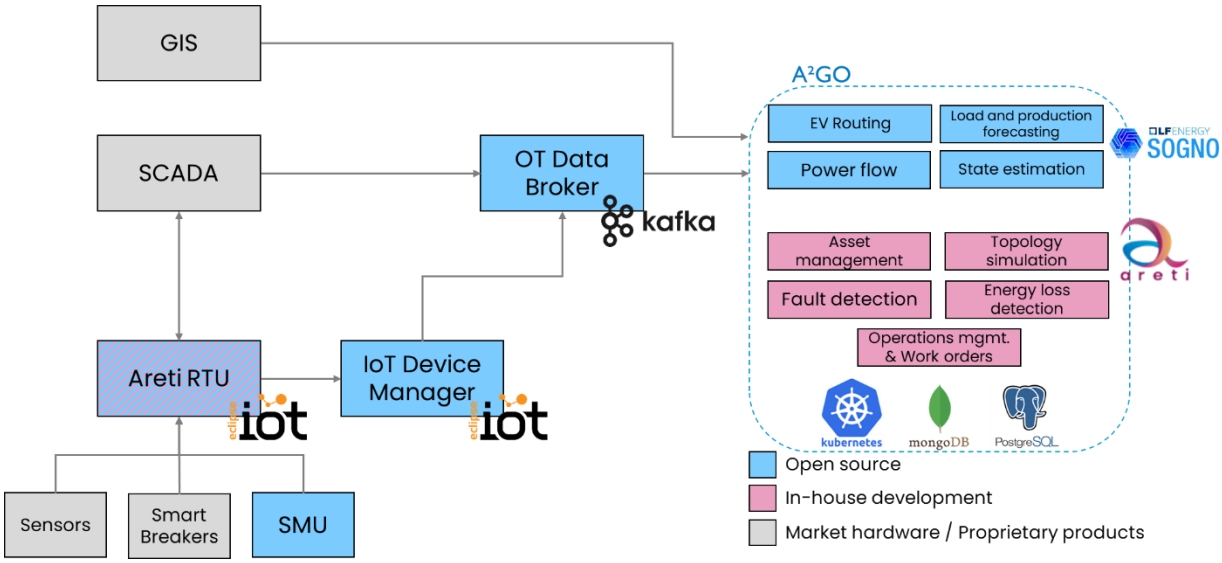

Figure 29. SOGNO Integration Architecture

5.2.3. Definition of the portion of the grid

ARETI will test the EvRich service within the context of the city of Rome. The scope of the experimentation will be the identification of a simulated portion of the grid in a residential area, to test the EvRich service for the reduction of loads derived from the EV charging stations on the LV grid. The test will evaluate the current consumption of charging stations and the consumption with the integration of the service.

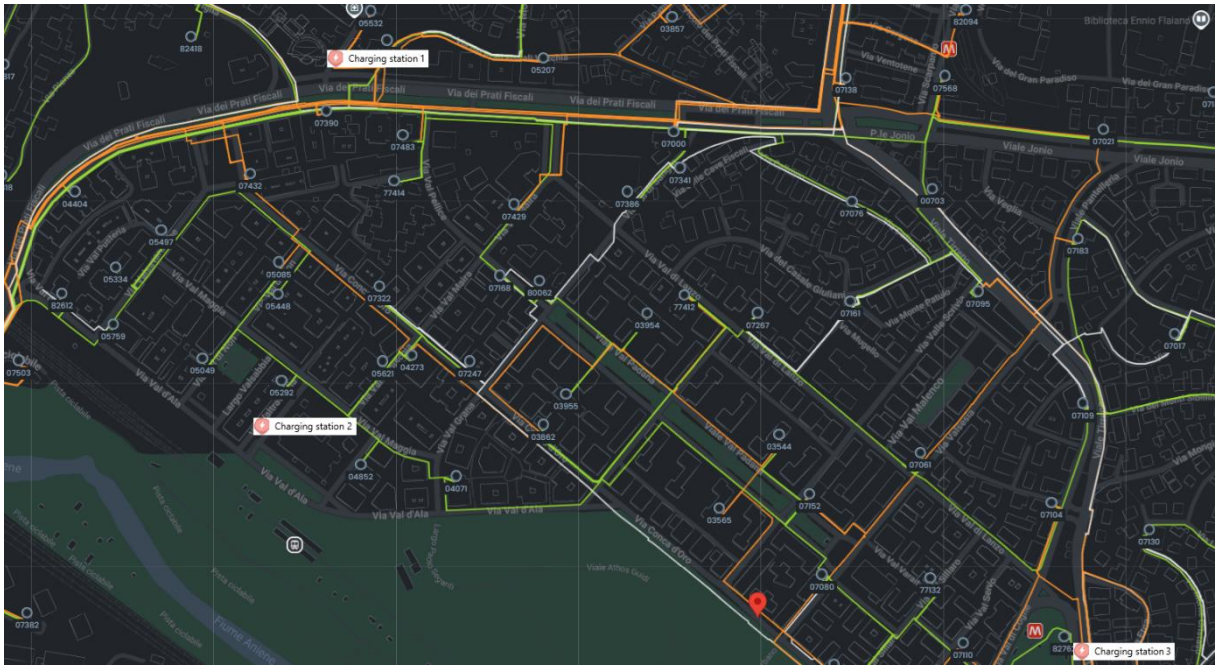

Figure 30. LV EVs charger Residential area in Rome

5.2.4. Data

This set of data will allow ARETIto integrate the EvRich service of the SOGNO Platform. By analysing these factors, Areti can prevent equipment overloads while allowing the maximum number of public charging stations to operate within the area grid's constraints.

Grid historical data comes from Areti's experience:

- Grid constraints for the CPO.
- Historical load data for each LV/MV transformer (e.g., daily, weekly, monthly) in kW/MW.
- Peak load times (historical maximum load periods).
- Load variations by time of day, season, or events.

Charging station data from CPO comes from open data or literature:

- Historical charging patterns of users (average session duration, power demand by time of day).
- Usual charging tariffs.
- Location and distribution of EV chargers.

EV data comes from the RWTH elaboration.

With the help of Datafev from Python, it's possible to build new scenarios based on EVs historical data

- EVs arrival and departure at the SoC.
- EV arrival and departure charging times.
- EV Model.

As such, the pilot will be tested by applying an emulated EV fleet to a portion of the grid updated with a real-life representation of its usage. EvRich output will then be compared to grid's actual usage to validate its suggestions.

5.2.5. Goals and benefits

EvRich enables a smart and efficient EV charging experience, improving on one side the user experiences, ensuring fast, reliable charging and allowing for pricing benefits during off-peak hours. On the other side, also the grids benefit from the service by distributing the charging load intelligently across the grid to avoid peaks in energy demand and prevent overloading of transformers or feeders. The service is scalable and can be adapted to the increasing numbers of EVs and the expansion of charging infrastructure. As EV adoption grows, EvRich ensures that the grid can handle the demand without compromising efficiency or reliability.

6. Conclusions

The work done at this stage allowed to identify technologies, architectures and scenarios for implementing a data-driven ecosystem for the electromobility sector.

In particular, the document goes into detail on how to technically enable VGI at the system level, analyzing requirements, technical specifications, technologies and developments that characterize the main scenario of the Italian demo. It proposes a reference model to enable the integration of single and aggregated EV resources provided by BSP with the CBP for the global TSO flexibility market to technically validate the flexibility that EV aggregates can actually provide to the grid.

In this context, the CBP Connector has been developed to propose new features for the exchange of data, signals, and services between the CBP and the EV market stakeholders to technically enable VGI at the system level. More in detail, the CBP Connector used by the BSP allows, in a CBP sandbox environment, the registration of EV resources on the TSO/DSO platform, including the features of Grid Connection Point, Flex Device and Resource Aggregator (UVAM).

A second high-level scenario is described based on new services offered by the SOGNO framework integrated with the DSO technical platform to accomplish FLOW requirements discussing the main scope, benefits, and goals that will be run in the Italian demo of the project.

The outcome of this task will be validated and tested in a dedicated scenario of the Italian Demo, Additional use cases and scenarios can be evaluated in a later stage.

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