edgeFLEX

D4.2

Description of edgeFLEX MVP

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Abstract

The goal of the edgeFLEX project is to advance the role of the VPP with the use of advanced grid management techniques, effective optimisation, flexibility provisioning and trading combined with enabling solutions such as Service Level Agreement Monitoring tools, edgePMU devices and 5G capabilities. This report details how these techniques, tools, services and technologies can be delivered to the customer as a Minimum Viable Product so that it can be assessed and refactored and also, used as a tool to gain knowledge relevant to the customer's needs with respect to the tools and services from the edgeFLEX Platform. It also describes the MVP in the context of the customer, the trials and outlines the role of the MVP and its components to the advancement of the VPP.

Keyword list

Minimum Viable Product, Agile, Assessment, Customers, Virtual Power Plant, Optimisation, Flexibility Provisioning, Control, enhanced measuring, grid management, 5G, Automatic SLA Monitoring, Architectures

Executive Summary

Core to the edgeFLEX project is the advancement of the Virtual Power Plant (VPP) and from a technical perspective developing tools and services to help with this advancement. These tools and services are designed to enable the dynamic controlling and optimisation of the VPP and the surrounding grid with optimisation, control, enhanced measuring, and estimation at its core in a way that is both considerate of the Energy Community and the Grid Operator. These tools and services are further enhanced and enabled by the features of 5G that powers a real-time and reliable ICT solution that is further enhanced by the edge cloud capability of 5G.

In Phase 1 of the edgeFLEX project there was a focus on gathering requirements, building and researching the tools and services, defining the architecture, building the software components, and integrating them so that they would be ready for the trials in Phase 2. This work is detailed in D4.1- Description of edgeFLEX Platform Design and summarised in this report in a dedicated section.

This report takes a view of the edgeFLEX platform as a Minimum Viable Product (MVP) and how the MVP can be assessed, utilised by the customer and how it will have an impact on the advancement of VPPs and in the trials. Central to this report is the concept of the MVP, what it is used for and how it is used and in what context and early in this report we detail this. It is explained that the MVP is not for sale as such and is essentially a tool that is used to learn from the customer and their implementation of the product. How the concept of the MVP and scope of the edgeFLEX platform relate is important also and this report also states that the platform does not equate to one MVP but instead there can be multiple MVPs derived from the platform. The report also details the architecture of the platform and particularly its modular nature which by designed is allows individual components or groups of components be used in a way specific to the customer use case.

Central to the concept MVP is the customer and this report aligns the customer to the platform and to the MVP. It specifically outlines how the customer, using formulised user exploration tools, can choose the components they need to perform a task and by doing so define the MVP that is specific to their needs.

An MVP is a tool designed to enable stakeholders to learn about what they are offering and key to this is assessment. An important aspect of the edgeFLEX project is the Agile based improvement model that involves the delivery of the MVPs to the trials for assessment and in turn the results are returned to the core research tasks where learnings can be made, improvements made either to the algorithms or the supporting software and the enhanced MVP redeployed for further assessment. This report details the criteria and process for this assessment and feedback loop and how it will be used to gain learnings from the customers and systems at the trials in conjunction with enhancing the edgeFLEX platform and its components.

A key goal of the edgeFLEX project is the advancement of the role of the VPP and this report details the role the edgeFLEX MVP and its components can play in achieving this. It looks at the offering that it provides to Systems Operators, Virtual Power Plant Operators, RES Asset Owners and Energy Communities and outlines the benefit to them, their business processes, and the assets they manage in the context of advancing the role of the VPP.

This work will be expanded upon further throughout the remainder of the project where the assessments at the trials will lead to new insights being gained, enhancements made, new MVPs discovered all of which will be demonstrated and reported upon in subsequent deliverables, trials, and presentations.

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1. Introduction

The edgeFLEX project is divided into two phases, Phase 1, which is from month 1 to month 12 of the project, and Phase 2, which extends from month 1 to month 36, and this report describes the work carried out in the first phase of the platform in terms of defining the requirements, the components, architecture, and the delivery of the platform. These early stages of the project were geared towards providing the technical partners, platform developers, integrators and trial site managers with the software components and services that can be tested in laboratories, assessed and integrated with each other in lieu of their implementation in trials in M18 of the project. In D4.1 - Description of edgeFLEX platform design we state that the components developed in Phase 1 compose a minimum viable product (MVP) of sorts, that is true in software terms but the edgeFLEX MVP has to be defined in a broader context which describes not only the platform as a set of software components but also as

- a platform that is built in a flexible and modular way so that it can suit a wide range of architectures that is cognisant of the needs of the system while being considerate of the company boundary
- a platform that is centred on the needs of the user
- a platform that has the advancement of the role of the Virtual Power Plant (VPP) at its core

This report will present an overview of the software components and services that form the MVP and look at how they combine to form the MVP in a way that has flexibility, modularity, the user and the VPP at its core.

1.1 Related Work

This report is based on work carried out in the first phase of the project and also the early stage of phase 2 of the project. The precursor to this report is D4.1 Description of edgeFLEX platform design where the platform was described from a technical perspective with the individual architectures focused on the trial site implementation and the data flows between the services and the trial site components. This report focuses on taking the architectures developed in Task 4.1 and based on the requirements, both functional and non-functional, gathered from WP1 and WP2 and using them to frame the edgeFLEX MVP. The control services from WP1 and WP2, the VPP Optimisation, the edgePMU and the 5G API from WP3 are also considered as part of the MVP along with the Flexibility Trading, the interaction with the GOFLEX platform (Task 4.5) and the SLA Monitoring Tool (Task 4.4). In this report we detail how the MVP is validated and improved in the trials in WP5 and how the solutions derived from it feed into the activities in WP6 and how they are developed in a user centric way and how they can play a part of advancing the role of the VPP towards VPP 2.0. Figure 1 details graphically the task linkages from the technical tasks of the project and how they feed into the edgeFLEX MVP and how the MVP is in turn linked to the trials in WP5 as a method of validation and verification and then disseminated and analysed from an impact perspective in WP6.

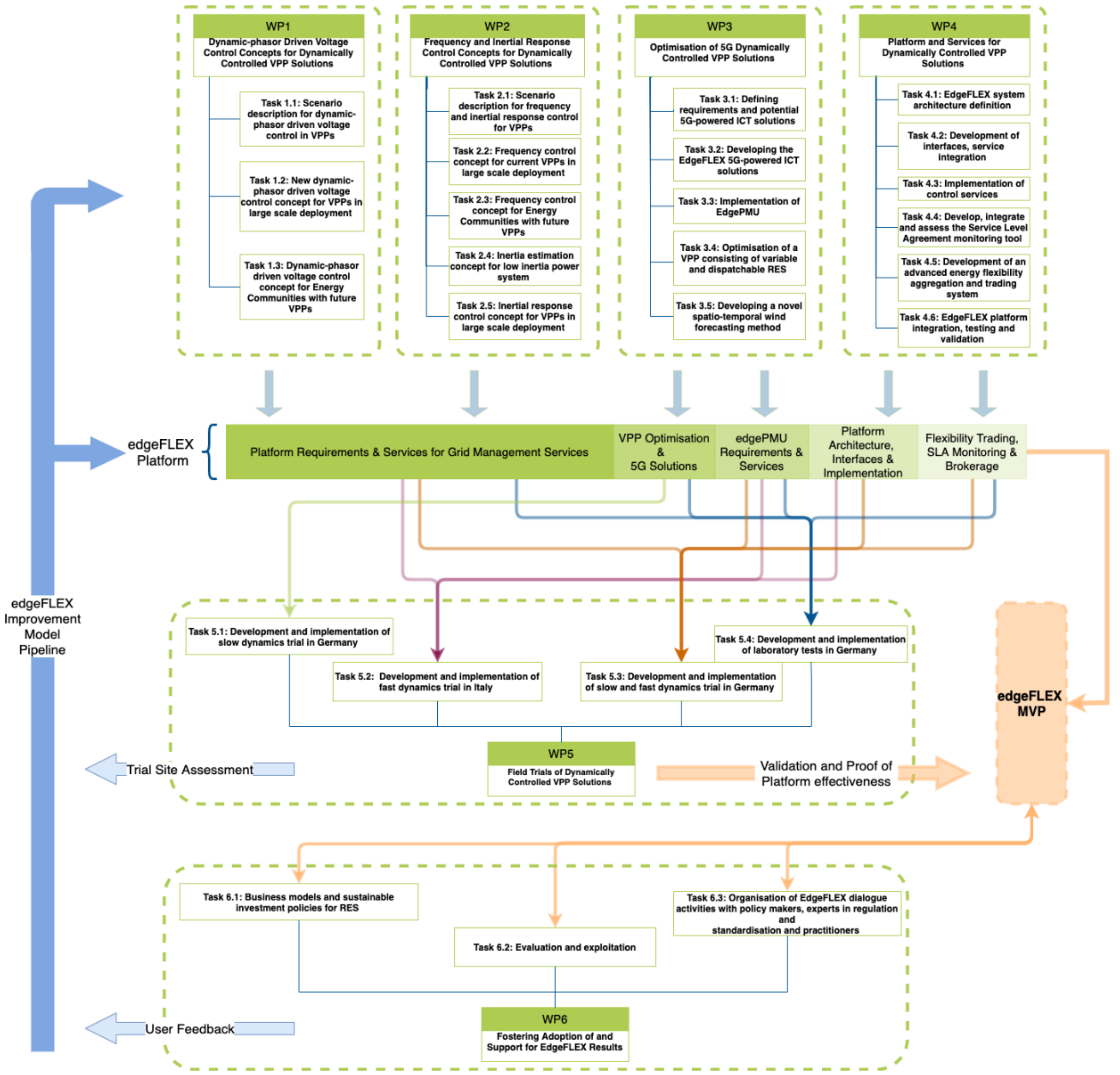

Figure 1 – edgeFLEX Tasks and the MVP

1.2 Objectives of the Report

The main objective of this report is to describe the edgeFLEX MVP as a vehicle that will take the technical research carried out in the project that have been integrated into the platform and look at it in the context of a product that can provide solutions to the grid actors to allow them to better interact with VPP assets and systems so that the VPP can play a larger role in a more harmonised energy supply sector.

1.3 Outline of the Report

This report (in Section 1) defines an MVP in a formal way and how the edgeFLEX platform and services, which are, at a high-level described in Section 3, relate to it. The report then describes (in Section 4) how the platform is designed in a modular way meaning it can be deployed and used to facilitate the presentation of the solutions that edgeFLEX is offering to the customer in the form of an MVP. In section 5 we define the customers that will potentially adopt the MVP and describe their relevance by example to a use case that we are proposing. Core to the edgeFLEX project is how the control services and the edgeFLEX platform will advance the role of the VPP in the energy sector and in Section 6 we explore how the edgeFLEX MVP can help achieve this. To describe an MVP fully it is very important to look at it in the context of the trials and the solutions it offers and in Section 7 this report details the trials and how the MVP is assessed in the system it is designed for.

1.4 How to Read this Document

This document follows up on the description of the platform in D4.1 and in the initial section summarises briefly the platform, the services and the architecture. In there we mention such concepts as Voltage Control, Inertia Estimation, VPP Optimisation and Frequency Control and while D4.1 provides details of their implementation a more in-depth view of the research is contained in the following deliverables.

- D1.1: Scenario description for dynamic-phasor driven voltage control for VPPs and D1.2: Dynamic-phasor driven voltage control concept for current VPPs
- D2.2: Frequency control concept for current VPPs D2.4: Inertia estimation concept for low inertia power system
- D3.2: Report on VPP optimisation

All other concepts that are not in a deliverable from another work package will be explained in a comprehensive way or linkages to prior research from other projects will be cited and referenced where appropriate.

While D4.1 looked at the implementation and the technical aspects of describing the platform this deliverable looks very much at the validation of the platform in Work Package 5 as an MVP or set of MVPs and how they are linked to the proposed customers and solutions that the MVP is intended developed in activities in WP6. For this we feel it prudent to align the content of this report with these activities and with the solutions detailed in Section 5 of **D6.6: Preparing exploitation.**

2. What is an MVP?

A minimum viable product (MVP), as described by the (Aglie Alliance, 2009), is a concept from Lean Startup that stresses the impact of learning in new product development. (Reis, 2009), defined an MVP as *“that version of a new product which allows a team to collect the maximum amount of validated learning about customers with the least effort. This validated learning comes in the form of whether your customers will purchase your product”*.

A key premise behind the concept of an MVP is that you produce a product, not one that is complete in any way but a basic version of the product that you can offer to the customer to observe their behaviour and interest in the product. The benefit of having an MVP is so that you can gain an understanding of the customers’ interest in the product without developing the product fully with high cost, effort and risk.

It must be pointed out, however, that an MVP needs not be the minimum marketable piece of functionality or service and normally at this stage the product or service might have no marketable appeal as it might not have sufficient quality in order to assess if and how much a customer will pay for it.

In terms of the edgeFLEX MVP, the product can be multi layered and span multiple customer bases and cannot be presented as one single MVP and to try would lead us away from the true definition of what an MVP is. This is because if we present all services to all customers as one MVP, we will not learn much as some components of the MVP will be redundant for some customers. Based on this it is fair to say that the edgeFLEX Platform and functional architecture is an enabler and a placeholder for a set of MVPs that can facilitate learnings from different customers and from an electrical perspective have an impact on different systems. It is these learnings, when applied through the improvement model, that can take the solutions and services that are being provided by edgeFLEX to a position where they can have a strong impact on the role of the VPP in future energy systems and markets. Furthermore, if we are to look at the energy sector, an MVP that is relevant to the situation in one country might not be relevant in another or, for example, one VPP might have a different focus from another and may strategically choose to have one set of edgeFLEX components over another to achieve their goals.

3. edgeFLEX MVP Architecture

The edgeFLEX platform MVP is described as a loosely coupled set of configurable services that can be either deployed together or in isolation. In this way, the edgeFLEX platform can be distributed across multiple entities, interacting with field devices and grid management, flexibility trading, control and optimisation services depending on the specific requirements of the user.

The edgeFLEX functional architecture was designed with this type of flexibility in mind and utilised to design, develop and implement the edgeFLEX platform MVP and first version of the control services. In phase 2 of the project, the edgeFLEX platform and services will be enhanced and expanded, continuing to use the functional architecture at its base. This architecture encompasses the entirety of the edgeFLEX platform, communications and the interaction between internal interfaces and services and external entities such as the TSO, DSO and the VPP. A representation of the edgeFLEX functional architecture is illustrated in Figure 2.

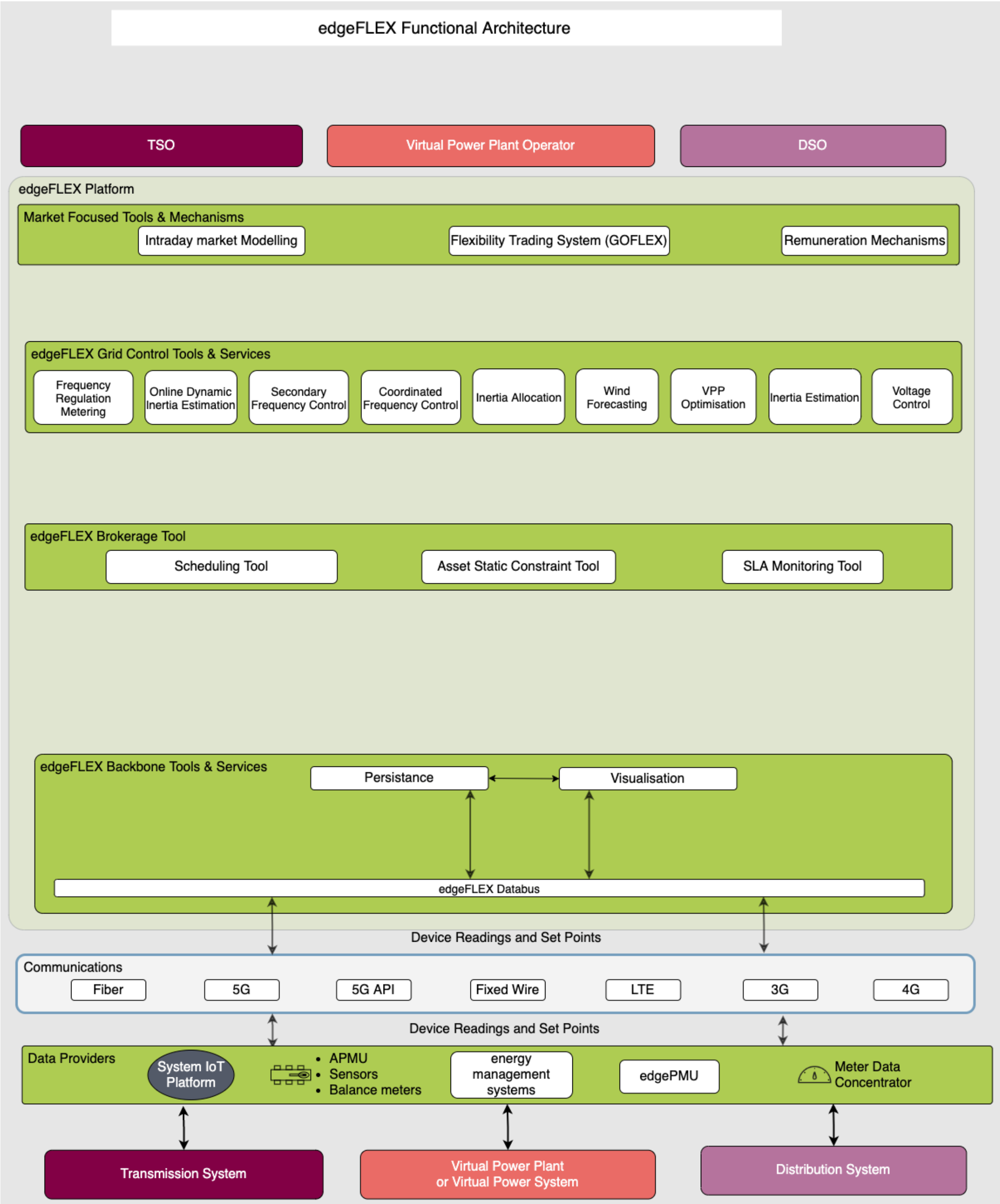

Figure 2 – The edgeFLEX Functional Architecture

As illustrated in the architecture figure, the functional architecture includes external data providers, communications, the edgeFLEX platform and its various components like the backbone tools and services, brokerage, grid control tools and services and market focused tools and mechanisms. A detailed description of the edgeFLEX architecture components can be found in D4.1, but for completeness they will be briefly explained in the following subsections.

3.1 Data Providers

All grid services rely on the availability of measurements coming from the grid as well as from the assets connected to it. The knowledge of the grid state, in terms of voltage and currents, is fundamental to identify critical situations that need the execution of an appropriate control action, such as in the case of Voltage Control, as well as the acquisition of frequency measurements is necessary to correctly perform fast frequency control or estimate the overall system inertia.

For this reason, one of the innovation concepts conceived for the edgeFLEX project is the so called edgePMU. The edgePMU is an advanced Phasor Measurement Unit (PMU) which samples voltage and current signals at high sampling rates and then estimates the relative phasors, in terms of magnitude and phase, as well as the grid frequency and the Rate of Change of Frequency (ROCOF).

The edgePMU concept, as described in (H2020 edgeFLEX, 2021), is based on a field device responsible for data acquisition and a cloud service which performs data processing and phasor estimation. For this reason, as part of the edgeFLEX platform, a dedicated edgePMU service was developed and implemented as part of the edgeFLEX MVP. While the data acquisition unit is physically deployed on the field, as part of the Data Providers layer, the cloud phasor estimator service is deployed on the edgeFLEX architecture, as part of the Grid Services layer. The edgePMU service gathers the raw samples coming from the data acquisition unit and estimates voltage and current magnitude and phase as well as frequency and ROCOF values.

The integration with the edgeFLEX solution is then realized by providing the estimated phasors to the data bus, as MQTT messages published on dedicated topics, and then forwarded to all the services which would need such input for their processing.

The overall structure of the edgePMU service, integrated in the edgeFLEX architecture, is shown in Figure 3. The dashed red arrows identify the raw data stream generated by the data acquisition device on the field and transmitted, over a wired or wireless communication interface, to the edgePMU phasor calculator service deployed in the edgeFLEX platform. The estimated phasors, encapsulated as MQTT messages, are then published to the edgeFLEX Databus and thus made available to all grid services which may use such measurements.

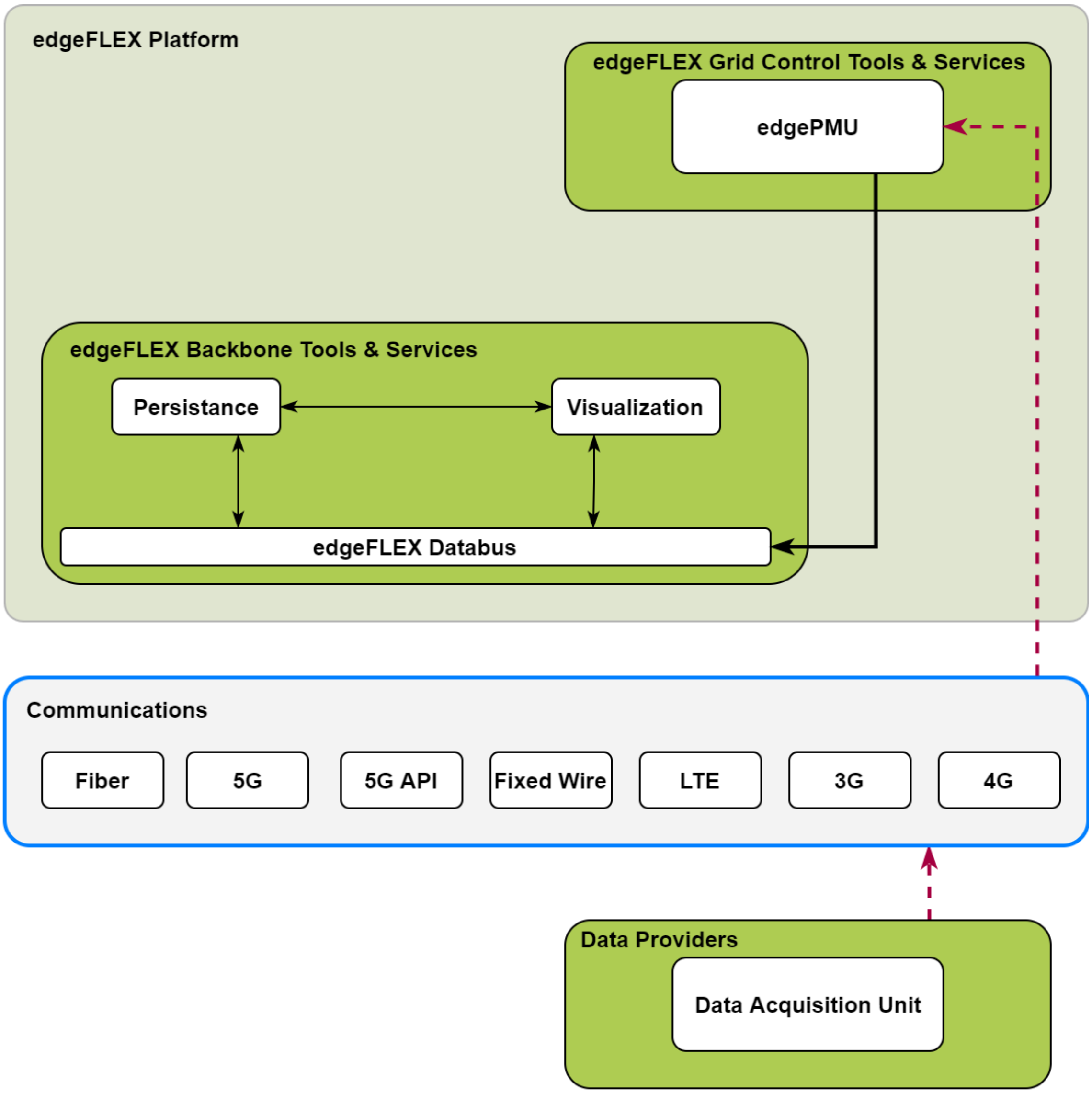

Figure 3 – edgePMU integration into edgeFLEX architecture

Together with the edgePMU phasor estimator there is also a dedicated visualization interface, part of the edgeFLEX backbone services, which allows the operator to quickly visualize the estimated values for the phasors, both instantaneous and historical ones. The visualization interface is developed with Grafana and is shown in Figure 4.

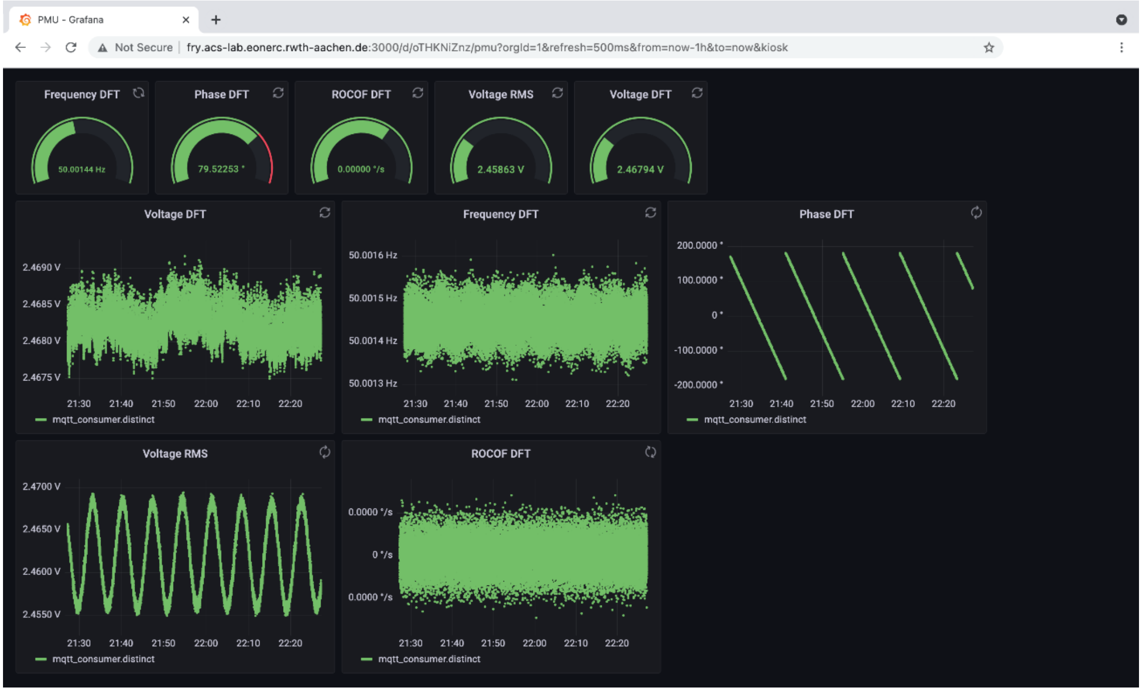

Figure 4 – edgePMU phasor visualization interface

3.2 Communications

5G provides new features that will advance the role of the VPP and system operators and corresponding edgeFLEX services that they can use. In the project edgeFLEX, the following 5G features are utilised in this purpose: the 5G device management capabilities exposure, the edge computing and Ultra Reliable Low Latency Communication (URLLC) feature. This chapter describes the benefits that each of them can bring to the edgeFLEX services.

The network exposure makes the network capabilities, such as data and network services of both 5G and 4G network, available for user applications and services. Exposure is critical to achieve programmable networks that can communicate with all IoT devices in a convenient and secure way. In the edgeFLEX project, we are focusing on an innovative **5G device management capabilities exposure** to the edgeFLEX services. **Error! Reference source not found.** Figure 5 illustrates the principal diagram of the 5G network capabilities exposure to the edgeFLEX service.

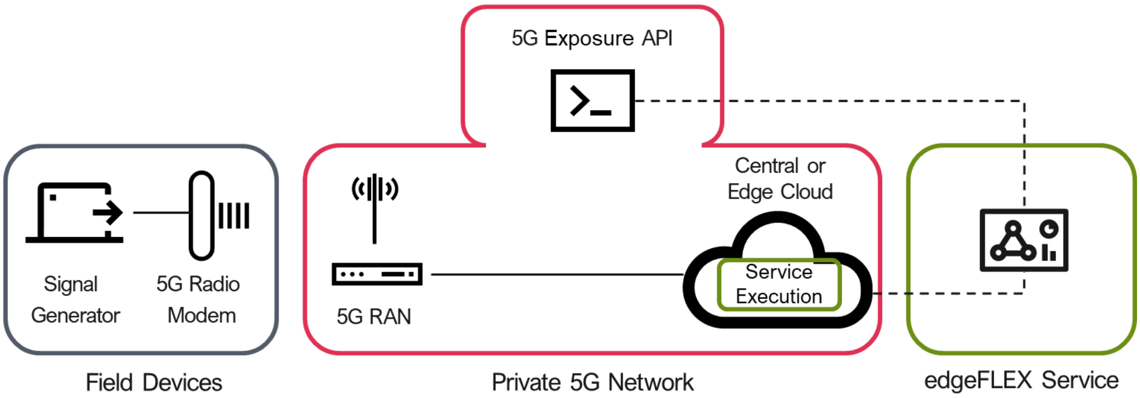

Figure 5 – Device management capabilities exposure in the 5G network

Provisioning, onboarding and grouping of field devices can be exposed through the 5G device management capabilities exposure API. This information can be used by the edgeFLEX service to optimise the service execution or to take necessary actions in real-time. These device management functions are being implemented in the project.

In order to meet the low latency requirements over the wireless link, and to enable hosting of distributed edgeFLEX services close to the assets, **edge computing** can be utilised. Edge and distributed cloud can be utilised as an execution environment for the edgeFLEX services and enablers.

URLLC brings in a set of 5G features that provide low latency and ultra-high reliability for mission critical services. It can fulfil the stringent requirements for high reliability and security requested by the edgeFLEX services as well for low latency requested by some of the services such as VPP coordinated frequency control service. Although the URLLC will be available in the market in a few years, we have an opportunity in the project to test the edgeFLEX service performance on one of the first URLLC prototypes in Ericsson.

3.3 edgeFLEX Back Bone

The edgeFLEX backbone provides key services and interfaces for collecting, storing and visualising data from the data providers. The edgeFLEX databus provides the interfaces for collecting this data. Some services implicitly require persistence for the scheduled analysis of stored data, while for others this is not a requirement, the same is true of the visualisation service. The flexibility in the deployment of these backbone services allows the user to pick and choose whether persistence and/or visualisation are required on deployment. The visualisation service makes use of the open-source data analysis tool Grafana, the generation of data graphs is fully dynamic and updates at a set interval of time, this means the user does not have to create graphs on deployment, nor update them when new assets come online and begin to communicate data. An example visualisation for Frequency Control can be seen in Figure 6.

Figure 6 – Frequency Control AGC Visualisation

3.4 edgeFLEX Brokerage

The edgeFLEX brokerage tool provides several features to enable greater control to SOs for enabling intelligent scheduling, static asset configuration control and flexibility trading parameters with an aim to realise more sophisticated use cases, which require brokered cross-sector actor support in terms of asset configuration and constraint details, external asset interaction, data acquisition, external platform interaction and flexibility trading.

The edgeFLEX brokerage service is built on the concept of Policy Based Network Management, where Service-Level Agreements (SLAs), asset and scheduling configurations take the form of user-defined policies, which are created and managed via a user-interface provided by the SLA brokerage tool shown in Figure 7.

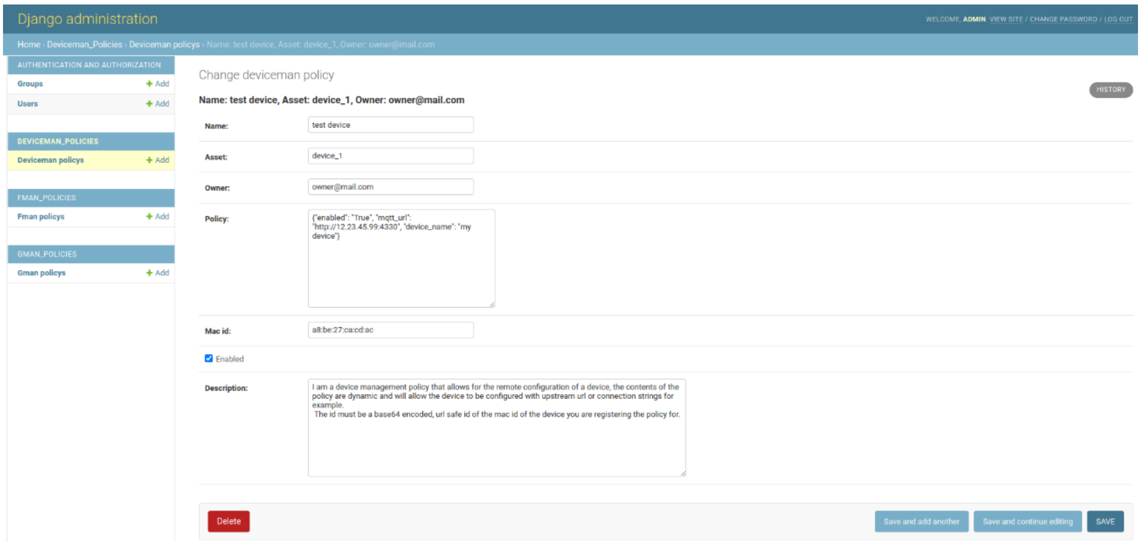

Figure 7 – Policy Management Interface

This GUI separates policies into their respective areas of concern, those being device management (Deviceman), grid management (Gman) and flexibility management (Fman) related policies. Each policy has a set of parameters which are populated by the user, some of these are common to each policy type, such as the policy name, the particular asset the policy pertains to and the owner of the policy. Other parameters are unique to the policy type, for example device policies include a "Mac id" parameter which is used as a unique identifier for that particular device, flexibility policies include a "flex offer template" which is used in requests for flexibility and contains information related to the requested times for flexibility to be offered and constraints which include upper and lower bounds for tariffs and energy amount offered.

The GUI also enables users to manage existing policies by either changing them or removing them if necessary. The administration section also allows for more fine-grained controls to govern user-access to policies in terms of viewing, editing and deleting policies, thereby regulating the level of control and access users and user groups have to each area of the system.

External interactions with the edgeFLEX brokerage system to request policies are event-based and accessed through REST and MQTT interfaces, whereby services request policy information from the brokerage tool, which then intelligently decides which policy to utilise and actions to enforce. In this way, once policies have been added to the brokerage system by the SO, the system then acts independently and autonomously based on the types of events identified (i.e., grid, device or flexibility) and takes the correct course of action based on the specific device parameters set by the user in the policy.

In phase 1 of edgeFLEX, an initial version of the edgeFLEX brokerage was developed, allowing for the creation and management of policies and requesting said policies via REST and includes Swagger API documentation to improve usability and to give a greater understanding of how to interact with and use the SLA brokerage systems interfaces, as illustrated in Figure 8.

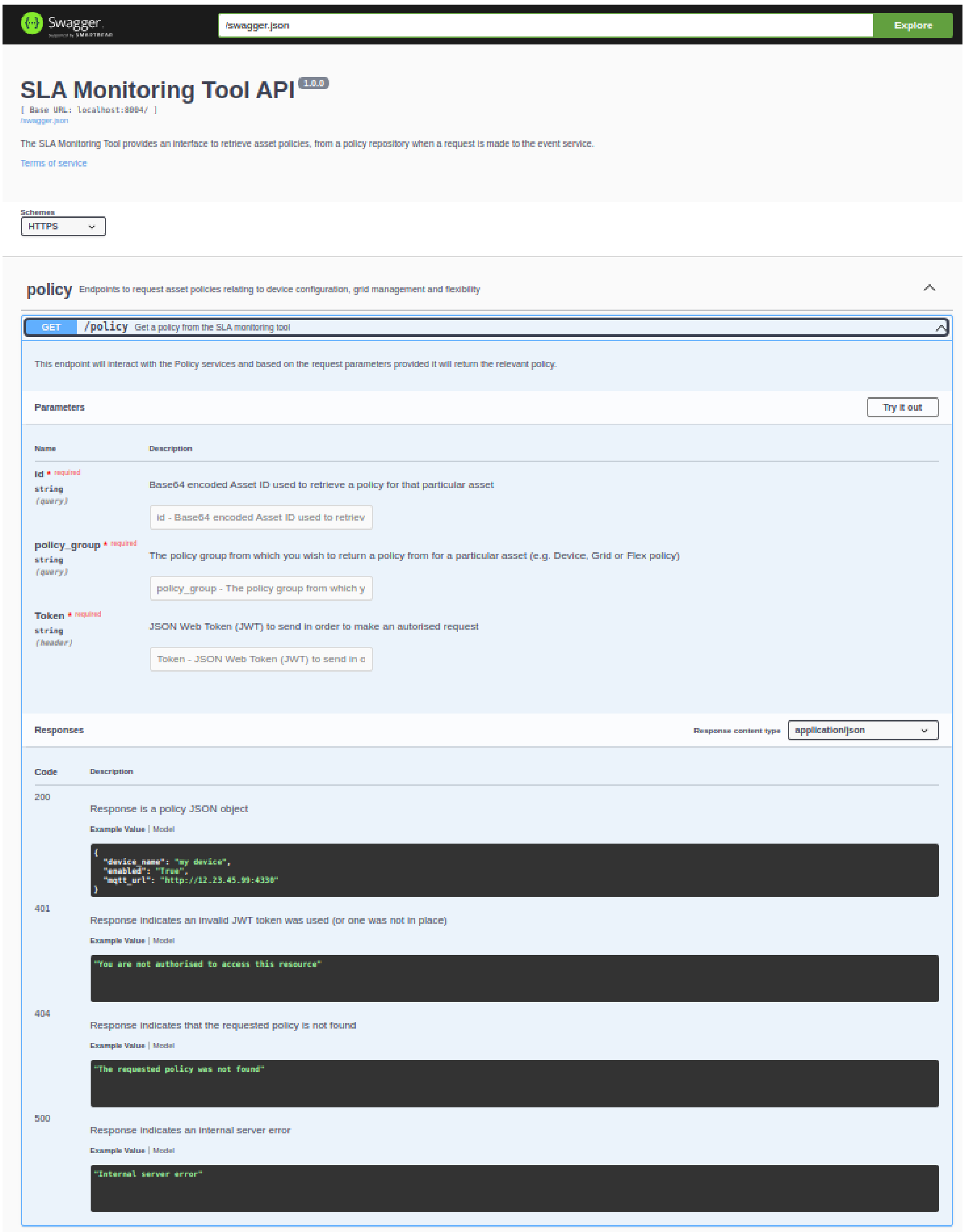

Figure 8 – SLA Brokerage Swagger Interface

During the initial stages in phase 2 of edgeFLEX an early interaction between the SLA brokerage system and a control service, in this case Frequency Control, was achieved. The Frequency Control service was enhanced with a meta-data loader, which enables the service to not only operate within the bounds set by the SO on initial deployment, but also allows the service to periodically check for updates to its operational bounds which are set via policy and stored in the SLA brokerage system. Through this method of management, the SO can change the operational bounds of the service via the SLA brokerage GUI and have them take effect within a set period (e.g. five seconds).

The example below illustrates this with a version of the Frequency Control service using simulated data, but which is polling for any changes in a sample policy stored in the SLA brokerage system, presented in Figure 9.

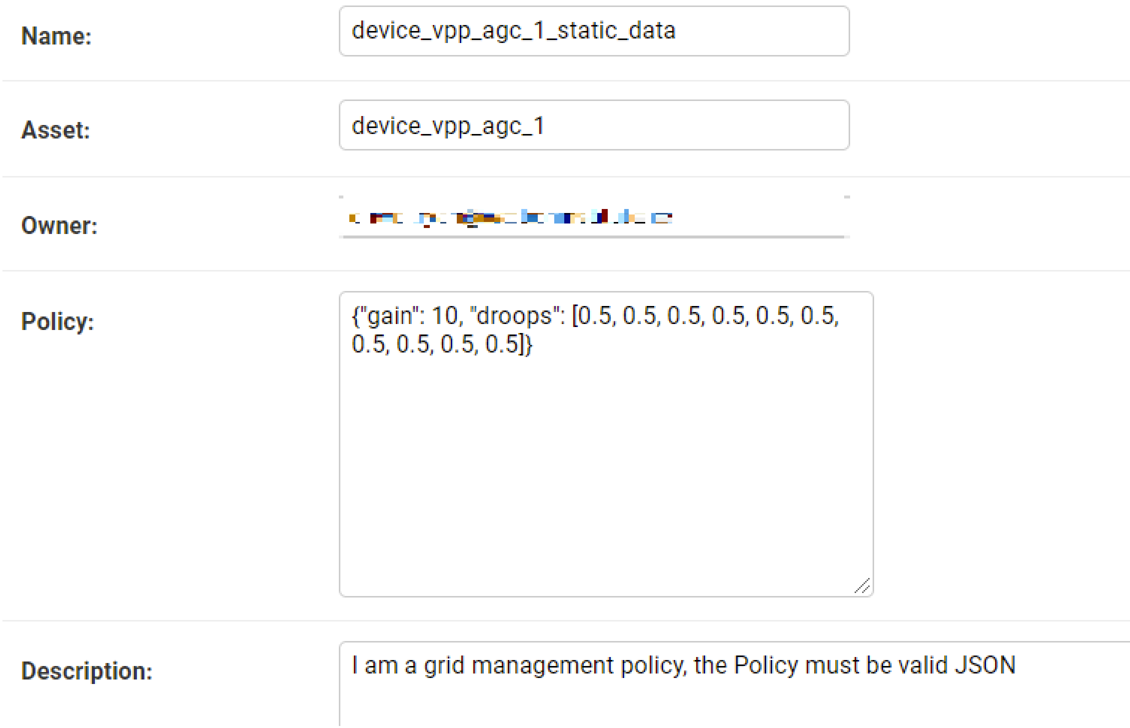

Figure 9 – Frequency Control asset policy sample

The relevant parameter here is the “gain”, the Frequency Control is polling for this policy every five seconds and the SLA brokerage tool is aware of the asset this policy belongs to and returns it on each request made by the service. By making a change to the “gain” the SO is dynamically changing the bounds of the system, this is illustrated in Figure 10 where the changes in gain are reflected in the visualisations and highlighted in the figure.

Figure 10 – Frequency Control asset dynamic gain change

Continued development in phase 2 of edgeFLEX will expand this functionality by implementing policy interactions with additional services and requests for flexibility.

The possibility for historical analysis of requests made to the SLA brokerage system has been realised by capturing and storing details of each request make to the SLA broker such as the origin of the request, the specific policy as it was at that time and request and response times (for performance metrics). This functionality has been added as an output of partner feedback on the system. Further development in phase 2 will expand on this by including visualisations and analysis based on this historical data.

3.5 edgeFLEX Grid Services

A core set of services, developed in the scope of edgeFLEX project, is devoted to providing system operators and VPPs a set of active tools for monitoring and controlling different aspects of their grids and assets.

Among the services specifically tailored for system operators we can identify two main groups: services related to frequency and inertia and the services related to voltage. To the first group belong the frequency regulation metering, the inertia estimation, the inertia allocation and the online dynamic inertia estimation. For the voltage control, instead, there are two different implementations acting with direct assets' control in real time and with a flexibility trading-based model predictive control, respectively.

Another set of services, designed specifically for VPP operators, provide tools for the optimization of the VPP operation, the forecasting of wind generation and the optimal provision of frequency services to grid operators, with the VPP Coordinated Frequency Control and the VPP Automatic Generation Control.

All these services have been containerized as docker packages to be deployed on the edgeFLEX platform and directly integrated with the data handling and persistence features offered by edgeFLEX backbone services together with its visualisation capabilities as described in Figure 11.

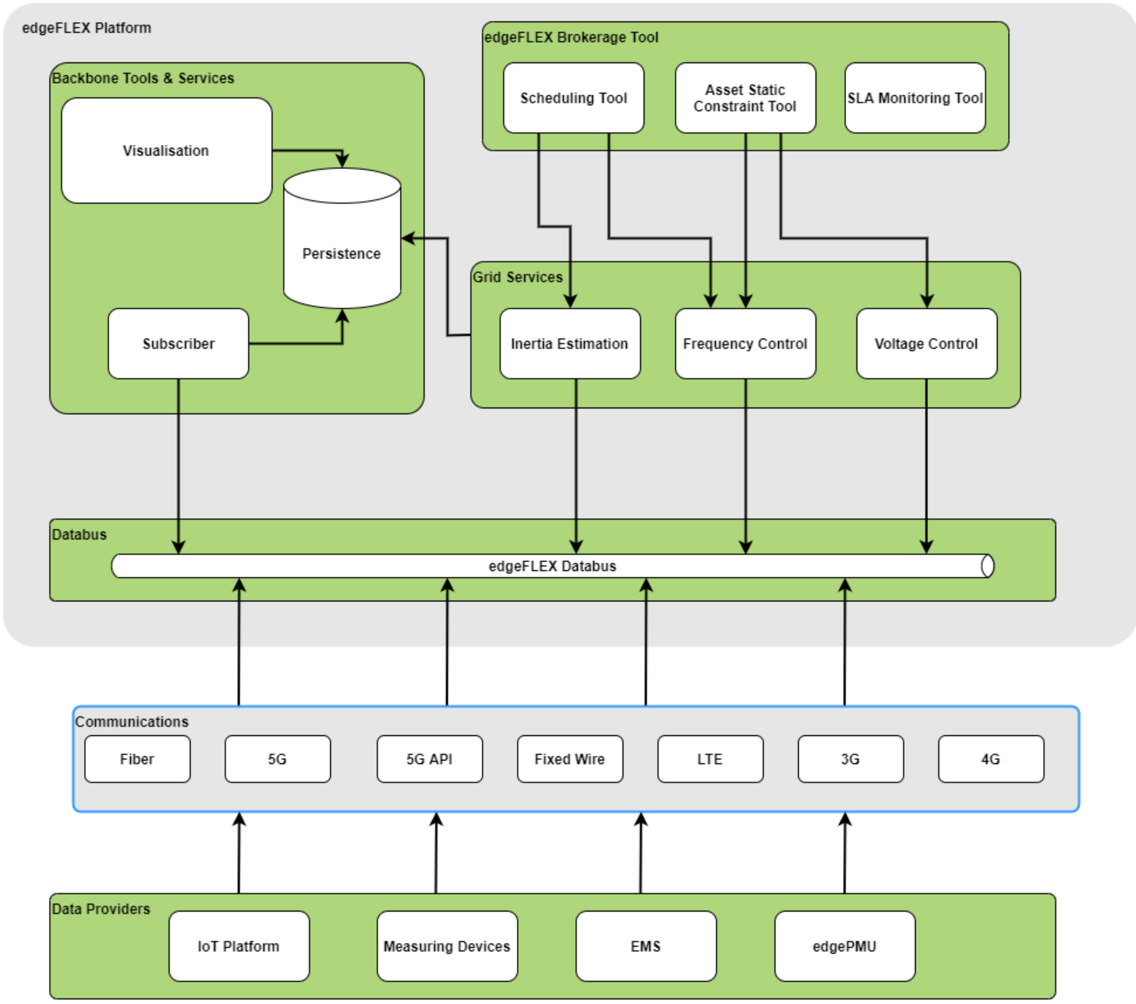

Figure 11 – edgeFLEX platform grid services

3.6 VPP Optimisation

Included within the edgeFLEX platform MVP will be the VPP optimisation service, the goal of which is to increase the efficiency of VPP operations using an optimisation algorithm. This algorithm and the related software services with which it interacts will produce actions on the market for flexible VPP assets on whether to buy, sell or store energy from these assets – thereby enhancing the return on investment.

There are several data flows which support the operation of the optimisation algorithm, such as asset data from the field, intermittent energies production forecast data, day ahead and intraday, price forecast and trading floor results on the assets of the VPP which serve as the status quo to assess the performance (further details on these data flows can be found in D4.1). The optimisation process consists of several stages, firstly, the aggregation of data from the various data flows. The volume of data obtained from these sources is substantial, so a simplified model is used to aid processing time while still ensuring an acceptable amount of precision in the results. To determine the effectiveness of the algorithm and to support optimising further iterations of the algorithm, an ex-post analysis is conducted, based on the criteria of speed and projected profitability of the optimisation generated.

The data is then dis-aggregated and further used to generate control actions towards the flexible assets included in the VPP, another ex-post analysis is run on the actions generated to determine their effectiveness and again used to improve further iterations of the optimisation algorithm.

As part of WP4 activities, the VPP optimisation service has been prepared for inclusion within the edgeFLEX MVP as a containerised service which receives data from assets through the edgeFLEX backbone services, specifically the edgeFLEX databus and includes persistence for aggregated data and visualisation functionality through Grafana. The VPP optimisation service also has the capability obtain static asset data from the SLA monitoring tool (described in section 3.4) through a meta-data loader submodule which is included as part of the deployment.

3.7 edgeFLEX Market Focused Tools and Mechanisms

In the edgeFLEX project the Flexibility Trading Platform (FTP) is responsible for trading the flex-offers. The FMAR (in the concept of the GOFLEX project stands for Flexibility Market) is a component of the FTP and is a stand-alone Automated Trading Platform (ATP) system, responsible for matching the production and consumption flex-offers issued by active prosumers and other market actors (e.g., grid operator or an aggregator represented by the DOMS component).

The FMAR algorithms provides various necessary market functionalities like

- price matching optimisation
- hierarchical market organization
- rebound effect control

The FMAR component operates with the flex-offer object, which is not only the energy bid, because beside the price it contains also energy and/or execution time variation.

3.7.1 Flex-offer description

The flex-offer contains the following main information

- **Energy amount.** Adaptation request is formed as a time series of required energies. Positive value is declared as a production and matches with the consumption and vice versa for negative values.
- **Duration** of the adaptation. Duration of the adaptation is defined by the length of the energy time series. The length may vary form 1 interval (15 min by default) to several hours. The optimal length depends on the accuracy of the long-term predictions of the flex-offer issuer and characteristic length of the counterpart offers.
- **Price.** The price defines the limit cost that is allowed for contracted flexibilities. The available capacity will not be activated if its price exceeds the limit price of the counterpart one. The price may vary from interval to interval and is defined separately for production and consumption. In normal circumstances the price is positive, however also negative prices are allowed what is also occasional situation on the electricity market.
- **Start time variation.** The parameter describes the time flexibility, which defines the time frame of the device's operation. The flexibility is defined as a deviation from the default operation.

According to the flex-offer type the energy and time flexibilities are distinguished.

3.7.1.1 Energy Flexibility

The device offering the energy flexibility is capable to control production and/or consumption power within “min” and “max” constraints for a specified amount of time.

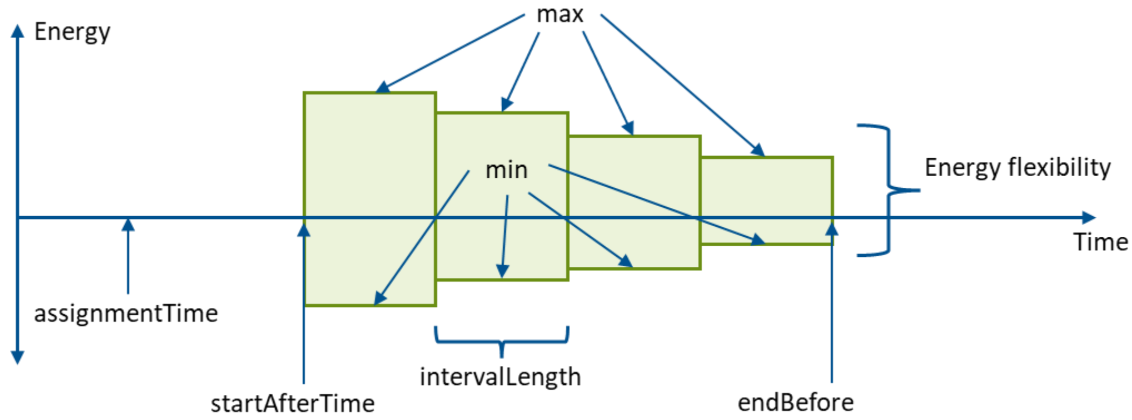

Figure 12 – Energy Flexibility visualization

The flexibility description is a time series described with the following main parameters:

- *startAfterTime* – time moment in the future when the proposed schedule will be started,
- *intervalLength* – the length of the time series elements usually set to 15 minutes,
- *min* & *max energies* for each interval – top and bottom limits of the energy the adaptable device is capable to provide,
- *assignmentTime* – the latest moment when the prosumer expects the assigned schedule,
- *price* for each interval – the price of the refund claimed by the prosumer,
- *endBefore* – in the case of energy flexibility it is implicitly defined with startAferTime and time series of “min & max energies”.

Some devices like batteries, are capable to provide adaptation in both directions – production and consumption. In the case the energy flexibility describes it with *max energy > 0* and *min energy < 0*. At the realization only one option is allowed per interval.

3.7.1.2 Time flexibility

The time flexibility is usually applied to the devices like HVAC system, EVs and various energy related production processes with storage device.

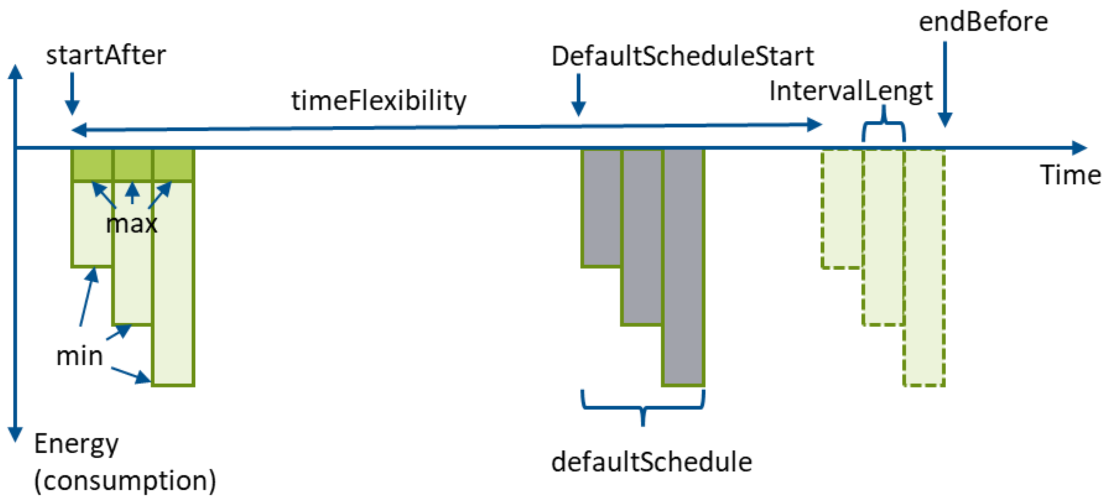

Figure 13 – Time flexibility visualisation

The flexibility description is a time series described with the following main parameters:

- *startAfterTime* – the earliest moment of the operation start.
- *timeFlexibility* – the longest time for operation delay.
- *min* & *max energies* for each interval – top and bottom limits of the energy the adaptable device is capable to provide.
- *assignmentTimeRelative – t*he latest moment when the prosumer expects the assigned schedule before its operation start.
- *intervalLength* – the length of the time series elements usually set to 15 minutes.
- *defaultOperation* time series. The start moment and energy profile of the load operation in the case no assignment is received.

The edgeFLEX market supports both types of flex-offers as also their combinations.

3.7.2 Optimisation technique

The matching process selects the available FOs with prices from the pool and searches the optimal combination from the total cost point of view. The matching is based on an auction process (Figure 14) where production energy is sorted from cheapest to most expensive, and consumption energy is sorted from the most expensive to cheapest in order to define the cut-off (marginal) price (λ_t^p) and amount of energy. The matching is performed for each (15 min) trading interval and is successful, if the consumption price is larger than the production price. However, the selected FOs have different start times and durations, therefore the matching algorithm also provides time combinations and permutations with the linear programming algorithm to find the optimal solution.

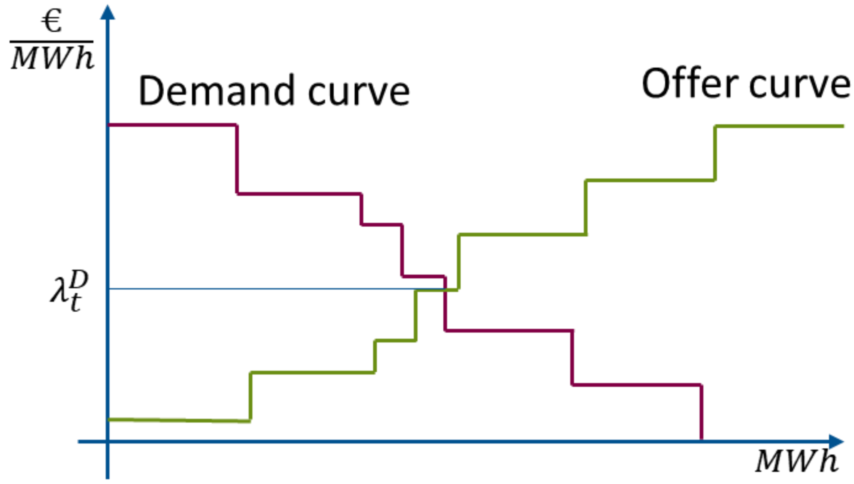

Figure 14 – Auction at meeting the consumption demand and production offer (two-sided pool)

The FMAR component support many-to-many trading where several production FOs are matched against several consumption FOs. This trading mode is suitable for the general market organization e.g., microgrid. In the edgeFLEX FMAR mainly one-to-many will be used where “one” refers to the DSO entity adaptation request and “many” to prosumers offering their adaptation capacity.

FMAR also operates an implicit FO called imbalance, which defines the penalty amount and price when the matching between production and consumption is not perfect. The price of this FO may be internally configured by the user or may refer to the real imbalance price on the external market. The goal of matching in FMAR is the minimization of the imbalance amount.

3.7.3 Market structure

The prosumers offering the adaptation potential are dispersed on different location over the grid. The FTP is capable to sort the prosumer into the tree structure (Figure 15), which reflects the topology of the grid. That enables to the distribution operator to target the adaptation request only to the specific sub-area, where only the properly located prosumers are selected or to the whole area of control.

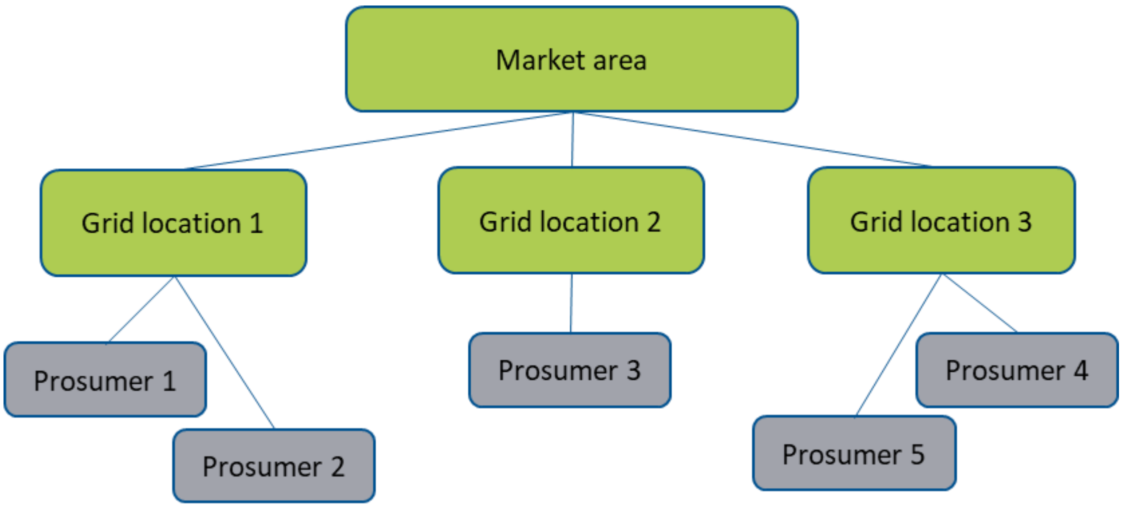

Figure 15 – Market area topology

The FMAR on FTP organizes the market hierarchically where the matching can be performed on different sub-areas concurrently, where the trading performed in different grid locations is performed independently.

3.7.4 Rebound control

The activation of the prosumers adaptation capacity on FTP capacity may cause the rebound effect which may not be welcome at managing the congestion. The rebound effect is caused by certain flexible devices, which offer time flexibility – they need to produce/consume energy for their proper operation, but their time schedule may be flexible.

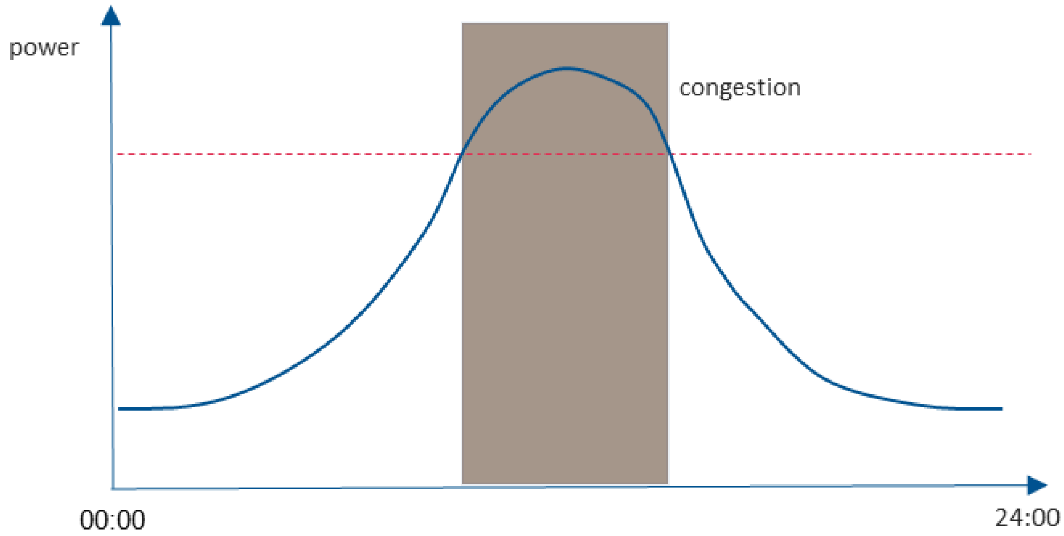

Figure 16 – Electricity congestion on the grid node

For example, the rebound may occur when the external adaptation request triggers the VPS's production FOs to manage congestions. If the adaptation capacity with the time flexibility (or energy shift) is activated, it may result in undesired contrary effect with consumption increase during congestion (Figure 17).

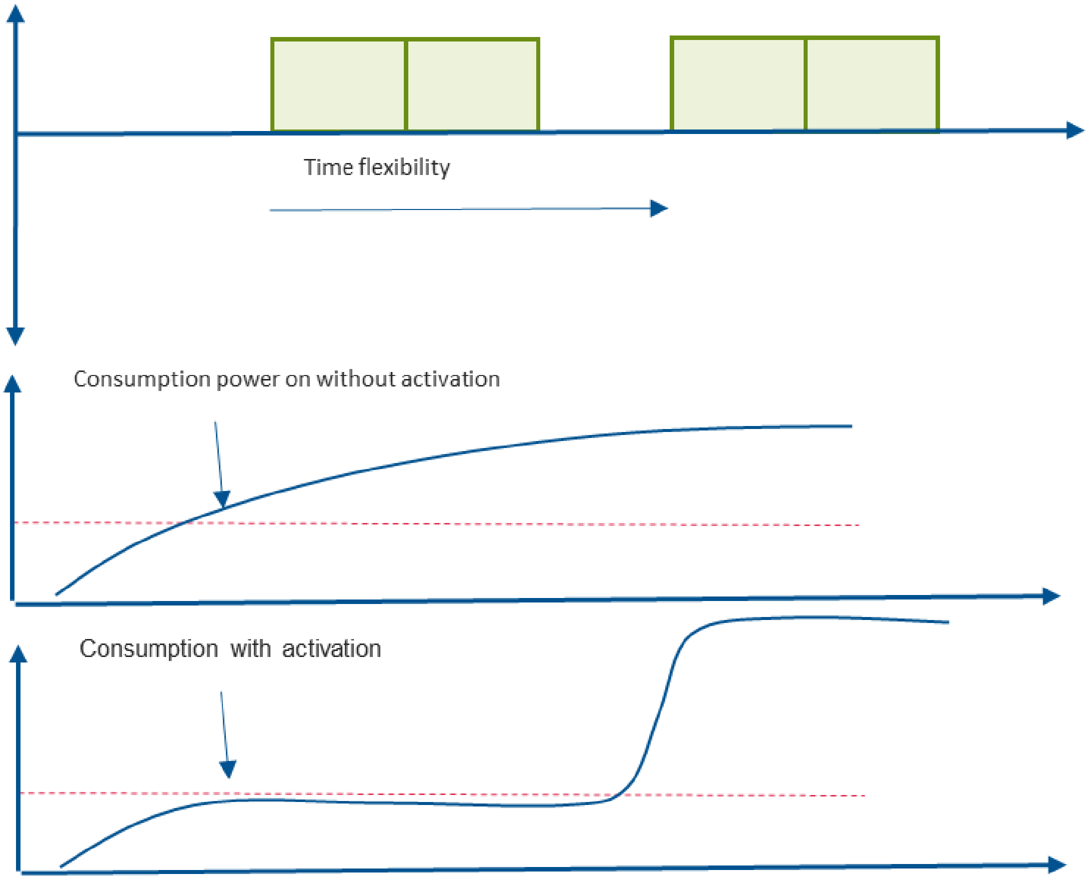

Figure 17 – Undesired rebound at matching the flexibilities with external adaptation requirement

The FTP enables two approaches to avoid undesired rebound.

- Avoid the time flexibility activation. The DSO request contain only adaptation during congestion interval while the time outside it, is treated as imbalance and penalized. The penalty price is defined by the FRP controlling the operation region or may be linked to the external market imbalance price.
- Control the rebound within the grid constraint. The DSO request beside the adaptation during congestion interval supplies also the information of the available grid capacity outside the congestion interval. That part of the request is assigned with proper (low) price to allow the assignment of the time flexibilities. This approach allows the activation of time flexibility at the end (or beginning) of the congestion interval (Figure 18)

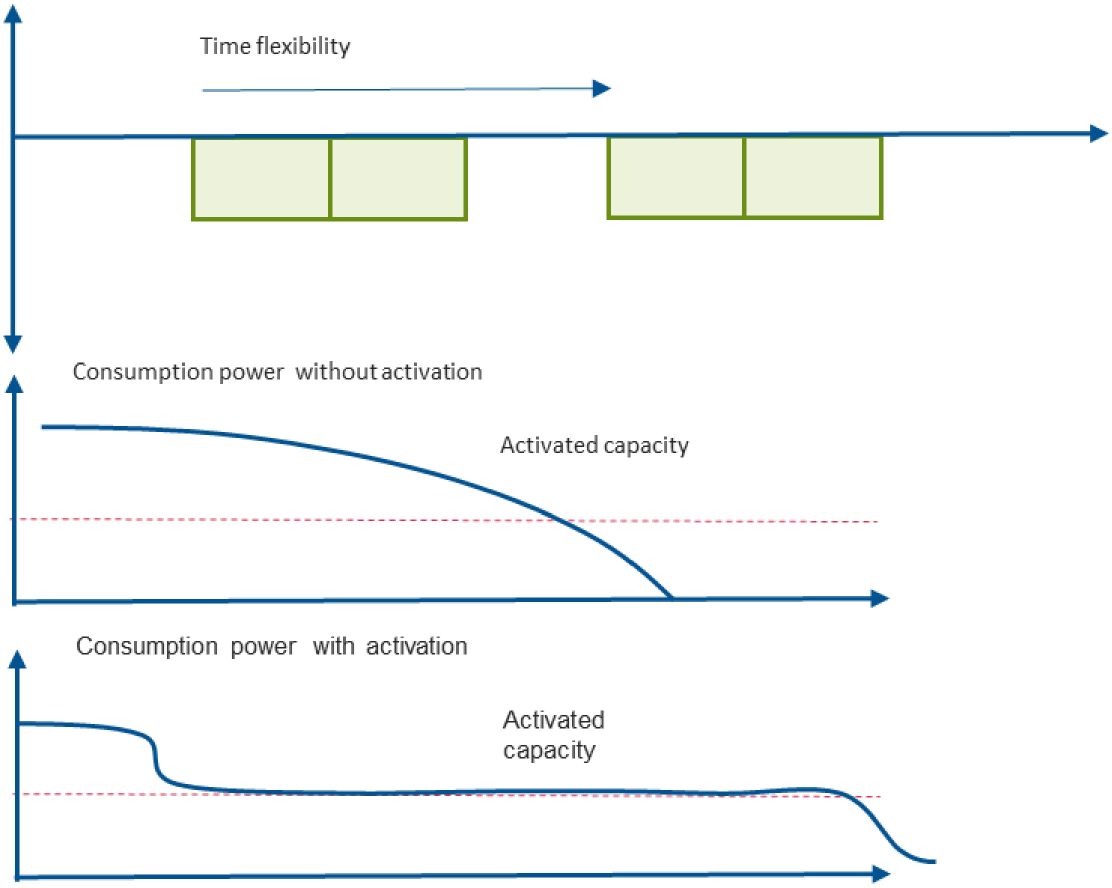

Figure 18 – Controlled rebound

4. The edgeFLEX MVP and the Modular Approach

In section 2 we state that rather than the edgeFLEX MVP being only one MVP it could be conceived as being more than one. The edgeFLEX Platform is built with its components loosely coupled and configurable which means that the entire platform does not need to be deployed in the same place for it to perform its intended function. This means that the edgeFLEX Platform is modular in terms of design structure and deployment and indeed it can be viewed as a suite of services and solutions that a customer might need.

An example, if a customer, in this case the DSO, wants to employ a voltage control strategy to help maintain the voltage at a stable operational limit, that customer would not need any of the frequency services or VPP optimisation, they would just need Voltage Control and the services needed to facilitate it and support it as illustrated in Figure 19.

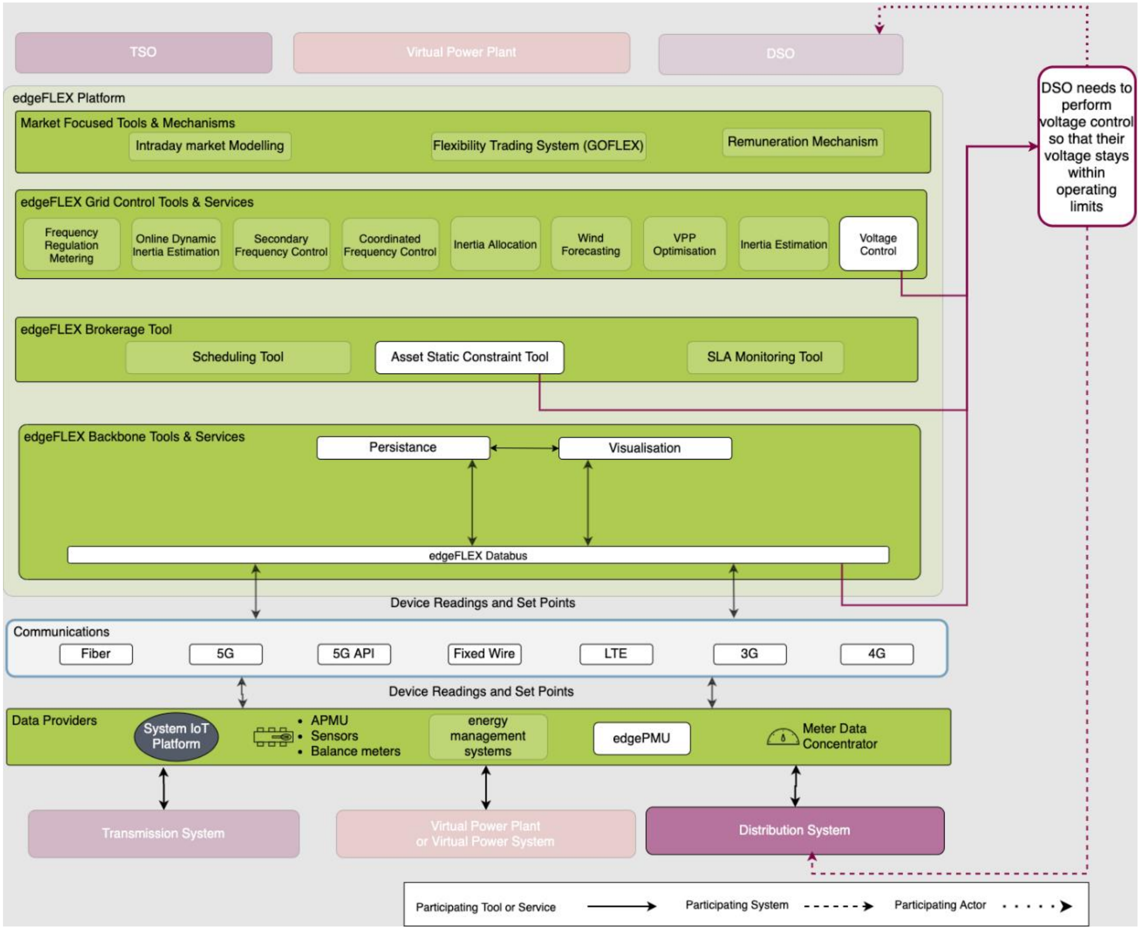

Figure 19 – Voltage Control MVP in the edgeFLEX Functional Architecture

Similarly, if the DSO wanted to engage with the VPP to ensure that the voltage in the system remained within operating limits they would need to incorporate more components into their instance of the edgeFLEX MVP, like the SLA Monitoring tool and the Flexibility Trading System offered by the VPP, as illustrated in Figure 20.

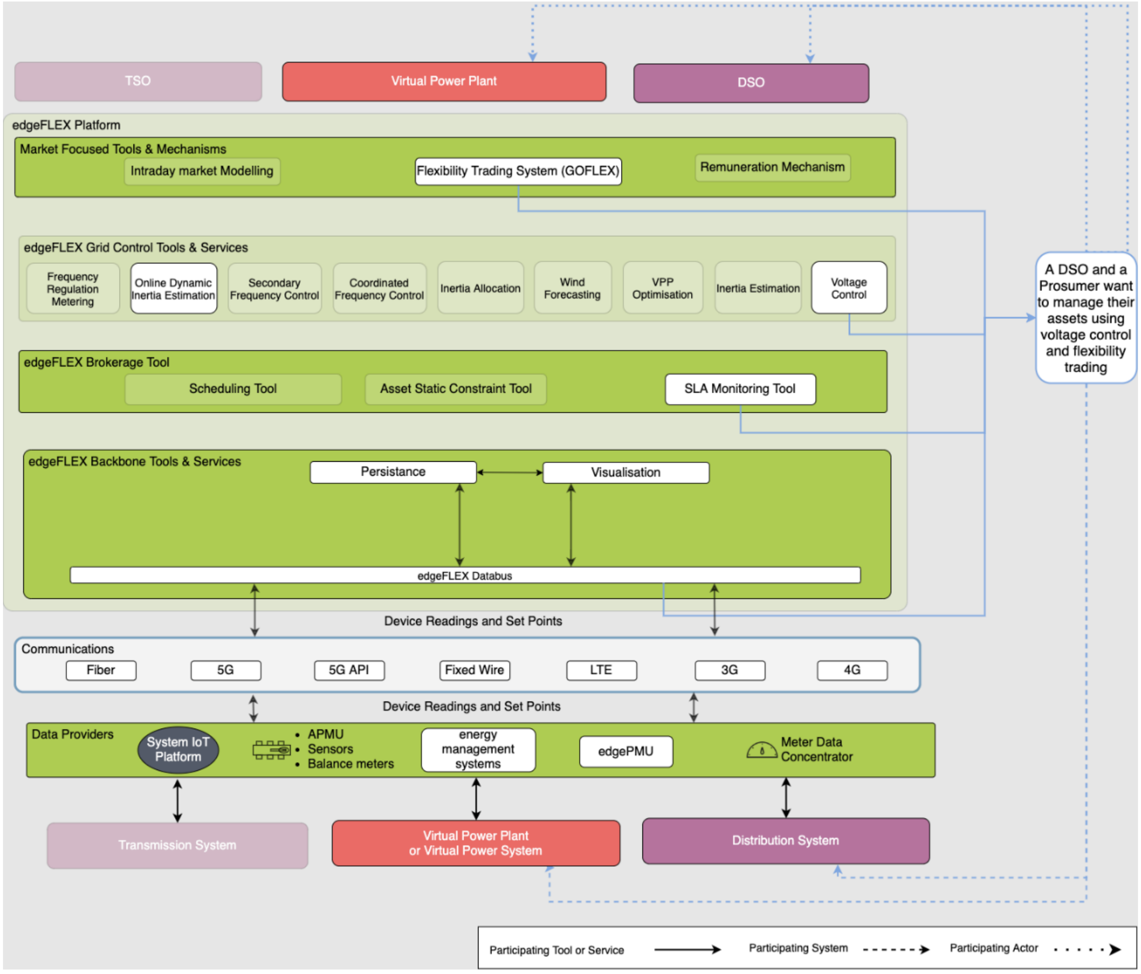

Figure 20 – Voltage Control & FlexOffer MVP in the edgeFLEX Functional Architecture

While the components being loosely coupled in terms of their usage the components are also configured in a dynamic way in terms of how they communicate to and interact with each other. If we take the example above, we note that there is a box named *edgeFLEX Back Bone and Services* which contains a data bus, a persistence service and a visualisation tool, these components are used by the Voltage Control to get data, store the data and monitor the operation of service. These components are part of the edgeFLEX platform and can be deployed as part of it but similarly these could be already present, operational and part of the organisation's current business processes in the system of the customer. By configuration, the components of the edgeFLEX platform can connect to these components and can do so in a way that does not impact on their roles existing business processes.

The modularity of the edgeFLEX platform and the role it plays in the edgeFLEX MVP cannot be understated in terms of providing solutions that can be deployed in an existing customer's system in a non-invasive way and with a low level of redundancy. It is also an approach that is mindful of the company boundary because it can be deployed entirely within the customer's system with no need for data transfer outside it for processing.

All this means that the barriers for the trialling of the edgeFLEX MVP by customers are low, the goals of the deployment can be flexible and tailored to the customer's existing architecture and needs with a low level of redundancy and risk to existing business processes.

5. edgeFLEX MVP and the Customer

One of the key aspects of any MVP is its relationship to the customer and in edgeFLEX linking the customer's needs to the MVP is core to defining the components that are required for the specific MVP for the customer. To define these needs, we would need to first define the customer, in this case identify their role in the system, based on their role outline their goals, explore the issue they are having in reaching their and then using the components from the edgeFLEX Platform define a means to achievement of solving the issue hindering them from achieving their goals. In the agile methodology having the customer at the centre of the process is an important element of having the software built for the customer in a way that is flexible and a way that allows for changing conditions and user requirements throughout the development process. This is linked to the use of the MVP as a discovery tool and a tool used to link the MVP to the improvements are User Stories. User Stories are small simply worded statements that describe a piece of functionality that a system should perform that is linked to the user, their role and their goals. In their purest form they should address, **who** it is for, **what** they expect and **why** is it important to them and be relevant to a concise goal. The crude example in Figure 21 shows how the key components of a user story are framed within the sentence.

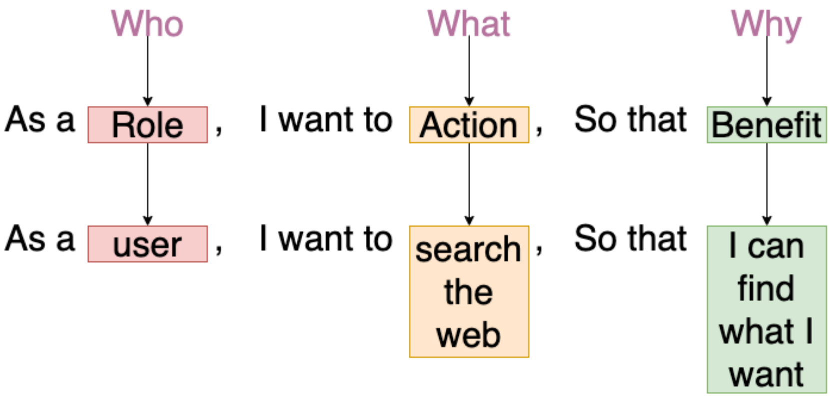

Figure 21 – User Story Outline

While the example given is very crude and the means to achievement it is not a simple one, but it is in fact what the user wants and may need to be broken down further if the user wanted their own custom search engine (in the most complicated scenario) or a simple install of a browser-based search engine on the user's system (in the simplest scenario). If we relate this to edgeFLEX and look to make a similar statement based on the role of the System Operator (SO) where their role is to ensure that the grid functions within operational limits, we can see from Figure 22 that it fits the same narrative.

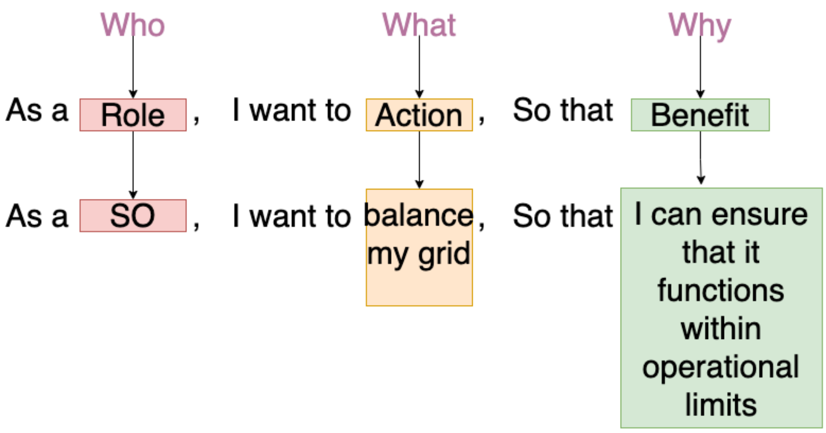

Figure 22 – Grid Balancing User Story

There are potentially many ways that this can be achieved, maybe the TSO can develop a strategy based on Frequency Control or the DSO maybe employ Voltage Control on a problematic section of the network as a means of achievement, but the goal remains the same, to ensure it functions within operational limits. This approach leads to a more fine-grained look at the user story and from this a scenario (or set of scenarios) can be developed from which a clearer picture of how this goal can be achieved is derived. These scenarios are also, like the user stories, a simple set of statements that frame the interaction and are often utilised by software tools that run integration tests on the system. The typical statements that would comprise a scenario would be (strictly speaking) one or (could be) many of the following, **Given** some context, **When** some action is carried out, **Then** a particular set of observable set of consequences should occur and if we create a simple scenario from the outline example in Figure 21 we get the following. This example, in Figure 23 is crude but it does present the means of achievement of the goal of the user or customer and contains a set of statements that detail the most basic preconditions, the simplest action and the most basic outcome.

Given	I have a PC
Given	I have an internet connection
When	I install a browser with an inbuilt search engine
Then	I should be able to search the web

Figure 23 – Outline User Scenario Example

In the context of the edgeFLEX platform the development of the scenarios is a key step in defining the components of the MVP that will fulfil the goal for the SO. Expanding on the Grid Balancing User Story in Figure 22 and taking it from the perspective of the DSO who is looking to employ a Voltage Control strategy on an asset to ensure the grid is balanced and ensure that it functions within operational limits we can develop a basic scenario.

Given	I have an asset capable of receiving a set point
Given	I have a measuring device with connectivity to a databus
Given	I have access to static asset data and operational limits
Given	I have Voltage Control deployed
When	the readings from the asset are detected as being outside the operational limits
Then	a reactive power set point is sent to the asset
Then	the set point is applied to the asset
Then	the readings from the asset return to within the operational limits

Figure 24 – Scenario for Grid Balancing Using Voltage Control

From the scenario in Figure 24 we can identify the components required from the edgeFLEX platform to form the MVP for the DSO that is aligned to a key concern they have in maintaining a balanced grid. If we map, as done in Figure 25, the preconditions that are identified in the **“GIVEN”** statements on to the functional architecture of the components provided within the edgeFLEX Platform.

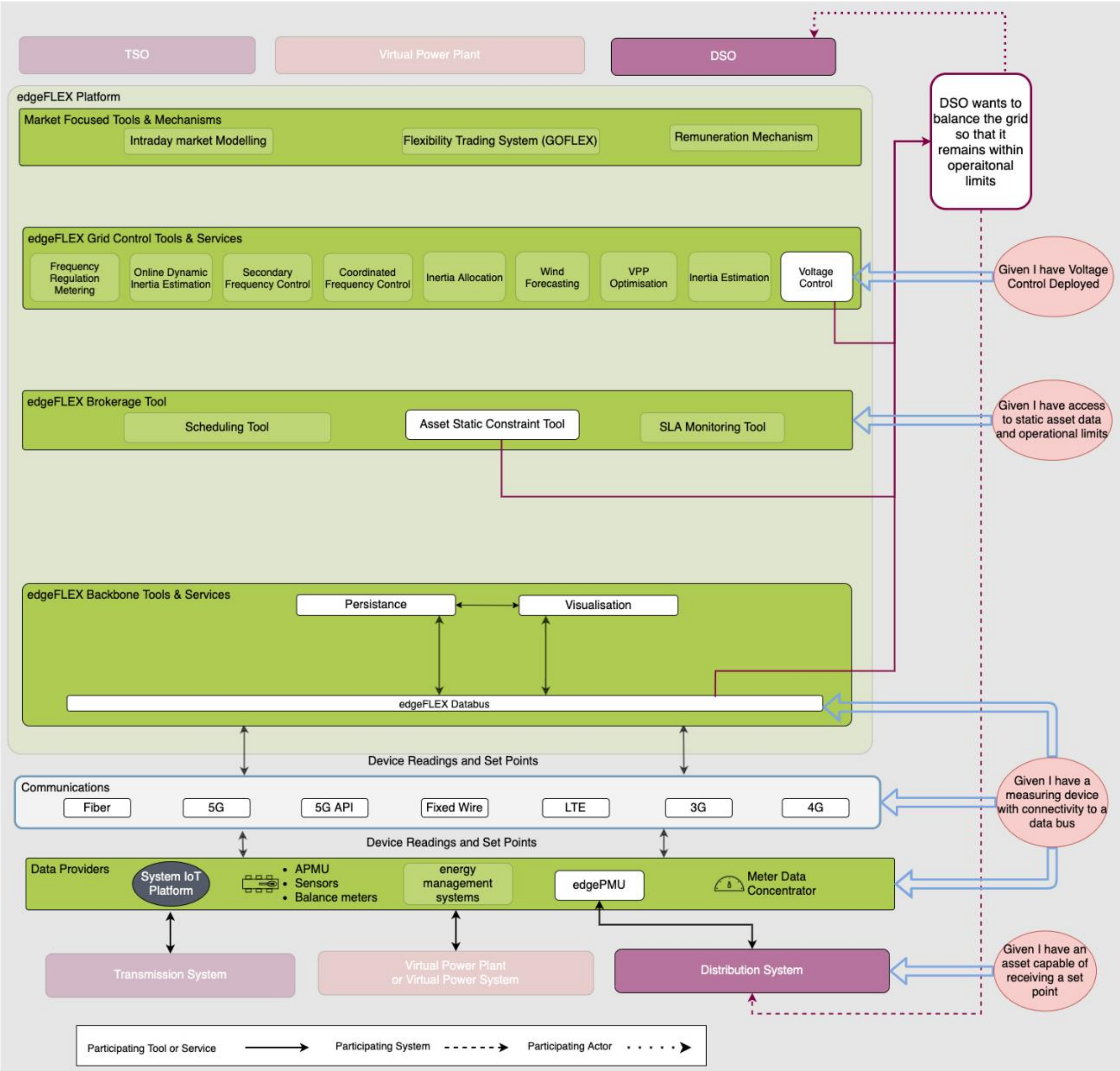

Figure 25 – Voltage Control Scenario Mapped to Architecture

This approach can be applied to any of the actors and their goals and once a scenario or scenarios are defined the components of the MVP can be identified.

The scenario detailed above is a single actor scenario, but it is possible to apply this approach when multi actors are involved and have a complimentary set of goals and aims. For example, a SO and a VPP Operator might have an arrangement where they both work together in order to provide grid balancing so the grid remains within the allowed operational limits. It would be accepted in this case that both actors would have a separate set of goals, and maybe goals that conflict with each other, and for this reason separate user stories would be required. This approach would frame the goals for each actor and place them at the centre of defining the MVP, while the scenarios developed from each user story would identify the components needed from the edgeFLEX platform to form a means of achievement for both actors.

The identification of the MVP components in this way ensures that a concise set of functionalities is delivered to the customer, that is aligned to their goals and is, as far as possible compatible with a typical scenario that can occur in their system.

As already described, the edgeFLEX project is developing different services with relevance for different actors of the energy system / energy supply structure. These services range from grid management to the optimisation of virtual power plants to a combination of services for the realisation of an economic and, if possible, renewable power supply in an energy community that can simultaneously provide grid services for the grid operator. The basis for this is the flexibly adaptable edgeFLEX platform described above, which marries different services to specific solutions depending on the application.

Based on initial and target results, the target groups for edgeFLEX solutions were identified as grid operators - both TSOs and DSOs, VPP operators, aggregators of plants as well as RES owners and energy communities. The diversity of the target groups confirms the modular approach of the platform as well as the multiple options of implementation at the appropriate place (e.g., cloud, user’s hardware) to be available to the user. A first mapping of the edgeFLEX services, as they currently exist but also as they are intended by end of project, to the target groups was developed and is described in Deliverable D6.6 "Preparing Exploitation".

6. The edgeFLEX MVP and its role in the advancement of the VPP

From a technical perspective, edgeFLEX as a project is centred on advancing the role of the VPP by either providing the VPP technological components directly or providing the System Operators with the technological supports to enable the VPP play an extended role in supporting grid operations while fulfilling the growing interests of local energy communities. This will be done by offering the VPP service providers the tools that can enable them to offer new ancillary services to grid operators for flexibility based on fast and dynamic services and advanced optimisations and similarly offering the System Operators with a new market offering them fast dynamics ancillary services and enabling them to locally manage the balancing of the grid increasing its stability. The goal is also to provide smaller RES asset owners and Energy Communities with new techniques enabling them to actively contribute to the stability of the grid.

6.1 The edgeFLEX Platform

In section 3 we describe the edgeFLEX architecture and the services that it frames and in section 4 we describe how it is modular and can be deployed in full or in a use case specific group of components. What this means is that a VPP operator can present a use case and alongside what they currently have deployed from a technical perspective and tailor the edgeFLEX MVP to suit. For example, the VPP might have the components that fulfil the purpose of the edgeFLEX Backbone already deployed for the purpose of data ingress, persistence and monitoring in which case the MVP would just consist of the service to match the use case and the service would be configured to tap into the existing components. Similarly, the VPP might have limited capabilities in terms of measuring, data ingress, persistence and monitoring and in this case a more comprehensive set of edgeFLEX components could be deployed including the backbone and the edgePMU. What this demonstrates is that the edgeFLEX MVP is developed in such a way that its offering is flexible and can be offered in a targeted way that is cognisant of the existing capabilities of the VPP.

6.2 Communications

This chapter describes the 5G solutions and how they can advance the role of the VPP. Some of the 5G solutions described in this chapter are utilised in the project whereas some 5G solutions can be utilised in the future commercial full roll-out deployments. The following 5G solutions are utilised in the project: the 5G device management capabilities exposure, the edge computing and URLLC. In addition to the 5G solutions utilised in the project, the following 5G solutions can be utilised in the future commercial full roll-out deployments: the central cloud, private and hybrid 5G networks and the network slicing.

The **5G device management capabilities exposure** enables simplified utilisation of 5G capabilities hiding the complexity of the network. The following exposure functions have been identified as the most beneficial to the edgeFLEX services and accordingly considered in the project:

- Device provisioning and onboarding,
- Device group management,

Edge computing can host user services by providing execution resources (compute and storage) including networking near to users' premises and devices. Edge computing infrastructure can be integral part of the 5G network or deployed at the network boundary. It can be hosted by communication service providers or other types of service providers such as hyperscale service providers. On the other side, it could be placed at enterprise premises such as VPP and power grid system operator servers. In some cases, user services can be deployed on cloud instances located at different physical sites. In such scenarios, a distributed cloud can be utilised which can be perceived as an execution environment for user services over multiple sites including networking managed as one solution. Edge computing enables deployment of the edgeFLEX services in distributed manner in edge and distributed cloud. The following edgeFLEX services should be deployed using edge computing infrastructures: the voltage control, the VPP optimisation and the advanced trading flexibility service. The main benefits that edge and distributed cloud solutions provide to the edgeFLEX services include low latency, high bandwidth, device processing and data offload as well as trusted computing and storage.

Central cloud can be managed or hosted by communication service providers or other types of service providers such as hyperscale service provider or power grid system or VPP operators. It can host the following edgeFLEX services that should be deployed in centralised manner: the inertia estimation, the frequency regulation metering, the VPP coordinated frequency control and the VPP automatic generation control. Additionally, central cloud can host visualisation components of all edgeFLEX services as well as the edgePMU, SLA monitoring and brokerage tool.

URLLC feature can fulfil the stringent requirements for high communication reliability requested by all edgeFLEX services except for the inertia estimation service. The inertia estimation service requests standard communication reliability since it does not request a real-time communication. Additionally, URLLC provides ultra-low communication latency that is requested by the VPP coordinated frequency control service.

Isolated **5G private networks** deployed in restricted geographical areas can support local communications, for example in VPP facilities, transmission and distribution network substations and the restricted distribution network area fed by a substation. These networks are also referred to as campus networks. Campus networks offer to the network owner, in this case the VPP or system operator, full control over the use and configuration of the network.

VPP and power grid assets are usually distributed over wide areas or even throughout a whole country. They exchange data with the control centre located tens or hundreds of kilometres away. The communication among them can be achieved by combining both private and public networks. The combination of a private and a public network is referred to as **hybrid network**. Different combinations are possible. We foresee that the following combination could be the most applicable to the edgeFLEX services. The radio base station is owned by a private user, a VPP or grid system operator, and the communication between the radio base station and the control centre takes place via the public network. In this combination, it is assumed that all networks provide all services and capabilities required by the private network operator at the defined level, and that corresponding service level agreements are in place between the private network operator and one or more public network operators.

The network slicing ensures the quality of service, reliability and security of the communications on end-to-end basis to all edgeFLEX services while utilising 5G public network infrastructure.

6.3 Measuring

The proposed edgePMU concept aims at providing grid operators with reliable and precise measurements from the grid, enabling the continuous monitoring of the grid state. The low cost approach used in the design of the data acquisition unit allows grid operators to install a significant number of measurement devices, which is highly beneficial especially in the case of distribution grids, where the number of measurements needed for the complete assessment of the state of the grid is quite high and thus reducing the cost of monitoring hardware significantly reduces needed investments and running costs.

On the other hand, a continuous monitoring of the state of the grid allows operators to assess in real time the needs in terms of power balancing and flexibility provision. This will allow more energy stakeholders, including VPP operators, to be part of the active control of the grid by providing balancing services and energy flexibility, especially at local distribution level.

Moreover, the integration in the edgeFLEX platform will allow all involved actors to access, when needed, to grid measurements, or at least part of them. These measurement data can help both grid operators and service providers to optimize their operations and maximise their revenues.

6.4 Control and Estimations

The control and estimation services developed in the edgeFLEX project can provide benefits to both grid operators and VPPs. System operators can better monitor their grids and control them in real time. They can assess the need of power balancing or flexibility quickly and decide how to acquire such services either from assets directly under their control or from other stakeholders and energy actors such as VPPs. Monitoring the system state and estimate the overall system inertia provides system operators with a clear understanding of the actual status of the systems as well as its robustness and can allow them to identify ahead of time possible criticalities and procure the needed flexibility and reserves to avoid degradation of power quality or even critical behaviours.

This knowledge of the system's needs translates directly into a precise assessment, both in terms of quantity and in terms of geographical distribution, of the grid's needs and this will enable also local energy communities and VPPs to actively participate into the grid control and stability by providing dynamic services to system operators.

The inertia estimation service provides the System Operator (SO) with estimates of the overall inertia and damping present in the system. Such knowledge could be utilized for different applications and would result in the following benefits: (i) reducing the operational cost for the SO by planning the network operation according to the available inertia at any given moment instead of considering the worst-case scenario, (ii) enabling higher penetration levels of renewable energy resources while ensuring the system stability and (iii) better market design for grid ancillary services.

The inertia allocation service constitutes an optimal scheduling problem of the VPP resources to enable them to participate in providing frequency support with a minimum energy storage capacity. The primary objective of the service is minimizing the cost of participating in grid frequency support and maximizing profits of VPPs.

Frequency control: The control strategies for primary and secondary frequency regulation developed within edgeFLEX and integrated in the edgeFLEX platform enhance the dynamic response of VPPs following severe power imbalances and thus improve the dynamic performance and increase the stability margin of the overall power system. Moreover, the frequency control services developed in the project are based on coordinated control of individual resources, which facilitates an efficient use of the available power reserve within the VPP. As a relevant by product, the proposed coordinated control fosters the participation in the energy market of small DERs because the task to manage the provision of flexibility is taken up by the aggregator and thus individual risks for small resources are avoided. The metering of frequency regulation according to the proposed in the project Rate-of-Change-of-Power (RoCoP) index [see deliverable D2.2] provides a novel solution to the challenge of determining through simple measurements "whether" and "how much" a device connected to the grid does control the frequency at a given time, thus helping the TSOs better monitor the state of the system, be proactive, and reward the VPPs in proportion to the provision of the service.

6.5 VPP Optimisation

Among and jointly with the other services of the MVP, the VPP optimisation is proposing added value to the user by allowing for him to extract more economic value from its conjunction of flexible and intermittent assets by managing them depending on one from the others (as a Virtual Power Plant) instead of independently.

The role of the VPP optimisation algorithm in the Minimal Viable Product is decoupled from all the other services, in the sense that it is a stand-alone approach that exist on its own, does not depend on others (except eventually for weather and price forecast data) and also do not feed other services.

The aim of the optimisation is to maximise the total revenue of the system of the assets involved in the VPP while providing balancing to the portfolio of wind parks. This involves weather and price forecasts which are used as the inputs. Price forecasts are directly used as inputs. Weather forecasts, or in other words production forecasts, are used for the modelling of the imbalance.

I.e., the historical differences (realised production vs forecasted production) are used for the modelling by means of autoregressive models. Then based on the autoregressive models, a predefined number of scenarios is used as inputs in the robust model predictive control. In this case instead of using a single scenario of imbalances, we use many scenarios for decision making, but many scenarios are used for decision making. The result of the optimisation is a schedule for biogas power plants and a battery.

6.6 Policy Based Grid Management

Engagement between sector actors is an important component of how the grid operates, there are agreements and market mechanisms between sector actors that are mature and those that are evolving with digitalisation of the grid. Policy Based Grid Management (PBGM), of which the edgeFLEX Brokerage and SLA Monitoring tool is a component, could, in the future, play an important role in the engagement between the VPP and other sector actors. This new method of engagement would allow negotiated policies to be created and defined by sector actors that would frame the terms of engagement between smart systems and assets running on both sides. These policies could be defined by the sector actor for use in their own system or be defined by one sector actor for use by another. In Figure 26, we list the categories of policy that we have identified so far that would enable the creation of use cases that would help advance the role of the VPP.

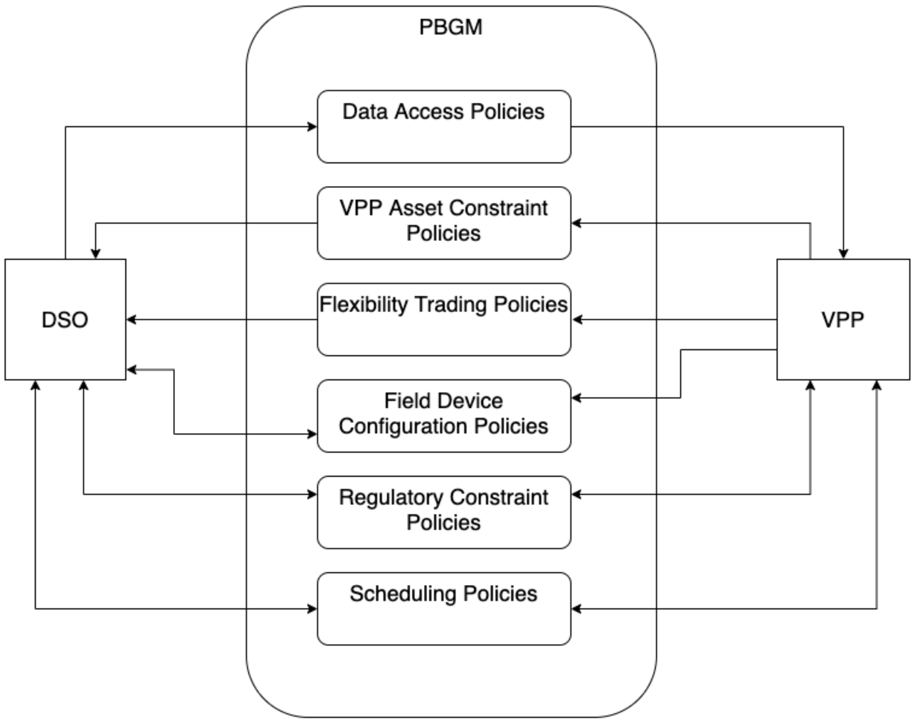

Figure 26 – PBGM Policy Categories

In terms of their potential role in the advancement of the VPP we can describe each category as follows:

- Data Access Policies: these policies can be used to expose data streams or data models and repositories from the Grid Side to the VPP so that they can better inform their decision-making processes and asset management.
- Asset Constraint Policies: these policies can be used to provide operational constraints or constraints on the level of participation of an asset. These policies would be used, upon request, by algorithms, such as Voltage Control or Frequency Control.
- Flexibility Trading Policies: these policies would be used to provide the details and rules of engagement for interactions between mechanisms that can trade flexibility between

the Grid Operator and the VPP. In edgeFLEX this is being caried out in a use case that is using a combination of Voltage Control and the FlexOffer protocol to utilise the assets from both the DSO and the VPP to maintain a stable grid.

- Field Device Configuration Policies: these policies can be used to remotely configure devices at the edge in a way that can enable them to connect with endpoints or data buses so that the devices at the edge can dynamically switch endpoints or be configured without the need for expert knowledge by the installer in terms of their expertise in communications.
- Regulatory Constraint Policies: these policies can be used to facilitate the input of grid code constraints and regulations as policies so that the PBGM system can validate interactions and the outputs of algorithms to ensure that they are being obeyed.
- Scheduling Policies: these policies can be used to run services or algorithms based on timings or triggers that are based on Frequency or Power changes.

By being able to define these policies and, where required, have them shared in a cross-sector way, so that they can form a new method of engagement between system actors that is linked to the business operations by the creation of the policies through negotiation between entities and have those policies enacted upon in an autonomous way by systems on both sides will advance the role of the VPP.

The role of PBGM as part of the MVP for edgeFLEX serves as an enabler for the other services to operate and as such provides a way for the services to be more flexible by abstracting the actual asset or trial site specific bounding's, schedules and meta data as Asset Constraint Policies and Scheduling Policies so that the software wrapping the algorithms can be built independently of trial site constraints. This is an important feature of the edgeFLEX MVP as it allows the grid services and the interactions with the flexibility trading elements take place in a way that requires minimal configurations of the algorithms or the hosting platforms allowing the MVP and its components be trialled by the customer is a less invasive way. It may also facilitate the portability of the services between System Operators and even allow them to be portable in different regions.

6.7 Flexibility and Reactive Energy Trading

The FTP is capable of trading matching several types of flexibilities, which beside the active energy can be also the reactive energy. The important condition is that flexibility description and its matching is based on price optimisation.

The reactive energy trading beside matching on FTP involves also the

- Description of the flexibilities on devices, which are capable to provide reactive energy
- Formation of adaptation request for reactive energy from DSO

6.7.1 Formation of the reactive energy flexibility

The prosumers offering reactive energy flexibility need to possess corresponding loads. The advanced control of the smart inverters on battery storage CHP or PV enables the prosumer to balance the ration between active and reactive energy. There are two approaches at formulation of the reactive energy flexibility

- The prosumer describes the flexibility with variation of apparent power and “cos phi” angle. This approach is close the technical feature of the smart inverter, because the amount of active and reactive energy flexibility depends on each other (larger amount of active energy reduces the amount of reactive energy and vice versa
- The prosumer describes the active and reactive energy separately. This approach enables separate pricing for active and reactive part.

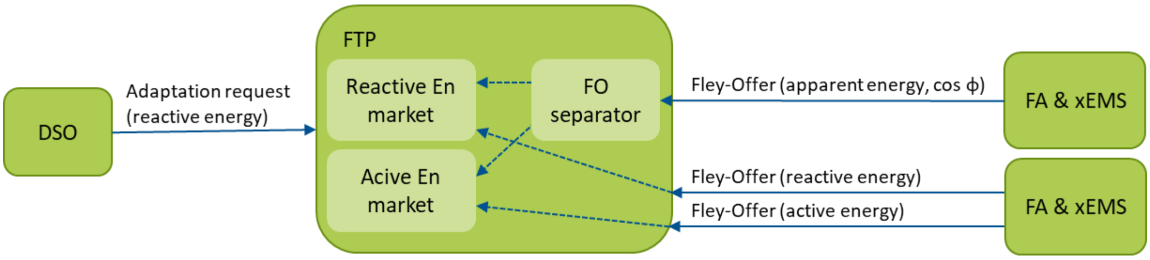

Figure 27 – Transformation to the reactive energy

6.7.2 Matching and assignment

The reactive energy trading is based on the same concept as market focused tools in 3.7. It uses auction technic with price optimisation.

In the case the prosumers use the apparent energy for the flexibility description the FTP algorithm of FO separation splits it into active and reactive part, where minimal and maximal constrains od the power factor is used. The flex offers are used exclusive – when one is activated the other is abandoned.

The FTP is capable to run several reactive markets concurrently for several grid locations as described in chapter 3.7.3.

At the assignment the operation schedule is created and sent to each prosumer. The operation schedule contains a time series of energies with both variation parameters – energy and power factor – fixed.

7. The edgeFLEX MVP and the Trials

Given that we have the MVP(s) defined for the customers at the given trials and these trials are running it is key that the assessment of the MVP takes place then and continuously for the duration of the trials so that the maximum learnings can be garnered about how the customer engages with the MVP, the evolution of the MVP and the impact of the MVP on the customer's business process or systems. This will be carried out through the edgeFLEX Improvement Model in Figure 28 where on a bi-monthly basis the MVP will be assessed and feedback will be relayed, interpreted, logged and if actionable improvements made and redeployed in the trials.

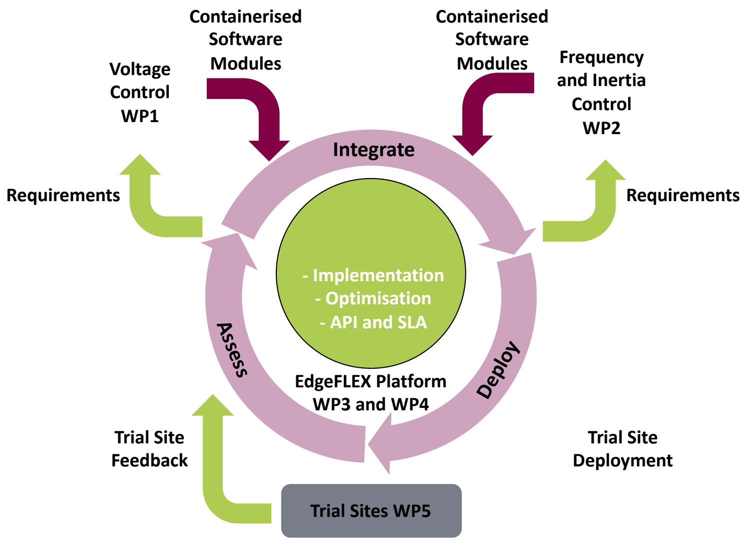

Figure 28 – edgeFLEX Continuous Improvement Model

The evaluation of the MVPs will use Task 4.6 as a point of contact to receive the evaluations from a technical perspective with WP6 taking a more business and societal view of the evaluation. To assess the MVP technically an evaluation form will be sent to the trial and completed bi-monthly. This evaluation will assess the MVP under the following criteria.

- Electrical: meaning that for whatever reason or constraint the electrical system will not allow the component to interact with it or be deployed on it.
- Communications: meaning that the communications capabilities on the trial are not at an acceptable level to allow to enable the service to run effectively in terms of data flows or monitoring.
- Software: meaning that the required components is not developed to a level that allow them to be deployed in the intended way on the trial site.
- Hosting: meaning that at the trial the service cannot be hosted as intended, one example would be having a database outside company boundaries because it cannot be hosted.
- Algorithm: meaning that the algorithm is not performing to a level, or it is not having the desired results.
- Security: meaning that the trial site is not secure or that the edgeFLEX components do not have an adequate level of security built into the platform.
- Data Access: meaning that the required data is not available at the trial at either an adequate volume, sampling rate or payload format for it to be picked up by the platform.

Assessing the MVP under these criteria will not only serve to improve the edgeFLEX platform by improving the MVP components but will also help learn about the customer in a manner that will gauge the level of positive the MVP is having on their system and processes through the monitoring of the performance of the MVP. At the time of writing this report the platform has been deployed in a laboratory trial in the 5G lab by Ericsson and the assessments carried out, while the results from an ICT perspective are still being correlated for the actual tests the assessment of the software and platform has been carried out. The assessment and the findings are now being ingested into WP4 where some refactor work will be carried out prior to redeployment.

8. Conclusion

The purpose of this deliverable is to provide the reader with a description of the edgeFLEX MVP, what components it consists of, how it is linked to the user, how it can advance the role of the VPP and how it can be used in conjunction with the field and lab trials to gain an insight into the customers and by doing so make the components of the MVP better. In the early stages of the project, we identified that the scope of the project and the activities undertaken are broad with a diverse set of technological, market and regulatory research and innovation actions all working towards the same goal. The broad scope is reflected in the nature of the edgeFLEX MVP and it was identified that there is not one MVP for edgeFLEX but rather many MVPs that can be derived from it. Each MVP is specific to the customer, what their goals are and what their current capabilities are from a technological and electrical perspective.

In Phase 1 of the project the activities from a WP 4 perspective centred on defining the architecture of the edgeFLEX platform based on the requirements gathered from the technical work packages, WP1, WP2 and WP3 and from that architecture the platform was built with the concept of modularity firmly at the forefront. It is this modularity that allows subsets of the components of the platform be used to accommodate the different MVPs. This is core to the platform and can enable the customer specific MVP to fit the architectures defined by the customer's infrastructure and on-site capabilities. Furthermore, the concept of edge computing is a core aspect of the design of the edgeFLEX platform and MVPs, where applicable, can avail of the features of 5G to enhance reliability, performance, and security by specifically harnessing the capabilities of network slicing, the 5G device management capabilities exposure, URLLC and the edge cloud.

As identified in section 2 the main function of the MVP is to learn about the customer and how they use the MVP with a view to refactor the MVP and its components to advance it towards being a product through refactoring. As the components of the MVP may be shared across other MVPs it was found necessary to define a common set of criteria around which the MVP could be assessed in the trials. This assessment will provide insights on the customers and how they intend to use the components of the MVP and will directly feed into the edgeFLEX improvement model that will drive the refactoring of the components and coupled with the gathering of measurable KPIs and customer engagement activities, provide a coherent view of the customer and how the platform overall will shape their activities.

For the remainder of the project the MVPs currently identified will be assessed in their relevant trials and the feedback used to learn more about the customers and in tandem feed development tasks to make the components better. At the time of writing an MVP centred on a customer wanting to control frequency is being trialled in the EDD lab trials over the 5G network and this assessment is currently being ingested into the improvement model to firstly learn how the components performed and secondly what is needed from a customer perspective to allow a real-world application of such a deployment. The first phase of the project has identified a synergy between potential customers of the edgeFLEX platform where an MVP could be shared or at least span a common use case, where a DSO and a VPP can share common components and functionalities to engage in order to maintain acceptable operational limits in terms of voltage. Further steps to fully explore and implement this common use case are ongoing and a core aspect of this is to explore how both customers use the MVP and further enhance it with new features, like Model Predictive Control to enable the Voltage Control Service decide when to engage with the VPP and a controlled data sharing element to the Policy Based Grid Management system to allow the VPP to have controlled access to data from the DSO to enable better decision making on their part.

With the impending rollout of Redispatch 2.0 in Germany the edgeFLEX platform will have a new context in which to be assessed and viewed and until the remainder of the project the MVPs, particularly those trialled in Germany, will need to be assessed in this context. Furthermore, explorations will be carried out around how the components of the edgeFLEX platform mentioned in section 3 could potentially play a role in helping actors become Redispatch 2.0 compliant.

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11. List of Abbreviations

ADM	Architecture Domains Methodology
API	Application Programming Interface
ATP	Automated Trading Platform
CSV	Comma-separated values
DB	Database
DER	Distributed Energy Resource
DG	Distributed Generator
DMS	Data Management System
DOMS	Distribution Observability and Management System
DSO	Distribution System Operator
EEX	European Energy Exchange
EMS	Energy Management System
ESS	Energy Storage System
FA	FlexAgent
FMAN	Flexibility Management
FMAR	Flexibility Market
FO	FlexOffer
FOA	FlexOffer Agent
FTP	Flexibility Trading Platform
GMAN	Grid Management
GUI	Graphical User Interface
HEMRM	Harmonised Electricity Role Model
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
KPI	Key Performance Indicator
LEC	Local Energy Community
LTE	Long Term Evolution

MBA	Market Balance Area
MQTT	Message Queue Telemetry Transport
MVP	Minimum Viable Product
PBNM	Policy based Network Management
PMU	Phasor Measurement Unit
PV	Photovoltaic
RES	Renewable Energy Source
REST	Representational state transfer
ROCOF	Rate of Change of Frequency
ROCOP	Rate of Change of Power
SLA	Service Level Agreement
SSL	Secure Sockets Layer
TOGAF	The Open Group Architecture Framework
TSO	Transmission System Operator
UDP	User Datagram Protocol
UE	User Equipment
VNF	Virtual Network Function
VPN	Virtual Private Network
VPP	Virtual Power Plant
VPS	Virtual Power System
WP	Work Package