edgeFLEX

D4.4

Description of assessment of platform control service performance

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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 provision and trading combined with enabling solutions such as Service Level Agreement Monitoring tools, edgePMU devices and 5G capabilities. Core to the activities of the edgeFLEX project is the improvement model based on the Agile Methodology that has been adopted since the beginning of the project. This report details how the control services and platform components are assessed and how the assessment process feeds into the Agile process. The report describes the assessment criteria and the process used to assess the components from their development to their implementation in the trials. The report also details the findings from the assessments and explores the potential actor targeted assessments that might be required to enable a widespread adoption of the edgeFLEX control services throughout industry.

Keyword list
Agile Methodology, Assessments, Architectures, Interfaces, Control Services, Voltage Control, Inertia Estimation, Frequency Control, Actor Targeted Assessments, Usability, Feedback

Executive Summary

The edgeFLEX platform is a core element of the edgeFLEX project as it enables deployment of each of the control services as well as communication of data and control messages between the control services and external interfaces. The platform was initially developed as a Minimum Viable Product (MVP), based on the requirements gathered in phase 1 of the project. In phase 2, the trials in WP5 are used to validate and improve upon the MVP as part of an iterative development cycle of deployment, gathering feedback, and further development. This report will detail the approach used to undertake this assessment as well as some of its preliminary findings.

This report gives an outline of the edgeFLEX architecture based on the work completed in phase 1 with a description of the various control services. Since there are a number of various deployment configurations depending on the use case, components of the platform are detailed from the perspective of trial site deployment and the user experience.

The report goes on to detail the criteria under which the platform would be assessed, which fall under the two categories of technical and user experience criteria. The technical assessment involves evaluating whether the platform can be deployed, where the components should be deployed and why, and whether the outputs of the services are actionable. Assessing user experience involves evaluating whether persons working with the services or platform can use it easily.

In creating the platform assessment, it was determined that the assessment should be carried out by multiple actors to ensure that it was comprehensive. The report details the various types of actors that should be involved in the assessment. In involving persons from different areas within an organisation, the aim is to increase confidence in the platform and to establish it as part of their usual suite of tools. This is an area that should be expanded upon as future work to improve uptake of research outputs at industry.

As mentioned previously, the technical work within the edgeFLEX project is completed as part of an iterative process of continuous assessment and continuous improvement in a manner consistent with agile methodology. When the platform is deployed at trial sites it becomes possible to gather feedback through assessment. Once the results of the assessment are gathered, development and refactoring work is carried out based on the feedback. This work is then integrated and redeployed, and the assessment is carried out again, forming a feedback loop. Future work will be undertaken to standardise this feedback process, as well as to expand the scope of the assessment process.

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1. Introduction

In the early stages of the edgeFLEX project, the focus was on defining and developing the platform given the requirements gathered from both the control services and trial sites. The output of this was an architecture, modelled on the SOGNO reference architecture, that encompassed the Flexibility Management systems from the GOFLEX platform. From this architecture a set of MVPs were defined based on a set of use cases derived from the customer needs, where the Control Services are used to solve problems in the grid in collaboration with VPP Optimisation and Flexibility Focused techniques. This architecture was facilitated using data persistence, secure data buses and monitoring, and utilised other outputs of the edgeFLEX project. These include the edgePMU and Policy Based Grid Management system, in conjunction with the use of 5G features. These tools are also forward scalable into a grid where 5G is deployed on mass.

This report will present an overview of the control services and the architecture that underpin them with the main goal of the report centred on detailing how the control services were assessed, the findings, and how the project team used the findings to form a feedback loop where the services and platform components were refactored and further developed to meet the needs of the trials, the customers, and the grid.

1.1 Related Work

The precursors to this report are:

- ***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, the requirements, both functional and non-functional, gathered from WP1 and WP2 and using them to frame the edgeFLEX MVP.
- ***D4.2 Description of edgeFLEX MVP***, where the platform and components are described in the context of the customer and in how the user's goals and aims can, using the edgeFLEX offering derive a solution and
- ***D4.3 Description of internal interfaces for control,*** where we describe the interfaces that enable the platform components to communicate with each other and also with the existing components at the trial sites.

The control services from WP1 and WP2, the VPP Optimisation, the edgePMU and the 5G Device Management 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, how the solutions derived from it feed into the activities in WP6, 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, 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. The work in this report will feed into the exploitation and end user assessment and engagement tasks in WP6.

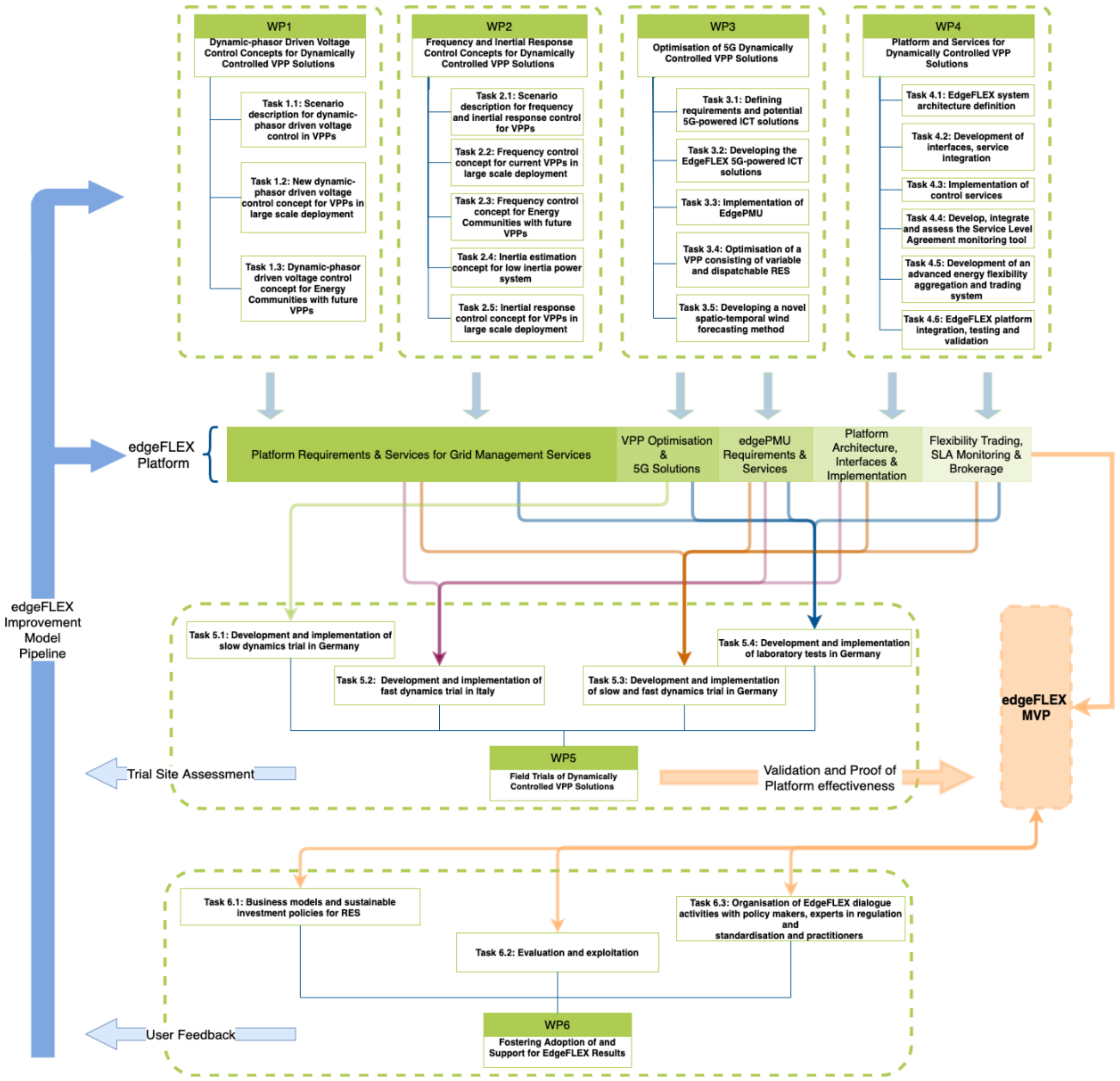

Figure 1 - edgeFLEX Tasks and their Assessment of the Control Services

1.2 Objectives of this Report

The main objective of this report is to detail how the edgeFLEX Control Services and the components that enable them are assessed. The assessment will take two main focuses, from the trial site perspective and from the perspective of the customer.

1.3 Outline of this Report

This report (in Section 2) provides an overview of the architecture and the control services to give context to the components that are to be assessed. The report then (in Section 3) details the assessment criteria under which the control services are assessed from technical and usability perspectives. Section 4 outlines how the control services can be assessed in different contexts and how it is pertinent to present the separate assessment criteria to the most suitable actors for validation. Core to the edgeFLEX project from a technical perspective is the assessment process and the project wide feedback loop, which is detailed in Section 5. While the assessment of the control services will be ongoing until the end of the trials, Section 6 will present the findings from the trial sites to-date and will outline where the improvements have been made to the control services based on the feedback. Finally, this report will summarise the work presented and conclude with some future work discussion around how continuous assessments and the feedback loop could be standardised and utilised in similar research actions.

1.4 How to Read this Document

This report follows up on the previous 3 deliverables, D4.1, D4.2 & D4.3 which describe the edgeFLEX platform and their components from design, customer, and data transfer interface perspectives. In there we mention such concepts as Voltage Control, Inertia Estimation, VPP Optimisation and Frequency Control; while they provide high-level details, 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
- 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, D3.3: Report on VPP optimisation, V1 and V2

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.

2. edgeFLEX Platform Overview

The edgeFLEX platform has been envisaged as set of loosely coupled configurable services which can be deployed in a centralised, decentralised or hybrid method depending on the specific use case. This flexibility means that the edgeFLEX platform can be deployed and configured in a way that best suits the specific requirements for the user while enabling interaction with field devices, the flexibility market, grid management, control services, and optimisation. Using Policy Based Grid Management (PBGM), these interactions can be controlled via user-defined policies meaning that the operational bounds of control services, device configuration and flexibility requests can be updated and changed dynamically as the needs of the system changes over time. The following section will provide an overview of the edgeFLEX platform architecture, describing the key components that enable these interactions and how the edgeFLEX platform enables dynamic operation of the VPP. Also included is an overview of the control services and how the interaction with the edgeFLEX platform enables dynamic control of the grid in the context of voltage control, frequency control and inertia estimation.

2.1 Architecture

To guide development of the edgeFLEX platform, a functional architecture was derived which describes the system actors, components, services, field devices and communications. In this way, the functional architecture captures all elements of the edgeFLEX platform including data collection and communications between internal and external services and entities. Figure 2 presents the edgeFLEX functional architecture, with the edgeFLEX backbone tools and services highlighted, as these services (as the name suggests) provide the key interfaces between the field, platform services, external systems (e.g., flexibility trading), data storage and visualisation.

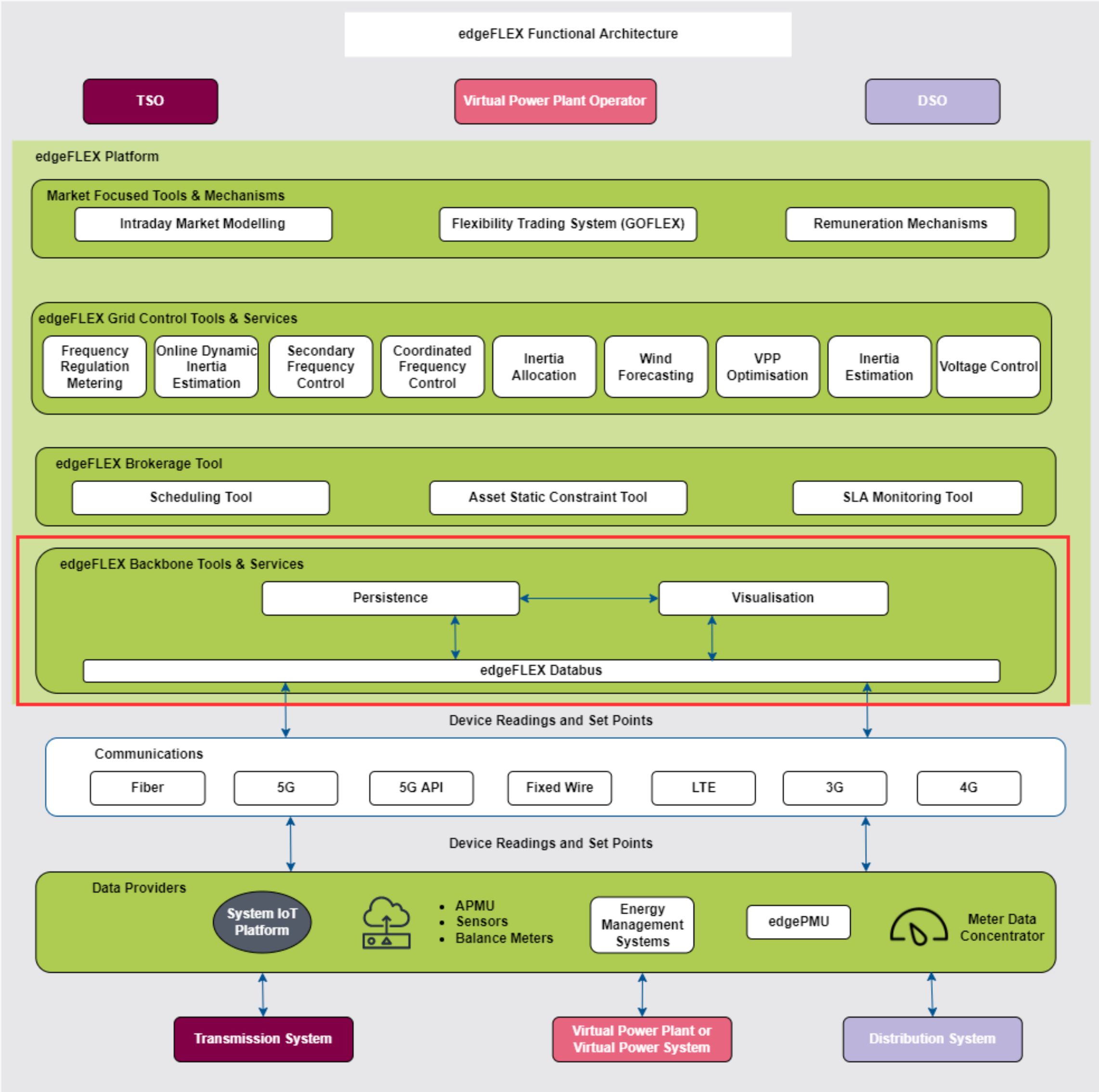

Figure 2 - edgeFLEX Functional Architecture

It is important to note however, that system operators have the capability to deploy only the components and services that they need, as is consistent with the configurable and flexible nature of the edgeFLEX platform. Therefore, the functionality provided by components such as the edgeFLEX persistence and visualisation services may be served through existing services in the SOs current system and are enabled by the internal and external data interfaces included in the edgeFLEX platform. Figure 3 below illustrates a use case for the voltage control service which describes how the edgeFLEX platform services and interfaces are utilised to enable operation of the control service and interaction with external entities such as the edgePMU, PBGM system and KIBERnet.

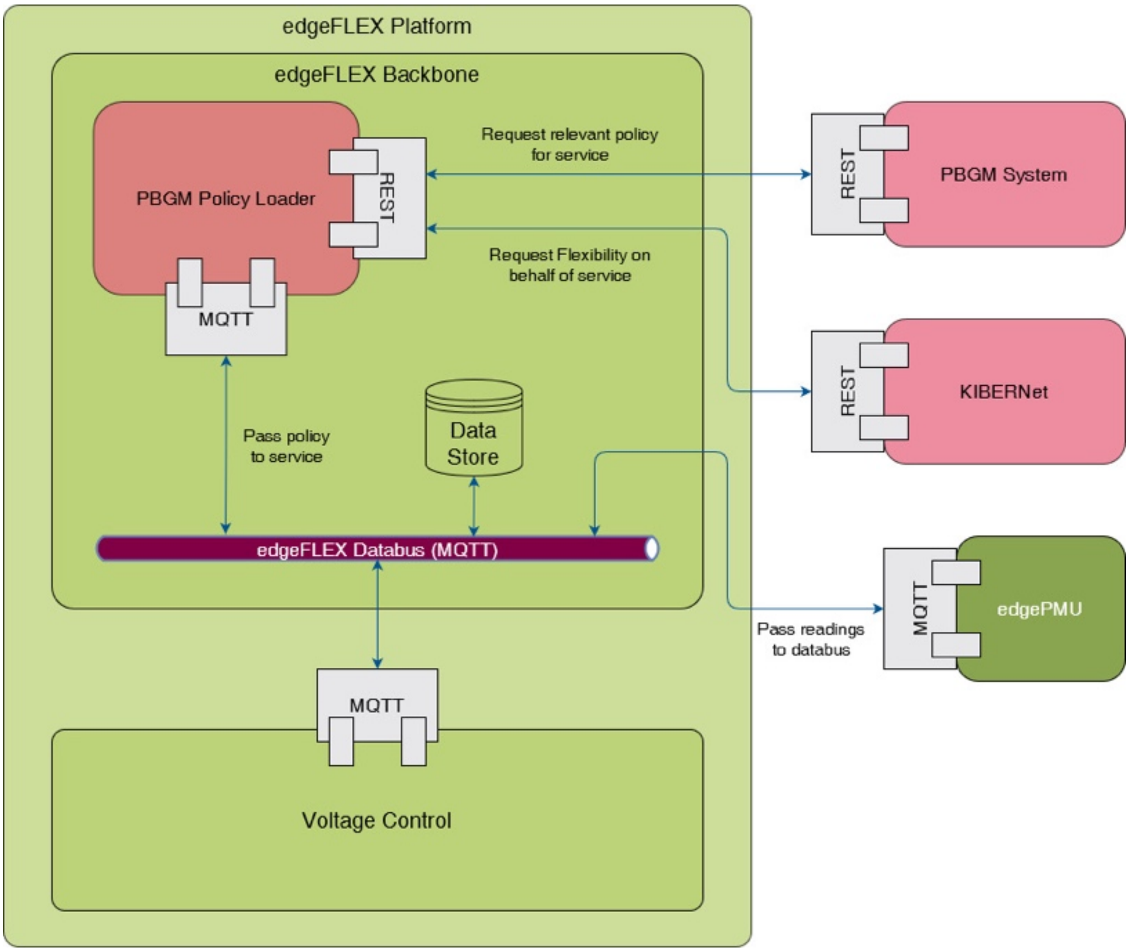

Figure 3 - edgeFLEX Platform Voltage Control use case interaction

As briefly described previously, each use case is unique and therefore the edgeFLEX platform has been designed to be loosely coupled, thereby supporting several deployment architectures to facilitate as many use cases as possible. Several example deployment architectures are described in more detail in D4.3 – Description of Internal Interfaces for Control Services, namely Centralised, Decentralised and Hybrid Edge. Figure 4 below illustrates an example of a decentralised deployment of the voltage control use case presented in Figure 3. In this example, the voltage control service is deployed at the edge of the network in a substation with data supplied via the main databus in the edgeFLEX platform, which also provides an interface for field devices (edgePMU) and policy loader, and to external systems such as PBGM and KIBERnet.

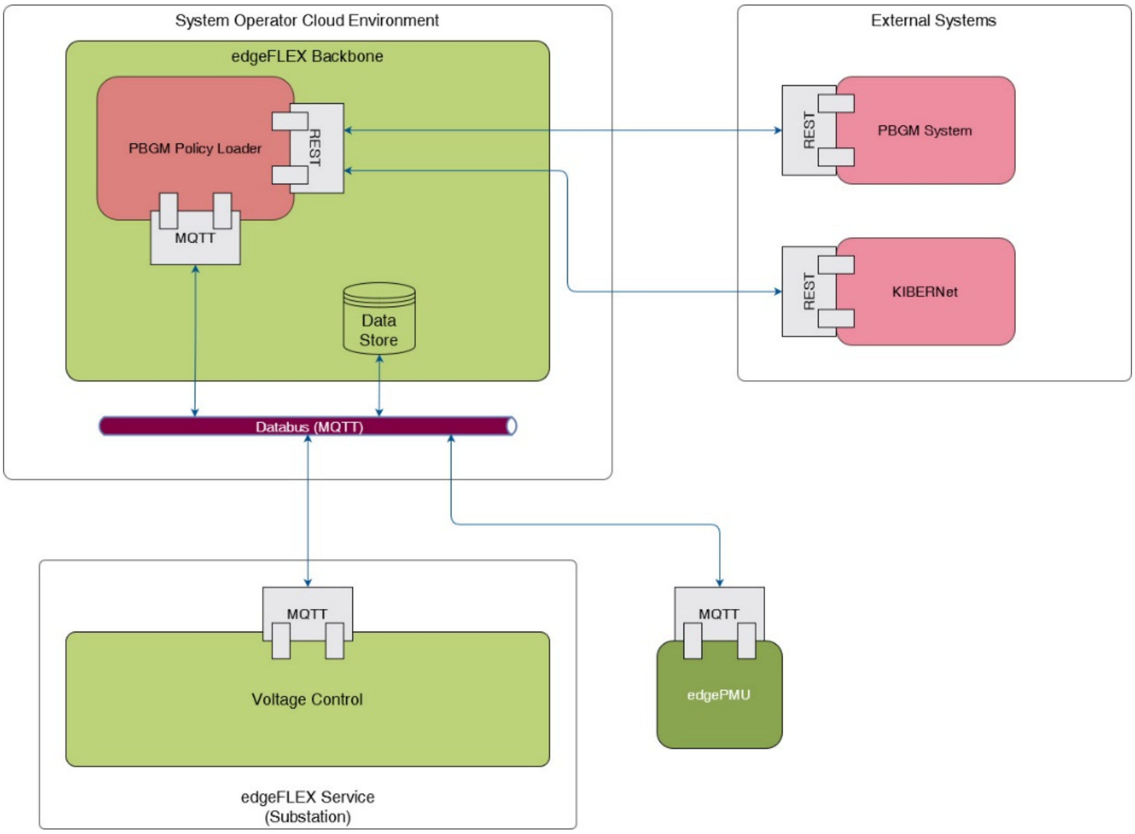

Figure 4 - Decentralised Voltage Control use case deployment

This use case deployment demonstrates the flexibility of the edgeFLEX platform, informed by the functional architecture developed in the early days of the project.

2.2 Control Services

Several control services such as Voltage Control, Inertia Estimation and Frequency Control may be deployed with the edgeFLEX platform depending on the use case as shown in the architecture above in Figure 2.

2.2.1 Frequency Control

Frequency Control in the edgeFLEX platform encompasses coordinated frequency control, secondary frequency control (also known as automatic generation control) and frequency regulation metering, each of which is detailed in D2.2 – Frequency Control Concepts for Current VPPs in Large Scale Deployment. The purpose of frequency control is to correct fluctuations in frequency resulting from power imbalance. In a conventional power plant, the frequency is corrected first by the primary frequency control (PFC) by varying the active power output of the generators over course of different time horizons, up to tens of seconds, then by the secondary frequency control (SFC) which restores the reserves of the generators and corrects the power exchange between the interconnected power systems over the course of several minutes. In the case of the VPP, the coordinated frequency control approach proposed in D2.2 uses a control structure similar to that of the conventional SFC within the same time scale as the PFC in order to improve the fast frequency response of the VPP. Frequency regulation metering provides an approach to determine if a device is providing frequency control at a given time. The following services are required to support the frequency control services and enable the required post-processing:

- edgeFLEX persistence
- Policy Based Grid Management event service

- Grafana visualisation
- edgeFLEX databus or existing MQTT broker

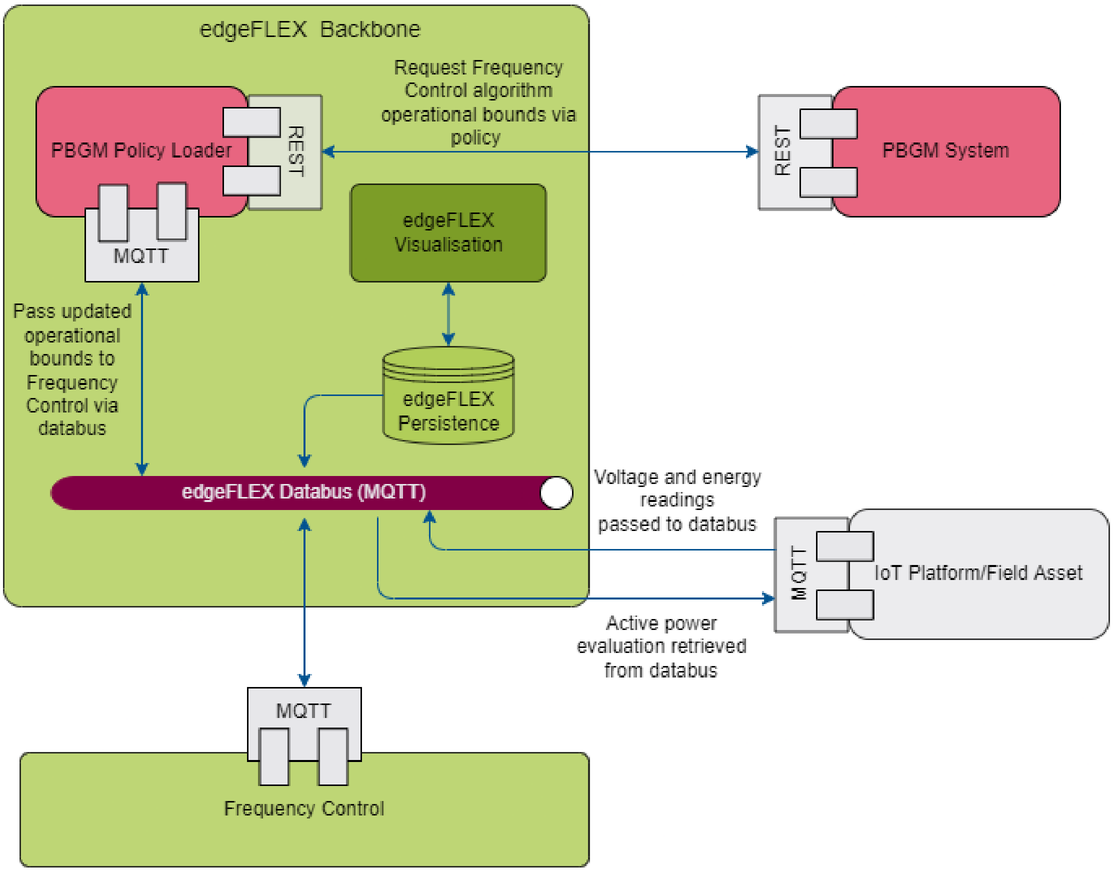

Figure 5 - Frequency Control within edgeFLEX architecture

2.2.2 Voltage Control

The purpose of voltage control is to ensure that the voltage at each of the nodes within the distribution grid remains within the defined limits. The edgeFLEX voltage control service utilises a dynamic-phasor driven voltage control algorithm detailed in deliverable D1.2 – Dynamic-phasor Driven Voltage Control Concepts for Dynamically Controlled VPP Solutions. The algorithm makes use of the phasor measurements of the voltage obtained by the edgePMUs in order to regulate active and reactive power injection, which allows the algorithm to control the voltage. The voltage control service interfaces with the edgeFLEX platform using the MQTT protocol and may be tested using the Powerflow service, as detailed in D1.2.

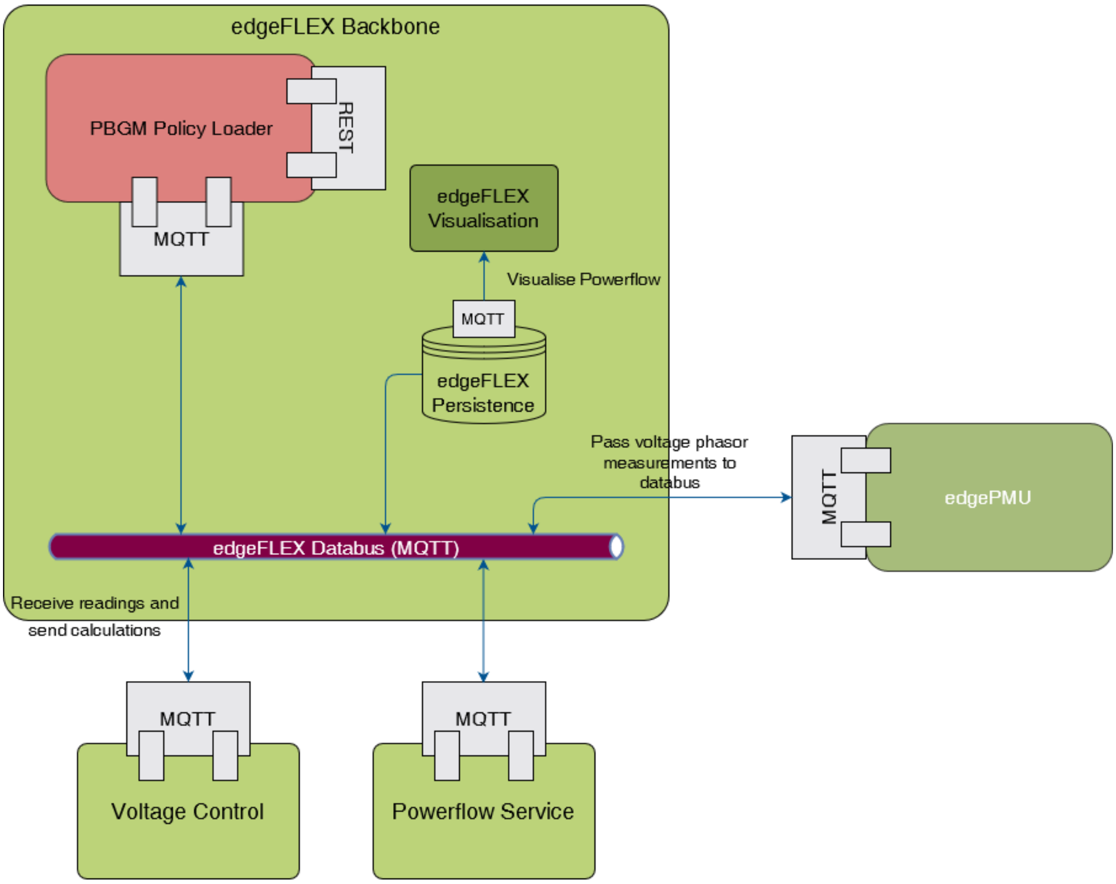

Figure 6 - Voltage Control within edgeFLEX architecture

2.2.3 Inertia Estimation

The edgeFLEX inertia estimation service allows the System Operator to accurately estimate the overall system inertia using an algorithm detailed in D2.4 – Inertia Estimation Concept for Low Inertia Power Systems. The algorithm applies post-processing to frequency and active power measurements from the grid and subsequently performs parametric regression to produce the inertia estimation. The following services are required to support the inertia estimation service and enable the required post-processing:

- edgeFLEX persistence
- Policy Based Grid Management
- Grafana visualisation
- edgeFLEX databus or existing MQTT broker

The inertia estimation service makes use of REST and MQTT communication protocols.

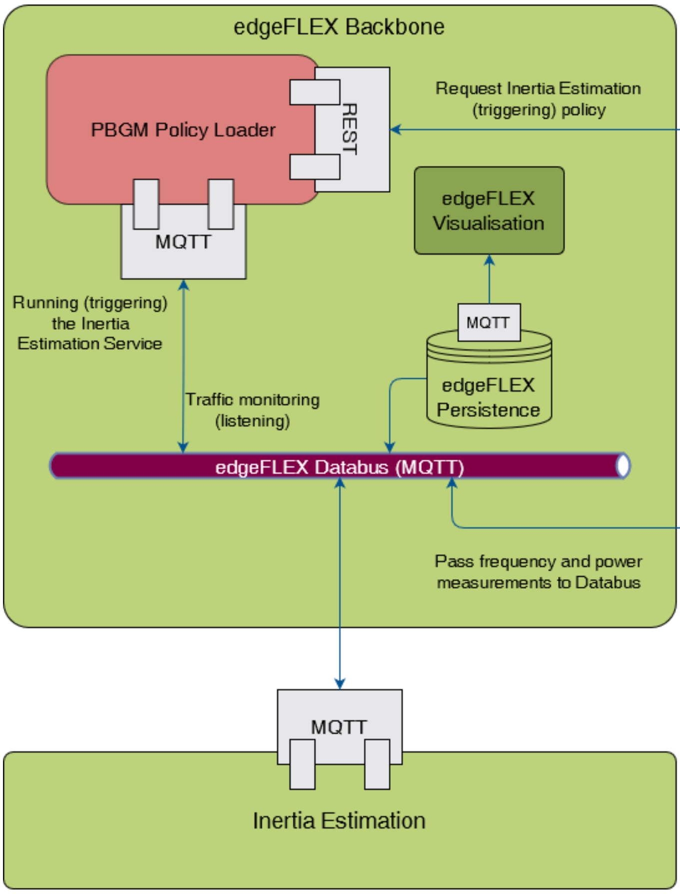

Figure 7 - Inertia Estimation within edgeFLEX architecture

3. Assessment Criteria

To assess the performance of the control service platform it was necessary to view the platform from two perspectives, a technical perspective and from the perspective of the user. This provides the developers of the control services and of the platform with a multifaceted assessment that can ensure that the technical standards are aligned to the user's goals and needs.

3.1 Technical Assessments

3.1.1 Electrical

The edgeFLEX platform and the control services are designed to integrate with existing electrical systems which require assurance that what is deployed is interoperable, safe and beneficial from an electrical perspective. Therefore, the platform and services are assessed with the electrical system in mind. The assessment evaluates whether the control service can be deployed and can control the asset, as well as the impact of the control service on the grid and whether it is beneficial. The aim of this assessment, and having it carried out continuously, is to discover ways to modify the control service, so that it can be improved, and thus providing a more interoperable, deployable, and electrically beneficial component. The findings of this assessment criteria would be directed to the researchers responsible for the development of the control service so that they could refactor the technique to better fit with the electrical system current in place.

3.1.2 Communications

The edgeFLEX platform is built in a way that is modular and designed to ensure that there is an effective and adequate flow of data to the control services and of control signals to the assets. The communication's capabilities can change the architecture required to ensure that the control service is performing at an optimal level. Prior to the development of the platform, an extensive set of requirements was gathered from both the service and platform developers and from the trial sites so that the platform can be developed to best accommodate the control services in the varying communications environments provided at the trials. This assessment will view the control service requirements, the communications available at the trial site and the platform architecture chosen for the site and will assess all three for their suitability to the running of the trial. The findings of this assessment could have multiple implications on the development or deployment of the control services. It may require an architectural change where the control service would be deployed in a way that better suits the communications capabilities or indicate that the communications infrastructure could be upgraded to facilitate the deployment.

3.1.3 Software

The control services and the platform components developed in the edgeFLEX project are primarily software based. This means that the algorithms rely on software applications to host and provide data to them. The assessment of this software aims to ensure that it is robust, scalable, secure and fault tolerant so that it can fulfil the primary goal of the control service or platform component. The findings of this assessment could be directed to the developer of the technique where the code implementation of the algorithm would be optimised or could also be directed towards the integrator technique into the platform to address the interfaces that encapsulate the service implementation of the control technique.

3.1.4 Algorithm

The control services are essentially algorithms that receive input, are subject to constraints and produce outputs. The assessment of these is geared towards ensuring that, when running with a certain set of inputs and constraints, the desired outputs are produced. The assessment will also look to verify and ensure that the constraints applied are appropriate in the given scenario. This assessment is iterative, and the end goal is to improve the performance of the control service. The results of this assessment would typically be sent to the developer of the control technique and their actions could include the refactoring of the grid models used to train the algorithm, the constraints used to control it, or the inputs used to feed it.

3.1.5 Hosting

The edgeFLEX platform and the architecture are microservice based, meaning that the platform components and the control services are deployed on devices and cloud platforms so that they can operate. The hosting capabilities of the trial sites rely heavily on the level of digitalisation of the grid where the platform is being deployed. This assessment will centre on ascertaining if the hosting capabilities of the trial site are adequate to host the software components and data flows required for the control service to operate at its optimal level. The feedback from this assessment would typically be used by the integrator of the control service, the developer of the platform or the trial site owner and would be used to inform further action on how to refactor or rearchitect the solution to better fit the hosting capabilities available.

3.1.6 Security

This assessment criteria are based on the three main principles of cyber security, which are confidentiality, integrity and availability. This assessment will examine each software component and control service under these principles. Furthermore, the security of the devices deployed at the edge, like the edgePMU, will be assessed from a physical perspective to ensure that the devices are safe and secure from weather and from unsolicited human tampering or interference. This assessment would typically be carried out by a security expert and the findings would be used by integrators and software and algorithm developers alike to ensure that the component was as secure as possible and aligned to the security needs of the scenario in which it is to be deployed.

3.1.7 Data Access

Core to the development and the deployment of the edgeFLEX control services is the need for data access. This data access can be assessed under the criteria of whether there is enough data, that data is of sufficient quality, the data is format compatible and the is data provided at an adequate sampling rate for the control service to operate in an optimal way. The findings of this assessment would be utilised by anyone involved with the development or integration of the component and would be used to develop better data streams to feed the control service or to provide input to the control service developer as to the data available on site. A typical action may be that the algorithm be developed or refactored to account for the data available.

3.2 User Experience Assessments

In addition to the technical assessment described above, aspects regarding user experience with the developed and tested solution are also assessed. Therefore, the following criteria described in brief were asked in the assessment template.

3.2.1 Information

This question in the assessment asks if all information required was available, understandable, and complete as needed by the user. For any user of any system, it is always important to be able to access all relevant information. This does not necessarily mean that all information is needed by the user but rather serves for building trust in the system, assuring the user that it working as it should. As an example, at a DSO this could be the control room operatives who would want to see on their screens what the tool is doing in their system.

3.2.2 Interaction

The interaction questions asks whether all actions required to be executed by the user were clear and understandable to the user. This is relevant as implementation of services might require user actions to run properly. If this is the case, it needs to be clearly communicated to the user what actions are required and where they are to be performed. In the case of the previous example, the control room operatives from a DSO might be asked for input parameters for initial configurations by the tool and it should be clear what parameters and data are needed.

3.2.3 Configuration

This aspect aims at assessing if all configurations essential for correct operation of the system can be executed or inputted by the user. This can become relevant when standards, grid codes, (national) regulations, etc. or contracts with other actors and players in the system predefine specific parameters in relevant parts of the system. For example, it could become necessary to reconfigure parameters in the tool due to changing assets in the system, therefore control room operatives should be able to make these configurations when needed.

3.2.4 Technical Expectations

Here, it is asked if all expectations of the user regarding any technical functionalities are met. The expectations of the user of the edgeFLEX services might differ from the expectations developers have. Also, there might still be misunderstandings regarding technical functions and functionalities between developer and user. With this question, these differences in understanding and possible misunderstandings shall be identified – if not in an early development, but still in an early deployment state.

3.2.5 Use case realisation

This aspect aims at identifying if the use case the user had in mind can be realised with the edgeFLEX solution deployed on the user’s system. In the example, the user would again be control room operatives who expected an automated voltage control on one line of their grid so that no action is required by persons in the control room and the assessment would identify whether the tool actually provides that or still needs humans to execute actions so that the tool can work as expected.

4. Actor Targeted Assessment

In the assessment of the control services within the edgeFLEX platform and through assessing the trials it became apparent that assessing the platform and the control services could not be carried out in a comprehensive way by one actor. By comprehensive here, it is not meant that the service is assessed under the criteria outlined in section 3, but that it is assessed in a way that would provide grid and VPP operators with enough confidence so that they would accept the control services as part of their tool suite and as "business as usual" tools or services. The lack of a comprehensive assessment of such research may inhibit the widespread adoption of the technique. Within the scope of the edgeFLEX platform, the goal of the assessment was to assess the control services with a view to their continuous improvement within the timeframe of the project but to not explore assessing such research in a wider context, even if briefly, would be an oversight. This section will outline some things that could be considered when assessing a control service from the multiple actors within an organisation. In this assessment we have broken down the actor types into four broad groups.

Business Focused Actor: This actor is mainly concerned with the corporate affairs of the organisation. Their main goal is to ensure that the actions of the company are financially viable and that the company activities are managed in a responsible way. From the perspective of the edgeFLEX platform and its deployment in the organisation, they would assess it from a "cost – benefit" perspective to ensure that the cost of maintaining, licencing, or purchasing the platform would not outweigh the benefits of using it.

Compliance and Governance Focused Actor: This actor would have the goal of ensuring that the operations at a grid and corporate level would comply with the company best practice on security, privacy, quality criteria and with regulatory and standards directives imposed by sectoral governing bodies. In terms of the deployment of the edgeFLEX components and services within their business, they may need to assess it from the perspective of it violating grid codes and standards, market rules and regulations, or agreements made with other sector actors. Furthermore, they may need to assess the platform components from a cyber security perspective to ensure that the software and the systems deployed are compliant to their best practice standards.

System Focused Actor: This actor would have the goal of ensuring that the grid system would be running in a safe and efficient way. An example would be control room operatives who would have screens and control tools that would present them with information which would allow them to make decisions and take actions. These actors would mainly be concerned with ensuring the grid is stable given multiple scenarios, identifying faults, planning upgrades, planning grid changes, instigating fault isolation and service restoration schemes and ensuring that the grid would maintain within operational limits at any time. Regarding the edgeFLEX components and control services, this actor would be concerned with monitoring the outputs of the control service and identifying and analysing their impact on the grid. They may need override mechanisms to disable the control service or change the inputs to account for changes to the grid.

Technically Focused Actor: This actor would primarily be concerned with the asset and the grid at a local level. This actor could be a field operative or a grid technician that would be charged with the maintenance and the upkeep of the grid assets. Their main concern would be physical safety, the stability of the grid at a local level and the work required to maintain devices that may be required to host components from the edgeFLEX platform. They may also be concerned with resetting breakers and switches if there was a trip event or replacing damaged physical assets in the grid.

From the actor descriptions the assessments that would need to be carried out by each of the actor groups are very different, as each actor has very different business or process goals. It also could be the case that the assessments required may be company specific, based on their current processes and the systems that they already have in place. To define these assessments, it would be necessary to engage with each actor group to analyse their concerns and build a set of actor group specific assessments that would specifically address their needs and concerns. Within the edgeFLEX project, the focus of the work was not only to assess with the aim of improving the control service and platform components but to raise the Technology Readiness Level (TRL) of the control services to a level where a company would deploy the services at scale within their organisation and assume it as a "business as usual" tool. Future work would be required to develop a multi-actor assessment process where all the actor groups would have a mechanism to assess the service in a way that it would provide confidence at all levels of the organisation. This differs from the comparative analysis from WP6, where the level of assessment is a bit higher and sets the focus rather on business model assessment, regulation and exploitation and the impact the developments presumably will have on the system and its actors.

5. Feedback Loop and Assessment Process

From the beginning of the edgeFLEX project (and indeed at the time of writing the proposal) it was envisaged that the technical work within the project would be framed within an Agile methodology which would enable the development, assessment, and trialling of the edgeFLEX control services in an incremental way with continuous assessment and continuous improvement at the core of activities. To facilitate this, we employed two interlinked processes that facilitate the assessments and improvement activities, a feedback loop, and an assessment process. Both these processes centre on aligning the work to the goals and needs of the trials, the grid and the customer while ensuring that the platform components are built with sufficient stability and robustness.

5.1 Feedback Loop

The feedback loop developed within the edgeFLEX project activities is centred on the getting the feedback from the point of assessment, whether that is an integrator of the control service, a researcher assessing the control service in a test environment, a trial site operator, an electrical engineer, or an end user of the platform, and delivering that feedback to the appropriate work package and to the appropriate researcher to best address it. As seen in Figure 9, the feedback loop we have employed involves a cohesive approach with 6 work packages involved in its implementation. This approach ensures that the researchers working on a particular component can leverage the diverse set of expertise from electrical engineers, end-users, software engineers and business focused experts to develop and assess the edgeFLEX components with a big picture view. While the assessment of the edgeFLEX control services was not due to begin until month 24 of the project, the assessment of them began when the first drop of the control services was made in month 9 due to the Agile based improvement model employed by the project as illustrated in Figure 8. This improvement model formed the basis of the feedback loop with concrete actions overlayed on it to form the steps used to get the feedback from the assessment point to the relevant researcher to where solutions are researched, the relevant developments made and to where the updated component is reintegrated back into the point of assessment for re-evaluation.

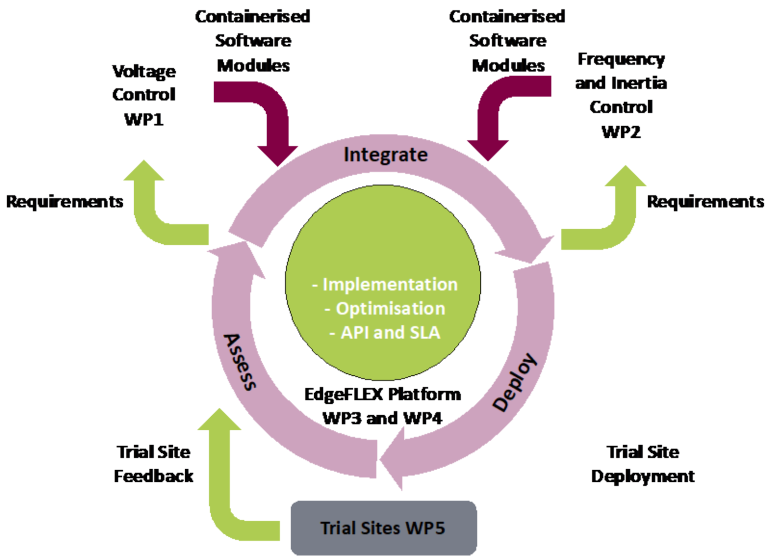

Figure 8 - edgeFLEX agile process

As seen in Figure 9 it all starts with the **Concept** which does not change from the inception of the work, the **Research**, **Develop/Refactor**, **Design** and **Integrate** components of the development process are focused on the delivery of the components, the **Trial** phase centred on placing the component in its intended environment where it can be assessed in the most appropriate way and the **Assess** phase centred on viewing the component against the criteria detailed in section 3. At this stage in the process, the component has been deployed and assessed, and the findings are ready to be conveyed to the appropriate researcher. This method of conveying the findings back is the most crucial in the loop because it is vital that the appropriate feedback is communicated to the most relevant researcher in a coherent way. Task 4.6 serves this purpose by ingesting the feedback, deciding where the feedback should go in the **Triage** phase and using the communications pipelines developed from the early stage of the project in the **Communicate** phase to convey the feedback to the relevant researcher. Once the feedback has been addressed the component will be handed back to Task 4.6 for reintegration where an initial assessment against the feedback will be carried out prior to subsequent trial and assessment phases where the loop begins again.

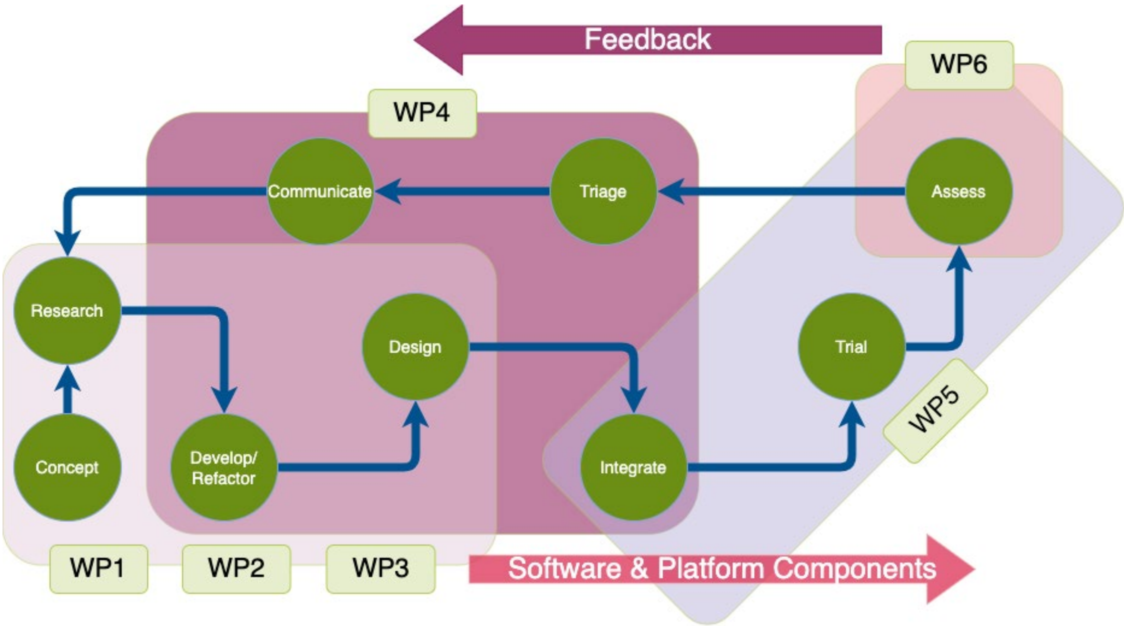

Figure 9 - edgeFLEX Feedback Loop

5.2 Assessment Process

While the assessment criteria detailed in Section 3 is how we assess the components, the feedback loop defined in section 5.1 is how we get the findings of the assessment to the relevant researcher. The process assessing the component involves assessing the component at snapshots in the development and trialling of the component or control service. As stated above, the assessment of the control services began not in month 24, but in month 9 when the first drop of the control services was delivered from WPs 1 and 2. The initial assessments served the purpose of evaluating the platform components that were built to enable integration of the control services into a proof-of-concept version of the platform. In the edgeFLEX project there are 5 environments in which the services are assessed:

- Development - where the algorithm or component is researched and developed, the data streams identified, and the code written
- Simulation - where the algorithm or component is containerised and hooked to data streams from simulated data streams and handed over for the initial stages of integration
- Integration - where the containerised component is deployed integrated with the relevant data interfaces, data streams and supporting components
- Lab - where the integrated system is deployed in a laboratory environment for assessment or trialling under varying criteria for demonstration, 5G testing and stability testing for example
- Trial - where the integrated system is deployed in the physical trial with real data from in situ systems and with real grid and end user assets.

These environments,, from development to trial vary in complexity and move closer to the user and their goals and as such the assessment process mirrors this with the focus shifting from a simple algorithm and software assessment to a more complex and deeper assessment at the trial where security, usability and grid impact are in focus. Figure 10 illustrates how the assessment criteria broaden with the complexity of the environment. As the assessment criteria broaden, so does the need for a broader set of expertise in the completion of the assessment at each stage. In the development phase for example, the expertise might be just an electrical engineer with a deep knowledge of the technique or control service that is being developed and potentially somebody with software engineering expertise, whereas in the trial, ICT, end users, electrical engineers or grid operators with local grid knowledge are needed with their concern focused solely on how the service or platform components are performing in their grid. This means that the control services or components are assessed and verified under the broadest set of criteria with the experts with broad perspectives (from the research to the end user).

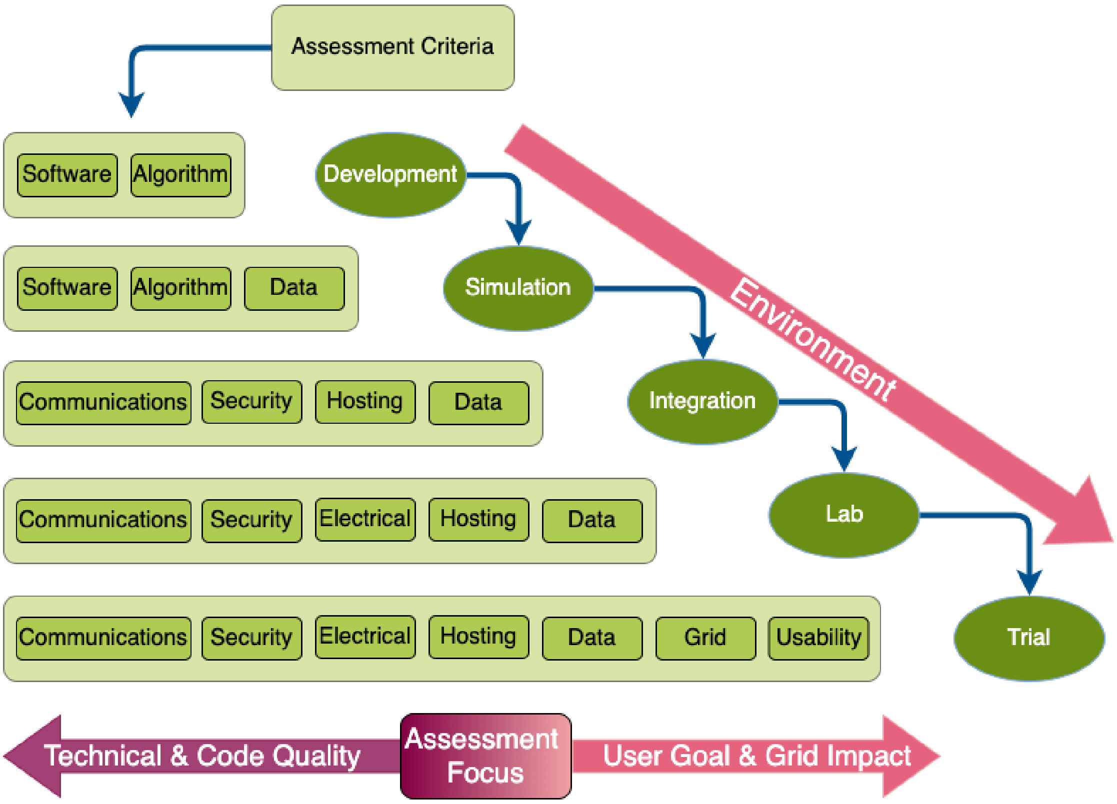

Figure 10 - edgeFLEX Assessment Paradigm

In the edgeFLEX project, the assessment process is running at each stage with the trials being assessed every two months using the assessment template in annex A.1 with the findings of each assessment entering the feedback loop for action to be taken by the relevant researcher.

6. Assessment Findings from the Trials

The following section will describe in detail the findings from the trials in the context of the assessments described above. These assessments took the form of a document which was delivered to each trial site partner. The assessment document focuses on the edgeFLEX services and platform, and the findings from the assessments as given by the trial site partners in WP5 are to be used to improve the operation and deployment of the edgeFLEX platform and services.

6.1 Assessment Proof of Concept and Requirements

In the early stages of developing the assessment, it was envisaged as a tool to be used as part of the edgeFLEX feedback loop, to gather results from the operation of the platform and services in the trials and to feed back into WP4 and the other technical work packages so that the services and platform can then be refactored and redeployed as part of the edgeFLEX deployment pipeline. In this way, the assessment will be a key item in the edgeFLEX Agile process and be used to continually improve the services and platform. Figure 9 describes the interaction between WP4, WP5 and the other technical work packages in the context of the edgeFLEX deployment pipeline and feedback loop, informed by the service and platform assessments.

The assessment document has been designed to gather requirements and assess the services and platform on two levels, a technical assessment which covers aspects such as deployment of the components and whether the outputs of the services are reasonable, understandable, and actionable on the grid. Secondly, usability is assessed to evaluate whether the personnel interacting with the platform and services can use it effectively. The specific criteria for both the technical and usability assessments are described in more detail in section 3.

6.2 EDD Lab Trial Assessment

The following section will describe the findings of the assessment from the lab trial as undertaken by EDD. This trial was somewhat unique due to the limitations in place within the 5G lab, therefore, the specific edgeFLEX platform components and services needed to be made available via a Docker container registry and packaged in such a way that would meet the needs of the lab environment's VM.

6.2.1 Assessment Description

The aim of the tests in the EDD (Ericsson) laboratory was to demonstrate and evaluate the benefits and advantages of the 5G Device Management API in the energy domain. To achieve this, the edgeFLEX frequency data simulator and edgeFLEX backbone components from the platform were deployed in the EDD laboratory, and the 5G Device Management API was utilised to establish end-to-end communications between the simulator and platform components.

The 5G Device Management API was used to attach devices to the 5G network, create device groups and manage and monitor the quality-of-service of device connectivity. Once communications were established between the components, data from the simulator was transmitted to the edgeFLEX databus, persistence and visualisation tools over the 5G link. The functionality of the 5G Device Management API was tested and validated by observing whether the simulated data could be sent from a device (simulator), received by the databus, stored via the persistence component, and visualised in Grafana.

6.2.2 Assessment Results

From the EDD lab trial, the following results were obtained from the assessment, summarised below. Excerpts from the assessment document can be found in Annex A2.1.

From a technical assessment perspective, it was found that the initial attempt to obtain the edgeFLEX components needed for the lab trial from the Docker container registry set up by South East Technological University (SETU, formerly WIT) was unsuccessful. This required some investigation, and it was found to be an issue with port access from SETU, and this issue was subsequently resolved, and EDD could then obtain the components from the registry.

Following a further assessment of the components in the lab trial, it was found they would not deploy correctly in the lab environment. SETU were made aware of this assessment outcome, which resulted in the pre-configuration of the components specifically for the lab trial. Once, complete, the components on the container registry were updated and on further testing EDD were able to deploy the edgeFLEX platform components.

Once deployed, it was found that the persistence component was not storing simulated frequency data which was passed to the databus component. To reduce load on the VM, a small-scale data simulator was built in-house by EDD for the lab trial based on example payloads provided by SETU. On assessing the data generated by this simulator, EDD and SETU found that the payloads generated by the simulator were incorrect. Once identified, this issue was resolved, and simulated data was being stored in the persistence component.

However, on further testing, it was found that while the data was being stored, it was not possible to visualise it via the edgeFLEX visualisation service, which utilises Grafana. On further assessment and investigation, it was found that the timestamps for the simulated data were incorrect, and therefore Grafana could not visualise them. The issue with the timestamps was resolved with the simulator code and data could be visualised. Once all issues identified through the assessment were resolved, the components were ready to be properly tested with the 5G network and 5G Device Management API.

In respect to usability, while not a key factor for the lab trial as for the field trials in WP5, it was found that making pre-configured components available via Docker container registry simplified the process of obtaining and running the components in a lab environment. In addition, it was found that the MQTT protocol was a good choice of communications between platform components.

6.3 ALPIQ Trial Assessment

This section will summarise the assessment findings from the ALPIQ trial, which centres on the optimisation of the VPP via an optimisation algorithm. Like the above section, a summarised overview of the assessment results will be described, and assessment document excerpts can be found in Annex A2.2.

6.3.1 Assessment Description

One of the key requirements identified in the deployment of the VPP optimisation algorithm was the need to maintain the company boundary in terms of the data being utilised to generate the optimisation outputs. As this data is commercially sensitive, a solution was found and architecture was designed whereby the deployment of the algorithm would be tightly coupled to the source of the price and forecast data, with the outputs of the algorithm being the only element exposed to external systems, which was the edgeFLEX platform in this case.

The trial in ALPIQ deployed the VPP optimisation algorithm internally, which passed the outputs to the edgeFLEX platform. In this way, the company boundary is maintained, and the assessment focused on the outputs of the algorithm and the communication of these outputs to the edgeFLEX platform as deployed in SETU.

6.3.2 Assessment Results

From the ALPIQ trial the following results were obtained from the assessment, summarised below. Excerpts from the assessment document can be found in Annex A2.2.

As described above, a key requirement was identified for the VPP optimisation algorithm to remain within the ALPIQ company boundary as part of the assessment. This involved an assessment with a particular focus on communications, hosting, and security. As the algorithm utilises commercially sensitive data, it was decided to deploy the service within the ALPIQ premises and pass the outputs to the edgeFLEX platform databus deployed in SETU. From there, the optimisation outputs can be monitored and validated.

Due to the sensitive nature of the VPP optimisation algorithm, a key assessment finding was to ensure that the edgeFLEX databus provided a secure means of publishing data. To meet this need, the databus communications were secured with TLS/SSL layers and connections secured with authentication credentials which are required to publish and subscribe to MQTT topics, therefore making data access limited only to those systems with the required credentials.

Internally, ALPIQ assessed the optimisation algorithm and software, the results being that the optimisation software was packaged for easier operations within production environments. In addition, some limitations of the optimisation algorithm were identified, such as certain forecasting factors being unavailable, or optimisation outputs not being within operation range of the asset. However, the assessment found that these limitations are due to necessary constraints within the algorithm.

6.4 SWW Trial Assessment

Like the previous sections, this section will summarise the assessment findings from the SWW trial located in Germany. This trial focuses on the application of advanced power measurement readings from the grid to feed a control service which interacts with the edgeFLEX platform and external flexibility systems.

6.4.1 Assessment Description

The SWW trial focuses on the investigation of the application of decentralised energy production and trading within the context of slow and fast dynamics. To enable this trial, advanced edgePMUs were installed in selected points on the trial site's grid, providing deeper visibility of grid operation. In addition, this data feeds into a deployment of the Voltage Control MPC service to monitor and actuate control in response to conditions on the grid, including requesting flexibility through the edgeFLEX PBGM system. Therefore, this assessment focuses on the operation and communication between these systems, as they are deployed in a decentralised manner, and on the usability of the outputs and visualisations produced.

6.4.2 Assessment Results

This section will summarise the assessment findings from the SWW trial, which centres on the application of fast and slow dynamics. Like the previous sections, a summarised overview of the assessment results will be described, assessment document excerpts can be found in Annex A.2.3.

The results of the SWW trial assessment from a technical aspect found that the Voltage Control MPC service was not able to be properly assessed. Based on this, the appropriate WP4 and WP5 discussed and devised requirements and plan for implementation to establish the interaction between the Voltage Control MPC, edgeFLEX platform and PBGM system, and KIBERnet for optimal operation.

In addition, it was found that edgePMU data being fed into the edgeFLEX platform and visualised was not correct. This was due to the configuration of the edgePMU simulator, which at the time was feeding simulated data to the platform. To address this, the relevant edgeFLEX backbone component for capturing and storing data from the databus was re-configured and re-deployed to capture live edgePMU data from the field and is now being visualised.

From a usability perspective, the assessment from the SWW trial focused on the application of the data visualisations from the field. These were assessed by a variety of personnel in SWW, the results of which found that the visualisations being produced currently are of a good quality, though there are some issues to be addressed. These findings include the ability for personnel to edit generated visualisations, as currently these are read-only. In addition, some elements of KIBERnet data are not being fed to the platform, and the Voltage Control MPC is not currently available.

6.5 Assessment Summary

The participation of the trial site partners in completing the assessment documents have proven to be a very useful tool in enhancing the Agile process and edgeFLEX improvement model. The results of the assessments highlighted key issues preventing the implementation of the trials. In addition, highlighting the specific problems encountered in the assessment document provides a basis for discussing and implementing solutions with the relevant partners, scoping work, and devising a timeline for resolving identified issues. From the early-stage assessments, it was clear that the software and the implementation of the techniques needed refactoring in terms of how they interacted with existing systems and how the actual application could be delivered to the laboratories and to the trials. The latter assessments have a focus more on the grid impact, usability, and quality of the results. What is clear from the assessments is that the closer the application is delivered to the trials the deeper the assessment and it is there that the focus must shift to the end user and the human directly impacted by the implementation of the control service.

7. Conclusion

This deliverable set out to detail the assessment process devised and used to assess the control services and their enabling components (like the databus and the other platform components) from their early delivery to their implementation in the field trials and the various stages of testing and refactoring in between. This assessment criteria centred on several aspects that may impact the working, effectiveness, usability, and security of the control service, and in order to gather these assessments, a survey was developed, which, accompanied the delivery of the control service to trial site owners to assess the platform. The assessment process was framed in the Agile methodology that starts with the concept and iteratively develops, assesses, delivers, and refactors upon that concept with multi-stakeholder input. Establishing this process from the beginning of the project enabled the effective gathering of requirements that initially positioned the concepts developed in edgeFLEX in the Agile methodology where the multi-stakeholders within the project (with a different perspective and expertise) could gain a common understanding and therefore enable the effective delivery of the platform to the trials. Through the stages of the process that delivers the platform to the trials, a set of environments were identified: Development, Simulation, Integration, Lab, and Trial. From the initial iterations of the assessment process, it became clear that the assessments differed in depth and complexity the closer the platform delivery got to the trial environment. For example, it was noticed that the focus shifted from assessing on criteria such as the software quality in the development environment to assessing the usability and grid impact in the trial environment. It is this tiered approach that allowed the targeted assessment of the platform with a focus on what can be assessed in the most suitable environment in which it can be assessed. Furthermore, this tiered approach enabled the effective delivery of the assessment findings to the most appropriate project partner with the best knowledge and expertise to address the findings.

While gathering the assessments and engaging with the trials, it became evident that to fully assess the control services and further develop them to a TRL level that they could be adopted as a “business as usual” solution by industry, a deeper level of assessment would be required. This assessment would centre on an actor specific approach where the assessment of the platform or service would be carried out by all levels of the business, from the technician in the field who may need to interact physically with the platform components to the actors concerned with the financial viability of its adoption. This, however, is future work and to define such an assessment a deeper engagement with all actors would be required so that all relevant aspects would be covered.

While the delivery of this report comes while the trials are still live, the assessment process will continue until the end of the project and during this phase a better sense of the usability and grid impact of the control services will be gathered and will provide valuable inputs into further research of the control services, the platform and indeed other techniques that solve similar problems.

8. List of Figures

9. List of Abbreviations

API	Application Programming Interface
DB	Database
DG	Distributed Generator
DMS	Data Management System
DSO	Distribution System Operator
GUI	Graphical User Interface
HTML	HyperText Markup Language
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
ICT	Information and Communication Technology
IoT	Internet of Things
IP	Internet Protocol
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
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
SLA	Service Level Agreement
SO	System Operator
SSL	Secure Sockets Layer
TCP	Transmission Control Protocol
TRL	Technology Readiness level
TSO	Transmission System Operator
UDP	User Datagram Protocol
UE	User Equipment

VPN	Virtual Private Network
VPP	Virtual Power Plant
VPS	Virtual Power System
WP	Work Package

ANNEX

A.1 Assessment Template

This assessment is a tool to be used within the edgeFLEX project as part of the feedback loop that will get the results of the assessments from the trials in WP5, to the integration and implementation tasks in WP4 and back to the technical work packages so that the services can be refactored and redeployed as part of the edgeFLEX deployment pipeline.

Description:

Describe the trial site here briefly

This form is designed to assess the services and platform on two levels. Frist, in terms of if they can be deployed, where the components should be deployed for whatever reason, where they are deployed, is the output of the service actionable on the grid and such things. In a second part, the usability will be assessed.

<u>Technical assessment:</u>

The assessment of the services and the platform implementation can be categorised into the following:

- 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 component 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.

The above reasons will have an explanation of the issue and a potential solution if one can be apparent upon at the time the assessment is being carried out.

There is also an electrical assessment that can be filled out if there is an issue identified in terms of the impact that the service is having on the electrical system.

Service	*Name the service*
Intended Trial	*where is the trial*
Backbone Services	*What are the backbone services needed*

Enablers	*What enablers are needed, eg 5G API*
Assessment Date	*Date assessment was carried out on*

Service	Category	Reason (if any)	Remedial Steps
Name the service VC	Electrical		
	Communications		
	Software		
	Hosting		
	Security		
	Data Access	Not getting correct data	Write middleware
	Algorithm		

Component	Category	Reason (if any)	Remedial Steps
Component 1	Electrical		
	Communications		
	Software		
	Hosting		
	Security		
	Data Access		

Component	Category	Reason (if any)	Remedial Steps
Component 2	Electrical		
	Communications		Provide other mode for next release
	Software		
	Hosting		
	Security		
	Data Access		

Component	Category	Reason (if any)	Remedial Steps
Component n	Electrical		
	Communications		
	Software		
	Hosting		
	Security		
	Data Access		

Electrical Assessment			
Expected Behaviour	Actual Behaviour	Suggested Changes (if any)	Any Other Information

Assessment of user experience:

In addition to technical functionality, it is also important to assess if persons getting in contact and working with the services or platform are able to easily use it. Relevant questions can be categorised as following:

- Information: meaning that all information given to user were available, understandable and complete as needed for user
- Interaction: meaning that all actions asked from user were clear and understandable
- Configuration: meaning that all configurations essential for operation (grid codes, national regulations, etc.) can be executed by the user
- Technical expectations: meaning that the implemented edgeFLEX solutions enable / support technical goals of the user (such as: protection of other components, prolonging lifetimes of other assets)
- Use case: meaning that targeted use case can be realized
- Anything else: How is your world changing though the new service? Any other comments/issues that need investigation e.g., to make developed tools most usable for other users? Hurdles for further usage of service?

User of service	*Type of user of the above-mentioned service (e.g., technical DSO employee in the field, DSO employee in control room, VPP operator, etc.)*
Used UI	*Which UI was used*

Category	Everything ok (Y/N)	Reason (if any)	Remedial Steps	Position / Person talked to in trial
Information				
Interaction				
Configuration				
Technical expectation				
Use case				
Anything else?				

A.2 Trial Site Assessment Samples

A.2.1 EDD Lab Trial

Component	Category	Reason (if any)	Remedial Steps
edgeFLEX Databus	Software	Initial pull of edgeFLEX components from the Docker container registry was unsuccessful. After components were pulled from the registry, they could not be run in the lab.	SETU resolved issue with the Docker registry and ensured access to EDD. A necessary configuration file was missing for the components. SETU updated the Docker image in the registry to resolve this.
Component	Category	Reason (if any)	Remedial Steps
edgeFLEX Persistence	Communications	Although the data simulator generated the frequency control data and transmitted MQTT messages to the databus, the persistence tool couldn't store these values and send them to visualization tool.	SETU realised that the data format of the frequency control messages was wrong from the data simulator. That's why the values couldn't be stored in persistence tool. The data simulator was updated to the correct JSON format and the MQTT messages sent again. Then, the values were successfully stored in persistence tool.
Component	Category	Reason (if any)	Remedial Steps
edgeFLEX Persistence	Communications	Although the data simulator generated the frequency control data and transmitted MQTT messages to the databus, the persistence tool	SETU realised that the data format of the frequency control messages was wrong from the data simulator. That's why the values couldn't be stored in persistence tool. The data simulator was updated to the correct

		couldn't store these values and send them to visualization tool.	JSON format and the MQTT messages sent again. Then, the values were successfully stored in persistence tool.

A.2.2 ALPIQ Trial

Service	**Category**	**Reason (if any)**	**Remedial Steps**
VPP Optimisation	Communications	Confirmation of Model result delivery	To validate the model output and communications with edgeFLEX optimisation results are stored on premise to enable comparison
	Software	Optimisation model integration with standard build and deploy processes	The optimisation model was packaged as part of the standard Loader Framework that provides easier operations of the model in productive environments
	Hosting	The vpp opt service had to be deployed on premise	The reason is that it was connected to real data streams that are commercially sensitive
	Data Access	The data was accessible	The outputs were sent to the edgeFLEX databus for monitoring
	Algorithm	The daily wind park imbalance forecast, or DA price forecast is not available. The optimization output (asset's schedule) is not within the operational range of the asset.	The algorithm does not co-optimize but rather acts (maximizes/minimizes the revenue/cost) only for the respective use-case for which the forecast is available. There is a hard constraint in the algorithm which does not allow any solution that is outside of the asset's operational range.
Component	Category	Reason (if any)	Remedial Steps
edgeFLEX Databus	Security	To safely allow ALPIQ to publish data we needed to add a layer of authentication to the connection.	The edgeFLEX databus connection is SSL/TLS secured with credentials required to publish/subscribe to MQTT topics.

A.2.3 SWW Trial

Service	Category	Reason (if any)	Remedial Steps
Voltage Control	Software	MPC Mode not ready	Complete functionality for MPC and interaction with Flex system & PBGM
	Hosting	Not hosted	Deployed in SETU once MPC mode is ready
	Security	SSL/TLS + Credentials in place	MQTT databus is secured using encrypted traffic and user credentials to connect. VM will be locked down to only required ports.
	Algorithm	MPC Algorithm	Needs assessment once software is complete
Component	Category	Reason (if any)	Remedial Steps
KIBERnet	Communications	KIBERnet-Platform connection not available.	SETU & INEA working on implementing interaction between MPC, PBGM and edgeFLEX Platform.
	Software	Read only.	Editing measures are to become available.
	Data Access	Data from KIBERnet integrated into edgeFLEX platform is still not available.	Live edgePMU data is now coming into the edgeFLEX platform and being visualised.
Component	Category	Reason (if any)	Remedial Steps
edgePMU	Communications		Provide other mode for next release
	Software	Read only	
	Data Access	Data from edgePMU integrated into edgeFLEX platform does not show real data	Live edgePMU data is now coming into the edgeFLEX platform and being visualised.
Component	Category	Reason (if any)	Remedial Steps
PBGM System	Communications	PBGM interfacing with external systems	Testing has been completed using live KIBERnet and Sandbox
	Software	Software ready to interact with flexibility and VC service	Complete interaction with MPC
	Hosting	Deployed	PBGM system has been deployed and will be hosted in SETU

	Security	SSL/TLS, HTTPS, Credentials	Communication via REST and MQTT utilise SSL/TLS, HTTPS and Auth token (JWT)
	Data Access	PBGM receiving outputs from KIBERnet	Will require more testing once MPC is ready
Component	Category	Reason (if any)	Remedial Steps
edgeFLEX Backbone Services	Communications	Backbone services interacting, not tested with complete MPC	Testing steps once MPC is deployed to verify comms
	Software	Backbone services software complete	Verify with VC MPC
	Hosting	Deployed	Backbone services have been deployed in SETU and are ready
	Security	SSL/TLS, HTTPS, Credentials	Communication via REST and MQTT utilise SSL/TLS, HTTPS and Auth token (data-manager) (JWT)

Category	Everything ok (Y/N)	Reason (if any)	Remedial Steps	Position / Person talked to in trial
Information	Y- data from KIBERnet available. N – still not communication to the edgeFLEX platform	Read-only. Data missing. Still not fully integrated.	Finding connection path between all platforms. Including e.g. protocols etc. Introducing one platform for all. Editing features are required	Control room employee
Interaction	Y			SWW employees
Configuration	Y – codes and regulation are available. BUT: N – Energy Community issues	Energy Community still cannot be performed due to legal restrictions	Virtually simulations for PoC	Power division and/or control room employee
Use case	Y – Voltage Control			