HEDGE-IoT

Holistic approach towards Empowerment of the Digitalization of the Energy Ecosystem through adoption of IoT solutions

D2.1
Requirements on an IoT Cloud/Edge System for the Energy Ecosystem

30/08/2024

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27	QUE TECHNOLOGIES KEFALAIOUCHIKI ETAIREIA	QUE	EL
28	ARETI S.P.A.	ARETI	IT
29	APIO S.R.L.	APIO	IT
30	ACEA ENERGIA SPA	AE	IT
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36	MC SHARED SERVICES SA	SONAE	PT
37	ELES DOO SISTEMSKI OPERATER PRENOSNEGA ELEKTROENERGETSKEGA OMREZJA	ELES	SI
38	ELEKTRO GORENJSKA PODJETJE ZA DISTRIBUCIJO ELEKTRICNE ENERGIJE DD	EG	SI
39	OPERATO DOO	OPR	SI
40	SVEUCILISTE U ZAGREBU FAKULTET ELEKTROTEHNIKE I RACUNARSTVA	UNIZG	HR
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42	KONCAR - DIGITAL DOO ZA DIGITALNE USLUGE	KONC	HR
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EXECUTIVE SUMMARY

This document makes up the first Deliverable of Work Package 2 within the HEDGE-IoT project. It comprises the complete results of five Tasks, defining the project's requirements in five areas respectively. These concern firstly an analysis of and positioning within the technological state-of-the art, followed by an analysis and design of End Users' Requirements and Business Use Cases. This is followed by a stakeholder's consultation on data harmonisation, real-time grid monitoring for resilience and flexibility. Further regarding user concern, this is finally followed by a mapping of the relevant regulatory, societal and technical barriers and AI ethics, and a definition of requirements regarding user engagement, awareness, and inclusiveness.

The submission of this deliverable marks the conclusion of the first big analysis phase of WP2. It serves as a base for the technical development to be done within HEDGE-IoT going forward.

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ABBREVIATIONS

AI	Artificial Intelligence
BSP	Balance Service Provider
BUC	Business Use Case
CA	Consortium Agreement
CI/CD	Continuous Integration / Continuous Deployment
CM	Congestion Management
DER	Distributed Energy Resources
DoA	Description of the Action
DPA	Data Protection Authority
DPIA	Data Protection Impact Assessment
DPO	Data Protection Officer
DMP	Data Management Plan
DSO	Distribution System Operator
EC	European Commission
ERGO	Ethics and Regulatory Governance
EU	European Union
FAIR	Findable, Accessible, Interoperable and Reusable
GA	Grant Agreement
GDPR	General Data Protection Regulation (EU 2016/679)
HEMRM	Harmonized Energy Market Role Model
IoT	Internet of Things
LFM	Local Flexibility Market
ML	Machine Learning
OT	Operational Technology
PoD	Point of Delivery
PMH	Project Management Handbook

SCADA	Supervisory Control and Data Acquisition
SUC	System Use Case
TSO	Transmission System Operator
WP	Work Package

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1 INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

The purpose of this document is to provide the HEDGE-IoT consortium with a set of requirements for the ongoing development, based on thorough analysis of five areas:

- Technological state-of-the-art and Conceptual Representation
- Business Use Cases and End Users' Requirements
- Stakeholders' Board Consultation towards Knowledge Diffusion, Promoting Data Harmonization, Real-Time Grid Monitoring for Resilience and Flexibility
- Ethics, Regulatory and Societal Aspects
- User Engagement, Awareness, and Inclusiveness Requirements

Each of these areas pertains to a Task within WP2 that ends with submission of this document. Accordingly, the submission of this deliverable marks the conclusion of the first big analysis phase of WP2. It serves as a base for the technical development to be done within HEDGE-IoT going forward.

1.2 REFERENCE AND APPLICABLE DOCUMENTS

1.2.1 Reference Documents

For the preparation of the present deliverable D2.1 "Requirements on an IoT Cloud/Edge System for the Energy Ecosystem", the authors used a set of reference documents, including scientific publications, manuals, technical reports and standards, representing valuable sources for the specific context. This list of sources is reported in the section REFERENCES.

1.2.2 Applicable documents

The general indications for the project implementation are defined in the HEDGE-IoT Grant Agreement (GA), the Consortium Agreement (CA), the Project Management Handbook (D1.1 - PMH) and the Data Management Plan (D1.4 – DMP). As a result, the present deliverable "Requirements on an IoT Cloud/Edge System for the Energy Ecosystem" (D2.1) does not replace any of these applicable documents, and partners should abide by the following order of precedence:

- **Grant Agreement**
- **Consortium Agreement**
- **D1.1 "Project Management Handbook"**
- **D1.4 "Data Management Plan"**
- **D2.1 "Requirements on an IoT Cloud/Edge System for the Energy Ecosystem"**

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1.3 STRUCTURE OF THE DOCUMENT

Going forward, the document structure will be as follows:

Chapter 2 contains the analysis of the technological state-of-the art and the development of a conceptual representation of Edge/Cloud IoT Ecosystems, making existing systems comparable and positioning HEDGE-IoT within that context.

Chapter 3 handles the analysis of end users' requirements and the development of Business Use Cases according to the needs of the project's demonstrators.

Chapter 4 consists of a Stakeholders' Board consultation towards knowledge diffusion promoting data harmonization, real-time grid monitoring for resilience and flexibility.

Chapter 5 considers the human-centric approach, based on EU values and rules, and identifies ethics, regulatory and societal concerns, principles to be followed and requirements to be embedded into the development process to ensure a responsible innovation, in compliance with the EU ethics and regulatory framework.

Chapter 6 develops requirements for HEDGE-IoT regarding user engagement, awareness and inclusiveness.

Finally, Chapter 7 gives a conclusion and the final summary of the developed requirements within this first phase of WP2.

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2 TECHNOLOGICAL STATE-OF-THE-ART AND CONCEPTUAL REPRESENTATION

Within Hedge-IoT, an Edge/Cloud IoT Ecosystem should be developed. As the definition of such a thing is rather fuzzy, Task T2.1 exists with the goal of collecting state-of-the-art examples and creating a conceptual representation to make them comparable to each other and to the goals of HEDGE-IoT.

2.1 COLLECTION OF SOTA IOT EDGE/CLOUD ECOSYSTEMS

This first section focuses on the collection of existing ecosystems and projects in the IoT Edge/Cloud area. A focus on the energy sector is optional, as the structure of such an ecosystem or project may be generic, or even focused on a different sector, and still be helpful to determining important differentiating characteristics. The regard is on systems that enable IoT devices to be accessed for distributed analysis and control.

2.1.1 Existing IoT Edge/Cloud Ecosystems

2.1.1.1 Apio IoT Platform

The first ecosystem to discuss is an IoT platform by Apio with a focus on the energy domain, supporting any HTTPS/MQTTS/SFTP enabled device/application. The platform is soon to be Open Source and built upon open standards. It provides, in addition to all the features required by an IoT platform, rich features for data analysis, such as Cloud Storage integration by default for time series data (with first class supports for new analytical formats such as Apache Parquet and Apache Arrow, and new tooling like DuckDB) to enable Data-Intensive use cases such as Machine Learning workloads and Analytical workloads.

- OpenApi specification
- Documentation Website

The Platform was the foundation used by a critical component of the Platone project, the Blockchain Access Layer, as it provided the IoT layer. The Outputs of the Platone Project are collected and further developed for the Romeflex Project by Areti. The Platform was also used as foundation for open-call projects within project Platoon (Smart Energy) and Ontochain (Energy Communities).

In addition, it currently serves as the foundation for several vertical products including Energy Consumption Monitoring, Renewable Plants Monitoring, Smart Building management, Energy Flexibility solutions, and Smart Grids. These verticals leverage the platform's capabilities to address specific challenges in the energy sector, handling thousands of concurrently connected devices.

The platform also includes features for assets management, alarms and notifications, (visual) rule engine, firmware management, OTA upgrades, fine grained user management and data quality tools.

Finally, the platform is distributed as containerized microservices. A Kubernetes distribution is also available through Helm.

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2.1.1.2 PGUI

PGUI (Power Grid User Interface) is a **Specification for implementing software interfaces for edge devices** capable for providing data exchange and edge functionalities required to enable ancillary services between grid operators (TSOs, DSOs and BSPs) and the distributed energy resource owner.

This specification was born as a further development on top of one of the KERs of H2020 project Platone: the consortium developed the concept of a device named Light Node with the objective of gathering and signing measurements from the field. Then, in 2023 it was refined to become the entry point for flexible assets in project Romeflex by Areti.

The PGUI is integrated with the Apio IoT Platform, which fully support every uplink/downlink message, supported by the PGUI, including secrets rotation, OTA upgrade and all the Flexibility related messages, such as measurements and set points.

2.1.1.3 KONČAR MARS

MARS is a commercial product designed for local use, tailored to meet specific local requirements. Given the input specifications outlined in Task 2.1., this product could serve as a good example, particularly due to its successful implementation within local initiatives aimed at data collection and visualization from diverse IoT/Edge devices (Energy Communities Repository - Short Guide - FINAL.pdf (europa.eu)).

KONČAR MARS represents a cutting-edge software solution tailored for the industrial Internet of Things (IoT), specifically designed to facilitate the sophisticated management of smart cities, critical infrastructure, and power systems. This adaptable and scalable platform harnesses the capabilities of IoT technology to seamlessly gather and fuse data from a variety of smart meters and advanced sensors. It accommodates diverse devices including solar panel inverters, energy meters, and various sensors.

Beyond mere data aggregation, the platform facilitates data processing, visualization, alert generation, event management, system integration, client application support, and more. Its applications span across multiple sectors such as power systems, water management, public lighting, electric vehicle infrastructure, consumption monitoring, loss prevention, environmental monitoring (including noise and air quality), waste management, and beyond.

The MARS platform aligns with the HEDGE-IoT project in its dedication to improving IoT standardization. One of its features is the ability to deliver collected data in standardized formats, enabling seamless integration and use in the development and implementation of AI/ML tools across various sectors. Its modular infrastructure ensures that different stakeholders can access data securely and effortlessly. Additionally, the platform's central management capabilities improve existing monitoring and control processes, making it an essential tool for enhancing system interoperability and efficiency.

2.1.1.4 InterConnect – Semantic Interoperability Framework

InterConnect was a flagship project, the largest project commissioned by DG CNEC T, with well over 80 involved partners and affiliated entities. The project received EU funding of €30M, and most InterConnect work packages were larger than a typical (individually granted) EU Horizon project.

Interoperability represents a serious problem as a change of energy providers could mean the replacement of installations. The InterConnect project achieved effective energy management

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using a resilient and practical ecosystem that is user-centric and market-driven. The project involved a range of specialized stakeholders, including advanced technology actors, manufacturers, providers, and energy users. Via seven pilots, InterConnect showcased an effective digital market for ensuring energy-efficiency at reduced costs that is beneficial to end-users.

Key parts and achievements of the InterConnect ecosystem include the Interoperable Recommender, the Semantic Interoperability Framework and the DSO interface. [1] For the purposes of this work, the Semantic Interoperability Framework is a very relevant contribution that will be reused. It aims to avoid the need for a central interoperability facilitator and instead provides tools to support SAREF-centric semantic interoperability between disparate devices and platforms. By establishing decentralized interoperability among existing systems and platforms, it solves some of the problems faced by centralized facilitators, such as limitations on security through the need of a third processing party. [2]

The Framework includes the following components:

- Semantic Interoperability Layer, based on TNO Knowledge Engine
- Service Store
- Generic Adapter
- P2P Marketplace enablers
- Set of supporting tools for integrators (SSA Test Tool, Graph pattern visualizer)

Each component provides data protection measures. Specific descriptions of each one can be found in the corresponding InterConnect Deliverable. [2]

2.1.2 Ongoing Projects

The following are brief descriptions of two (out of many) projects in this area that are running at time of submission. As they are ongoing, there is usually not final and stable information published to support a clear comparison with existing implementations. However, their expressed goals and progress can inform on the specific priorities that are prevalent in current developments within this research area.

2.1.2.1 ICOS

This project will cover challenges of the IoT-edge-cloud paradigm, proposing an approach to embed a set of functionalities, defining an IoT-Cloud Operating System (ICOS). Its aim is to design, develop and validate a meta-operating system by addressing the challenges of device volatility and heterogeneity, continuum infrastructure virtualization and diverse network connectivity, optimized and scalable service execution and performance, as well as resources consumptions. It will also cover security, privacy, and trust, and reduce integration costs and effective mitigation of cloud provider lock-in effects, in a data-driven system built on openness, adaptability, data sharing and a future edge market scenario for services and data. [3]

2.1.2.2 OpenContinuum

OpenContinuum supports the cloud-edge-IoT domain by focusing on the supply side of the computing continuum landscape. Its goal is to foster European strategic autonomy and interoperability through an open ecosystem for the computing continuum, with open source and

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open standards as two key enablers to be supported and leveraged throughout the community. Such an ecosystem will contain R&I projects in the cloud-edge-IoT portfolio to be coordinated, the diverse community evolved from the current cloud and IoT ones, with the addition of actors, initiatives, and significant alliances. The supply-side nature of OpenContinuum's agenda will orient the themes and focus of project activities but will not limit the scope of community building. The project's active landscaping and engagement work will bring the cloud and IoT communities together and express all points of view with a common understanding. It will then provide guidance to European actors to contribute to and lead open-source projects and standardisation efforts.

2.1.3 Conclusion

The listed ecosystems and projects are a non-exhaustive collection of the considered sources. Other tools and papers, such as the IDSA Position paper on Energy Interoperability [4], were compared and analysed to develop the following conceptual representation.

One main takeaway from this analysis is the wide diversity among the available sources. While there are many projects and institutions working on similar goals, the specific focus and especially the TRL vary significantly between them. This diversity was a main challenge for the creation of the representation shown in section 2.2.1

2.2 CONCEPTUAL REPRESENTATION

2.2.1 General representation

Based on the analysis of differentiating traits of these examples, a generic representation of Cloud/Edge IoT Ecosystems was developed. Due to the large variety among the considered instances (even regarding the most important characteristics), creating very fine-grained categories for each specific area turned out to be neither practical nor helpful. Instead, the representation asks the truly fundamental characteristics of each ecosystem and gives room to elaborate in a way that makes sense for the individual Ecosystem.

Table 1 shows the resulting categorization, including description of the necessary information.

Ecosystem Overview	
Ecosystem Name	*Name*
Domain	*E.g. Energy / Manufacturing / etc.*
Objectives	*Description of main goal / use case*
Developing Organization / Project	*Company or Project Name*
Existing applications	*Where has this ecosystem already been applied and by whom*
Accessibility	*Proprietary / Open Source / etc.*

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User Features	
User Interface	*CLI / GUI / etc.*
Asset Management	*Yes / No / Description of Asset Mgmt. feature(s)*
Data Features	
Data Trading	*Yes / No / Description of how separate participants (asset owners, service providers) can share and trade data amongst each other*
Data Analysis Support	*Native analysis features / integration options with analysis tools (e.g. Visualization Tools)*
Data Storage Support	*Integration options with Cloud DBs or other storage tools*
Applicability	
Hardware Requirements	*Requirements for participant devices (e.g. required support of certain protocols)*
Data Exchange	*Time Series / Event-Based*
Access & Usage Control	
Identity Management	*Yes / No / Description of IdM processes*
Access Control	*Yes / No / Description of how ecosystem participants can manage users' access to their assets and services*
Usage Control	*Yes / No / Description of Ecosystem-wide Usage Control Policies*
Communication & Security	
Supported Communication Protocols	*List of protocols*
Data Security Measures	*Description of security measures*
Participant Types	

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Types of Actors / Participants	Description
…	…
Ecosystem Structure	
Diagram of Ecosystem Structure, how participants relate to / communicate with each other	

TABLE 1. CONCEPTUAL REPRESENTATION

2.2.2 Representation of Examples

The following shows how this tool is applied so some of the examples that were used to build it. This representation makes those rather complicated ecosystems comparable in a structured and easy way.

Ecosystem Overview	
Ecosystem Name	Apio IoT Platform
Domain	Energy
Objectives	Multi-tenant IoT platform with a focus on the energy domain, supporting any HTTPS/MQTTS/SFTP enabled device/application. The platform is built upon open standards and provides, in addition to all the features required by an IoT platform, features for data analysis, such as Cloud Storage integration by default for time series data (with first class supports for new analytical formats such as Apache Parquet and Apache Arrow, and new tooling like DuckDB) to enable Data-Intensive use cases such as Machine Learning workloads and Analytical workloads.
Developing Organization / Project	Apio
Existing applications	• IoT Layer for Platone Project • Base for Open-Call projects in Platoon and Ontochain • Renewable Assets monitoring product • Smart Energy Management product • Smart Home / Smart Building product
Accessibility	Proprietary, "soon" to be Open Source

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User Features	
User Interface	CLI / GUI (Web dashboard)
Asset Management	Yes. Assets can have virtual properties, obtained by assigning its own properties to devices properties. For instance, it is possible to have an asset representing a manufacturing machine and an energy meter, which is measuring the machine's energy consumption: through property mappings it is possible to assign the energy property of the meter, to the consumption property of the asset. Furthermore, assets can have parent entities, allowing to create complex hierarchies of assets. Also, the platform supports geolocation and custom metadata.
Data Features	
Data Trading	No
Data Analysis Support	Visualization Tool Suite
Data Storage Support	Cloud Storage integration by default for time series data (supports e.g. Apache Parquet, Apache Arrow, DuckDB)
Applicability	
Hardware Requirements	Devices need to support HTTPS or MQTTS or SFTP
Data Exchange	Time Series and Event-Based
Access & Usage Control	
Identity Management	Yes - Users need at least one of the following types of credentials to access platform features • **Auth Tokens:** user scoped, short lived credentials, created by providing the correct user information in the form of email and password. • **API Keys:** namespace scoped credentials, created by authenticated users, can be used with mqtts/https/sftp clients. • **Access Tokens:** user scoped credentials, created by authenticated users, can be used in https mqtts/https/sftp clients.

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	• **X.509 Certificates**: asset scoped credentials, to be used with devices/gateways/applications that connect through mqtts.
Type of Access Control	Administrators can assign roles & access rights to Users. • **Users:** people who have access to the resources created within the project. Each user is assigned to a role, which determines the permissions of the user. • **Permission:** a string representing an action, such as apio.core.devices.read or apio.core.assets.write • **Roles:** Entities associated with a set of permissions. Users can be assigned to roles thanks to ACLRules. • **Groups:** Entities associated with a set of resources. Users can be assigned to groups thanks to GroupMemberships
Usage Control	No
Communication & Security	
Supported Communication Protocols	• MQTT • HTTP API • SFTP (only for uploading time series data)
Data Security Measures	The platform prevents **unauthorized access** through required authentication and authorization checks on every endpoint.
Participant Types	
Types of Actors / Participants	Description
Project	The "Project" resource is the container (or namespace) of every other resource inside the project, enabling multi-tenancy on the same deployment of the platform. When starting an Apio IoT project, you need to generate a project first.
Devices	Devices represents sensors, actuators and any other object which can be collect data from the field or receive commands from the cloud.

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	Devices can be assigned to Plants and Nodes.
Assets	Assets represent objects which are more interesting to your domain, such as a production machine, a solar panel or a robotic arm, which will be connected to sensors and actuators by sharing attributes and properties.
Nodes	Nodes are network devices often used to collect data from multiple sensors (or to send data to multiple actuators). Devices can be assigned to nodes.
Plants	Plants are logical entities used to represent a physical colocation of assets, devices and nodes. Nodes, devices and assets can be assigned to plants.

Ecosystem Structure

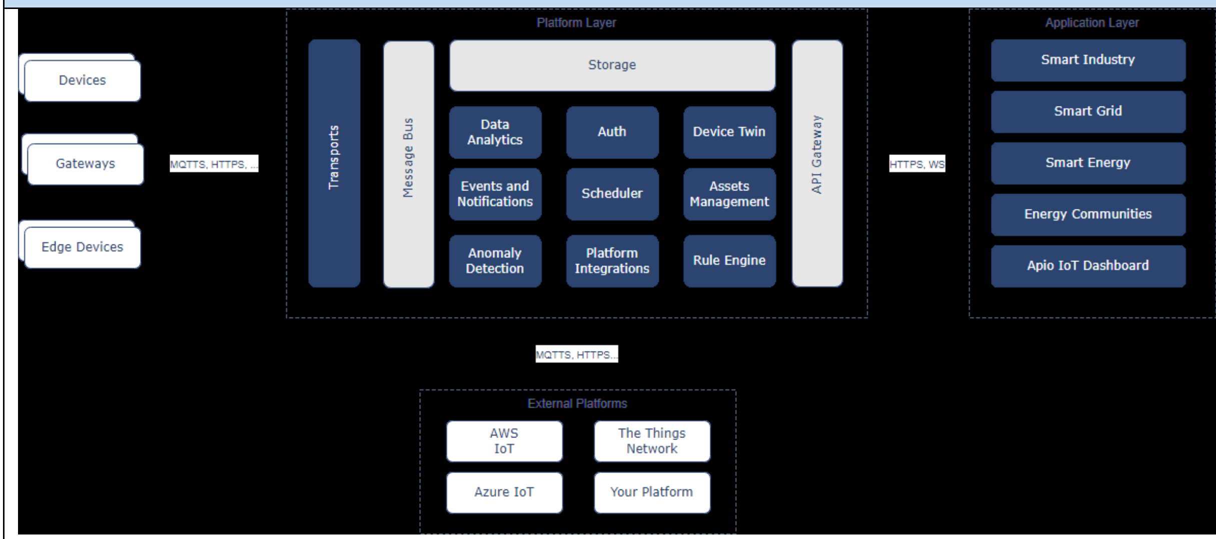

TABLE 2. CONCEPTUAL REPRESENTATION: APIO

Ecosystem Overview	
Ecosystem Name	KONČAR MARS
Domain	Energy / Environmental monitoring / Smart Infrastructure etc.
Objectives	Advanced management of smart cities, critical and urban infrastructure, meter data management
Developing Organization / Project	Končar Digital Ltd.

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Existing applications	Projects: "Smart city Karlovac" (SenzoriKA), IoT platforma, "Industrial IoT platform for intelligent and energy-efficient management of industrial IoT devices" etc.
Accessibility	Proprietary
User Features	
User Interface	GUI
Asset Management	Basic asset management features: • Manufacturer • Serial number • Date of installation • Unique identificatory etc. Hierarchy of data associated with assets.
Data Features	
Data Trading	API to read data related to own tenant data segmentation.
Data Analysis Support	Remote monitoring, data reading, maintenance, and management, integrated with real-time analysis and reporting.
Data Storage Support	A proprietary database that is part of the application. Accessible via the application interface or through an API.
Applicability	
Hardware Requirements	Ethernet, LoRaWAN, NBIoT, 4G/5G
Data Exchange	Time Series
Access & Usage Control	
Identity Management	No
Access Control	Module based access control per user and/or group
Usage Control	Data segmentation per user and/or group
Communication & Security	
Supported Communication Protocols	Modbus, Mbus, DLMS, MQTT, IEC104
Data Security Measures	Certified IEC 62443-2-4
Participant Types	
Types of Actors / Participants	Description
Water providers, Energy providers, Cities, Critical infrastructure owners	Participants are government or private parties, needing to read data from different sensor devices, and in some cases also sending control commands to devices.
Ecosystem Structure	

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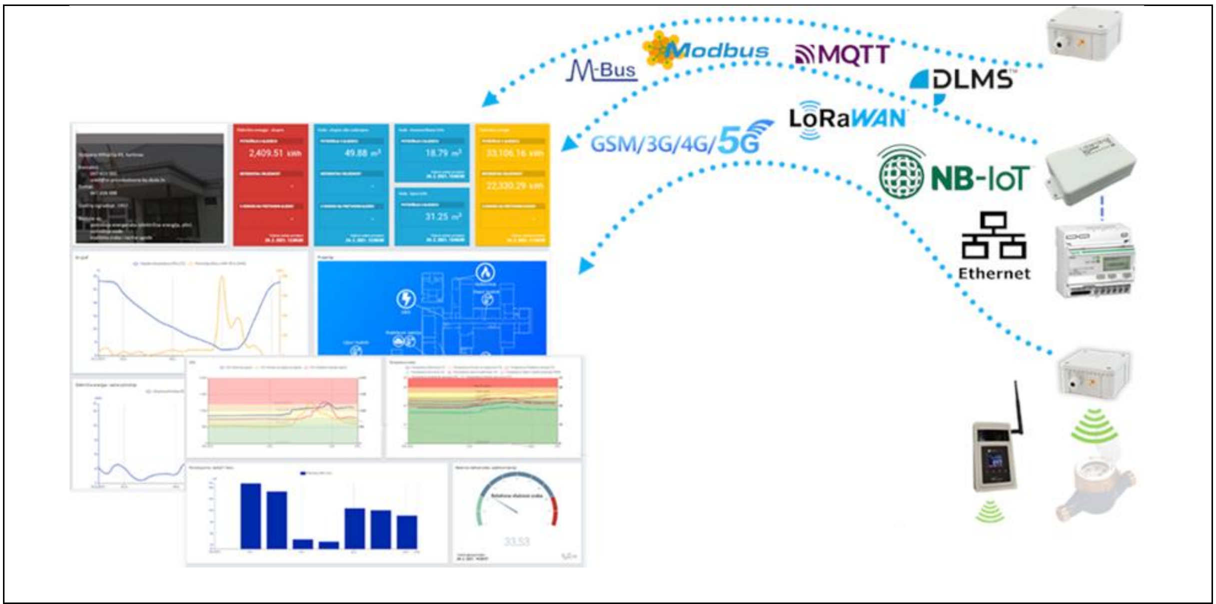

TABLE 3. CONCEPTUAL REPRESENTATION: KONCAR MARS

2.3 POSITIONING OF HEDGE-IOT

The following table contextualizes the initial Conceptual Representation of HEDGE-IoT project. Due to the early stage in which the project is, not all fields can be fully answered at time of submission. Instead, we can define what Tasks within the project are responsible to address these topics. The representation below serves as a first orientation and as a base to keep up to date within the project as questions are answered over time. It therefore contains references to defined requirements as well as Use Cases and Tasks of the project, which are in progress towards defining the platform's exact specifications.

Ecosystem Overview	
Ecosystem Name	HEDGE-IoT
Domain	Energy
Objectives	• Anomaly detection and fault forecasting to increase MV distribution network resilience • Predictive and real-time congestion management (CM) to increase network hosting capacity • Flexibility management through active prosumers/consumers engagement • Leveraging data exchange and AI edge algorithms for energy forecasting and prevention of critical grid events • Flexibility trading platform for mitigating problems of the T&D networks

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	• Energy flow optimisation with dynamic grid limits • Flexibility provided by Energy Community to solve a local congestion • Optimal flexibility management of a decentral energy grid • Anomaly detection in a decentralized electricity grid to optimize grid availability and grid resilience • GreenVale: Harnessing the potential of energy communities by leveraging Federated Learning strategies • Participation of industrial and residential energy communities in ancillary services market for the TSO • Flexibility aggregation at tertiary buildings • Maximizing asset capacity for increased lifetime of DSO and TSO equipment • Enhanced Network Manageability and Observability
Developing Organization / Project	Hedge IoT Consortium
Existing applications	None – Project in development
Accessibility	Open Source
User Features	
User Interface	TBD
Asset Management	Yes – specifics to be defined according to SUCs (e.g. SUC-GR-03.01)
Data Features	
Data Trading	Enabling of Data Exchange via a Data Space is planned e.g. within the Portuguese Pilot (see BUC-PT-01). Monetization schemes have not yet been defined at time of submission
Data Analysis Support	Several Data Analysis System Use Cases have been defined for the project: • Anomaly detection and fault prediction (SUC-FI-01.2, SUC-NL-05) • Predictive Maintenance (SUC-NL-06) • Congestion Prediction (SUC-FI-02.1) • CM planning (SUC-FI-02.2) • State monitoring (SUC-FI-02.03) • CM decision-making (SUC-FI-02.4) • Demand Forecasting (SUC-GR-01.02) • Production Forecasting (SUC-GR-01.03)

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	• Optimization of Flexibility Distribution (SUC-GR-01.01) • Flexibility Alignment (SUC-NL-04) • Grid Management and planning using Forecasting Data (SUC-GR-02.01, SUC-SL-02.2) • Computation of Grid Limits (SUC-IT-02.1,02.2,02.3) • Optimization of energy production & consumption (SUC-NL-03) • Bidding, Selection and Settlement within energy communities (SUC-PT-02.02, SUC-PT-02.04) • DTR on Edge calculation (SUC-SL-01.01) • DLR on Edge calculation (SUC-SL-01.02) The actual implementation & integration with the ecosystem will follow in upcoming project work, specifically in WP3.
Data Storage Support	System Use Cases relevant to Data Storage support have been identified: • Data collection and processing in EDGE (SUC-FI-01.01, SUC-GR-01.04) • Monitoring of energy nodes and (local) grid ((SUC-NL-01.01) The actual implementation & integration with the ecosystem will follow in upcoming project work, specifically in WP3.
Applicability	
Hardware Requirements	To be defined in detail as part of further project work (see SUCs in upcoming Deliverable 2.2)
Data Exchange	Time-Series and Event-Based Data need to be exchanged and considered as well as historical data
Access & Usage Control	
Identity Management	Planned as part of Interoperability Middleware. Details to be defined within T4.2.
Access Control	Required (ID 2.15). Planned as part of Interoperability Middleware. Details to be defined within T4.2.
Usage Control	Planned as part of Interoperability Middleware. Details to be defined within T4.2.
Communication & Security	

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Supported Communication Protocols	To be defined in detail as part of further project work (see SUCs in upcoming Deliverable 2.2)
Data Security Measures	To be defined in detail within Task 4.5 (Not started at time of submission)
Participant Types	
Types of Actors / Participants	Description
See "Actors" within BUCs, given in Chapter 3.	
Ecosystem Structure	
Reference Architecture in development, see upcoming Deliverable 2.2	

TABLE 4. CONCEPTUAL REPRESENTATION: HEDGE-IOT

The main takeaway from this positioning is the mapping of conceptual topics to the relevant tasks within the HEDGE-IoT project. While it is natural that a full positioning within the state-of-the-art will only be possible once the platform is clearly specified, at the current moment it is already clear that it will cover quite a comprehensive set of functionalities compared to the other considered systems. One of the most relevant open questions in this regard concerns the categories of "Data Analysis Support" and "Data Storage Support", specifically the decisions to be made on which of the listed required functionalities will be native part of the HEDGE-IoT platform vs. local implementation within each pilot.

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3 BUSINESS USE CASES AND END USERS' REQUIREMENTS ANALYSIS

In this section the results of task T2.2 "End Users' Requirements Analysis and Design of BUCs" are presented. The main objectives of this task were to design the business use cases (BUCs) from HEDGE-IoT pilot demonstrators and to analyze the end users' requirements, providing the necessary output for the specification of system use cases and the reference architecture design.

3.1 BUSINESS USE CASES OF THE HEDGE-IOT DEMONSTRATORS

3.1.1 Methodology for the definition of business use cases

A use case (UC) describes the interactions of various actors of a system to achieve specific goals. A business use case (BUC) depicts a business process, and a system use case (SUC) depicts a function that supports one or more business processes. Both types of UCs are essential for the description of a system and can be used for the system architecture definition. For HEDGE-IoT, the BUCs were the starting point for the pilots to define SUCs and will also be used for the definition of the reference architecture. In this deliverable, only the BUCs from the demonstrators are presented. The SUCs are part of Deliverable D2.2.

The BUCs from HEDGE-IoT demonstrators were designed following the standardized IEC-62559-2 template [5], which was also used for the SUCs. The full template is shown in Appendix A and has the following seven main sections:

1. Description of the use case
2. Diagrams of use case
3. Technical details
4. Step by step analysis of use case
5. Information exchanged
6. Requirements
7. Common terms and definitions

For the HEDGE-IoT project, the following sections and subsections of the template were defined as mandatory to be filled out by the pilot demonstrators for the BUCs:

1. Description of the use case
    1.1. Name of the use case
    1.2. Scope and objectives of the use case
    1.3. Narrative of the use case
2. Diagrams of the use case
3. Technical details
    3.1. Actors
4. Step by step analysis of use case
    4.1. Overview of scenarios
    4.2. Steps - scenarios
5. Information exchanged
6. Requirements

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The design and writing process of the BUCs was done in four steps, each resulting in a different and more complete version of the BUCs, shown in Figure 1.

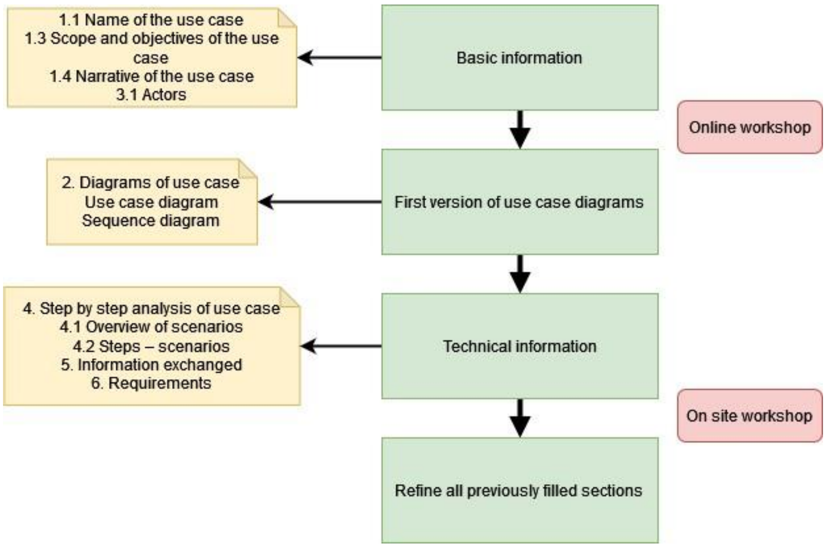

FIGURE 1. BUSINESS USE CASE DEFINITION METHODOLOGY

The minimum number of BUCs for each pilot was defined as two. For the first version, each pilot defined their BUCs describing the scope and objectives, the narrative and the actors involved. For the actors' names and descriptions, the Harmonized Energy Market Role Model (HEMRM)[1] was used as a reference. An overview of each BUC from all the six pilots were presented at an online workshop for all the task participants.

The next section of the template filled out for each BUC was the diagrams of use case. For this second step, the pilot partners designed a first version of UML (Unified Modelling Language) use case diagrams and sequence diagrams. The use case diagram shows how the actors interact within the use case and participate in technical functions. The sequence diagrams show the sequence of activities that are part of a functionality and can illustrate a scenario of the use case. A template was defined and shared with the partners with common elements to be used in the diagrams.

Having the basic information of the use case and a first version of diagrams, the next step was to write the scenarios overview and steps, information exchanged and requirements. With these sections, the pilots defined the use case with more details and identified the information flow and requirements involved in each possible scenario of the use case.

With all these sections filled out, the progress of the BUCs and the last refinements to be made were discussed in an in-person workshop that had the participation of at least two representatives from each pilot. The SUCs were also discussed during the workshop, as they were being defined in parallel and are connected to the BUCs through the functional processes involved.

Finally, the last version of the BUCs were defined after the refinement of all the previously filled sections.

[1] https://eepublicdownloads.entsoe.eu/clean-documents/EDI/Library/HRM/Harmonised_Role_Model_2023-01.pdf

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3.1.2 Business use cases

Following the methodology presented in the previous subsection, 14 BUCs were gathered from the six HEDGE-IoT demonstrators across six European countries and are listed in Table 5.

Pilot	BUC ID	BUC name
Finnish	BUC-FI-01	Anomaly detection and fault forecasting to increase MV distribution network resilience
	BUC-FI-02	Predictive and real-time congestion management (CM) to increase network hosting capacity
Greek	BUC-GR-01	Flexibility management through active prosumers/consumers engagement
	BUC-GR-02	Leveraging data exchange and AI edge algorithms for energy forecasting and prevention of critical grid events
	BUC-GR-03	Flexibility trading platform for mitigating problems of the T&D networks
Italian	BUC-IT-01	Energy flow optimisation with dynamic grid limits
	BUC-IT-02	Flexibility provided by Energy Community to solve a local congestion
Dutch	BUC-NL-01	Optimal flexibility management of a decentral energy grid
	BUC-NL-02	Anomaly detection in a decentralized electricity grid to optimize grid availability and grid resilience
Portuguese	BUC-PT-01	GreenVale: Harnessing the potential of energy communities by leveraging Federated Learning strategies
	BUC-PT-02	Participation of industrial and residential energy communities in ancillary services market for the TSO
	BUC-PT-03	Flexibility aggregation at tertiary buildings
Slovenian	BUC-SI-01	Maximizing asset capacity for increased lifetime of DSO and TSO equipment
	BUC-SI-02	Enhanced Network Manageability and Observability

TABLE 5. HEDGE-IOT BUSINESS USE CASES

In the following subsections, an overview of the BUCs for each demonstrator is presented, including the BUC's scope and objectives, the UML use case diagram and the actors involved. The full description of the BUCs is shown in Appendix B .

3.1.2.1 Finnish pilot

3.1.2.2 BUC-FI-01 Anomaly detection and fault forecasting to increase MV distribution network resilience

The objective of BUC-FI-01 is to improve the resilience of a MV distribution grid by providing early warning and fault forecasts to the grid operator leveraging high resolution measurements from IEDs.

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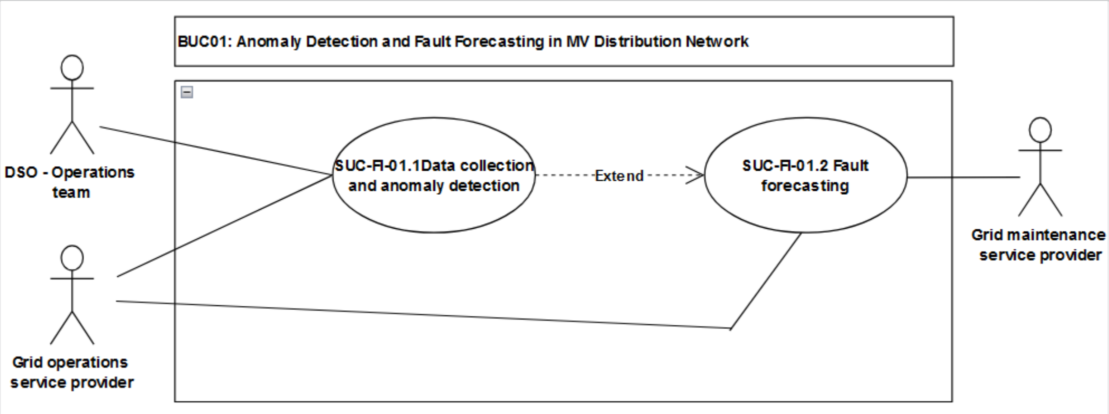
BUC ID	BUC-FI-01
BUC NAME	Anomaly detection and fault forecasting to increase MV distribution network resilience
SCOPE	Detection of anomalies and fault forecasting within MV distribution grid based on real-time data stream processing on edge level at primary substation.
OBJECTIVES	Use edge level data analysis to access real-time full-resolution data streams provided by IEDs to better detect abnormal situations in the grid. Collect logs and counters for identified events to be able to detect longer-time developing issues. Provide early warnings and fault forecasts to the grid operator.
USE CASE DIAGRAM	
	
ACTORS	
ACTOR NAME	ACTOR DESCRIPTION
DSO (Distribution system operator)	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in each area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity.
Grid maintenance service provider	The party conducting grid maintenance and repairs for DSO as a service. Depending on contracts, can have a more independent role in managing faults as well.
Grid operations service provider	The party providing operator room functions, field crew management, etc. as a service to DSO.

TABLE 6. BUC-FI-01 OVERVIEW

3.1.2.3 BUC-FI-02 Predictive and real-time congestion management (CM) to increase network hosting capacity

In this BUC, the goal is to increase the hosting capacity of the DSO's network through flexibility mechanisms by using predictive and real-time congestion management. With this use case, the DSO will be able to provide quicker grid connection services to customers and improve the utilization rate of the existing grid infrastructure.

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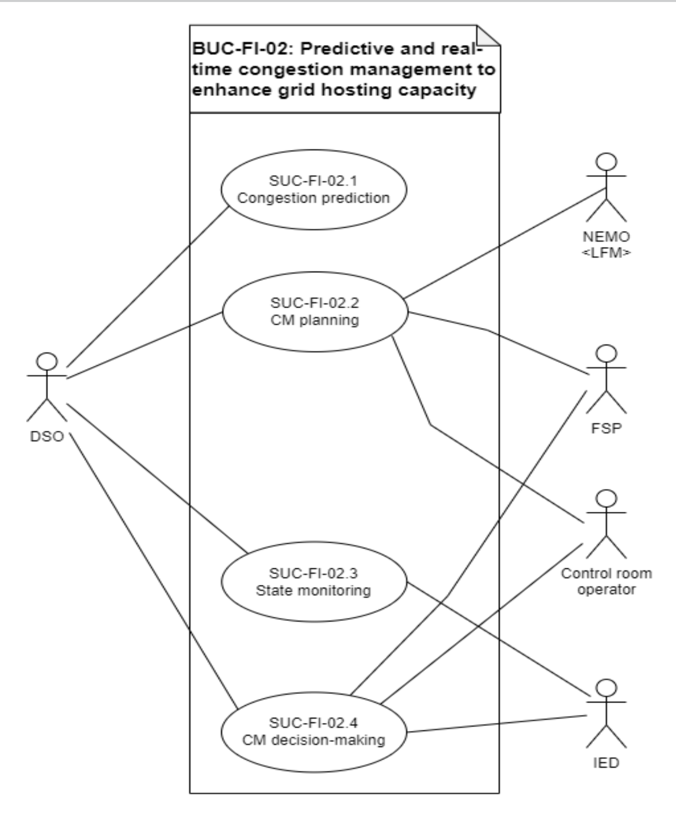
BUC ID	BUC-FI-02
BUC NAME	Predictive and real-time congestion management (CM) to increase network hosting capacity
SCOPE	Predictive and real-time CM in distribution grids.
OBJECTIVES	Increasing the hosting capacity of the distribution system operator's (DSO) network using congestion management that operates the network based on its actual state and not on worst cases identified during offline planning of the network. Reducing the time and costs when connecting new customers to the grid.

USE CASE DIAGRAM



ACTORS

ACTOR NAME	ACTOR DESCRIPTION
DSO	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in each area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity.
FSP	A party that aggregates resources for usage by a service provider for market services.

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Control room operator	A human operator in the control room is responsible for monitoring the system and applying control decisions in real-time.
Nominated electricity market operator (NEMO)	A party that provides a service whereby the offers to sell flexibility/electricity are matched with bids to buy flexibility/electricity.
Intelligent electronic device (IED)	A device that acts as a measurement device. It can also receive control signals and apply them to the controllable resource.

TABLE 7. BUC-FI-02 OVERVIEW

3.1.2.4 Greek pilot

3.1.2.5 BUC-GR-01 Flexibility management through active prosumers/consumers engagement

The aim of this BUC is to incentivize consumers and prosumers to actively engage in the flexibility market to foster flexibility procurement. Edge IoT devices will be deployed to monitor flexibility assets and obtain energy related information. With this monitoring, the aggregator can leverage insights to run machine learning algorithms and decide whether to offer incentives to its customers to participate in the flexibility market.

BUC ID	BUC-GR-01
BUC NAME	Flexibility management through active prosumers/consumers engagement
SCOPE	Prosumers can actively participate in a flexibility market using easy to operate and user-friendly GUIs. The key point is to focus on empowering prosumers to manage their energy consumption and production dynamically, thereby contributing to grid stability and reliability while potentially earning incentives for their flexibility.
OBJECTIVES	The main objectives are: • To enhance the participation of prosumers and consumers to a flexibility market. • To enhance the penetration of RES into the grid operation • To advise consumers/prosumers on their energy usage habits and their environmental impact.
USE CASE DIAGRAM	

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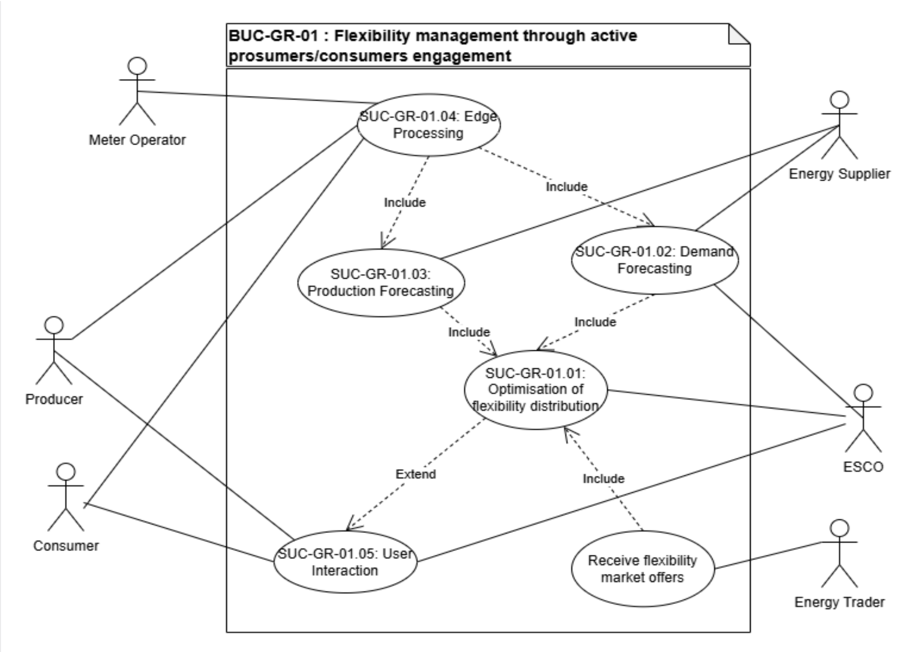

Actors	
Actor Name	**Actor Description**
Consumers	Consumers who possess IoT devices monitoring their consumption.
Producers	Small residential PV owners, promoting self-consumption (mostly under net-metering schemes
Control room operator	A human operator in the control room is responsible for monitoring the system and applying control decisions in real-time.
Meter Operator	An entity providing IoT submetering devices (smart plugs, smart meters, gateways, etc.).
ESCO	An entity processing, analyzing, and monitoring energy consumption/production data, operating the AI algorithms for demand/production forecasts, and performing the optimisation algorithms for the flexibility offers.
Energy Supplier	Collects consumer and prosumer data and is responsible for invoicing the consumers.
Energy Trader	The energy trader receives a flexibility offer from the LFM and decides to bid or not, based on the available flexibility resources available in the aggregator.

TABLE 8. BUC-GR-01 OVERVIEW

3.1.2.6 BUC-GR-02 Leveraging data exchange and AI edge algorithms for energy forecasting and prevention of critical grid events

This BUC will focus on ensuring the stability, efficiency, and sustainability of the grid infrastructure by forecasting future energy demands and identifying potential critical events on the grid by leveraging data collected from edge IoT devices.

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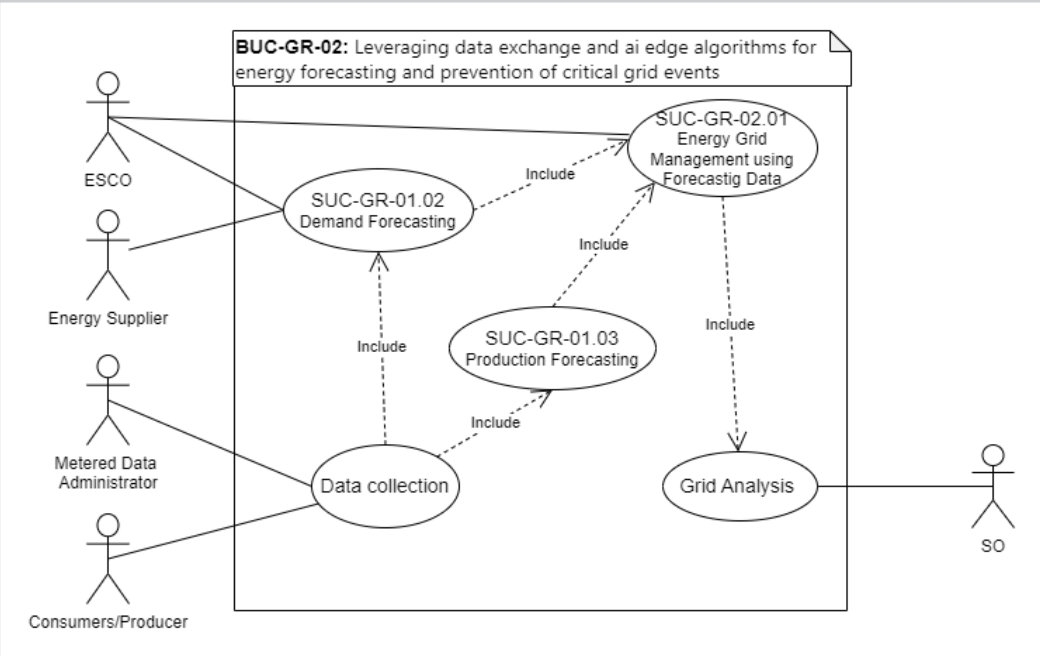
BUC ID	BUC-GR-02
BUC NAME	Leveraging data exchange and AI edge algorithms for energy forecasting and prevention of critical grid events
SCOPE	AI-IoT Edge-Cloud data exchange for assessing current and future grid security through consumption forecasting and the identification of optimal disaggregation and DR scenarios.
OBJECTIVES	The main objectives are: • To collect and process data from IoT devices. • To forecast long-term and day-ahead localized energy demand. • For the SOs to analyse and assess the grid status and identify the possibility of critical events. • To form flexibility requests for avoiding critical events and maintain grid stability.

USE CASE DIAGRAM



ACTORS

ACTOR NAME	ACTOR DESCRIPTION
Energy Supplier	An Energy Supplier supplies electricity to or takes electricity from a Party Connected to the Grid at an Accounting Point. Additional information: an Accounting Point can only have one Energy Supplier. When additional suppliers are needed the Energy Supplier delivers/takes the difference between established (e.g. measured or calculated) production/consumption and the (accumulated) contracts with other suppliers.
System Operator	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution or transmission of electricity.

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Consumer/Producer	A party that consumes energy and that generates electricity. Additional information: this is a type of Party Connected to the Grid.
Energy Service Company	A party offering energy-related services to the Party Connected to Grid, but not directly active in the energy value chain or the physical infrastructure itself. The Energy Service Company (ESCO) may provide insight services as well as energy management services.
Metered Data Administrator	A party responsible for storing and distributing validated measured data.

TABLE 9. BUC-GR-02 OVERVIEW

3.1.2.7 BUC-GR-03 Flexibility trading platform for mitigating problems of the T&D networks

This use case aims to implement a local flexibility market platform to address issues in the transmission and distribution networks and will include registration and prequalification, flexibility trading and settlement and remuneration.

BUC ID	BUC-GR-03
BUC NAME	Flexibility trading platform for mitigating problems of the T&D networks
SCOPE	Enable trading of residential Distributed Energy Resources (DERs) flexibility in a cloud-based Local Flexibility Market (LFM) by deploying near real-time measurements from behind the meter IoT devices for flexibility settlements and associated transaction management.
OBJECTIVES	The goal of the UC is to build an independent marketplace to procure flexibility generated through federated-learning algorithms at consumer level with the objective to solve T&D grid issues. The LFM acts as a central hub for all market relevant processes, related to registration & prequalification, trading and post trading and facilitates coordinated IoT Cloud-Edge data exchange and interaction among market participants, respecting their business needs and data exchange limitations.
USE CASE DIAGRAM	

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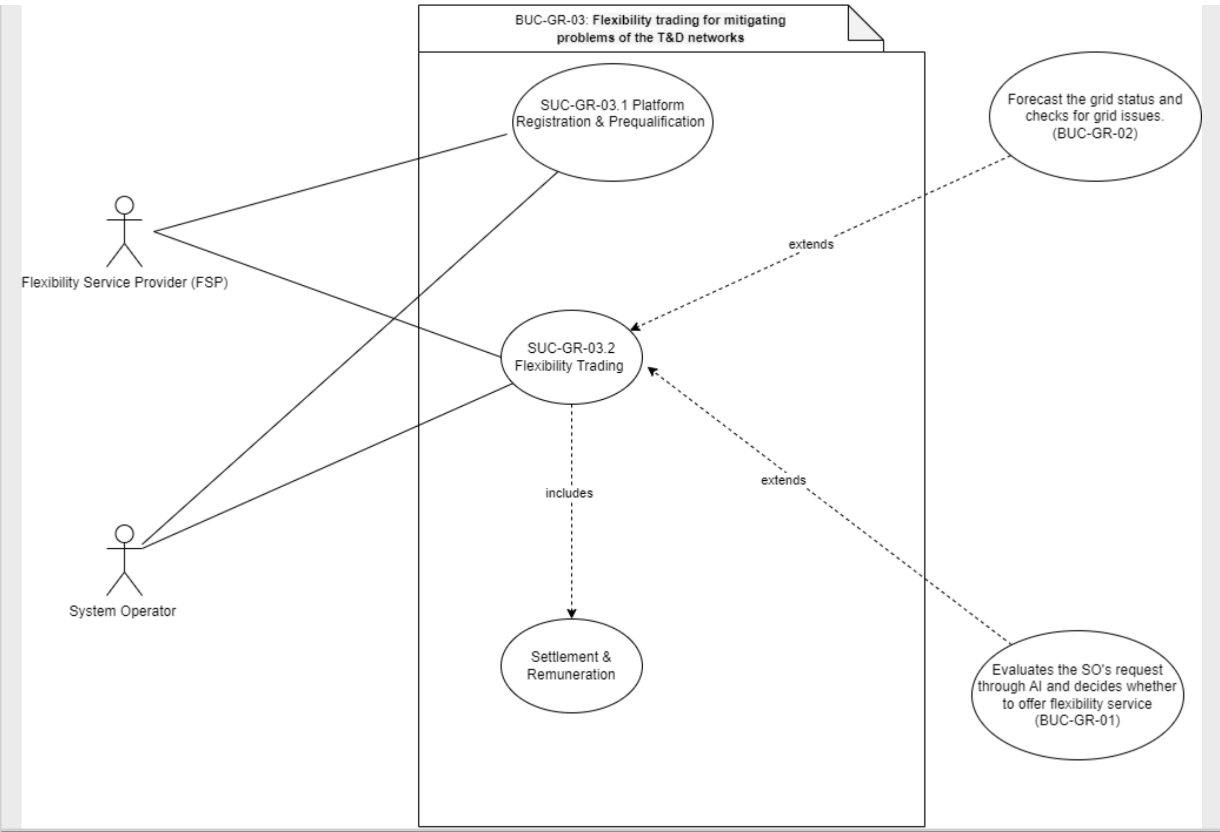

Actors	
Actor Name	**Actor Description**
System Operator	System Operators join the local flexibility market to request and purchase flexibility from the flexibility providers.
Flexibility Service Provider	Flexibility Service Provider joins the flexibility market and registers their clients (prosumers/consumers) assets to offer and sell flexibility.
Registration Layer	The service for prequalification of assets and participants.
Local Flexibility Market	The market for flexibility trading.

TABLE 10. BUC-GR-03 OVERVIEW

3.1.2.8 Italian pilot

3.1.2.9 BUC-IT-01 Energy flow optimisation with dynamic grid limits

The goal of this BUC is to optimize energy flow in the grid through energy communities. The DSO detects real-time limits of the distribution grid and timely communicates them to the Energy Community Manager to integrate this data in the optimization of energy flow in the energy community.

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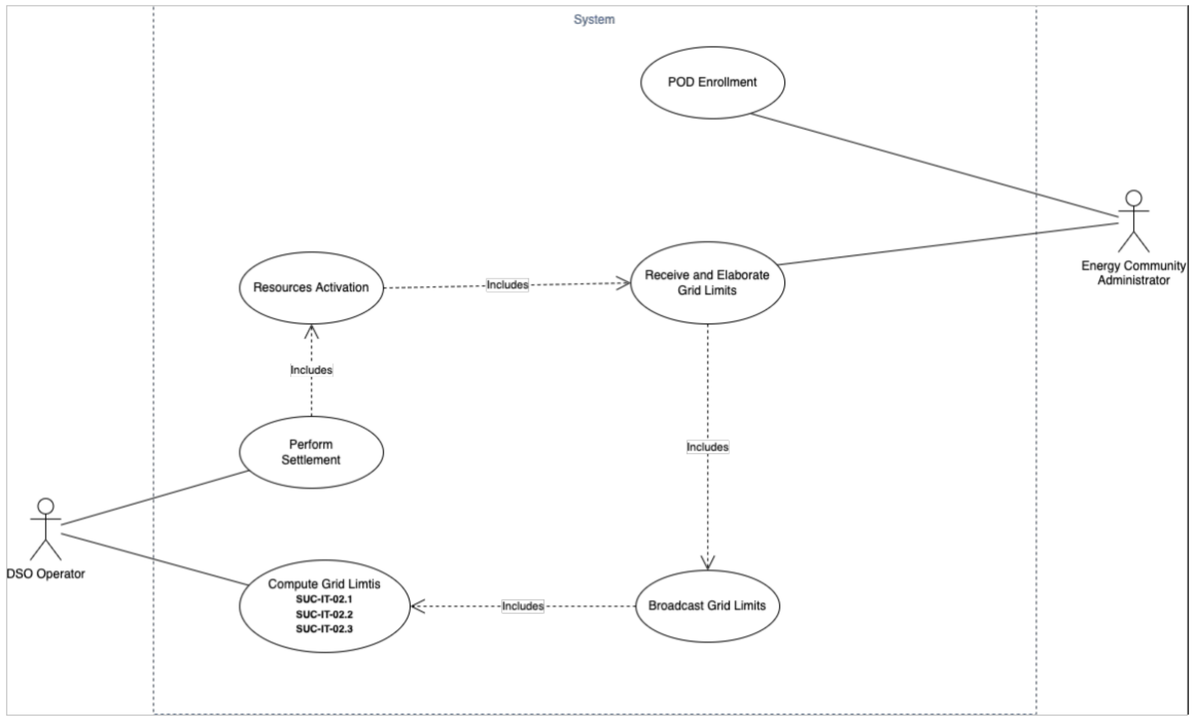
BUC ID	BUC-IT-01
BUC Name	Energy flow optimisation with dynamic grid limits
Scope	Optimize the real time energy flow in an Energy Community considering the dynamic local grid constraints.
Objectives	From the Energy Communities - Perform the tool for energy flow using the dynamic grid constraints. From the DSO – Detect the real time grid constraints.

Use case diagram



Actors

Actor Name	Actor Description
DSO	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of energy.
Flexibility Register Operator	Administrator of all the information that is stored in the Flexibility Register. Responsible for allocating access rights to the various actors and controlling the level of access. Stores flexibility assets, results of qualification (both product and grid), stores market results, grid information, aggregates flexibility information and stores the results of the settlement. Forwards activation signals to flexibility assets upon request of the SOs. The Flexibility operator should be a trusted authority due to the sensitivity level of the information being handled.

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Party Connected to the Grid	A party that contracts for the right to take out or feed in energy at a Point of Delivery (PoD).
Consumer	A party that consumes energy.
Producer	A party that generates electricity.
Energy Community Manager	A party offering energy management services to the Party Connected to Grid, but not directly active in the energy value chain or the physical infrastructure itself.

TABLE 11. BUC-IT-01 OVERVIEW

3.1.2.10 BUC-IT-02 Flexibility provided by Energy Community to solve a local congestion

In this use case, the aim is to solve local congestion issues using flexibility provided by energy communities, with attention of vulnerable users. The local flexibility market implemented in the use case treats the short-term sessions and the phases of procurement, activation and settlement.

BUC ID	BUC-IT-02
BUC NAME	Flexibility provided by Energy Community to solve a local congestion
SCOPE	Solving a local congestion issue acquiring flexibility provided by Energy Communities, through market approach.
OBJECTIVES	Provide flexibility to DSO. Ensure an inclusive and non-discriminatory access to the market.
USE CASE DIAGRAM	

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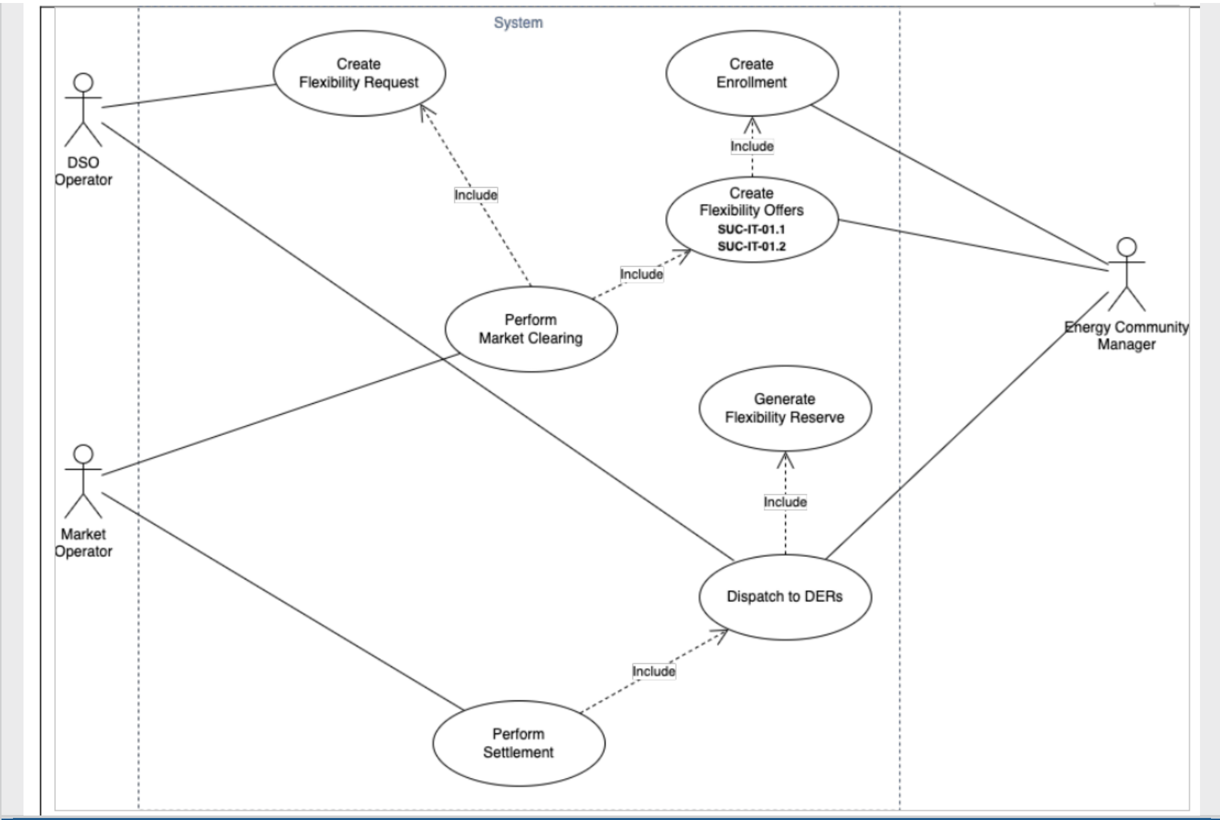

Actors	
Actor Name	Actor Description
DSO	System Operators join the local flexibility market to request and purchase flexibility from the flexibility providers.
Flexibility Register Operator	Flexibility Service Provider joins the flexibility market and registers their clients (prosumers/consumers) assets to offer and sell flexibility.
Flexibility Service Provider	The service for prequalification of assets and participants.
Market Operator	The market for flexibility trading.
Party Connected to the Grid	A party that contracts for the right to take out or feed in energy at a Point of Delivery (PoD).
Consumer	A party that consumes energy.
Producer	A party that generates electricity.
Energy Community Manager	A party offering energy management services to the Party Connected to Grid, but not directly active in the energy value chain or the physical infrastructure itself.
Customer	A party enrolled by FSP to participate to Flexibility Market and/or Energy Community.
Balance Service Provider	A party with reserve-providing units or reserve-providing groups able to provide balancing services to one or more LFC Operators.

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TABLE 12. BUC-IT-02 OVERVIEW

3.1.2.11 Dutch pilot

3.1.2.12 BUC-NL-01 Optimal flexibility management of a decentral energy grid

The goal of this BUC is to enable the expansion of the grid and support the decarbonization of energy consumption at a business park through the optimal real-time balance and control of energy flexibility. Energy nodes, such as PV, batteries and heat pumps, will be integrated into the energy management platform.

BUC ID	BUC-NL-01
BUC NAME	Gaining insight into the flexibility of the decentral energy grid (i.e., the Arnhems Buiten electricity campus) with connected energy nodes (including buildings) to optimally manage this flexibility through a platform (Energy Management System), thereby enabling the growth of users, adding more energy nodes and increase the sustainability of real estate.
SCOPE	Allow for expansion of business activities and residences with a limited grid connection.
OBJECTIVES	- Maximizing the amount of energy consumption and production of the grid of Arnhems Buiten within the real-time grid constraints of the DSO. - Remuneration and/or added value for the end-user and/or asset owners that provide energy flexibility. - Creating insights (and potential calculation models) into the various configurations possible in an electricity grid and the nodes and the advantages and disadvantages they offer in terms of energy flexibility.
USE CASE DIAGRAM	

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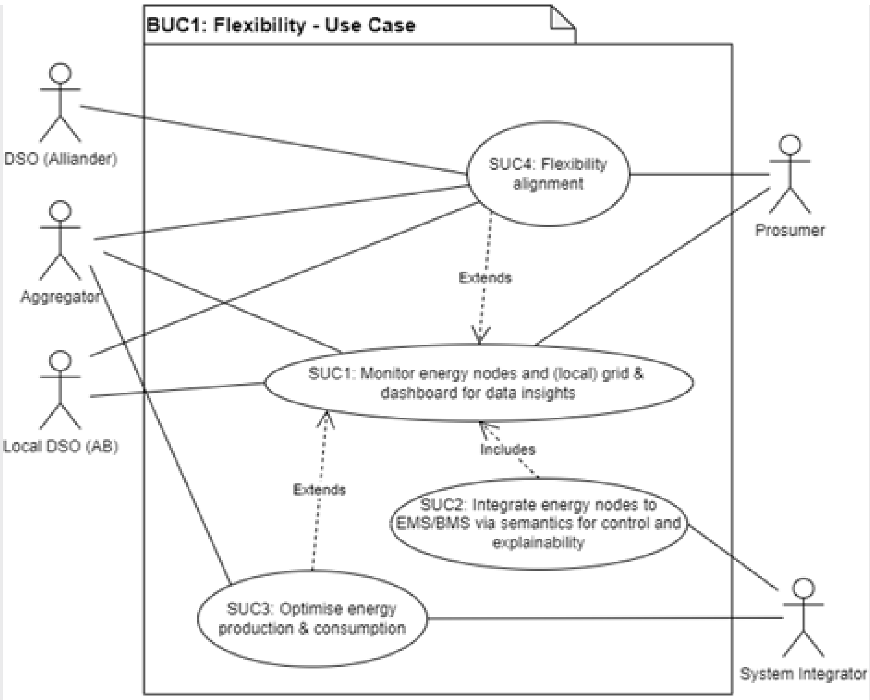

ACTORS	
ACTOR NAME	ACTOR DESCRIPTION
Prosumer	The combination of: - Visitor or tenant, paying (in)direct, via Grid operator) energy bill for using energy for charging EV, or using office (facilities), - Owner of buildings and (e.g. connected) PV, charging stations and batteries).
Local DSO	Local/decentral DSO. Owner of the Mid and Low voltage grid.
DSO - central	Central grid owner and operator.
Aggregator	Responsible for EMS.
System integrator	Responsible for semantic integration and explainability.

TABLE 13. BUC-NL-01 OVERVIEW

3.1.2.13 BUC-NL-02 Anomaly detection in a decentralized electricity grid to optimize grid availability and grid resilience

The focus of this BUC is to develop and use an open and robust platform with real-time anomaly detection and response to increase grid resilience by enhancing the stability and reliability of the system.

BUC ID	BUC-NL-02

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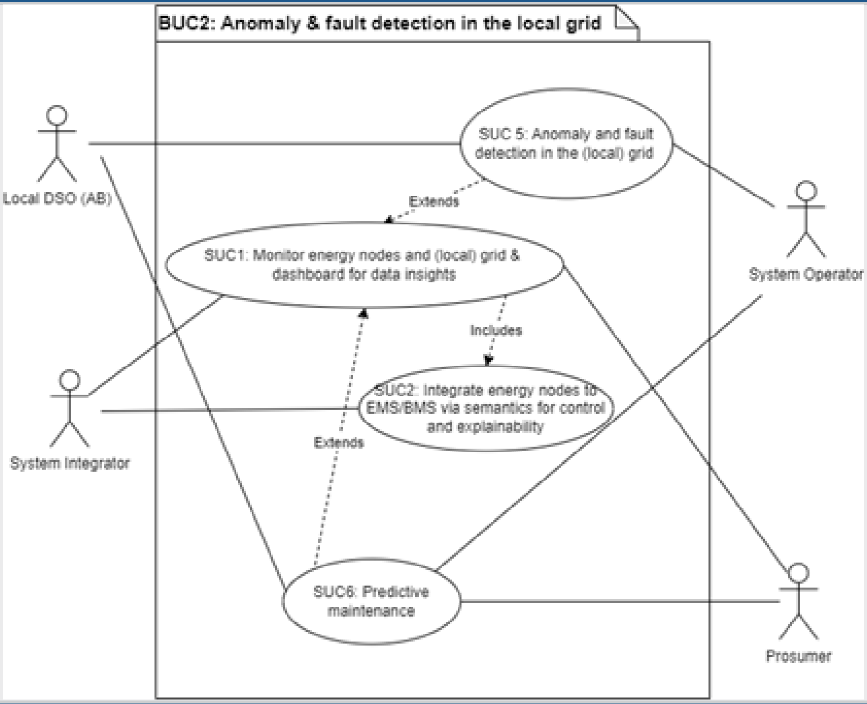
BUC NAME	Detecting anomalies in a decentralized electricity grid (i.e., the Arnhems Buiten electricity campus) to identify technical deviations such as, e.g., power quality issues and data (transmission) faults. The system monitors real-time data from various energy nodes in the grid, using (e.g. advanced ML) analytics and semantic reasoning to spot irregularities in voltage, frequency, and data flow. This provides the basis for a platform (hardware and software) to optimize grid availability and grid resilience.
SCOPE	Within the grid of the Electricity Campus realizing an open platform (hardware, software, and ecosystem) and process to make the operation of the grid and its connected energy assets (i.e., nodes) robust and more resilient.
OBJECTIVES	Strengthen the grid's ability to withstand and recover from technical faults and external disruptions by implementing advanced anomaly detection and automated response mechanisms, thereby enhancing overall system stability and reliability.

USE CASE DIAGRAM



ACTORS

ACTOR NAME	ACTOR DESCRIPTION
Prosumer	The combination of: - Visitor or tenant, paying (in)direct, via Grid operator) energy bill for using energy for charging EV, or using office (facilities), - Owner of buildings and (e.g. connected) PV, charging stations and batteries).
Local DSO	Local/decentral DSO. Owner of the Mid and Low voltage grid.
System operator	Responsible for operating, ensuring the maintenance of and, if necessary, developing the decentral grid/system.

System integrator	
Digital system and infrastructure	The Digital system and Infrastructure is a general-purpose logical function used in the BUCs that facilitates communication among energy nodes and other software components, allowing their automatic discovery. It also contains the intelligence for monitor and control, compute flexibility optimization options, detect anomalies and predict maintenance.

TABLE 14. BUC-NL-02 OVERVIEW

3.1.2.14 Portuguese pilot

3.1.2.15 BUC-PT-01 GreenVale: Harnessing the potential of energy communities by leveraging Federated Learning strategies

The main goal to be achieved with this BUC is the valorization of flexibility assets within a community of citizens allowing it to naturally become an energy community. The use case will include the identification of the most relevant assets to be controlled and the dynamic operation of the energy community using federated learning strategies.

BUC ID	BUC-PT-01
BUC NAME	GreenVale: Harnessing the potential of energy communities by leveraging Federated Learning strategies
SCOPE	Explore the energy flexibility of communities of citizens toward the creation of energy and non-energy services.
OBJECTIVES	The goals that the use case is expected to achieve: • Valorization of the existing flexibility (generation and load). • Use Federated Learning strategies to foster local optimization. • Enable Community-based renewable generation (investment/operational plan). • Enabling the flexibility on the community participants (new technologies) through the DPP 's flexibility value chain. • Support the ongoing living lab. Foster interoperability and the integration with data spaces (multi-domain)
USE CASE DIAGRAM	

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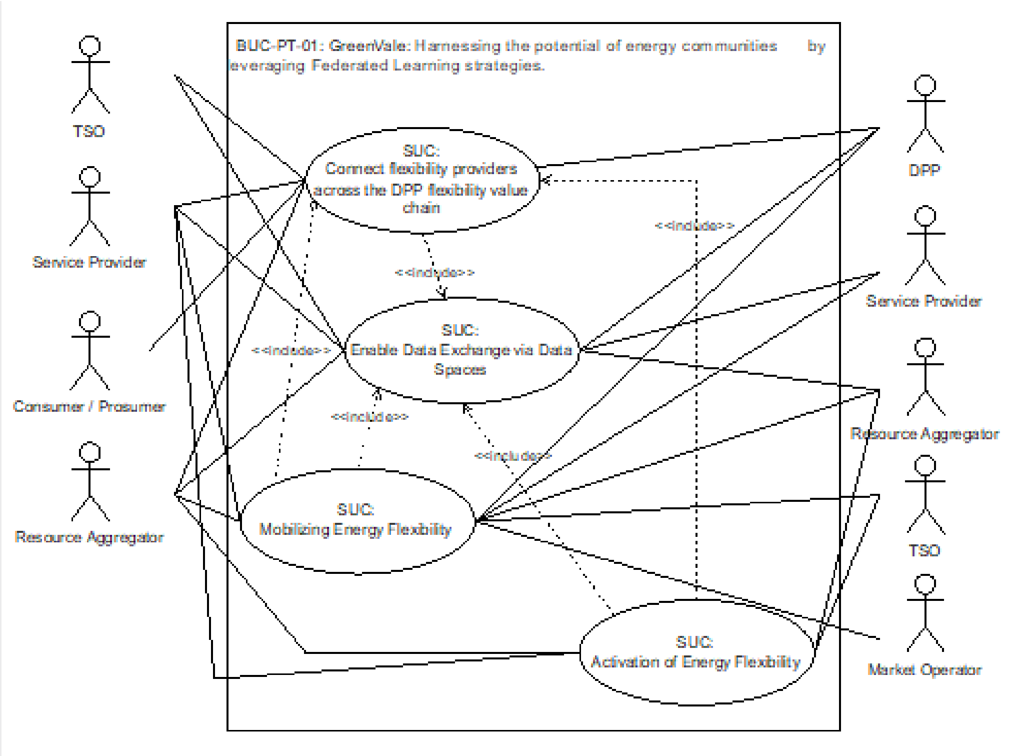

ACTORS	
ACTOR NAME	ACTOR DESCRIPTION
Resource Aggregator (HEMRM)	A party that aggregates resources for usage by a service provider for energy market services.
Consumer /Prosumer (HEMRM)	The Prosumer is a Consumer who can also produce electricity. In HEDGE-IoT role model (T1.3) it is assumed that a prosumer also adopts an active role in the energy chain, by, for example, being willing to join self-consumption structures or provide flexibility (sometimes Flexumer is also used). The EC members are assumed to be prosumers.
Data Hub Operator (HEMRM)	(The ICT/SW/DP Provider) Supports other entities with ICT (Information and Communications Technology), Software (SW) or Digital Platforms (DP).
Flexibility Service Provider (HEMRM)	Offers energy related services. Can provide insights and energy management services as well as implementing energy efficiency and renewable energy projects.
TSO (HEMRM)	Responsible for security of supply and reliability of a transmission network and real time operation and monitoring, building, expanding, and maintaining the transmission system. In this BUC the TSO is the main procurer of flexibility.
Market Operator (HEMRM)	Provides a service whereby the offers to sell electricity are matched with the bids to buy it.

TABLE 15. BUC-PT-01 OVERVIEW

3.1.2.16 BUC-PT-02 Participation of industrial and residential energy communities in ancillary services market for the TSO

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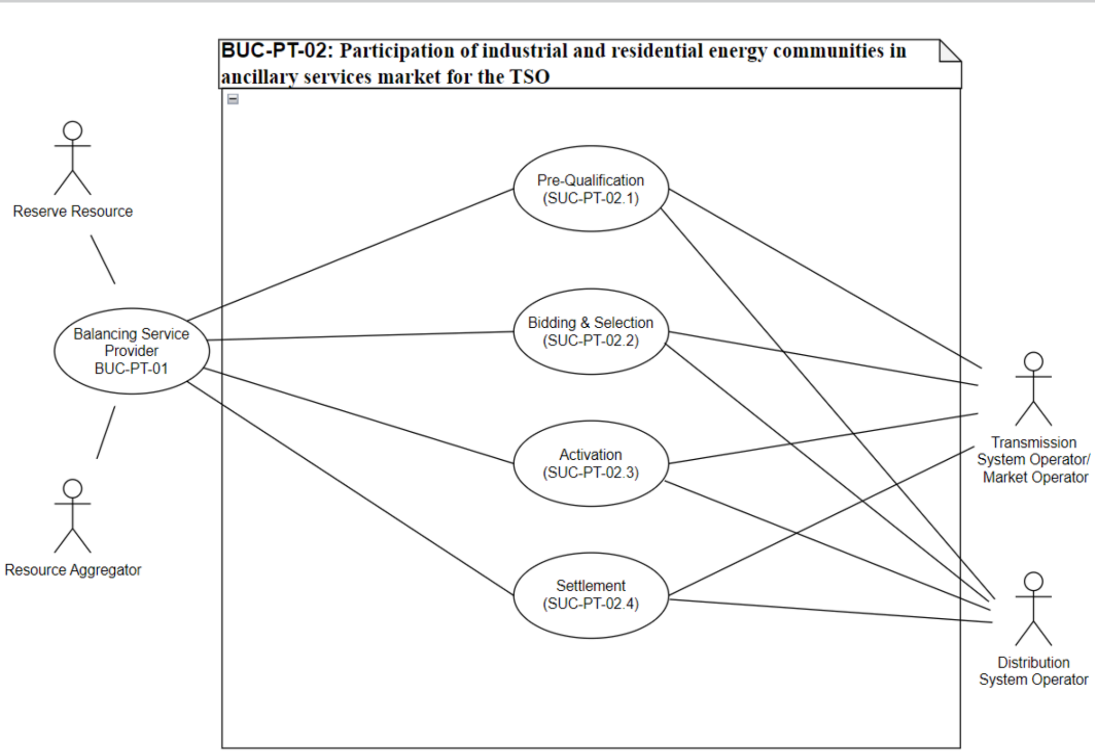
This use case assesses the ability of energy communities, made up of industrial and residential users with DERs, to provide ancillary services to the TSO over a given period to support the system. It will focus on two ancillary services, namely automatic frequency restoration reserves (aFRR) and manual frequency restoration reserves (mFRR).

BUC ID	BUC-PT-02
BUC NAME	Participation of industrial and residential energy communities in ancillary services market for the TSO
SCOPE	The scope of this BUC involves the assessment of industrial and residential Energy communities (ECs) with regard to their potential to offer ancillary services to TSOs, specifically in terms of Automatic Frequency Restoration Reserve (aFRR) and Manual Frequency Restoration Reserve (mFRR).
OBJECTIVES	• Evaluate the ability of ECs to provide ancillary service through a pre-qualification process, supported by hardware-in-the-loop real-time simulation. • Support the bidding strategy development by the BSP within the aFRR/mFRR service market participation. • Assess the performance of the aFRR/mFRR services provision by the ECs according to the MPGGS and TSO's rules. • Assess the economic viability of EC participation in ancillary services markets. • Evaluate the technical performance of supply and communication systems • Explore the role of ECs in promoting the integration of renewable energies and grid flexibility.
USE CASE DIAGRAM	
	
ACTORS	

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Actor Name	Actor Description
Resource Aggregator (RA)	The Resource Aggregator (RA) is an energy flexibility manager and aggregator that uses a flexibility management platform to deploy business models inside the energy community that monetize their customers' flexibility in order to deliver system services to the grid. It serves as a source of balancing resources for the Balancing Service Provider (BSP) from the grid/SO standpoint by submitting aFRR/mFRR bids to the TSO. Internally, starting with the Flexibility Platform, the RA oversees the entire procedure. In addition to promoting member engagement and community recruitment, it involves choosing the desired energy mix and carefully recruiting segmented customers. It also guarantees the proper operation and maintenance of the energy community through the installation of IoT equipment, regular site maintenance visits, and handling of member complaints and concerns.
Reserve Resource (RR)	A resource technically pre-qualified using a uniform set of standards to supply reserve capabilities to a System Operator and is associated with one or more tele measuring devices. It generates, consumes, distributes, and uses electricity with the intention of benefiting the local community on an economic, social, and environmental level. This can include producers, consumers, and prosumers. The RR flexibility will be utilized in this use-case to provide aFRR/mFRR services, a type of ancillary service, to Transmission System Operators (TSOs).
System operator (SO)	A system operator is responsible for ensuring the reliable and efficient operation of a power grid. Their primary role involves monitoring, controlling, and optimizing the flow of electricity across the grid to meet demand while maintaining system stability and reliability.
Market Operator (MO)	A party that provides a service of collecting offers to sell and bids to buy electricity and matching these offers and bids in order to determine a market price at the clearing point. This activity can be conducted in the forward, days-ahead and/or intraday timeframes, and can be combined with transmission capacity allocation in the context of market coupling. Organization in charge of calculating and delivering ancillary services' market results, as well as giving the Flexibility Platform instructions on service delivery and specifications.
Reserve Allocator (RA)	Informs the market of reserve requirements, receives bids against the requirements and in compliance with the prequalification criteria, determines which bids meet requirements and assigns bids.
Merit Order List Responsible (MOLR)	Responsible for the management of the available tenders for all Acquiring LFC Operators to establish the order of the reserve capacity that can be activated.
Reconciliation Responsible	A party that is responsible for reconciling, within a Metering Grid Area, the volumes used in the imbalance settlement process for profiled Accounting Points and the actual measured quantities.
Imbalance Settlement Responsible	A party that is responsible for settlement of the difference between the contracted quantities with physical delivery and the established quantities of energy products for the Balance Responsible Parties in a Scheduling Area.
Balancing Service Provider (BSP)	A party with reserve-providing units or reserve-providing groups able to provide balancing services to one or more LFC Operators (i.e. System Operators). Digital platform run by the BSP that serves as an autonomous link between the balancing markets and Reserve Resources.

TABLE 16. BUC-PT-02 OVERVIEW

3.1.2.17 BUC-PT-03 Flexibility aggregation at tertiary buildings

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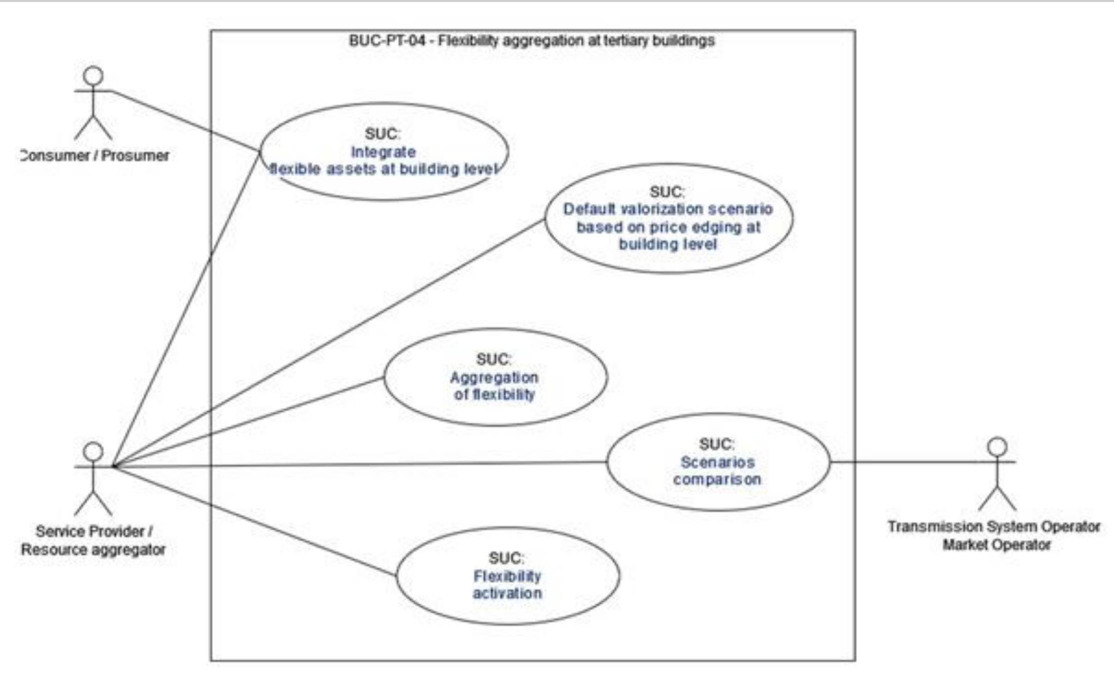
The aim of BUC-PT-03 is the flexibility aggregation for commercial applications, allowing the flexibility aggregator to manage heterogeneous flexible assets and offer incentives for the participation of prosumers.

BUC ID	BUC-PT-03
BUC NAME	Flexibility aggregation at tertiary buildings
SCOPE	Flexibility aggregation for commercial applications.
OBJECTIVES	Creation of services based on flexibility management, Benchmark valorisation of different flexibility scenarios, Demonstrate business case from aggregator / BSP perspective.
USE CASE DIAGRAM	
	
ACTORS	
ACTOR NAME	ACTOR DESCRIPTION
Resource Aggregator (RA)	The Resource Aggregator (RA) is an energy flexibility manager and aggregator that uses a flexibility management platform to deploy business models inside the energy community that monetize their customers' flexibility in order to deliver system services to the grid. It serves as a source of balancing resources for the Balancing Service Provider (BSP) from the grid/SO standpoint by submitting aFRR/mFRR bids to the TSO. Internally, starting with the Flexibility Platform, the RA oversees the entire procedure. In addition to promoting member engagement and community

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	recruitment, it involves choosing the desired energy mix and carefully recruiting segmented customers. It also guarantees the proper operation and maintenance of the energy community through the installation of IoT equipment, regular site maintenance visits, and handling of member complaints and concerns.
Reserve Resource (RR)	A resource technically pre-qualified using a uniform set of standards to supply reserve capabilities to a System Operator and is associated with one or more tele measuring devices. It generates, consumes, distributes, and uses electricity with the intention of benefiting the local community on an economic, social, and environmental level. This can include producers, consumers, and prosumers. The RR flexibility will be utilized in this use-case to provide aFRR/mFRR services, a type of ancillary service, to Transmission System Operators (TSOs).
System Operator (SO)	A system operator is responsible for ensuring the reliable and efficient operation of a power grid. Their primary role involves monitoring, controlling, and optimizing the flow of electricity across the grid to meet demand while maintaining system stability and reliability.
Balancing Service Provider (BSP)	A party with reserve-providing units or reserve-providing groups able to provide balancing services to one or more LFC Operators (i.e. System Operators). Digital platform run by the BSP that serves as an autonomous link between the balancing markets and Reserve Resources.
Prosumer	The Prosumer is a Consumer who can also produce electricity. In HEDGE-IoT role model (T1.3) it is assumed that a prosumer also adopts an active role in the energy chain, by, for example, being willing to join self-consumption structures or provide flexibility (sometimes Flexumer is also used). The EC members are assumed to be prosumers.

TABLE 17. BUC-PT-03 OVERVIEW

3.1.2.18 Slovenian pilot

3.1.2.19 BUC-SI-01 Maximizing asset capacity for increased lifetime of DSO and TSO equipment

The BUC-SI-01 will implement real-time dynamic thermal rating (DTR) of distribution transformers and dynamic line rating (DLR) for transmission lines using local telemetry data and local weather conditions, in order to gain insights into the actual potential load of transformers and power lines and ensure optimal use of available resources. By performing DTR and DLR calculations on IoT devices located at the network's edge, the system gains independence from server and cloud communication, ensuring robustness even in communication failure scenarios.

BUC ID	BUC-SI-01
BUC NAME	Maximizing asset capacity for increased lifetime of DSO and TSO equipment
SCOPE	Real time Dynamic thermal rating (DTR) calculation for distribution transformers in secondary transformer substations and dynamic line rating (DLR) calculations for transmission power lines that will take place on edge IoT devices.
OBJECTIVES	The objective of this Business Use Case (BUC) is to enhance the efficiency and reliability of energy assets by developing and deploying real-time dynamic thermal rating (DTR) and dynamic line rating (DLR) calculations on edge IoT devices for distribution transformers and power lines. These real-time calculations will provide accurate data on thermal load capacity, helping to

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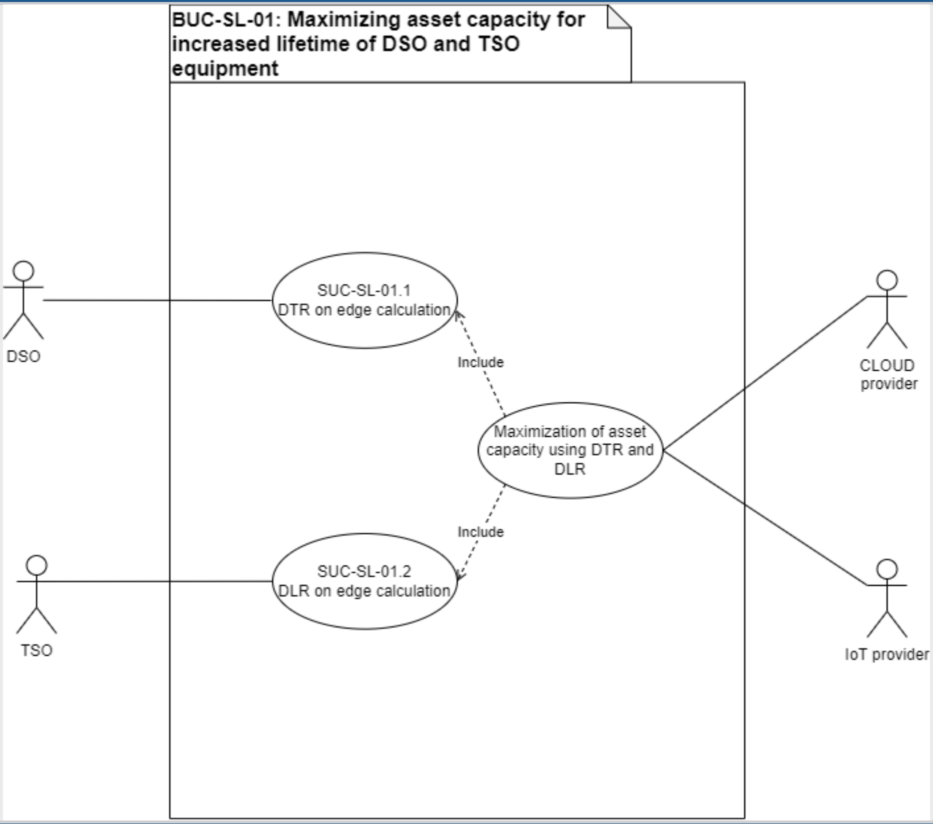
	prevent overheating and overloading of critical infrastructure or ensuring a safe overload if the weather is ideal. Understanding dynamic ratings allows for optimal asset utilization, extending their lifespan, improving grid reliability, and reducing maintenance costs, thereby enhancing overall operational efficiency and customer service. The DLR calculations will be initially implemented in a pilot program with the Slovenian Transmission System Operator (TSO), ELES. Meanwhile, DTR calculation will be introduced and evaluated within the Slovenian Distribution System Operator (DSO), EG.

USE CASE DIAGRAM



ACTORS

ACTOR NAME	ACTOR DESCRIPTION
Distribution System Operator (DSO)	A party who will use DTR calculation on distribution transformers. DSO is responsible for determining locations, where the DTR device will be implemented and for providing the specific PQ data for transformers.
Transmission System Operator (TSO)	A party who will use DLR calculation on transmission power lines. TSO is responsible for determining locations, where the DLR device will be implemented and for providing the specific PQ data for power lines.
Cloud Service Provider	Company that provides cloud service for saving DTR and DLR data, where the data exchange and additional ML/AL algorithms can be applied.
IoT Provider	A party responsible for the development of the IoT device and the deployment of code for DTR/DLR to IoT devices.

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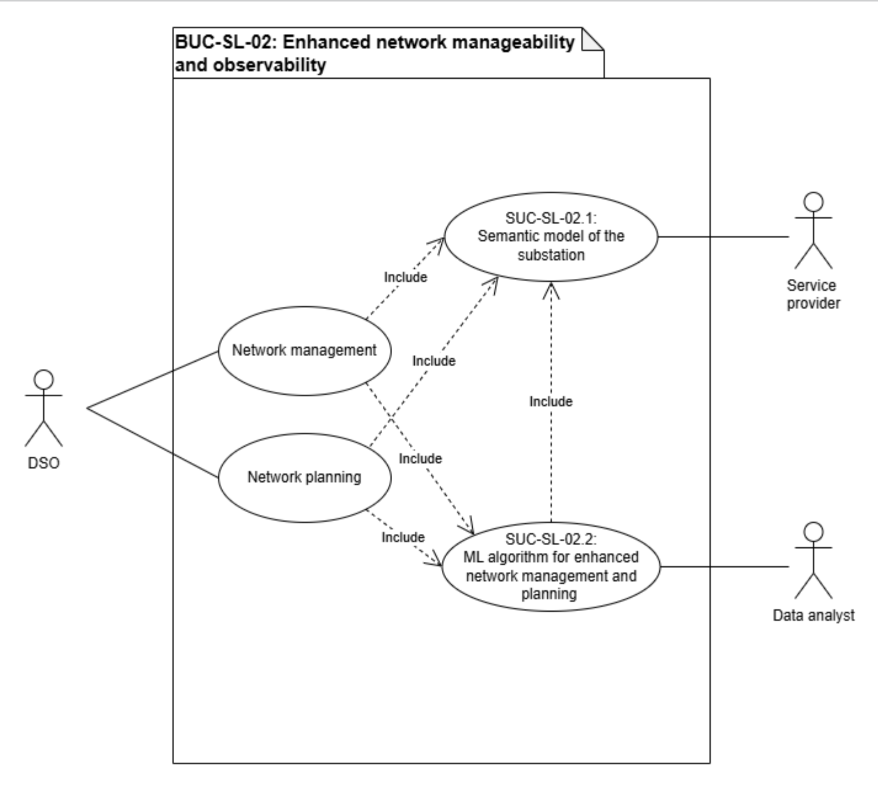
TABLE 18. BUC-SI-01 OVERVIEW

3.1.2.20 BUC-SI-02 Enhanced Network Manageability and Observability

This BUC focuses on the integration of machine learning algorithms and semantic model of the substation to enhance the efficiency of asset management and grid analysis practices, leverage the data collected from IoT devices and enhance the observability and capacity assessment of distribution networks.

BUC ID	BUC-SI-02
BUC NAME	Enhanced Network Manageability and Observability
SCOPE	Gathering and utilizing data for further improvement of network operations management and planning, thereby increasing system observability.
OBJECTIVES	• Increasing the observability of the distribution network at the substation level. • Enhancement of network management and planning processes at the distribution level. • Resolving interoperability issues within a distribution system.
USE CASE DIAGRAM	
	
ACTORS	
ACTOR NAME	ACTOR DESCRIPTION

DSO	Distribution System Operator (DSO) utilize the enhanced network manageability and observability by using IoT/edge measurement devices for better monitoring and planning of the distribution network.
Data Analyst	Responsible for interpreting and deriving insights from the aggregated data for decision-making purposes and for developing the algorithms enhancing the planning and operation of a network.
Service Provider	Provides appropriate tools for both DSOs and Data Analysts enabling unified data identification and semantic interpretation within distribution level.

TABLE 19. BUC-SI-02 OVERVIEW

3.2 END USERS' REQUIREMENTS

The requirements listed in section 6 of the IEC-62559-2 template were used for the end user's requirements identification. A list of all requirements from each BUC of all HEDGE-IoT demonstrators was built and used to identify unique requirements, filtering repeated or similar requirements. From the information of the BUCs, the possible end users were identified as the following:

- System operator,
- Grid operator,
- Grid maintenance provider,
- Control room operator,
- Consumers, producers, prosumers,
- Energy service company,
- Energy supplier,
- Flexibility service provider,
- Energy community manager,
- Market operator,
- Aggregator,
- System integrator,
- Balancing service provider.

Considering the end users, the initial list of requirements was refined down to 25 requirements. The final list of general end user's requirements extracted from the demonstrator's BUCs is presented in Table 20. The specific requirements for each BUC are available at the detailed BUCs descriptions on Appendix B .

ID	Requirement	Description
2.01	Real-time data collection	The measurement data platform must be able to collect the data from sensors in real-time
2.02	Data availability and reliability	Data needs to be available, reliable, and dependable
2.03	Availability of information flows	Information flows should be available either continuously or at specific times or under specific conditions

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2.04	Usefulness of source data	Source data should be correct
2.05	Historical data	Historical data are needed from IoT devices and smart meters
2.06	Type of source data	The solution should support the utilization of multiple data types
2.07	Interoperability	Different elements of the system should be able to communicate
2.08	Management of data formats in data exchanges	Data in data exchanges should have the same format
2.09	Management of large volumes of data that are being exchanged	The solution facilitates the utilization and management of large models along with their dependencies
2.10	Frequency of data exchange	A time window for data exchanges should be established
2.11	Validation of data exchanges	Data and models should be validated
2.12	Semantic enrichment	Data must be semantically enriched to offer proper explainability data and advanced insights
2.13	System integration	Ensure that IoT devices are compatible and integrate with existing grid infrastructure
2.14	Compliance with standards	Ensure that all deployed IoT devices and associated software comply with relevant national and international standards and regulations for data security, privacy, and grid security
2.15	Authentication and access control	Ensure that authentication and access control mechanisms are used, and that data comes from the stated source or goes to authenticated receiver
2.16	Management of data across organizational boundaries	Define and manage data exchanges across boundaries
2.17	Ensuring that data cannot be resent by any unauthorized source	The data needs to follow the outlined flow and not used or resent by any unauthorized party
2.18	Confidentiality of data	Define and ensure the confidentiality of data
2.19	Data Encryption	Implement encryption for data transmitted between IoT devices and the cloud to ensure data security and integrity
2.20	GDPR (General Data Protection Regulation)	Compliance with the EU GDPR

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2.21	Data processing consent	Personal data may not be processed unless there is at least one legal basis to do so
2.22	Data transfer consent	Personal data may not be transferred to a third party if the data subject does not agree, and the third party provides appropriate safeguard
2.23	Data retention policy	The time period specific sensitive data can be retained and the method of their disposal when the defined time period ends
2.24	Right to access, rectify, erasure, restriction	The data subject shall have the right to obtain from the controller without undue delay the access/rectification/erasure/restriction of inaccurate personal data concerning them
2.25	Report of user wills	The decision of the end user on the usage of his devices should be respected

TABLE 20. END USERS' REQUIREMENTS EXTRACTED FROM BUCS

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4 STAKEHOLDERS' BOARD CONSULTATION TOWARDS KNOWLEDGE DIFFUSION PROMOTING DATA HARMONISATION, REAL-TIME GRID MONITORING FOR RESILIENCE AND FLEXIBILITY

In the evolving landscape of energy management, the integration of advanced data management strategies into real-time grid monitoring systems is crucial for enhancing resilience and flexibility. The consultation task aims to foster knowledge diffusion and promote data harmonization among Transmission System Operators (TSOs), Distribution System Operators (DSOs), and partners engaged in standardization activities. This initiative is designed to leverage the experiences of these entities in data management and orchestration, enabling system operators to become data-empowered and transforming data into a significant asset for integration and resilience.

Knowledge Diffusion and Data Management

Knowledge diffusion in the context of grid monitoring involves the transfer of insights, methodologies, and best practices from experienced entities to those less familiar with advanced data management techniques. TSOs, who already employ multiple resilient data paths and have standardized data exchanges, possess a wealth of knowledge in managing complex data ecosystems. By consulting with these operators, DSOs and other stakeholders can learn about the challenges and solutions associated with real-time data management and apply these lessons to their specific contexts.

Promoting Data Harmonization

Data harmonization is essential for ensuring that diverse data sets can be seamlessly integrated and utilized across various systems and organizations. This task focuses on developing guidelines for "grid data codes," which aim to standardize data formats, protocols, and exchange mechanisms. Such standardization facilitates interoperability between different grid monitoring systems, enabling more efficient data sharing and analysis. By harmonizing data, system operators can ensure that data from various sources is consistent and compatible, enhancing the overall quality and reliability of grid monitoring.

Enhancing Real-Time Grid Monitoring

Real-time grid monitoring is vital for maintaining the stability and efficiency of the power grid. It involves continuously collecting, processing, and analysing data from various points in the grid to detect anomalies, predict potential issues, and optimize performance. The consultation task aims to improve the real-time monitoring capabilities of system operators by providing them with the tools and knowledge needed to effectively manage large-scale data. By learning from the experiences of different actors in the industry and adopting standardized data practices, operators can enhance their ability to monitor the grid in real time, respond to disruptions swiftly, and maintain grid stability.

Building Resilience and Flexibility

Resilience in grid monitoring refers to the ability to withstand and recover from disruptions, while flexibility involves the capability to adapt to changing conditions and demands. The consultation task emphasizes these aspects by promoting the use of resilient data paths and flexible data management strategies. By incorporating redundancy and ensuring that data can be rerouted in

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case of failures, system operators can maintain continuous monitoring even under adverse conditions. Additionally, flexible data management practices allow operators to adapt to new technologies and emerging data sources, ensuring that the grid monitoring system remains robust and responsive.

The Role of System Operators as Data Infrastructural Backbones

As the task progresses, it aims to position system operators as the infrastructural backbones of data management within the grid monitoring ecosystem. By developing and adhering to the grid data codes, operators can establish themselves as central hubs for data collection, processing, and dissemination. This role not only enhances the efficiency of grid monitoring but also positions system operators as key players in the broader energy management landscape. Their ability to manage and harmonize data becomes a critical asset for ensuring the reliability and resilience of the power grid.

Conclusion

The task is a strategic initiative designed to promote knowledge diffusion and data harmonization in real-time grid monitoring. By leveraging the experiences of TSOs, DSOs and other partners, and fostering collaboration among various stakeholders, the task aims to enhance the resilience and flexibility of grid monitoring systems. The development of grid data codes and the emphasis on data management as an integration and resiliency asset will empower system operators to become pivotal in the energy management landscape. Ultimately, this initiative has the potential to significantly improve the efficiency and reliability of real-time grid monitoring, ensuring a more stable and adaptable power grid for the future.

4.1 CHALLENGE 1: NON-STANDARDIZED DATA STRUCTURES IN REAL-TIME GRID MONITORING

4.1.1 INTRODUCTION

The contemporary energy grid faces unprecedented challenges and opportunities as it evolves in response to increasing demand, renewable energy integration, and technological advancements. One critical aspect of this evolution is the management and harmonization of data, particularly in real-time grid monitoring. However, a significant obstacle in achieving efficient and resilient grid monitoring is the lack of standardized data structures among participants in various demonstration projects. This issue is compounded by the continued reliance on outdated data structures rooted in Operational Technology (OT), often excluding the benefits of the Internet of Things (IoT). This paper explores the current landscape of data structures in grid monitoring, identifies best practices within the industry, and proposes strategies for adopting these practices among Transmission System Operators (TSOs).

4.1.2 The Landscape of Data Structures in Grid Monitoring

The integration of Operational Technology (OT) with Industrial Internet of Things (IIoT) represents a significant opportunity for the energy system industry to enhance real-time grid monitoring, improve operational efficiency, and foster innovation. However, the combination of these technologies also highlights the fragmented nature of data ecosystems. This section delves deeper into the challenges and solutions related to the integration of OT and IIoT, with concrete examples illustrating the complexities involved.

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4.1.2.1 1. Diverse Data Formats and Standards in OT and IIoT

Example: Legacy OT Data Formats vs. Modern IIoT Data Standards

Traditional OT systems in substations, such as SCADA (Supervisory Control and Data Acquisition) systems, often use proprietary data formats and standards. In contrast, IIoT devices, such as smart meters, sensors, and IoT-enabled equipment, typically generate data in modern, open formats like JSON, MQTT, and OPC UA.

- **Challenge:** The disparity between legacy OT data formats and modern IIoT data standards creates significant integration challenges. Data from IIoT devices may need to be transformed to be compatible with OT systems, resulting in increased complexity and potential data inconsistencies.
- **Strategy:** Implementing middleware solutions that can translate between legacy OT formats and modern IIoT standards can facilitate smoother integration. Additionally, moving towards unified data standards like IEC 61850 for communication and CIM for data modeling can help bridge the gap between OT and IIoT systems.

Example: Data Standards in Renewable Energy Integration

The integration of renewable energy sources, such as solar panels and wind turbines, involves IIoT devices for monitoring and control. These devices often use different data standards compared to traditional grid components managed by OT systems.

- **Challenge:** Inconsistent data standards make it difficult to integrate data from renewable energy sources with existing grid management systems. This can hinder the ability to optimize the use of renewable energy and ensure grid stability.
- **Strategy:** Adopting industry standards like IEEE 2030.5 for smart energy profiles and IEC 61850 for communication in substations can help standardize data exchange between renewable energy IIoT devices and traditional OT systems.

4.1.2.2 2. Inconsistent Communication Protocols

Example: Communication Protocols in Smart Grids

Smart grid initiatives often involve a mix of OT and IIoT components, each with its own communication protocol. For example, legacy OT devices might use DNP3 or Modbus, while IIoT devices might use MQTT or CoAP.

- **Challenge:** The lack of a common communication protocol results in fragmented data ecosystems, where data from different devices and systems cannot be easily integrated or analyzed together. This fragmentation limits the ability to achieve real-time visibility and control over the entire grid.
- **Strategy:** Standardizing communication protocols, such as adopting IEC 61850 for substation automation and MQTT for IIoT communication, can improve interoperability. Middleware solutions that support protocol translation can also help integrate diverse systems.

Example: Communication in Distributed Energy Resources (DERs)

Distributed Energy Resources (DERs), such as rooftop solar panels and home battery storage systems, use IIoT devices to communicate with grid operators. However, these IIoT devices often use different protocols than those used by traditional OT systems managing the main grid.

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- **Challenge:** The use of different communication protocols complicates the integration of DERs into the grid, making it difficult to manage and optimize energy flows. This can lead to inefficiencies and potential grid instability.
- **Strategy:** Implementing communication standards like IEEE 1547 for interconnecting DERs with the grid and using protocols like IEC 61850 can facilitate seamless communication between DERs and traditional grid infrastructure.

4.1.2.3 3. Legacy Systems and Infrastructure

Example: Upgrading Legacy OT Systems

Many OT systems in the energy industry, such as SCADA and Distributed Control Systems (DCS), are based on legacy infrastructure that was not designed to handle the data-intensive requirements of modern IIoT applications.

- **Challenge:** Upgrading these legacy systems to integrate with IIoT devices requires significant investment and technical expertise. The closed and proprietary nature of many legacy OT systems also poses challenges to interoperability with IIoT platforms.
- **Strategy:** Gradual modernization of OT systems, including upgrading hardware and software to support open standards and protocols, can improve their integration with IIoT devices. Utilizing edge computing can also help by enabling local processing of IIoT data, reducing the load on legacy OT systems.

Example: Historical Data Integration

Legacy OT systems have accumulated vast amounts of historical data stored in proprietary formats and databases. IIoT devices generate new data streams that need to be integrated with this historical data for comprehensive analysis.

- **Challenge:** Integrating historical data from legacy OT systems with real-time data from IIoT devices is complex due to differences in data formats, storage technologies, and access methods.
- **Strategy:** Developing data integration platforms that support data transformation and harmonization can facilitate the integration of historical OT data with real-time IIoT data. Implementing data lakes or centralized data warehouses that can ingest and process diverse data formats can also help.

4.1.3 Best Practices for Integrating OT and IIoT

To address the challenges of fragmented data ecosystems in the energy industry, the following best practices can be adopted for integrating OT and IIoT systems:

4.1.3.1 1. Standardization and Interoperability

Adopting Unified Standards

- **Common Information Model (CIM):** Standardizing data models across OT and IIoT systems using CIM ensures consistent data representation and easier integration.
- **IEC 61850:** Adopting IEC 61850 for communication protocols in substation automation and extending its use to IIoT devices improves interoperability.

Implementing Middleware Solutions

- **Protocol Translation:** Middleware that translates between different communication protocols used by OT and IIoT devices facilitates seamless data exchange.
- **Data Harmonization:** Middleware that harmonizes data formats and structures from diverse sources ensures data consistency and usability.

4.1.3.2 2. Data Governance and Quality Management

Comprehensive Data Governance Frameworks

- **Roles and Responsibilities:** Clearly defining roles and responsibilities for data management ensures accountability and consistency.
- **Data Handling Policies:** Establishing policies for data collection, storage, processing, and sharing ensures data quality and security.

Data Quality Assurance

- **Validation and Cleansing:** Implementing automated data validation and cleansing processes ensures data accuracy and reliability.
- **Metadata Management:** Maintaining detailed metadata about data sources and transformations enhances transparency and traceability.

4.1.3.3 3. Leveraging Advanced Technologies

Edge Computing

- **Local Processing:** Utilizing edge computing to process IIoT data locally reduces the burden on legacy OT systems and improves real-time data processing capabilities.
- **Latency Reduction:** Edge computing reduces latency by processing data closer to the source, enhancing the responsiveness of grid monitoring and control systems.

AI and Machine Learning

- **Predictive Analytics:** Applying AI and machine learning to analyze integrated OT and IIoT data can provide predictive insights for maintenance, load forecasting, and anomaly detection.
- **Automated Decision-Making:** AI-driven systems can automate routine decisions, improving operational efficiency and response times.

4.1.3.4 4. Cybersecurity

Robust Security Measures

- **Encryption and Authentication:** Implementing strong encryption and authentication protocols ensures the security of data and communications between OT and IIoT devices.
- **Regular Audits:** Conducting regular security audits and assessments helps identify and mitigate vulnerabilities.

Incident Response Plans

- **Preparedness:** Developing and regularly updating incident response plans ensures that the organization can quickly and effectively respond to cybersecurity threats.

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4.1.4 Case Study: Integrating OT and IIoT

To illustrate the implementation of these best practices, we present a detailed case study of HEDGE-IoT, a hypothetical TSO that undertakes a comprehensive project to integrate OT and IIoT systems.

4.1.4.1 Project Objectives

HEDGE's integration project aims to achieve the following objectives:

- **Standardize Data Formats and Protocols:** Align OT and IIoT systems with unified data standards to ensure interoperability.
- **Enhance Real-Time Monitoring:** Leverage IIoT devices and advanced analytics to improve real-time grid monitoring and management.
- **Ensure Data Security:** Implement robust cybersecurity measures to protect data and communications.

4.1.4.2 Implementation Steps

1. Data Inventory and Standardization

HEDGE-IoT conducts a comprehensive inventory of existing OT and IIoT data sources, identifying their formats, protocols, and models. The organization adopts CIM and IEC 61850 standards to standardize data models and communication protocols across all systems.

2. Middleware Development

HEDGE-IoT develops middleware solutions to translate between legacy OT protocols (e.g., DNP3, Modbus) and modern IIoT protocols (e.g., MQTT, OPC UA). The middleware also harmonizes data formats, ensuring consistent data representation across the organization.

3. Edge Computing Deployment

Edge computing devices are deployed at key points within the grid to locally process data from IIoT devices. This reduces the load on legacy OT systems and improves the responsiveness of real-time monitoring and control.

4. AI and Machine Learning Integration

HEDGE-IoT implements AI and machine learning platforms to analyze integrated OT and IIoT data. Predictive analytics models are developed to forecast equipment failures, optimize load distribution, and detect anomalies. One particular AI/ML technique to be explored is federated learning.

5. Cybersecurity Enhancements

HEDGE-IoT strengthens its cybersecurity posture by implementing strong encryption, authentication protocols, and regular security audits. Incident response plans are developed and regularly updated to ensure preparedness for potential cyber threats.

4.1.4.3 Outcomes and Benefits

1. Improved Interoperability and Data Exchange

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By standardizing data formats and protocols, HEDGE-IoT achieves seamless interoperability between OT and IIoT systems. This facilitates efficient data exchange and integration, enhancing the overall efficiency of grid operations.

2. Enhanced Real-Time Monitoring

The integration of IIoT devices and edge computing enables detailed, real-time monitoring of grid conditions. Advanced analytics provide predictive insights, allowing actors involved in the HEDGE-IoT ecosystem and especially System Operators to anticipate and address potential issues before they escalate, thereby enhancing the resilience and reliability of the grid.

3. Increased Operational Efficiency

Automated decision-making enabled by AI and machine learning reduces the need for manual intervention, improving the speed and accuracy of responses to grid conditions. Predictive maintenance models minimize downtime and extend the lifespan of critical infrastructure components.

4. Strengthened Cybersecurity

The implementation of robust cybersecurity measures protects data and communication networks involved in HEDGE-IoT from potential threats. Regular security audits and updated incident response plans ensure that the organization remains prepared for and resilient against cyberattacks. Additionally federated learning could also provide contributions to the security and privacy challenges.

5. Scalability and Flexibility

The standardized data infrastructure and use of edge computing provide a scalable foundation for future technological advancements. HEDGE can easily integrate new IIoT devices and leverage emerging technologies to continuously improve grid management and operational efficiency.

4.1.5 Conclusion

The integration of OT and IIoT in the energy system industry presents both significant challenges and substantial opportunities. The fragmented data ecosystems currently seen in the industry, characterized by diverse data formats, inconsistent communication protocols, and legacy systems, hinder the ability to achieve seamless interoperability, efficient data exchange, and advanced real-time grid monitoring.

By adopting best practices such as standardizing data formats and communication protocols, implementing middleware solutions, leveraging edge computing, integrating AI and machine learning, and enhancing cybersecurity, TSOs but most importantly DSOs who in most cases are still lagging behind, as well as other stakeholders of the energy industry, can overcome these challenges. The successful integration of OT and IIoT not only improves operational efficiency and grid resilience but also paves the way for continuous innovation and adaptation to future technological advancements.

The case study of HEDGE exemplifies how a focused and strategic approach to integrating OT and IIoT can transform fragmented data ecosystems into cohesive and efficient systems. Through careful planning, robust implementation, and ongoing management, HEDGE-IoT successfully enhances grid monitoring capabilities, ensuring a more stable, flexible, and reliable power grid.

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Ultimately, the journey towards a fully integrated and standardized data ecosystem in the energy industry is complex and multifaceted. However, with a commitment to best practices and a proactive approach to addressing challenges, the benefits of such an integration far outweigh the difficulties, leading to a more resilient and efficient energy system for the future.

4.2 CHALLENGE 2: LEGACY SYSTEMS AND OPERATIONAL TECHNOLOGY

Legacy systems and Operational Technology (OT) form the backbone of the energy industry's infrastructure, facilitating the monitoring, control, and management of physical processes and equipment. While these systems are essential for maintaining grid stability and reliability, they also present significant challenges in the context of modernization and integration with newer technologies like IIoT. This section delves deeper into the specific issues posed by legacy OT systems, the implications for the energy industry, and strategies to overcome these challenges.

4.2.1 Characteristics of Legacy OT Systems

Legacy OT systems in the energy sector are characterized by:

1. **Proprietary Architectures**: Many legacy OT systems were developed using proprietary technologies and protocols, which were not designed for interoperability with other systems.
2. **Long Lifespans**: OT equipment and systems often have long operational lifespans, sometimes spanning several decades, which leads to the persistence of outdated technologies.
3. **Closed Systems**: Legacy OT systems typically prioritize security and reliability, leading to closed and rigid architectures that resist integration with external systems.
4. **Real-Time Operations**: OT systems are designed to manage real-time operations, requiring deterministic responses and high reliability to ensure the safety and stability of the grid.

4.2.2 Challenges of Legacy OT Systems

1. **Interoperability Issues**
    - **Vendor Lock-In**: Proprietary systems create dependency on specific vendors for maintenance, upgrades, and expansions, leading to increased costs and limited flexibility.
    - **Inconsistent Data Formats**: Different legacy systems use varying data formats, making it difficult to aggregate and analyze data from multiple sources.
2. **Scalability Limitations**
    - **Aging Infrastructure**: Older systems lack the capacity to handle the increased data volumes and processing requirements of modern applications, such as real-time analytics and IIoT integration.
    - **Limited Upgrade Paths**: Many legacy systems cannot be easily upgraded to support new technologies without significant investment in new hardware and software.
3. **Security Vulnerabilities**

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- **Outdated Security Protocols**: Legacy OT systems often use outdated security protocols, making them vulnerable to cyber threats.
- **Lack of Patching and Updates**: Due to their proprietary nature and long lifespans, legacy systems may not receive regular security patches and updates, increasing the risk of vulnerabilities.

4. **Integration Challenges**
   - **Closed Architectures**: The closed nature of many OT systems makes it difficult to integrate with modern IT and IIoT systems, hindering the flow of data and limiting the ability to leverage advanced analytics.
   - **Data Silos**: Legacy systems often operate in isolation, creating data silos that prevent the sharing and utilization of valuable operational data across the organization.

4.2.3 Strategies for Modernizing Legacy OT Systems

1. **Adopting Open Standards**
   - **Migration to Open Protocols**: Transitioning from proprietary protocols to open standards such as IEC 61850 and OPC UA can enhance interoperability and facilitate integration with other systems.
   - **Standardized Data Models**: Implementing standardized data models like the Common Information Model (CIM) ensures consistent data representation and easier data exchange.
2. **Incremental Modernization**
   - **Phased Upgrades**: Modernizing OT systems in phases allows organizations to spread out costs and minimize disruptions. For example, starting with critical systems or components and gradually expanding to other areas.
   - **Hybrid Approaches**: Combining legacy systems with modern technologies through hybrid solutions, such as using middleware or edge computing, can extend the lifespan of existing infrastructure while gaining new capabilities.
3. **Implementing Middleware Solutions**
   - **Protocol Translators**: Middleware that translates between legacy protocols and modern communication standards can facilitate interoperability and data integration.
   - **Data Aggregation Platforms**: Middleware platforms that aggregate and harmonize data from various sources can create a unified data environment, enabling comprehensive analysis and decision-making.
4. **Enhancing Cybersecurity**
   - **Security Audits and Assessments**: Regular security audits and assessments can identify vulnerabilities and areas for improvement in legacy OT systems.
   - **Implementing Modern Security Measures**: Upgrading to modern security protocols, such as encryption and multi-factor authentication, can enhance the security of legacy systems.

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5. **Leveraging Edge Computing**
    - **Local Data Processing**: Deploying edge computing devices allows for local processing of data close to the source, reducing latency and the load on legacy OT systems.
    - **Real-Time Analytics**: Edge computing enables real-time analytics and decision-making, enhancing the responsiveness and efficiency of grid operations.
6. **Training and Workforce Development**
    - **Skills Development**: Investing in training and development for the workforce ensures that staff have the necessary skills to operate and maintain modernized OT systems.
    - **Cross-Functional Teams**: Creating cross-functional teams that include both OT and IT specialists can foster collaboration and knowledge sharing, facilitating the integration of new technologies.

4.2.4 Case Study: Legacy System Modernization in HEDGE-IoT

To illustrate these strategies in action, we present the same hypothetical case study of HEDGE-IoT, a large utility company undertaking a comprehensive modernization of its legacy OT systems.

Project Background

The HEDGE-IoT digital system operates an extensive network of legacy OT systems, including SCADA, Distributed Control Systems (DCS), and various proprietary communication protocols. These systems, while reliable, have become increasingly difficult to integrate with modern IT and IIoT technologies, limiting the company's ability to leverage real-time data and advanced analytics.

Modernization Objectives

The modernization project of HEDGE-IoT aims to:

- Enhance interoperability between legacy OT systems and modern IT/IIoT technologies.
- Improve real-time data processing and analytics capabilities.
- Strengthen cybersecurity measures across the organization.
- Ensure scalability and flexibility for future technological advancements.

Implementation Plan

1. Assessing Existing Infrastructure

HEDGE-IoT conducts a thorough assessment of its existing OT infrastructure, identifying critical systems, communication protocols, and data formats. This assessment provides a clear understanding of the current state and areas that require modernization.

2. Adopting Open Standards

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HEDGE-IoT begins migrating its legacy communication protocols to open standards such as IEC 61850. This migration is carried out in phases, starting with the most critical systems to minimize operational disruptions.

3. Implementing Middleware Solutions

To facilitate data integration and interoperability, HEDGE-IoT develops middleware solutions that translate between legacy protocols (e.g., DNP3, Modbus) and modern standards (e.g., OPC UA, MQTT). These middleware platforms also aggregate and harmonize data from various sources, creating a unified data environment.

4. Deploying Edge Computing

HEDGE-IoT deploys edge computing devices at key points within its network. These devices process data locally, reducing the load on central systems and enabling real-time analytics and decision-making.

5. Enhancing Cybersecurity

Modern cybersecurity measures are being implemented, including encryption, multi-factor authentication, and regular security audits. An incident response plan is developed and regularly updated to ensure preparedness for potential cyber threats.

6. Training and Workforce Development

Organizations could invest in training programs for their workforce, ensuring that staff have the skills needed to operate and maintain modernized OT systems. Cross-functional teams are created to foster collaboration between OT and IT specialists.

Outcomes and Benefits

1. Improved Interoperability and Data Exchange

The migration to open standards and the implementation of middleware solutions significantly improves the interoperability between legacy OT systems and modern IT/IIoT technologies. This facilitates efficient data exchange and integration, enhancing the overall efficiency of operations.

2. Enhanced Real-Time Monitoring and Analytics

The deployment of edge computing and the integration of advanced analytics platforms enable detailed, real-time monitoring of grid conditions. Predictive analytics models provide insights into potential equipment failures, optimizing maintenance schedules and reducing downtime.

3. Strengthened Cybersecurity

The implementation of robust cybersecurity measures protects data and communication networks from potential threats. Regular security audits and an updated incident response plan ensure that the organization remains prepared and resilient against cyberattacks.

4. Increased Operational Efficiency and Flexibility

Automated decision-making enabled by AI and machine learning reduces the need for manual intervention, improving the speed and accuracy of responses to grid conditions. The standardized data infrastructure and use of edge computing provide a scalable foundation for future technological advancements.

5. Enhanced Workforce Skills and Collaboration

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Investment in training and the creation of cross-functional teams foster a skilled and collaborative workforce, capable of effectively managing and maintaining modernized OT systems.

4.2.5 Conclusion

Legacy OT systems are essential for the stability and reliability of the energy grid, but they also pose significant challenges in the context of modernization and integration with newer technologies like IIoT. By adopting strategies such as standardizing data formats and communication protocols, implementing middleware solutions, leveraging edge computing, enhancing cybersecurity, and investing in workforce development, the energy industry can overcome these challenges.

The case study of HEDGE exemplifies how a focused and strategic approach to modernizing legacy OT systems can transform fragmented data ecosystems into cohesive and efficient systems. Through careful planning, robust implementation, and ongoing management, HEDGE successfully enhances its grid monitoring capabilities, ensuring a more stable, flexible, and reliable power grid.

Ultimately, the modernization of legacy OT systems is a complex and multifaceted process, but with a commitment to best practices and a proactive approach to addressing challenges, the benefits far outweigh the difficulties. This transformation leads to a more resilient and efficient energy system, better equipped to meet the demands of the future.

4.3 CHALLENGE 3: THE EXCLUSION OF IOT IN GRID MONITORING

The exclusion of IoT (Internet of Things) from grid monitoring significantly hampers the progress towards modern, efficient, and resilient grid operations. IoT technologies offer unprecedented capabilities for real-time data collection, advanced analytics, and automated decision-making, all of which are crucial for achieving data harmonization, real-time monitoring, resilience, and flexibility in grid management. This section elaborates on how the absence of IoT impacts these key areas and the broader implications for the energy industry.

4.3.1 Impact on Data Harmonization

Fragmented Data Ecosystems

Traditional OT systems and legacy infrastructure typically generate and manage data in silos. Different systems use varying data formats and communication protocols, resulting in fragmented data ecosystems.

Implication: Inefficient Data Integration

Without IoT, there is a lack of standardized data formats and seamless data integration across different systems. This makes it difficult to aggregate, analyse, and leverage data from multiple sources effectively.

Example: In a grid without IoT, data from various subsystems (e.g., transmission, distribution, and metering) are often stored in disparate formats and databases. Integrating this data for comprehensive analysis requires significant manual effort and complex data transformation processes. IoT devices, on the other hand, can standardize data collection and communication protocols, facilitating easier and more efficient data harmonization.

4.3.2 Impact on Real-Time Grid Monitoring

Limited Data Granularity and Frequency

Traditional grid monitoring systems provide data updates at periodic intervals rather than continuous real-time monitoring. This limitation reduces the granularity and frequency of data available to grid operators.

Implication: Delayed Response to Grid Conditions

Without real-time data from IoT devices, grid operators cannot promptly detect and respond to dynamic changes in grid conditions. This delay can lead to inefficiencies, increased downtime, and higher operational costs.

Example: In the absence of IoT, grid operators might receive data on load levels or equipment status every 15 minutes or more. During these intervals, significant changes in grid conditions, such as a sudden increase in demand or an equipment malfunction, may go unnoticed until they cause disruptions. IoT-enabled real-time monitoring provides continuous data streams, allowing for immediate detection and response to such events.

4.3.3 Impact on Grid Resilience

Inability to Perform Predictive Maintenance

Excluding IoT from grid monitoring prevents the implementation of predictive maintenance strategies. Traditional OT systems often rely on reactive maintenance, addressing issues only after they have occurred.

Implication: Increased Risk of Unplanned Outages

Reactive maintenance leads to higher risks of unplanned outages and equipment failures, reducing the overall resilience of the grid. Predictive maintenance enabled by IoT can pre-emptively identify potential failures, allowing for timely interventions.

Example: IoT sensors can continuously monitor the health and performance of critical grid assets, such as transformers and circuit breakers, and predict potential failures based on data analytics. Without IoT, grid operators lack the necessary data and tools to implement predictive maintenance, leading to a higher likelihood of unexpected equipment failures and prolonged outages.

4.3.4 Impact on Grid Flexibility

Inadequate Support for Renewable Energy Integration

Traditional grid systems are less adaptable to the dynamic nature of renewable energy sources, which require precise and real-time management for optimal integration.

Implication: Limited Flexibility in Energy Management

Without IoT, the grid's ability to adapt to fluctuations in renewable energy generation and varying demand patterns is significantly constrained. This limits the grid's flexibility and its capacity to incorporate a higher share of renewable energy sources.

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Example: IoT devices can provide real-time data on the generation and consumption of renewable energy, enabling better demand forecasting and load balancing. This data allows grid operators to adjust energy distribution dynamically to match supply with demand. In the absence of IoT, the grid relies on less frequent and less precise data, making it challenging to manage the variability of renewable energy sources effectively.

4.3.5 Broader Implications for the Energy Industry

4.3.5.1 1. Suboptimal Utilization of Resources

Inefficient Resource Management

Excluding IoT from grid monitoring leads to inefficient management of energy resources, as traditional systems lack the granularity and timeliness of data needed for optimal decision-making.

Implication: Higher Operational Costs

Inefficient resource management results in higher operational costs and reduced profitability for energy providers. IoT-enabled systems can optimize resource utilization, reducing waste and improving overall efficiency.

Example: IoT devices can monitor energy consumption patterns at a granular level, providing insights that enable more efficient energy distribution and reducing peak demand. Without IoT, energy providers may overproduce or underutilize resources, leading to higher costs and inefficiencies.

4.3.5.2 2. Reduced Customer Satisfaction

Lack of Proactive Service Management

Traditional grid systems are less capable of providing proactive and personalized services to customers. IoT can enable utilities to offer tailored energy management solutions based on real-time data.

Implication: Lower Customer Satisfaction and Engagement

Without IoT, utilities are less able to engage with customers proactively, address their needs promptly, and offer innovative services. This can lead to lower customer satisfaction and reduced loyalty.

Example: IoT-enabled smart meters can provide customers with real-time insights into their energy consumption, helping them manage their usage more effectively and reduce costs. Utilities can also offer dynamic pricing models and demand response programs based on real-time data. In the absence of IoT, such personalized and proactive services are not feasible, limiting customer engagement and satisfaction.

4.3.5.3 3. Hindered Innovation and Technological Advancement

Limited Foundation for New Technologies

Excluding IoT from grid monitoring limits the ability to leverage new technologies and innovations that depend on real-time data and connectivity.

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Implication: Slower Technological Progress Without IoT, the grid remains constrained by legacy technologies, slowing the adoption of advancements such as AI, machine learning, and blockchain. This hinders the overall progress and competitiveness of the energy industry.

Example: AI and machine learning algorithms require large volumes of real-time data to train models and provide accurate predictions. IoT devices can generate this data, enabling advanced applications such as predictive maintenance, energy forecasting, and automated decision-making. Without IoT, the grid lacks the data foundation necessary for these technologies, limiting innovation and technological advancement.

4.3.6 Conclusion

The exclusion of IoT from grid monitoring presents significant challenges and implications for the energy industry. It hinders data harmonization, real-time grid monitoring, grid resilience, and flexibility, ultimately limiting the efficiency and effectiveness of grid operations. The absence of IoT leads to fragmented data ecosystems, delayed responses to grid conditions, increased risks of unplanned outages, and constrained integration of renewable energy sources.

To overcome these challenges, the energy industry must embrace IoT technologies and integrate them into grid monitoring and management systems. This integration will enable real-time data collection, advanced analytics, and automated decision-making, fostering a more efficient, resilient, and flexible grid. By leveraging the capabilities of IoT, the energy industry can optimize resource utilization, enhance customer satisfaction, and drive innovation, ensuring a sustainable and competitive future.

4.4 CHALLENGE 4: DATA STANDARDIZATION IN REAL-TIME GRID MONITORING

4.4.1 Introduction

Data standardization is a critical component in the advancement of real-time grid monitoring systems. In the context of energy grids, data standardization involves the harmonization of data formats, protocols, and models to ensure interoperability and efficient data exchange between diverse systems and stakeholders. This section delves deeper into the current challenges posed by non-standardized data structures, explores existing best practices for data standardization, and provides a detailed roadmap for TSOs to implement these practices effectively.

4.4.1.1 Current Challenges with Non-Standardized Data Structures

4.4.1.2 Fragmentation and Incompatibility

In the energy sector, data fragmentation and incompatibility are significant issues. Different organizations and systems use varied data formats, protocols, and models, creating silos that hinder effective data sharing and integration. This fragmentation leads to inefficiencies, as data must often be manually converted or processed to be used across different systems.

- **Data Formats:** Various data formats such as CSV, XML, JSON, and proprietary formats are used, leading to difficulties in data integration.

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- **Communication Protocols:** Diverse protocols like IEC 61850, DNP3, Modbus, and proprietary protocols are employed, each with unique characteristics and limitations.
- **Data Models:** Custom data models developed for specific applications lack the flexibility needed for broader integration, resulting in data silos.

4.4.1.3 Legacy Systems

Legacy OT systems, which form the backbone of many grid monitoring operations, are often not designed to handle the dynamic and data-intensive demands of modern energy grids. These systems prioritize reliability and safety over data flexibility and integration, further complicating standardization efforts.

- **Closed Architectures:** OT systems are typically closed and proprietary, limiting interoperability with newer technologies.
- **Static Data Models:** Designed for specific scenarios, these models lack adaptability to the evolving data landscape.
- **Limited Data Analytics:** OT systems are optimized for real-time control, not for advanced analytics, which limits their utility in modern grid management.

4.4.1.4 Best Practices in Data Standardization

Implementing best practices in data standardization involves adopting industry standards, developing comprehensive data governance frameworks, and leveraging advanced technologies to ensure data consistency and interoperability.

4.4.1.5 Adoption of Industry Standards

Common Information Model (CIM)

The Common Information Model (CIM) is an IEC standard that provides a common vocabulary and structure for representing electrical networks and related information. CIM facilitates interoperability and data exchange by standardizing how data is described and exchanged.

- **Data Model Standardization:** CIM standardizes the representation of grid components, relationships, and attributes, ensuring consistent data descriptions across different systems.
- **Interoperability:** By adopting CIM, organizations can ensure that their data can be easily integrated with other systems and applications that also use CIM.

IEC 61850

IEC 61850 is a standard for the design of electrical substation automation. It defines communication protocols for intelligent electronic devices (IEDs) and supports interoperability between devices from different manufacturers.

- **Communication Standardization:** IEC 61850 standardizes the communication protocols used by IEDs, facilitating seamless data exchange and integration.
- **Flexibility and Scalability:** The standard supports both real-time and non-real-time data exchange, making it suitable for a wide range of applications in grid monitoring.

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Green Button Initiative

The Green Button initiative promotes a standardized format for sharing energy usage data with consumers. It aims to make energy data accessible, understandable, and useful for consumers, fostering energy efficiency and management.

- **Consumer Data Standardization:** By standardizing how energy usage data is presented to consumers, the Green Button initiative ensures that data is consistent and comparable across different utilities.
- **Data Accessibility:** Standardized data formats make it easier for third-party developers to create applications and services that help consumers manage their energy usage.

4.4.1.6 Data Governance and Quality Management

Effective data governance and quality management practices are essential for ensuring the reliability and accuracy of grid monitoring data.

Data Governance Frameworks

Implementing comprehensive data governance frameworks helps organizations define roles, responsibilities, and processes for managing data.

- **Roles and Responsibilities:** Clear definition of roles and responsibilities ensures that data management tasks are assigned and executed effectively.
- **Processes and Policies:** Establishing processes and policies for data handling, including data collection, storage, processing, and sharing, ensures consistency and compliance with regulatory requirements.

Data Quality Assurance

Regular data quality assessments and validation processes are necessary to identify and rectify errors, inconsistencies, and gaps in the data.

- **Data Validation:** Implementing automated validation checks during data collection and processing helps detect and correct errors in real time.
- **Quality Metrics:** Defining and monitoring key data quality metrics, such as accuracy, completeness, and timeliness, helps maintain high data standards.

Metadata Management

Maintaining detailed metadata about data sources, formats, and transformations ensures transparency and traceability in data management processes.

- **Metadata Repositories:** Creating centralized repositories for metadata helps document and manage information about data assets, facilitating data discovery and integration.
- **Standardized Metadata Formats:** Using standardized metadata formats ensures consistency and interoperability across different systems and applications.

4.4.2 Roadmap for Implementing Data Standardization

Adopting data standardization practices involves several strategic steps, including assessing current data infrastructures, aligning with industry standards, and developing tools and processes to support data harmonization.

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4.4.2.1 Assessment of Current Data Infrastructure

Data Inventory

Conducting a comprehensive inventory of existing data assets is the first step in the standardization process.

- **Cataloging Data Sources:** Identifying and documenting all data sources, including their formats, protocols, and models, provides a clear understanding of the current data landscape.
- **Data Mapping:** Mapping data flows and relationships between different systems helps identify areas of fragmentation and incompatibility.

Gap Analysis

Performing a gap analysis helps identify discrepancies between current data practices and desired standards.

- **Standards Comparison:** Comparing existing data formats, protocols, and models with industry standards highlights areas that require alignment.
- **Integration Challenges:** Identifying integration challenges, such as data silos and compatibility issues, informs the development of targeted solutions.

4.4.2.2 Alignment with Industry Standards

Adopting CIM and IEC 61850

Aligning data models and communication protocols with CIM and IEC 61850 standards involves updating data systems and processes.

- **Data Model Updates:** Converting legacy data models to align with CIM ensures consistent data representation and interoperability.
- **Protocol Integration:** Integrating IEC 61850 communication protocols into existing systems facilitates seamless data exchange with IEDs and other devices.

Implementing Standardized Data Formats

Standardizing data formats across the organization ensures consistency and compatibility.

- **Format Conversion Tools:** Developing or deploying tools to automate the conversion of data from proprietary formats to standardized formats reduces manual effort and errors.
- **Data Validation and Transformation:** Implementing validation and transformation processes ensures that data adheres to standardized formats and quality standards.

4.4.2.3 Development of Tools and Processes for Data Harmonization

Data Integration Platforms

Deploying data integration platforms supports the harmonization and integration of data from diverse sources.

- **Middleware Solutions:** Middleware solutions facilitate data exchange between different systems and applications, ensuring that data is consistently formatted and validated.

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- **ETL Processes:** Implementing Extract, Transform, Load (ETL) processes automates the extraction, transformation, and loading of data into standardized formats, streamlining data integration.

Data Governance Policies

Establishing data governance policies ensures consistent and compliant data management practices.

- **Data Handling Guidelines:** Developing guidelines for data collection, storage, processing, and sharing ensures that data is managed consistently and securely.
- **Compliance and Auditing:** Implementing compliance and auditing mechanisms ensures that data management practices adhere to regulatory requirements and industry standards.

Training and Change Management

Training and change management are critical for ensuring that employees understand and adopt new data standardization practices.

- **Training Programs:** Developing training programs for employees on data standards, governance frameworks, and new tools and processes ensures that they have the necessary skills and knowledge.
- **Change Management Strategies:** Implementing change management strategies, including communication plans and support mechanisms, helps employees transition to new data management practices smoothly.

4.4.3 Case Study: Data Standardization at HEDGE-IoT

To illustrate the implementation of data standardization practices, we present a detailed case study of HEDGE-IoT, the same hypothetical TSO used previously undertaking a comprehensive data standardization project.

4.4.3.1 Project Objectives

HEDGE-IoT's data standardization project aims to achieve the following objectives:

- Standardize data formats, protocols, and models across the organization to ensure interoperability and efficient data exchange.
- Enhance data quality and reliability through robust data governance and quality management practices.
- Facilitate the integration of IoT technologies and advanced data analytics to improve real-time grid monitoring capabilities.

4.4.3.2 Implementation Steps

1. Data Inventory and Gap Analysis

HEDGE-IoT conducts a comprehensive inventory of its existing data assets, cataloging all data sources, formats, protocols, and models. A gap analysis is performed to identify discrepancies between current practices and industry standards, highlighting areas that require alignment.

2. Adoption of Industry Standards

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HEDGE-IoT adopts the Common Information Model (CIM) and IEC 61850 standards for its data models and communication protocols. This involves updating data systems to align with these standards, including converting legacy data formats and integrating standardized protocols.

3. Development of Data Integration Platforms

HEDGE-IoT deploys a data integration platform that includes middleware solutions and ETL processes. These tools facilitate the harmonization and integration of data from diverse sources, ensuring that data is consistently formatted and validated.

4. Establishment of Data Governance Policies

HEDGE-IoT establishes comprehensive data governance policies that define roles, responsibilities, and processes for managing data. Data handling guidelines are developed to ensure consistent and secure data management practices, and compliance and auditing mechanisms are implemented to ensure adherence to regulatory requirements.

5. Training and Change Management

HEDGE-IoT develops training programs for employees on data standards, governance frameworks, and new tools and processes. Change management strategies are implemented to support employees through the transition to new data management practices.

4.4.3.3 Outcomes and Benefits

1. Improved Interoperability and Data Exchange

By standardizing data formats, protocols, and models according to CIM and IEC 61850 standards, HEDGE-IoT achieves seamless interoperability across its systems and with external stakeholders. This facilitates efficient data exchange and collaboration with other TSOs, DSOs, regulatory bodies, and third-party service providers, enhancing overall operational efficiency.

- **Seamless Integration:** Systems and devices from different vendors can communicate and exchange data without compatibility issues.
- **Enhanced Collaboration:** Easier data sharing fosters collaboration with partners and stakeholders, supporting coordinated grid management efforts.
- **Reduced Operational Silos:** Standardized data eliminates silos, enabling a more integrated and holistic approach to grid monitoring and management.

2. Enhanced Data Quality and Reliability

The implementation of robust data governance policies and quality management practices ensures high data quality and reliability. HEDGE-IoT can confidently rely on accurate and timely data for decision-making and operational purposes.

- **Consistency and Accuracy:** Standardized data formats and rigorous validation processes ensure data consistency and accuracy.
- **Timeliness:** Real-time data processing capabilities ensure that data is up-to-date, supporting timely decision-making.
- **Transparency and Traceability:** Comprehensive metadata management provides transparency and traceability, enabling quick identification and resolution of data issues.

3. Advanced Real-Time Grid Monitoring

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The integration of IoT technologies and advanced data analytics enhances HEDGE-IoT's real-time grid monitoring capabilities. Detailed, real-time data from numerous points within the grid provides a comprehensive view of grid conditions, enabling proactive management.

- **Granular Data Collection:** IoT devices provide detailed data on various grid parameters, such as voltage, current, temperature, and equipment health.
- **Real-Time Analytics:** Advanced data analytics platforms enable real-time processing and analysis of data, supporting rapid detection and response to potential issues.
- **Predictive Maintenance:** Data analytics support predictive maintenance strategies, allowing HEDGE-IoT to address potential equipment failures before they occur, reducing downtime and improving reliability.

4. Increased Resilience and Flexibility

The standardized, real-time data infrastructure enhances the resilience and flexibility of HEDGE-IoT's grid monitoring system. The ability to quickly adapt to changing conditions and demands ensures that HEDGE can maintain grid stability even under adverse conditions.

- **Dynamic Response:** Real-time data and analytics enable dynamic responses to grid conditions, improving operational flexibility.
- **Resilience to Disruptions:** Robust data infrastructure and predictive maintenance strategies enhance grid resilience, reducing the impact of disruptions.
- **Scalability:** Standardized data models and protocols provide a scalable foundation for future technological advancements and expansions.

4.4.3.4 Challenges and Mitigation Strategies

While the benefits of data standardization are substantial, HEDGE-IoT must address several challenges to ensure successful implementation.

1. Cost and Resource Allocation

The transition to standardized data structures, integration of IoT technologies, and enhancement of data analytics capabilities require significant investment in infrastructure, technology, and training. HEDGE-IoT must carefully manage its budget and resources to ensure the successful execution of the project.

- **Cost Management:** Developing a detailed budget and project plan helps manage costs effectively. HEDGE-IoT can also seek funding and grants from governmental and industry bodies supporting grid modernization initiatives.
- **Resource Allocation:** Prioritizing critical areas for initial investment and gradually expanding the scope of standardization efforts ensures efficient resource allocation.

2. Change Management

The adoption of new technologies and practices necessitates a shift in organizational culture and workflows. HEDGE-IoT must implement effective change management strategies to ensure that employees embrace the changes and are equipped with the necessary skills and knowledge.

- **Employee Engagement:** Engaging employees early in the process and involving them in decision-making helps build support for the changes.

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- **Training and Development:** Comprehensive training programs ensure that employees have the skills and knowledge needed to adopt new technologies and practices.
- **Communication:** Clear and consistent communication about the goals, benefits, and progress of the project helps manage expectations and address concerns.

3. Cybersecurity

The increased connectivity and data flow resulting from IoT integration and real-time data processing pose significant cybersecurity risks. HEDGE-IoT must prioritize cybersecurity measures to protect its critical infrastructure from potential threats.

- **Robust Security Measures:** Implementing robust encryption, authentication, and monitoring systems ensures the security of data and communications.
- **Regular Audits and Assessments:** Regular security audits and assessments help identify and address vulnerabilities.
- **Incident Response Plans:** Developing and regularly updating incident response plans ensures that HEDGE-IoT can quickly and effectively respond to potential cybersecurity incidents.

4. Regulatory Compliance

HEDGE-IoT must ensure that its data management practices and technologies comply with regulatory requirements and industry standards. This includes adhering to data privacy and security regulations, as well as meeting the standards set by industry bodies and regulatory agencies.

- **Regulatory Alignment:** Engaging with regulatory bodies and industry groups helps HEDGE-IoT stay informed about regulatory requirements and best practices.
- **Compliance Monitoring:** Implementing compliance monitoring mechanisms ensures that data management practices continuously meet regulatory standards.

4.4.3.5 Future Directions and Innovations

As HEDGE-IoT advances in its data standardization journey, several future directions and innovations can further enhance its grid monitoring capabilities.

1. Advanced AI and Machine Learning Applications

Leveraging advanced AI and machine learning applications can provide deeper insights and more sophisticated analyses of grid data. These technologies can support more accurate predictions, automated decision-making, and enhanced anomaly detection.

- **Predictive Analytics:** Advanced algorithms can analyze historical and real-time data to predict equipment failures, load patterns, and other critical events.
- **Automated Decision-Making:** AI-driven decision-making systems can automate routine operational decisions, improving efficiency and response times.
- **Enhanced Anomaly Detection:** Machine learning models can identify subtle patterns and anomalies that may indicate potential issues, enabling proactive management.
- **Train on the edge:** Federated learning strategies allow machine learning applications to train directly on multiple edge devices independently, gaining insights from multiple grids while preserving data federation and privacy.

2. Integration with Distributed Energy Resources (DERs)

The increasing prevalence of distributed energy resources (DERs), such as solar panels, wind turbines, and battery storage systems, necessitates the integration of these resources into grid monitoring systems. Standardized data structures and protocols can facilitate this integration, ensuring that data from DERs is seamlessly incorporated into grid operations.

- **Data Integration:** Standardized data models and communication protocols ensure that data from DERs is compatible with existing grid monitoring systems.
- **Operational Coordination:** Integrating DER data into grid monitoring systems supports coordinated management of these resources, enhancing grid stability and efficiency.

3. Blockchain for Secure Data Management

Blockchain technology offers a secure and transparent method for managing and sharing data. By implementing blockchain solutions, HEDGE-IoT can enhance data security, integrity, and traceability.

- **Data Security:** Blockchain's decentralized and encrypted nature provides robust security for data transactions.
- **Transparency and Trust:** Blockchain's immutable ledger ensures transparency and trust in data management processes.
- **Smart Contracts:** Smart contracts can automate and enforce data sharing agreements, ensuring compliance and efficiency.

4. Enhanced Customer Engagement

Standardized data and advanced analytics can also enhance customer engagement by providing consumers with detailed and understandable energy usage data. Initiatives like the Green Button can be expanded to offer more personalized and actionable insights to consumers.

- **Personalized Insights:** Advanced analytics can provide consumers with personalized recommendations for energy efficiency and cost savings.
- **Interactive Dashboards:** User-friendly dashboards and mobile applications can make it easier for consumers to understand and manage their energy usage.
- **Proactive Notifications:** Automated notifications can alert consumers to potential issues or opportunities for energy savings, enhancing their engagement and satisfaction.

4.4.4 Conclusion

The challenge of non-standardized data structures in real-time grid monitoring is a significant obstacle to achieving efficient, resilient, and flexible grid operations. However, by adopting best practices in data standardization, integrating IoT technologies, and enhancing data analytics capabilities, energy actors involved in HEDGE-IoT can overcome these challenges and realize substantial benefits.

Through the implementation of standardized data structures, HEDGE-IoT achieves seamless interoperability and efficient data exchange, facilitating collaboration and innovation. The integration of IoT technologies provides granular, real-time data, enhancing grid monitoring and enabling proactive management. Advanced data analytics empower HEDGE-IoT to implement predictive maintenance and anomaly detection, improving reliability and reducing downtime.

While the implementation of these best practices involves significant challenges and considerations, the potential benefits far outweigh the costs. By prioritizing cost management,

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change management, cybersecurity, and regulatory compliance, HEDGE-IoT can successfully navigate these challenges and achieve its objectives.

Ultimately, the Consultation task serves as a focused initiative to promote knowledge diffusion and data harmonization for real-time grid monitoring. By leveraging the experiences of TSOs and fostering collaboration among various stakeholders, this task aims to enhance the resilience and flexibility of grid monitoring systems. The development of grid data codes and the emphasis on data management as an integration and resiliency asset will empower system operators to become pivotal in the energy management landscape. With the adoption of best practices and the successful implementation of strategic initiatives, TSOs and DSOs can significantly improve the efficiency and reliability of real-time grid monitoring, ensuring a more stable and adaptable power grid for the future.

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5 ETHICS, REGULATORY AND SOCIETAL ASPECTS

This section deals with activities and results from task T2.4 "Mapping of regulatory, societal and technical barriers and AI ethics at EU and national levels". Specifically, this task aims at ensuring compliance with ethics and regulatory principles, according to the specific context of the HEDGE-IoT project, use cases, data and technology enablers. This objective is achieved through:

- The establishment of the "Ethics and Regulatory Governance" (ERGO) methodological framework, that performs continuous monitoring and assessment of the project activities and outcomes. Based on these assessments, it identifies relevant EU ethics and regulatory principles (i.e., **EU values and rules**) to be adopted during the whole development lifecycle.
- Therefore, these EU values and rules are mapped into guidelines, recommendations and requirements to be embedded in the technological solutions and processes.

The European Union (EU) is a 'union of values', as enshrined in Article 2 of the Treaty on European Union, founded on respect for human dignity, freedom, democracy, equality, the rule of law and respect for human rights, including the rights of persons belonging to minorities. [6]

5.1 ETHICS AND REGULATORY GOVERNANCE FRAMEWORK

The Ethics and Regulatory Governance (ERGO) methodological framework has been introduced in the HEDGE-IoT Data Management Plan (DMP – D1.4) to assess the data generated and processed by the project during its lifecycle. Indeed, the ERGO framework aims at ensuring compliance with the EU ethics and regulatory framework, including inter-alia FAIR data management [7].

It builds on four key pillars (see Figure 2):

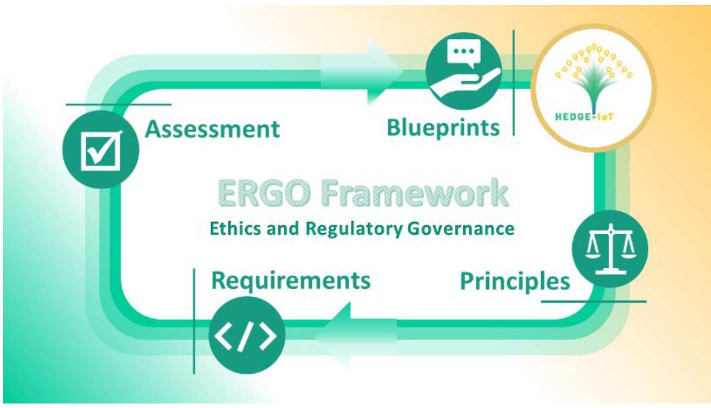

FIGURE 2. THE HEDGE-IOT ERGO FRAMEWORK

1. Identifying key **principles**, in line with the EU ethics and regulatory framework, to be adopted during the whole project lifecycle;
2. Deriving **requirements** from principles to be embedded into the technology solutions developed by the project;
3. Performing continuous monitoring and **assessment** of the project activities and outcomes;
4. Providing recommendations and policy options (**blueprints**) based on lessons learned and results of the assessments.

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The HEDGE-IoT ERGO framework is considering provisionally relevant **principles**, such as:

- **GDPR - General Data Protection Regulation (EU 2016/679)** [8], which lays the foundation to ensure privacy and data protection rights of individuals when dealing with their personal data treatment;
- **Data Act (EU 2023/2854)** [9], ensuring fair use of, share and access to data (i.e., who can use what data and under which conditions) generated by IoT devices. The Data Act was published in December 2023, entered in force in January 2024, and it will become applicable from September 2025;
- **AI Act (EU 2024/1689)** [10], which is entering in force in August 2024, together with The EU Ethics Guidelines for Trustworthy AI (2019) [11] and the UN Interim Report "Governing AI for Humanity" [12] to ensure the trustworthiness, robustness and safety of AI systems and their adherence to EU values within the European market;
- **Directive NIS 2 (EU 2022/2555)** [13], which is in force from December 2022, provides measures for a high common level of cybersecurity across the Union and updates the Network and Information Systems (NIS) Directive of 2016, aiming to enhance cybersecurity resilience across the European Union;
- **Joint Declaration on Digital Rights and Principles for the Digital Decade (2022)** [6], this joint declaration of the European Parliament, the Council and the Commission aims at ensuring human-centricity toward the digital transition, in line with EU values and fundamental rights.

During the first phase of the HEDGE-IoT project, in the context of the ERGO framework, it has been carried out the baseline assessment by submitting an online questionnaire (see Annexes to DMP). This allowed to gather and collect data on:

1. **Activity** - Main activities of the partner in the project
2. **Personal Data** - Generated, processed, managed by the partner in the project
3. **Personal Data Processing** - Techniques and rules applied to process personal data
4. **Data Management** - Data types, flow and principles adopted by the partner
5. **Technology** - Technology deployed and adopted by the partner in the project

While the DMP focused on Activity and Data Management perspectives, this document reports the analysis on Personal Data and Technology aspects, which could potentially impact the social sphere and therefore raise ethics and regulatory concerns.

In so doing, the baseline assessment allows the HEDGE-IoT consortium to derive ethics, regulatory and societal (ERS):

- **Challenges** (ERSC) to pay attention during the project lifecycle;

- **Principles** related to EU values and rules;
- **Requirements** (ERSR) to be integrated in the development process and be embedded into the developed solutions;
- **Countermeasures/Tasks** (ERST) to be planned and carried out for improving the efficacy of project implementation.

5.2 ETHICS, REGULATORY AND SOCIETAL CHALLENGES

From the baseline assessment it comes to light that the majority of partners (more than 60%) will not collect and process personal data (see **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**), and the rest of the consortium is divided in two groups: mostly 20% will process personal data and 17% is not yet sure if they will use or not. This uncertainty is reflected also in a second question (Q2) concerning the processing of "sensitive data".

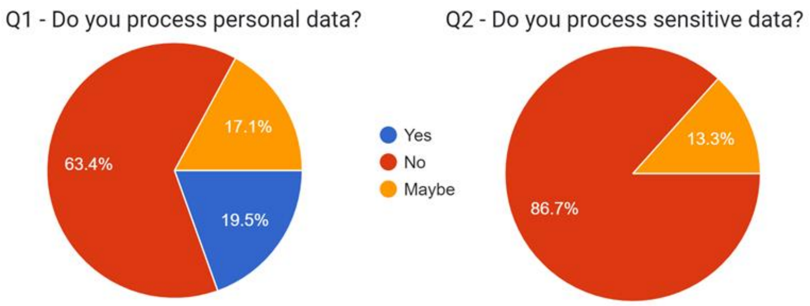

FIGURE 3. PERSONAL DATA IN HEDGE-IOT

Although the question provides the definition of sensitive relies on the GDPR Regulation (EU 2016/679) (i.e., *special category of personal data revealing racial or ethnic origin, political opinions, religious or philosophical beliefs* […]), there is a group of 13% (among the partners processing personal data) that is still in doubt about processing of "sensitive data". This result means that a limited group (i.e., 2 over 15 partners processing personal data) is considering "sensitive" as "confidential", rather than as a special category of personal data (i.e., the meaning assigned in GDPR). This is a quite frequent interpretation; however, it is reasonable to continuously monitor the evolution and take appropriate countermeasures (e.g., one-to-one calls to clarify doubts, provide a set of practical guidelines and recommendations in the updated project management handbook).

For the sake of clarity, the results of the questionnaire highlight that the consortium is 100% aware that personal data require a specific purpose and this has to be clearly specified to the owner of personal data (i.e., the data subject according to GDPR) through a process of information and request for consent. Therefore, this result identifies the first main concerns and related compliance principles, requirements and countermeasures to be considered during the development process.

	Concern	**#ERSC1** "Personal data"
	Principles	EU 2016/679 "General Data Protection Regulation" (**GDPR – art.5**)
	Requirements	**#ERSR 4.1** "Legal basis for processing personal data" - Personal data processing will be based on the principles of lawfulness (e.g.,

		permission by the data owner), fairness, transparency, purpose limitation, data minimisation, accuracy, storage limitation, integrity, confidentiality and accountability.
	Countermeasures/ Tasks	• **#ERST1** - Add a check for personal data lawfulness in the self-assessment checklist • **#ERST2** - Provide practical guidelines and recommendations on personal data processing according to GDPR • **#ERST3** - Provide templates for information sheet and consent form in updated project management handbook

TABLE 21. ETHICS/REGULATORY/SOCIETAL CONCERN 1 - PERSONAL DATA

	Concern	**#ERSC2** "Sensitive data - Special Category of Personal data"
	Principles	EU 2016/679 "General Data Protection Regulation" (**GDPR – art.9**)
	Requirements	**#ERSR 4.2** "Processing of special category of personal data" – Processing of special category of personal data (sensitive data), including gathering and collection, shall be prohibited. Indeed, it is out of the HEDGE-IoT scope dealing with data revealing personal orientation/opinions/beliefs/health of human beings.
	Countermeasures/ Tasks	• **#ERST4** - Add a check for special category of personal data in the self-assessment checklist • **#ERST5** - Provide practical guidelines and recommendations on special category of personal data processing according to GDPR

TABLE 22. ETHICS/REGULATORY/SOCIETAL CONCERN 2 – SPECIAL CATEGORY OF PERSONAL DATA

The HEDGE-IoT consortium is also aware of the need of applying appropriate protection mechanisms to personal data: anonymisation and aggregation are the two main mechanisms mentioned by the partners. However, it is important to consider that anonymisation and aggregation have to be applied from the data source, avoiding to identify/make identifiable data subjects from any of their characteristics. Therefore, this aspect identifies another ethics/regulatory concern.

	Concern	**#ERSC3** "Protection measures on personal data"
	Principles	EU 2016/679 "General Data Protection Regulation" (**GDPR – art.32**)
	Requirements	**#ERSR 4.3** "Security of processing" – Implement appropriate technical and organisational measures at the data source, to ensure

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		a level of security appropriate to the risk, including inter alia anonymisation, pseudonymisation, aggregation, encryption.
	Countermeasures/ Tasks	• **#ERST6** - Add a check for protection measures in the self-assessment checklist • **#ERST7** - Provide practical guidelines and recommendations on protection measures according to GDPR in the updated project management handbook

TABLE 23. ETHICS/REGULATORY/SOCIETAL CONCERN 3 – PROTECTION MEASURES ON PERSONAL DATA

The baseline assessment confirmed the adoption of Blockchain, or in general any Distributed Ledger Technology (DLT), in many use cases to also ensure integrity of data processed (10% of the project consortium). Although this technical measure addresses the ERSR 4.3, the peculiar characteristics of this technology must be considered, that is the "immutability" of the storage. When dealing with personal data, DLT shall not be adopted to ensure compliance with GDPR as shown in Table 24. Moreover, it is recommended to adopt best practices for the architectural solutions [14].

	Concern	**#ERSC4** "Personal Data and Blockchain/DLT"
	Principles	EU 2016/679 "General Data Protection Regulation" (**GDPR – artt.16, 17**)
	Requirements	• **#ERSR 4.4** "Personal data and DLT" – Personal data shall not be stored in DLT to ensure two fundamental rights of the data subject: i) right to rectification (art.16); ii) right to erasure/right to be forgotten (art.17). • **#ERSR 4.5** "Personal data and DLT – architectural solutions" – It is suggested to apply best practices from the state of the art, allowing to divide personal data from data to be stored in DLT.
	Countermeasures/ Tasks	• **#ERST8** - Add a check for DLT and personal data in the self-assessment checklist • **#ERST9** - Provide practical guidelines and recommendations on DLT and personal data according to GDPR in the updated project management handbook

TABLE 24. ETHICS/REGULATORY/SOCIETAL CONCERN 4 – PERSONAL DATA AND BLOCKCHAIN/DLT

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HEDGE-IoT proposes an innovative digital framework to deploy and exploit connected products (IoT) across the whole energy ecosystem (i.e., from "behind-the-meter" to the transmission level), their generated data generated, leveraging AI/ML tools to enhance efficiency and flexibility in the smart grid, both at the edge (i.e., in proximity of the IoT) and the cloud layers. In doing so, HEDGE-IoT project has to consider the compliance with the Data Act (EU 2023/2854), by considering these two main concerns and related requirements: i) Data Access and Sharing Provisions; ii) Data Security and Privacy.

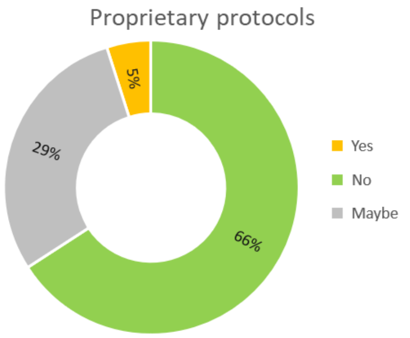

FIGURE 4. PROPRIETARY

The concern "Data Access and Sharing Provisions" is also justified from the analysis of the baseline assessment (see Figure 4), where most of the consortium (66%) is evaluating to do not use proprietary protocols (i.e., non-standard protocols). Therefore, the following concerns and related requirements aim at spotting the light in considering widely adopted protocols, facilitating data sharing.

Concern	**#ERSC5** "Ensure user rights to access data and facilitate data sharing"
Principles	EU 2023/2854 "Data Act" (**artt.3, 4, 5, 8, 9**)
Requirements	• **#ERSR 4.6** "User right to access data" – Users should have the right to access data generated by their devices easily and in a structured, commonly used, and machine-readable format. • **#ERSR 4.7** "Data availability user conditions" - Data holders have to make data available to the user without undue delay and free of charge. IoT systems should include mechanisms for users to request and obtain their data promptly. • **#ERSR 4.8** "Facilitate data sharing" – Data holders are allowed to share data with third parties, based on permission of the user, who is involved in a fair, transparent, and non-discriminatory manner. • **#ERSR 4.9** "Interoperability" – Data holders have to ensure interoperability for data sharing, by adopting standardised and secure methods to facilitate data transfer.
Countermeasures/ Tasks	• **#ERST10** - Add a check for access and sharing conditions in the self-assessment checklist

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		• **#ERST11** - Provide practical guidelines and recommendations on IoT and data access and sharing according to Data Act in the updated project management handbook

TABLE 25. ETHICS/REGULATORY/SOCIETAL CONCERN 5 – DATA ACCESS AND SHARING

	Concern	**#ERSC6** "Data privacy and security"
	Principles	EU 2023/2854 "Data Act" (**artt.5, 11**)
	Requirements	• **#ERSR 4.10** "Robust Data Protection Measures" – Connected products and systems have to implement strong security protocols to protect data from unauthorised access, breaches, and misuse. • **#ERSR 4.11** "Privacy compliance" – Connected products and systems have to enable data owners explicitly consenting for data collection, processing, and sharing, as well as providing them with the ability to manage their privacy settings and data retention preferences.
	Countermeasures/ Tasks	• **#ERST12** - Add a check for privacy and security settings and mechanisms in the self-assessment checklist • **#ERST13** - Provide practical guidelines and recommendations on privacy and security settings according to Data Act and GDPR in the updated project management handbook

TABLE 26. ETHICS/REGULATORY/SOCIETAL CONCERN 6 – DATA PRIVACY AND SECURITY

The HEDGE-IoT digital platform will leverage AI/ML tools for optimisation purposes and the adoption of the AI/ML technology is widely confirmed in the baseline assessment (around 32% of the project consortium): this is the most relevant technology adopted in the project.

In the light of the new regulation on Artificial Intelligence (the AI Act) that is entering in force during the editing of this document (August 2024). For the sake of clarity, the AI Act classifies AI technology according to a risk-based approach in 4 levels:

- **Unacceptable risk** – the highest level of risk prohibited in the EU market and banned from February 2025 (6 months from the enter in force of the AI Act). These AI systems might "deploy subliminal techniques", "exploit vulnerabilities", "evaluate or classify", "infer emotions", "use biometric categorisation", "use real-time remote biometric" and therefore might impact and harm the behaviour of a person or a group of persons, contravening EU values (i.e., fundamental rights). This level of risk is deeply treated in Chapter II "Prohibited AI practices" and its art.5 of the AI Act.

- **High-risk** – the level of risk regulated under the Chapter III "High-Risk AI Systems" and its art.6 – 49. This includes the AI system that are intended to be used as a safety component of a product, or the AI system is itself a product, as listed in areas of the Annex III of the AI Act (i.e., biometrics, critical infrastructures, education and vocational training, employment management, access to public services, law enforcement, migration and border management, administration of justice and democratic processes). For this category of AI, a "conformity assessment" is necessary demonstrating the fulfilment of requirements specified in Chapter III, Section 2 of the AI Act.
- **Limited risk** – this category includes tools raising risks associated with lack of transparency, and that are usually intended for interacting with consumers (e.g., chatbots), for emotion recognition and for generating or manipulating content. Therefore, AI systems of this category undergo to transparency compliance obligation (AI Act art. 13, Chapter IV art. 50).
- **Minimal or no risk** – the level of risk that includes AI-based spam filters and video games. For this category of AI systems that can be deployed without restrictions and it is suggested the adoption of AI code of ethics during their development to avoid bias, ensuring privacy of users and their own personal data, and mitigating environmental risks.

Based on these definitions and due to the fact that the HEDGE-IoT technology is still under specification, it is definitely important to consider seven main concerns: i) prohibited AI practices (i.e., AI solutions with "unacceptable risks" that are banned from February 2025); ii) bias; iii) transparency; iv) privacy; v) ethics; vi) sustainability and vii) security. These concerns are considered in the technical report of the CEN/CENELEC TR18115:2024 "Data governance and quality for AI within the European context" (in balloting phase during the editing of this document) and other ongoing standardisation initiatives of the CEN/CENELEC JTC21 and ISO/IEC JTC1/SC42 dealing with "Artificial Intelligence".

Concern	**#ERSC7** "Prohibited AI practices"
Principles	EU 2024/1689 "AI Act" (**art.5**)
Requirements	• **#ERSR 4.12** "Prohibited AI practices" – AI-based solutions shall not be intended to "deploy subliminal techniques", "exploit vulnerabilities", "evaluate or classify", "infer emotions", "use biometric categorisation", "use real-time remote biometric". Contravening this requirement can result in fines up to 35 million EUR or 7% of a company's annual turnover.
Countermeasures/ Tasks	• **#ERST14** - Add a check for AI risk levels in the self-assessment checklist

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		• **#ERST15** - Provide practical guidelines and recommendations on Ethics of AI according to The EU Ethics Guidelines for Trustworthy AI (2019), the UN Interim Report "Governing AI for Humanity" and the "Joint Declaration on Digital Rights and Principles for the Digital Decade" in the updated project management handbook

TABLE 27. ETHICS/REGULATORY/SOCIETAL CONCERN 7 – PROHIBITED AI PRACTICES

	Concern	**#ERSC8** "Bias in AI systems and data"
	Principles	EU 2024/1689 "AI Act" (**art.10**)
	Requirements	• **#ERSR 4.13** "Data Quality and Governance" – AI-based solutions shall be developed on the basis of training, validation and testing data sets that meet the quality criteria, including inter-alia provenance.
	Countermeasures/ Tasks	• **#ERST16** - Add a check for bias in AI and data in the self-assessment checklist

TABLE 28. ETHICS/REGULATORY/SOCIETAL CONCERN 8 – BIAS IN AI SYSTEMS AND DATA

	Concern	**#ERSC9** "Transparency of AI systems"
	Principles	EU 2024/1689 "AI Act" (**art.13**)
	Requirements	• **#ERSR 4.14** "Provision of information" – AI-based solution shall be developed, deployed and provided with sufficient information to enable users to interpret system's output and use it appropriately.
	Countermeasures/ Tasks	• **#ERST17** - Add a check for AI documentation in the self-assessment checklist

TABLE 29. ETHICS/REGULATORY/SOCIETAL CONCERN 9 – TRANSPARENCY OF AI SYSTEMS

	Concern	**#ERSC10** "Privacy in AI systems"
	Principles	EU 2024/1689 "AI Act" (**artt.2, 10, 13**)
	Requirements	• **#ERSR 4.15** "Right to privacy" – AI-based solution shall be developed, trained and validated considering that the right to

		privacy and to protection of personal data must be guaranteed throughout the entire lifecycle of the AI system.
	Countermeasures/ Tasks	• **#ERST18** - Add a check for use of personal data and privacy mechanisms in the self-assessment checklist

TABLE 30. ETHICS/REGULATORY/SOCIETAL CONCERN 10 – PRIVACY IN AI SYSTEMS

	Concern	**#ERSC11** "Ethics of AI"
	Principles	• EU 2024/1689 "AI Act" • The EU Ethics Guidelines for Trustworthy AI (2019) • The UN Interim Report "Governing AI for Humanity" • The Joint Declaration on Digital Rights and Principles for the Digital Decade
	Requirements	• **#ERSR 4.16** "Ensure fundamental rights through ethics principles" – AI-based solution shall be conceived, developed, trained and validated ensuring fundamental rights through adoption of ethics principles.
	Countermeasures/ Tasks	• **#ERST19** - Add a check for ethics of conduct in the self-assessment checklist

TABLE 31. ETHICS/REGULATORY/SOCIETAL CONCERN 11 – ETHICS OF AI

The last two concerns, Sustainability and Security, should not be considered only for the AI-based technology, but rather as a recommendation for the whole technology platform that HEDGE-IoT is building.

	Concern	**#ERSC12** "Sustainability"
	Principles	• EU 2024/1689 "AI Act" • The Joint Declaration on Digital Rights and Principles for the Digital Decade
	Requirements	• **#ERSR 4.17** "Sustainability information" – Technology providers should produce an accurate, easy-to-understand documentation on the societal and environmental impacts (e.g., energy consumption of digital products and services, their reparability

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		and lifetime) enabling technology adopters to make responsible choices.
	Countermeasures/ Tasks	• **#ERST20** - Add a check for sustainability information in the self-assessment checklist

TABLE 32. ETHICS/REGULATORY/SOCIETAL CONCERN 12 – SUSTAINABILITY

	Concern	**#ERSC13** "Security"
	Principles	• EU 2024/1689 "AI Act" • The Joint Declaration on Digital Rights and Principles for the Digital Decade • EU 2022/2555 "NIS2"
	Requirements	• **#ERSR 4.18** "Encryption" – Adopt encryption tools and software to automatically encrypt data when it is saved to storage devices and transmitted. • **#ERSR 4.19** "Need to know" - To ensure that only authorised personnel can access personal and non-personal data, based on their role and necessity, define roles and permissions within the data management system, regularly review access logs, and conduct audits to ensure compliance. • **#ERSR 4.20** "Integrity and availability" - Regularly back up encrypted data to secure, off-site locations to ensure data recovery in case of a data breach or system failure. Use a backup schedule, automated backup solutions, and test recovery procedures periodically to ensure data integrity and availability.
	Countermeasures/ Tasks	• **#ERST21** - Add a check for security procedures in the self-assessment checklist

TABLE 33. ETHICS/REGULATORY/SOCIETAL CONCERN 13 – SECURITY

5.3 REQUIREMENTS

The baseline assessment allowed to identify 13 concerns, addressed in 5 preliminary relevant ethics and regulatory principles from which have been derived 20 requirements and 21 countermeasures/tasks for validation and ensuring compliance. The following Table 34 resumes these requirements and provides the means of validation.

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ID	Requirement	Description	Validation
4.1	Legal basis for processing personal data	Requirement from GDPR art.5	ERST1, ERST2, ERST3
4.2	Sensitive data - Special Category of Personal data	Requirement from GDPR art.9	ERST4, ERST5
4.3	Protection measures on personal data	Requirement from GDPR art.32	ERST6, ERST7
4.4	Personal data and DLT	Requirement from GDPR artt.16, 17	ERST8, ERST9
4.5	Personal data and DLT – architectural solutions	Requirement from GDPR artt.16, 17	ERST8, ERST9
4.6	User right to access data	Requirement from Data Act artt.3, 4, 5, 8, 9	ERST10, ERST11
4.7	Data availability user conditions	Requirement from Data Act artt.3, 4, 5, 8, 9	ERST10, ERST11
4.8	Facilitate data sharing	Requirement from Data Act artt.3, 4, 5, 8, 9	ERST10, ERST11
4.9	Interoperability	Requirement from Data Act artt.3, 4, 5, 8, 9	ERST10, ERST11
4.10	Robust Data Protection Measures	Requirement from Data Act artt.5, 11	ERST12, ERST13
4.11	Privacy compliance	Requirement from Data Act artt.5, 11	ERST12, ERST13
4.12	Prohibited AI practices	Requirement from AI Act art.5	ERST14, ERST15
4.13	Data Quality and Governance	Requirement from AI Act art.10	ERST16
4.14	Provision of information	Requirement from AI Act art.13	ERST17

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4.15	Right to privacy	Requirement from AI Act artt.2, 10, 13	ERST18
4.16	Ensure fundamental rights through ethics principles	Requirement from AI Act, EU Ethics Guidelines for Trustworthy AI, UN Interim Report "Governing AI for Humanity", Joint Declaration on Digital Rights and Principles for the Digital Decade	ERST19
4.17	Sustainability information	Requirements from AI Act, Joint Declaration on Digital Rights and Principles for the Digital Decade	ERST20
4.18	Encryption	Requirement Requirements from AI Act, Joint Declaration on Digital Rights and Principles for the Digital Decade, NIS2	ERST21
4.19	Need to Know	Requirement Requirements from AI Act, Joint Declaration on Digital Rights and Principles for the Digital Decade, NIS2	ERST21
4.20	Integrity and availability	Requirement Requirements from AI Act, Joint Declaration on Digital Rights and Principles for the Digital Decade, NIS2	ERST21

TABLE 34. SUMMARY OF ETHICS/REGULATORY/SOCIETAL REQUIREMENTS

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6 USER ENGAGEMENT, AWARENESS, AND INCLUSIVENESS REQUIREMENTS

6.1 TASK 2.5 OVERVIEW

6.1.1 Objectives

The primary objectives of Task 2.5 are to ensure robust user engagement, raise awareness, and promote inclusiveness throughout the HEDGE-IoT project. Specifically, the aims include:

1. **Engaging Diverse Stakeholders:** Conducting a comprehensive analysis to involve a wide range of stakeholders, including citizens and end-consumers, ensuring their needs, interests, and potentialities are considered.

2. **Awareness Raising:** Developing strategies to effectively raise awareness about the HEDGE-IoT project's benefits and opportunities.

3. **Inclusiveness**: Ensuring that the project's initiatives are inclusive, addressing the needs of vulnerable and digitally excluded citizens.

4. **Social Science Framework:** Defining a framework that incorporates citizen engagement, intersectionality, and co-creation research to guide the project's awareness-raising efforts.

5. **Stakeholder Engagement Strategy:** Creating a strategy to identify appropriate methodologies and frameworks for assessing engagement processes and results, considering multi-level governance models and incentive mechanisms.

6.1.2 Planning

To achieve these objectives, the following methodologies and approaches are planned:

1. **Literature Review:** Conducting an in-depth review of existing literature on user engagement, awareness, and inclusiveness to identify best practices and theoretical foundations.

2. **Identification of Target Users:** Developing a detailed process to identify different user groups based on various criteria, and understanding their key characteristics and needs.

3. **Preliminary Engagement Plan:** Formulating initial plans to engage each identified user type with tailored actions and methods.

4. **Multi-level Governance Models:** Considering governance models that facilitate stakeholder engagement at various levels.

5. **Incentive Mechanisms:** Exploring both monetary and non-monetary incentives to boost citizen participation in the project.

6. **DoEAP Principles:** Ensuring digital inclusion for vulnerable citizens by providing affordable access to new digital technologies and tools.

6.2 LITERATURE REVIEW

Existing Literature on User Engagement, Awareness, and Inclusiveness in Energy Systems and IoT

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A thorough review of the literature specific to energy systems and IoT reveals several best practices and theoretical foundations that can inform the HEDGE-IoT project:

1. **User Engagement:**

- Best Practices: Successful engagement in IoT and energy projects involves clear communication of benefits, participatory design, and continuous feedback mechanisms.

Example: The deployment of smart grids often involves pilot projects that engage users by demonstrating cost savings and increased control over energy usage.

Example: Co-creation workshops that include stakeholders in the design of IoT systems can improve user acceptance and system relevance.

- Theoretical Foundations:

Stakeholder Theory: This theory underlines the importance of involving all relevant stakeholders, from energy providers to end-users, in the development and implementation of new technologies to ensure their needs and concerns are addressed.

Unified Theory of Acceptance and Use of Technology (UTAUT): This model suggests that performance expectancy, effort expectancy, social influence, and facilitating conditions affect users' acceptance and usage of technology.

2. **Awareness Raising:**

- Best Practices: Effective awareness strategies for IoT and energy technologies often leverage demonstrations, pilot programs, and educational campaigns that highlight tangible benefits.

Example: Energy-saving competitions and interactive dashboards that show real-time energy usage can effectively raise awareness among users about the benefits of IoT-enabled energy management systems.

- Theoretical Foundations:

Diffusion of Innovations Theory: This theory explains the process through which new ideas and technologies spread, emphasizing the importance of early adopters and social networks in driving awareness and acceptance.

Environmental Communication Models: These models focus on the role of communication in shaping public understanding and engagement with environmental issues, which can be applied to raise awareness about IoT in energy systems.

3. **Inclusiveness:**

1. Best Practices: To ensure inclusiveness in IoT projects, it is crucial to address barriers to access and tailor communication to different user groups, particularly those that are often marginalized.

Example: Projects that offer free or subsidized access to IoT devices for low-income households can help bridge the digital divide and promote inclusiveness.

2. Theoretical Foundations:

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Intersectionality: This concept highlights how overlapping social identities, such as socioeconomic status and access to technology, can impact individuals' experiences and opportunities, necessitating targeted inclusion strategies.

Digital Inclusion Frameworks: These frameworks emphasize the need for accessible and affordable digital solutions, digital literacy education, and inclusive design principles to ensure broad participation.

6.3 IDENTIFICATION OF TARGET USERS

Based on the HEDGE-IoT project's objectives and the updated context, the following target user groups have been identified:

1. **Urban Energy Consumers:**
   - Characteristics: High digital literacy, interested in smart home solutions and energy efficiency.
   - Needs: Information on integrating IoT for energy management, insights into energy usage, and potential cost savings.
2. **Rural Energy Users:**
   - Characteristics: Limited access to digital infrastructure, lower awareness of IoT solutions.
   - Needs: Education on the benefits of IoT, assistance in accessing technologies, and reliable energy solutions.
3. **Economically Disadvantaged and Vulnerable Groups:**
   - Characteristics: Limited resources and digital skills, diverse cultural backgrounds.
   - Needs: Affordable and easy-to-use IoT solutions, culturally appropriate communication, and digital literacy support.
4. **Small and Medium Enterprises (SMEs):**
   - Characteristics: Varied levels of technological adoption, focused on cost efficiency.
   - Needs: Information on integrating IoT into operations, case studies on cost benefits, and incentives for adopting new technologies.
5. **Policy Makers and Regulators:**
   - Characteristics: Focused on policy development and regulatory frameworks.
   - Needs: Data-driven insights, evidence of IoT benefits, and guidelines for policy creation that support innovation and inclusiveness.

6.4 PRELIMINARY PLAN FOR EACH USER TYPE

1. **Urban Citizens:**
   - o Actions:
     - Launch a social media campaign on platforms like Linkedin and Twitter, featuring infographics, quick tips, and user testimonials.
   - o Methods:
     - Create visually engaging posts and stories with key information about the project.

2. **Rural Communities:**
   - o Actions:
     - Leverage local radio stations and online community forums to share success stories and benefits of IoT.
   - o Methods:

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- Create short, engaging audio clips and digital flyers that can be easily shared in local online communities.

3. **Economically Disadvantaged and Vulnerable Groups:**
   - Actions:
     - Create simple, accessible, and mobile-friendly web content in multiple languages.
     - Partner with local NGOs and community organizations to distribute information through their channels.
   - Methods:
     - Use platforms like Facebook and local community apps to disseminate information, ensuring accessibility for non-English speakers.
     - Work with organizations that already have established relationships with these populations for broader reach.

4. **Businesses and SMEs:**
   - Actions:
     - Organize brief, informative webinars or live Q&A sessions on LinkedIn to discuss IoT benefits and case studies.
     - Share success stories and practical guides on professional networks and forums.
   - Methods:
     - Use LinkedIn posts and articles to share relevant information quickly.
     - Host short and focused virtual events to engage business professionals.

5. **Policy Makers and Regulators:**
   - Actions:
     - Develop and share concise policy briefs and summaries via professional networks like LinkedIn.
     - Conduct quick virtual roundtable discussions with key stakeholders to gather input and share insights.
   - Methods:
     - Publish policy briefs and updates on LinkedIn and relevant government platforms.
     - Use platforms like Microsoft Teams or Webex for focused, high-level discussions.

6.5 CONCLUSIONS

Main Insights from the Literature Review

- **Effective Engagement:** Requires continuous, multi-channel communication and active stakeholder involvement.
- **Awareness Raising:** Must leverage social influence and perceived benefits to motivate action.
- **Inclusiveness:** Demands targeted efforts to remove barriers and ensure accessibility for all user groups.

Actionable Recommendations

- **Develop Tailored Engagement Plans:** Based on user group characteristics and needs.
- **Leverage Partnerships:** With community organizations and NGOs to extend reach and support.
- **Implement Multi-level Incentives:** To encourage participation across different user groups.

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Broader Implications
The findings from this task underscore the importance of a comprehensive, inclusive approach to stakeholder engagement in technological projects. By addressing the diverse needs of all user groups, the HEDGE-IoT project can enhance its impact and ensure broad-based support and participation.

This strategic approach will guide the project's next steps, ensuring that engagement, awareness, and inclusiveness remain central to its implementation and success.

6.6 REQUIREMENTS

ID	Requirement	Description	Validation
5.1	Stakeholder Engagement Plan	Develop a plan to engage a diverse range of stakeholders, ensuring their needs and potentialities are considered in the project.	The plan should include diverse stakeholder inputs, documented through engagement activities and feedback.
5.2	Awareness Campaigns	Create targeted campaigns to raise awareness about the benefits of the HEDGE-IoT project.	Campaigns should reach target audiences effectively, measured by engagement metrics such as reach and feedback.
5.3	Inclusion of Vulnerable Groups	Ensure that vulnerable populations, such as the economically disadvantaged and digitally excluded, are included in the project activities.	Conduct outreach activities and provide evidence of participation from vulnerable groups.
5.4	Social Science Framework Implementation	Implement a social science framework that incorporates citizen engagement, intersectionality, and co-creation research.	Framework should be integrated into project plans and evidenced by user-centric design practices.
5.5	Multi-level Governance Models	Consider multi-level governance models to facilitate effective stakeholder engagement at various levels of the project.	Document governance model integration in project processes, showing engagement across different levels.
5.6	Communication Accessibility	Ensure communication materials are accessible and available in multiple languages and formats to accommodate all users.	Validate by having all communication materials audited for accessibility and language inclusivity.
5.7	Digital Literacy Support	Provide digital literacy training and support to ensure all stakeholders can effectively participate in the project's digital components.	Evidence of training sessions and improved digital engagement metrics among previously low-literacy groups.

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5.8	Technology Adoption Support	Offer support and resources to help stakeholders adopt IoT technologies implemented through the project.	Track adoption rates and stakeholder feedback to measure the effectiveness of support mechanisms.

TABLE 35. SUMMARY OF USER ENGAGEMENT, AWARENESS AND INCLUSIVENESS REQUIREMENTS

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7 CONCLUSION AND FINAL REQUIREMENTS

This Deliverable documents the development of Requirements for an Edge/Cloud IoT Ecosystem from several perspectives. After positioning the HEDGE-IoT project within the state of the art, its Business Use Cases and resulting Functional Requirements are developed and defined. This is followed by an analysis of the challenges such a project faces regarding data integration, knowledge diffusion and harmonization. Finally, Requirements are defined relating to ethical, regulatory as well as societal aspects, followed by those relevant for user engagement, awareness and inclusion.

Table 36 consolidates the complete list and assigns project-wide IDs.

ID	Task IDs	Requirement	Description	Validation
R1	2.01	Real-time data collection	The measurement data platform must be able to collect the data from sensors in real-time	
R2	2.02, 4.20	Data availability, integrity, reliability	Data needs to be available, reliable, and dependable. Requirement Requirements from AI Act, Joint Declaration on Digital Rights and Principles for the Digital Decade, NIS2.	ERST21
R3	2.03	Availability of information flows	Information flows should be available either continuously or at specific times or under specific conditions	
R4	2.04	Usefulness of source data	Source data should be correct	
R5	2.05	Historical data	Historical data are needed from IoT devices and smart meters	
R6	2.06	Type of source data	The solution should support the utilization of multiple data types	
R7	2.07, 4.9	Interoperability	Different elements of the system should be able to communicate. Requirement from Data Act artt.3, 4, 5, 8, 9.	
R8	2.08	Management of data formats in data exchanges	Data in data exchanges should have the same format	

R9	2.09	Management of large volumes of data that are being exchanged	The solution facilitates the utilization and management of large models along with their dependencies	
R10	2.10	Frequency of data exchange	A time window for data exchanges should be established	
R11	2.11	Validation of data exchanges	Data and models should be validated	
R12	2.12	Semantic enrichment	Data must be semantically enriched to offer proper explainability data and advanced insights	
R13	2.13	System integration	Ensure that IoT devices are compatible and integrate with existing grid infrastructure	
R14	2.14	Compliance with standards	Ensure that all deployed IoT devices and associated software comply with relevant national and international standards and regulations for data security, privacy, and grid security	
R15	2.15	Authentication and access control	Ensure that authentication and access control mechanisms are used, and that data comes from the stated source or goes to authenticated receiver	
R16	2.16	Management of data across organizational boundaries	Define and manage data exchanges across boundaries	
R17	2.17	Ensuring that data cannot be resent by any unauthorized source	The data needs to follow the outlined flow and not used or resent by any unauthorized party	
R18	2.18	Confidentiality of data	Define and ensure the confidentiality of data	
R19	2.19, 4.18	Data Encryption	Implement encryption for data transmitted between IoT devices and the cloud to ensure data security and integrity.	ERST19

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			Requirement Requirements from AI Act, Joint Declaration on Digital Rights and Principles for the Digital Decade, NIS2	
R20	2.20, 4.1, 4.2, 4.3, 4.4, 4.5	GDPR (General Data Protection Regulation)	Compliance with the EU GDPR	ERST 1 , 2, 3, 4, 5, 6, 7, 8, 9
R21	2.21	Data processing consent	Personal data may not be processed unless there is at least one legal basis to do so	
R22	2.22	Data transfer consent	Personal data may not be transferred to a third party if the data subject does not agree, and the third party provides appropriate safeguard	
R23	2.23	Data retention policy	The time period specific sensitive data can be retained and the method of their disposal when the defined time period ends	
R24	2.24, 4.6	Right to access, rectify, erasure, restriction	The data subject shall have the right to obtain from the controller without undue delay the access/rectification/erasure/restriction of inaccurate personal data concerning them. Requirement from Data Act artt.3, 4, 5, 8, 9.	
R25	2.25	Report of user wills	The decision of the end user on the usage of his devices should be respected	
R26	4.7	Data availability user conditions	Requirement from Data Act artt.3, 4, 5, 8, 9	ERST10, ERST11
R27	4.8	Facilitate data sharing	Requirement from Data Act artt.3, 4, 5, 8, 9	ERST10, ERST11
R28	4.10	Robust Data Protection Measures	Requirement from Data Act artt.5, 11	ERST12, ERST13
R29	4.11	Privacy compliance	Requirement from Data Act artt.5, 11	ERST12, ERST13

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R30	4.12	Prohibited AI practices	Requirement from AI Act art.5	ERST14, ERST15
R31	4.13	Data Quality and Governance	Requirement from AI Act art.10	ERST16
R32	4.14	Provision of information	Requirement from AI Act art.13	ERST17
R33	4.15	Right to privacy	Requirement from AI Act artt.2, 10, 13	ERST18
R34	4.16	Ensure fundamental rights through ethics principles	Requirement from AI Act, EU Ethics Guidelines for Trustworthy AI, UN Interim Report "Governing AI for Humanity", Joint Declaration on Digital Rights and Principles for the Digital Decade	ERST19
R35	4.17	Sustainability information	Requirements from AI Act, Joint Declaration on Digital Rights and Principles for the Digital Decade	ERST20
R36	4.19	Need to Know	Requirement Requirements from AI Act, Joint Declaration on Digital Rights and Principles for the Digital Decade, NIS2	ERST21
R37	5.1	Stakeholder Engagement Plan	Develop a plan to engage a diverse range of stakeholders, ensuring their needs and potentialities are considered in the project.	The plan should include diverse stakeholder inputs, documented through engagement activities and feedback.
R38	5.2	Awareness Campaigns	Create targeted campaigns to raise awareness about the benefits of the HEDGE-IoT project.	Campaigns should reach target audiences effectively, measured by engagement metrics such as reach and feedback.
R39	5.3	Inclusion of Vulnerable Groups	Ensure that vulnerable populations, such as the economically	Conduct outreach activities and

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			disadvantaged and digitally excluded, are included in the project activities.	provide evidence of participation from vulnerable groups.
R40	5.4	Social Science Framework Implementation	Implement a social science framework that incorporates citizen engagement, intersectionality, and co-creation research.	Framework should be integrated into project plans and evidenced by user-centered design practices.
R41	5.5	Multi-level Governance Models	Consider multi-level governance models to facilitate effective stakeholder engagement at various levels of the project.	Document governance model integration in project processes, showing engagement across different levels.
R42	5.6	Communication Accessibility	Ensure communication materials are accessible and available in multiple languages and formats to accommodate all users.	Validate by having all communication materials audited for accessibility and language inclusivity.
R43	5.7	Digital Literacy Support	Provide digital literacy training and support to ensure all stakeholders can effectively participate in the project's digital components.	Evidence of training sessions and improved digital engagement metrics among previously low-literacy groups.
R44	5.8	Technology Adoption Support	Offer support and resources to help stakeholders adopt IoT technologies implemented through the project.	Track adoption rates and stakeholder feedback to measure the effectiveness of support mechanisms.

TABLE 36. FINAL LIST OF REQUIREMENTS

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APPENDIX A - IEC-62559-2 USE CASE TEMPLATE

1 Description of the use case

Use case describes functions of a system in a technology-neutral way. It identifies participating actors which can for instance be other systems or human actors which are playing a role within a use case. Use cases can be specified on different levels of granularity and are according to their level of technological abstraction and granularity either described as **Business Use Case (BUC)** or **System Use Case (SUC)**.

BUCs describe how Business Roles interact to execute a business process and are system agnostic. The Actors involved are business roles (organisations, organisational entities, or physical persons). SUCs depict a function or sub-function supporting one or more business processes. Actors involved are business roles and system roles (devices, information systems).

1.1 Name of the use case

ID	***Area / Domain(s) / Zones(s)***	***Name of Use Case***

1.2 Version management

Version Management			
Version No.	***Date***	***Name of Author(s)***	***Changes***
	DD.MM.YYYY		

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	The aim and boundaries of the use case.
Objective(s)	The goals that the use case is expected to achieve.
Related business case(s)	

1.4 Narrative of use case

Narrative of Use Case
Short description
Short text intended to summarize the main idea as service for the reader who is searching for a use case or looking for an overview. Recommendation: This short description should have not more than 150 words.
Complete description

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Provides a complete narrative of the use case from a user's point of view, describing what occurs when, why, with what expectation, and under what conditions. This narrative should be written in plain text so that non-domain experts can understand it. The complete description of the Use Case can range from a few sentences to a few pages. This section often helps the domain expert to think through the user requirements for the function before getting into the details required by the next sections of the Use Case.

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
May be used to define further, general assumption for this use case. In some use cases, it is critical to understand which preconditions or other assumptions are being made. · Any assumptions shall be identified, such as: which systems already exist, which contractual relations exist, and which configurations of systems are probably in place. · Any initial states of information exchanged in the steps in the next section shall be identified.
Prerequisites
Describes what condition(s) should have been met prior to the initiation of the use case, such as prior state of the actors and activities.

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Relation to other use cases in the same project.
Level of depth
Prioritisation
Generic, regional or national relation
Nature of the use case
This field can help to classify the main focus of the use case. EXAMPLE: Technical/system use case, business use cases (e.g., market processes), political, test use cases.
Further keywords for classification
Keywords can be defined in order to support extended search functionalities within a use case repository. Multiple keywords should be provided as a comma-separated list. EXAMPLE: Smart grid, electric vehicles, loading of vehicles, electricity metering, storage.

1.8 General Remarks

General Remarks

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Further comments which are not considered elsewhere.

2 Diagrams of use case

The diagram aims to illustrate the structure of the use case.
For clarification, in general it is recommended to provide drawing(s) by a graphic or as UML graphics. The drawing should show interactions which identify the steps where possible.

Diagram(s) of use case
Use case diagrams, activity diagrams, sequence diagrams illustrating the narrative.

3 Technical details

3.1 Actors

Use case actors, types, description, and further information specific to the use case; use case actors should be present in the narrative of the use case.
To improve consistency among Use Case descriptions, the [Harmonized Electricity Market Role Model (HEMRM)] can be used for actor names and description. Thus, the information included in the fields of the following table could be obtained from the Actors List defined in HEMRM. Nevertheless, it is possible to add new Actors if needed.

Actors			
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***

3.2 References

References (which are standards, reports, mandates and regulatory constraints) associated with the use case.

References						
No.	***Reference Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***

4 Step by step analysis of use case

Template section 4 focuses on describing scenarios of the use case with a step-step analysis (sequence description). There should be a clear correlation between the narrative and these scenarios and steps.

4.1 Overview of scenarios

The table provides an overview of the different scenarios of the use case like normal and alternative scenarios which are described in section 4.2 of the template.
In general, the writer of the use case starts with the normal sequence (success). In case precondition or post-condition does not provide the expected output (e.g., no success = failure), alternative scenarios have to be defined.

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**

			Refers to the actor that triggers the scenario. It is worth pointing out that the names of the Actors should be consistent with Actors List in all sections of the Use Case description.		Describes the state of the system before the scenario starts.	Describes the expected state of the system after the scenario is realized.

4.2 Steps – Scenarios

For this scenario, all the steps performed shall be described going from start to end using simple verbs like – get, put, cancel, subscribe etc. Steps shall be numbered sequentially – 1, 2, 3 and so on. Further steps can be added to the table, if needed (number of steps are not limited).
Should the scenario require detailed descriptions of steps that are also used by other use cases, it should be considered creating a new "sub" use case, then referring to that "subroutine" in this scenario.

Scenario								
Scenario name:		Name of the scenario						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
	Event that triggers the activity.	Label that would appear in a process diagram.	This describes what action takes place in this step. The focus should be less on the algorithms of the applications and more on the interactions and information flows between actors.	Identifies the nature of flow of information and the originator of the information (*).	Name of the actor that produces the information.	Name of the actor that receives the information.	Here the information can use a short ID referring to template section 5 for further details. Several information exchanged IDs can be listed, comma separated.	Refer to the identifiers (R-ID) of the detailed requirements that apply for each activity.

(*) Available options are:

- CREATE means that an information object is to be created at the Producer.
- GET (this is the default value if none is populated) means that the Receiver requests information from the Producer (default).
- CHANGE means that information is to be updated. Producer updates the Receiver's information.
- DELETE means that information is to be deleted. Producer deletes information from the Receiver.
- CANCEL, CLOSE imply actions related to processes, such as the closure of a work order or the cancellation of a control request.
- EXECUTE is used when a complex transaction is being conveyed using a service, which potentially contains more than one verb.
- REPORT is used to represent transferral of unsolicited information or asynchronous information flows. Producer provides information to the Receiver.
- TIMER is used to represent a waiting period. When using the TIMER service, the Information Producer and Information Receiver fields shall refer to the same actor.

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- REPEAT is used to indicate that a series of steps is repeated until a condition or trigger event. The condition is specified as the text in the "Event" column for this row or step. Following the word REPEAT, shall appear, in parenthesis, the first and last step numbers of the series to be repeated in the following form REPEAT(X-Y) where X is the first step and Y is the last step.

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5 Information exchanged

These information objects are corresponding to the "Name of Information" of the "Information Exchanged" column referenced in the scenario steps in template section 4 "Step by Step Analysis". If appropriate, further requirements to the information objects can be added.

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
Refers to an identifier used in the field "Information Exchanged" of Table 4.2.	Is a unique ID which identifies the selected information in the context of the use case.	Brief description, in case a reference to existing data models/information classes should be added. Using existing canonical data models is recommended.	Can be used to define requirements referring to the information and not to the step as in the step-by-step analysis (see template section 6 below).

6 Requirements

Requirements		
Categories ID	**Category name for requirements**	**Category description**
Unique identifier for the category.	Name for the category of requirements.	Description of the requirement category.
Requirement R-ID	**Requirement name**	**Requirement description**
Unique identifier which identifies the requirement within its category and which can link the requirement to an external requirement document.	A name of the requirement.	Description of the requirement (this might be populated automatically from the repository, if the requirement has already been described in the external document before).

7 Common Terms and Definitions

Should be defined in a common glossary for all use cases. Here relevant terms belonging to this use case are listed.

Common Terms and Definitions	
Term	**Definition**

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APPENDIX B - DETAILED DESCRIPTION OF BUCS

The BUCs available at the time of the writing of this deliverable are presented in this section and might be subject to minor changes and refinements with the execution and progress of the demonstrations.

BUC-FI-01 ANOMALY DETECTION AND FAULT FORECASTING TO INCREASE MV DISTRIBUTION NETWORK RESILIENCE

1 Description of the use case

1.1 Name of the use case

ID	Area / Domain(s) / Zones(s)	Name of Use Case
BUC-FI-01	System Resilience	Anomaly detection and fault forecasting to increase MV distribution network resilience

1.2 Version management

Version Management			
Version No.	**Date**	**Name of Author(s)**	**Changes**
0.1	26.3.2024	Kari Mäki (VTT) Sayawu Diaba (VTT)	first draft
	30.05.2024	Kari Mäki (VTT) Sayawu Diaba (VTT)	updated version
	31.05.2024	Anna Kulmala (ABB)	small adjustments
0.2	11.6.2024	Kari Mäki (VTT)	updated according to comments
	12.5.2024	Kari Mäki (VTT)	Further updates for requirements and information exchange
0.21	13.8.2024	Kari Mäki (VTT)	Minor terminology updates in SUC naming

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Detection of anomalies and fault forecasting within MV distribution grid based on real-time data stream processing on edge level at primary substation.
Objective(s)	Use edge level data analysis to access real-time full-resolution data stream provided by IEDs to better detect abnormal situations in the grid. Collect logs and counters for identified events to be able to detect longer-time developing issues. Provide early warnings and fault forecasts to grid operator.
Related business case(s)	

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1.4 Narrative of use case

Narrative of Use Case
Short description
The purpose is to offer new tools for network operator for managing grid faults and improving system resilience. The opportunity is around modern IEDs such as protection relays, which are able to measure different parameters with extremely high resolutions that would allow detailed analysis. However, this data cannot be stored or transferred to SCADA systems with full details due to big data masses. The data brought to operator room level through SCADA is currently filtered and less detailed, and only for occurred faults a more detailed fault information package (disturbance recording package) is saved. The purpose is to apply latest edge and AI capabilities within the substation where full resolution data stream is available and perform online analysis that can use full details and could thus forecast events that are slowly building up in the grid. The solution does not store full-detail data but rather processes it online and keeps logs on any potentially deviating measurements or events. This analysis should serve two purposes: to provide grid operator with early warnings considering certain grid parts, and to be able to trigger the detailed fault package recording on correct timing.
Complete description
The piloted solution will improve grid operators' awareness and possibilities for preparing for and reacting to disturbances and faults in a more timely manner. The use case will focus on possibilities of utilizing full-resolution data stream on substation bus level for improved analytics. In current status, grid operator is mostly monitoring the grid and taking actions based on data available through SCADA system. While SCADA data is accurate and real-time as such, it does not include the finest details that are available from modern IEDs such as protection relays. The SCADA level data is always aggregated and filtered, since transferring and storing full-detail data is practically not possible. In case of faults, more detailed data is saved through buffer system that is triggered by the fault and also includes moments before fault occurred. At the same, IEDs have progressed a lot and they would already be able to support advanced data analytics. Currently these possibilities are underused due to data collection, transfer and storing related challenges. Applying latest developments in edge computing and AI based analysis offer exciting possibilities for taking the analysis on site on substations and being able to utilize all details available. Different faults and incidents taking place in MV distribution grid often develop over time. Typical examples are cable insulation faults that are evolving slowly or breaker malfunctions which normally first show slower opening or closing times before actual malfunctions. Also transformer faults are often preceded by temperature rise. Many of these parameters are measured all the time; for instance, cable feeder harmonics or partial discharge measurements can indicate developing insulation fault. Likewise, breaker operation times are measured. Especially when combining different data sources, new ways for identifying phenomena in the grid could be found. However, monitoring of faults evolving on different time steps is still challenging. The approach is to provide an early warning system for the grid operator. In case there is a warning for coming fault on certain grid part, the operator can take preparatory measures like performing grid topology changes to move important customers on other feeder, or otherwise trying to limit the risk area. At the same, manual inspections or closer look at measurements can be done to detect the problematic part. This could be implemented as "traffic light" model for the operator room: the system would show green-yellow-red light for specific grid parts, and thus improve awareness of operator. As the system is a warning system and not a direct protection function, false triggers can also be tolerated to certain level. In practice the system would be self-learning so that reinforcement learning type solutions are used for operator feedback to improve the model. With this approach, the main idea is to apply machine learning for defining the normal status of the grid, and deviations from this normal state can trigger the yellow light and warnings. In this sense the system does not need to exactly know what kind of fault is about to occur, but instead be able to detect that system is not in the normal state. In practice, this use case will consider several steps: • Process bus level data processing in edge to provide uniform and timestamped data • Machine learning for defining the normal operational status of grid

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• AI-based data analysis with live data stream to identify any abnormalities • Collection of logs for abnormality indicators • Methodology for following the indicators and deciding whether the status deviates from normal, also for slowly developing events • Criteria for issuing traffic lights, warnings and triggering more detailed recording

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
• The use case assumes that there is a continuous and reliable flow of high-quality, full-resolution data stream from IEDs at the substation bus level. • Data volumes are so huge that data cannot be stored locally. Instead, logs and counters are maintained based on observations from real-time data stream. • It is assumed that the deployed AI and ML systems have the capability to process large volumes of data in real time. The AI/ML should be sophisticated enough to differentiate between normal and anomalous patterns effectively. • The system must be seamlessly integrated with management systems such as SCADA. The integration should also support both the upstream flow of insights and alerts towards operator level.
Prerequisites
• Installation and maintenance of advanced Intelligent IEDs capable of capturing detailed, high-resolution data. • Adequate computational power for processing the data streams and performing on-line analysis. • Development and deployment of state-of-the-art AI models and machine learning infrastructure that can process complex datasets in real time.

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Level of depth
Prioritisation
To be demonstrated in Finland (Finnish pilot)
Generic, regional or national relation
Generic
Nature of the use case
Business use case
Further keywords for classification
Artificial intelligent, anomaly detection, distribution networks, distribution system operation, machine learning, smart grid

1.8 General Remarks

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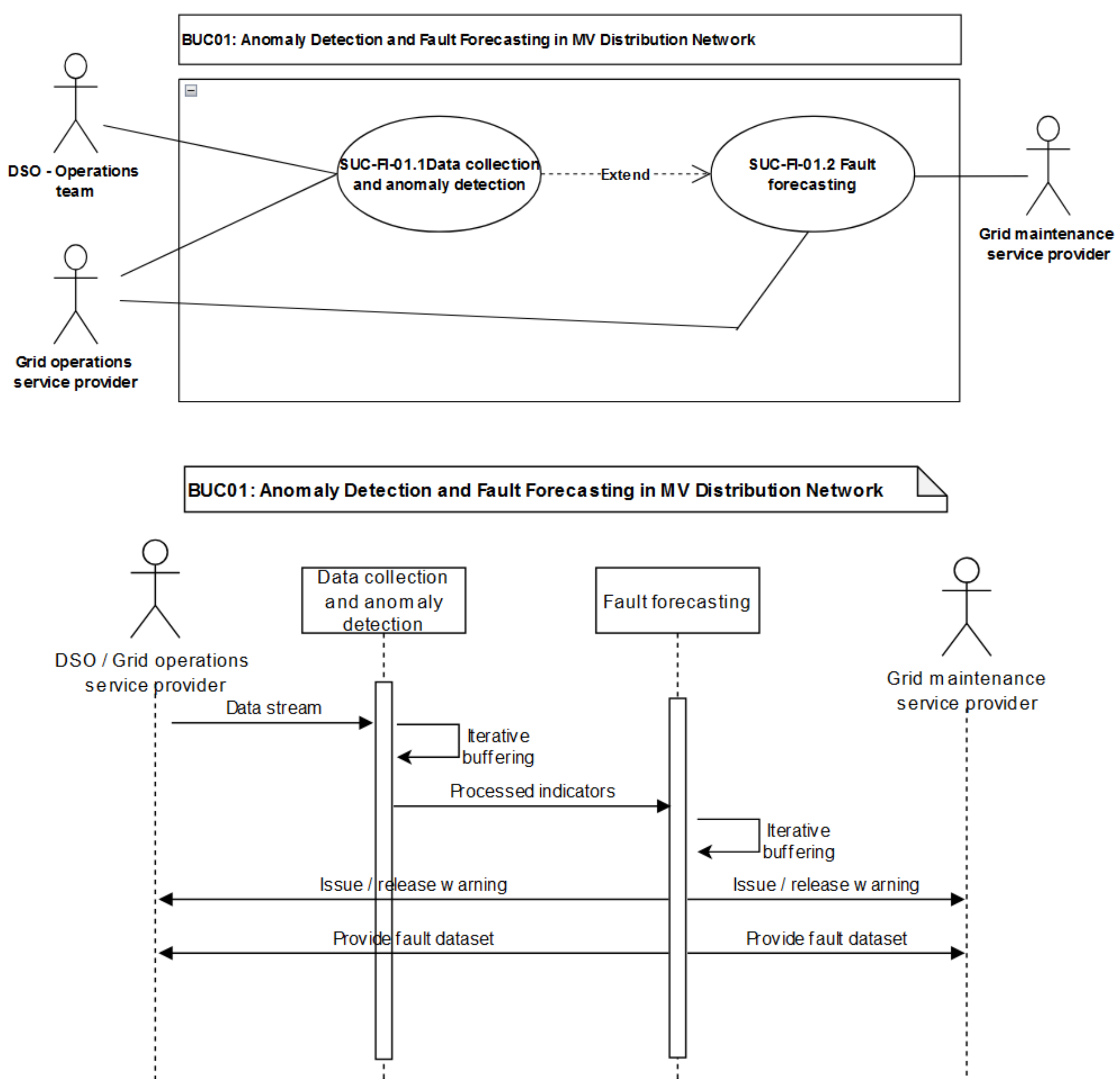
General Remarks

2 Diagrams of use case

Diagram(s) of use case


3 Technical details

3.1 Actors

Actors			
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***

DSO (Distribution system operator)	Role	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in each area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity.	
Grid maintenance service provider	Role	The party conducting grid maintenance and repairs for DSO as a service. Depending on contracts, can have a more independent role in managing faults as well.	
Grid operations service provider	Role	The party providing operator room functions, field crew management, etc. as a service to DSO.	

3.2 References

References						
No.	***Reference Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc. 1	Data collection and anomaly detection	Process for collecting data, observing any abnormalities with AI analytics, and storing indicators or logs for further analysis.	Grid operations service provider	Continuous live operation	IEDs providing sampled value data with full measurement resolution	Indicator logs and counters are continuously updated The system remains actively collecting more data
Sc. 2	Fault forecasting	Process for analysing the indicators and identifying the anomalies that are above the thresholds and need to be issued as warning.	Grid operations service provider	Continuous live operation Warning triggered where threshold met	Indicators being available based on real-time data processing	Warning issued where needed The system remains active analysing the situation

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4.2 Steps – Scenarios

Scenario								
Scenario name:		Sc. 1 - Data collection and anomaly detection						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St. 1	Data stream available	Data processing	IEDs providing data stream through process bus in a uniform and timestamped format	Create	Grid operation service provider	Process	Inf.1	R1, R2
St.2	Anomaly identified in data	Indicator calculation	Based on data stream, continuous calculation of anomaly indicators and storing logs for longer-term events	Execute	Process	Process	Inf.2	R1, R2, R3, R4
St. 3	Anomaly identified in data	Triggering of disturbance recording	Where any anomaly is detected, a trigger signal is given out to external disturbance recording process	Execute	Process	Disturbance recording	Inf.3	R5
St.3	Indicator data available	Provision of indicators	The process continuously updates the indicators and logs for following steps	Execute	Process	Anomaly detection	Inf.4	R6

Scenario								
Scenario name:		Sc. 2 - Fault forecasting						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St.1	Analyse data	Anomaly analysis	Indicator data is continuously analysed to find deviations from normal status	Execute	Data collection	Process	Inf.4	R3, R6, R7
St.2	Threshold crossed	Anomaly detection	Anomaly is flagged when indicator data exceeds defined thresholds	Execute	Process	Process	Inf.5	R3, R6, R7
St.3	Event dataset	Anomaly	Indicator data is stored into	Report	Process	Grid	Inf.5	R8

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	compilation	information	dataset that can be provided for user			maintenance service provider Grid operation service provider		
St.4	Issue warning	Anomaly reporting	When flagged, a warning is issued to operators	Report	Process	Grid maintenance service provider Grid operation service provider	Inf.5	R8

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5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
Inf.1	IED data stream	All measurement data available through process bus and IEC61850 sampled value format. Phase voltages, currents, harmonics, component data, other trigger data, etc.	R1, R2
Inf.2	Anomaly indicator data stream	Indicators for abnormal datasets, including their timing and frequency. Includes the data source, parameter, the measured value, timestamp, duration, etc. Also counters for frequency of such data being observed.	R1, R2, R3, R4
Inf.3	Trigger for disturbance recording	The trigger information can be simple signal like integer value provided through interface.	R5
Inf.4	Anomaly identification data	Data for the observed anomaly that exceeds flagging threshold. Type of parameter, value, duration, data source/IED and threshold criteria information.	R3, R6, R7
Inf.5	Warning data	The warning is issued and transferred to grid maintenance and operation service providers. Includes involved IED, network part, type of fault, likelihood, and numerical parameters for the anomaly.	R6, R8

6 Requirements

Requirements		
Requirement R-ID	**Requirement name**	**Requirement description**
R1	Data stream available and accurate enough	Full detail data from IEDs need to be continuously flowing, it needs to be presented with adequate resolution and it needs to be properly timestamped. The data link interface needs to provide the data, so it is continuously accessible by the later process parts.
R2	Data being reliable and of good quality	Data needs to be reliable and dependable. Any missing data or missing communication needs to be clearly indicated, so that the real-time status of the data can be verified.
R3	Computational power adequacy available	The EDGE level computing power needs to be adequate for processing the real time data stream and for identifying the abnormalities.
R4	Efficiency of the identification algorithm	The algorithm seeking to identify abnormalities needs to be efficient and robust, and it needs to have proper level of accuracy and dependability.
R5	Available interface and format for disturbance recording trigger	The trigger signal is simple, but it needs uniform format and interface to integrate into.
R6	Indicator data available in a uniform format	The indicator data needs to be available, in a properly good quality and level of reliability.
R7	Efficiency of the decision-making algorithm	The algorithm drawing decisions based on the indicator data needs to make proper decisions that are reliable and dependable.
R8	Anomaly warning information in a uniform format	The warning data must be properly communicated for grid operations with adequate details. An interface for transferring the information needs to be defined.

7 Common Terms and Definitions

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Common Terms and Definitions	
Term	**Definition**
DSO	Distribution System Operator
CM	Congestion Management
GDPR	General Data Protection Regulation
IED	Intelligent Electronic Device
AI	Artificial Intelligence
ML	Machine Learning
MV	Medium Voltage
DER	Distributed Energy Resource

BUC-FI-02 PREDICTIVE AND REAL-TIME CONGESTION MANAGEMENT (CM) TO INCREASE NETWORK HOSTING CAPACITY

1 Description of the use case

1.1 Name of the use case

ID	*Area / Domain(s) / Zones(s)*	*Name of Use Case*
BUC-FI-02		Predictive and real-time congestion management (CM) to increase network hosting capacity

1.2 Version management

Version Management			
Version No.	*Date*	*Name of Author(s)*	*Changes*
	27.03.2024	Mehdi Attar and Sami Repo (TAU)	First draft
	28.03.2024	Antti Mutanen (ABB)	Additions and modifications of the first draft
	5.4.2024	Anna Kulmala (ABB)	The first version to be shared with WP2
	16.05.2024	Mehdi Attar (TAU)	Second version
	31.05.2024	Mehdi Attar and Sami Repo (TAU)	Third version
	13.06.2024	Mehdi Attar and Sami Repo (TAU)	Fourth version

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Predictive and real-time CM in distribution grids
Objective(s)	Increasing the hosting capacity of the distribution system operator's (DSO) network using congestion management that operates the network based on its actual state and not on worst cases identified during offline planning of the network. Reducing the time and costs when connecting new customers to the grid.
Related business case(s)	

1.4 Narrative of use case

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Narrative of Use Case
Short description
The use case aims to represent a case where a DSO utilizes predictive and real-time CM solutions to give customers quicker access (than otherwise would be using grid reinforcement) by enhancing its grid's hosting capacity (HC). HC is a power system-oriented term [1] that describes the maximum distributed energy resources (DERs) penetration for which the power system operates satisfactorily within permissible voltage and thermal limits. Flexibility resources within the use case encompass grid-side, storage-side, demand-side, or generation-side solutions [2]. It's worth noting that the term 'flexibility' is inherently technology-neutral, encompassing various solutions and functionalities, and they are used toward removing congestion in the grid. The use case addresses situations where a customer seeks to either connect to the grid or expand the capacity of its existing connection. Traditional grid reinforcement methods for large-scale customers like wind or solar farms, electric boilers, heat pumps, or electric vehicle parking houses can be time-consuming, often taking several years to complete, and also capital-intensive. Consequently, they are not considered an appealing solution for either the DSO or the customer in the short to medium term. Therefore, enhancing HC through flexibility mechanisms becomes an attractive alternative. Flexibility solutions on the demand, storage, and generation sides based on bilateral flexibility contracts (e.g., non-firm connection contracts) or trading on a flexibility market fall under market-based flexibility. Technical flexibility measures like advanced voltage control, dynamic line/transformer rating, mandatory grid code requirements (e.g., primary voltage control of DERs), etc., fall under grid-side flexibility. Market-based flexibilities may be directly provided by the customer or through a flexibility service provider (FSP) acting on behalf of the customer. The grid-side flexibility is entirely under the DSO's control, and activation signals are sent through the DSO's automation system or through a third-party automation system. The following summarizes the benefits of predictive and real-time CM from the perspectives of DSOs and customers. DSO's point of view: • Providing grid connection services quicker to new customers. • Improving the utilization rate of the existing grid infrastructure. • Grid reinforcement deferral. Customers' point of view: • Quicker connection to the grid. (short-term) • Cheaper grid connection costs compared to when grid reinforcement is done. (short-term) • Reduced tariffs due to reinforcement deferral. (long-term)
Complete description
The UC includes two timeframes: predictive and real-time. The predictive timeframe will only be simulated in the demonstration, while the real-time part will be piloted in the demonstration. The UC includes DSO, FSP, DERs, and market operator (MO) at the stakeholder level. Customer relations and contractual aspects are excluded, and it is assumed that necessary contracts and agreements have been signed with DER owners. The HC enhancement starts in the predictive timeframe followed by the real-time timeframe, allowing the DSO to do the preparatory actions in the predictive timeframe and utilize them for a more effective real-time CM. The prediction could occur in the day ahead or in an intraday time frame, and it aims to prepare the DSO and FSPs for any possible upcoming congestion problem. In real-time, the DSO combines already agreed flexibility with grid-side flexibility to mitigate/avoid congestion. Market-based flexibility is realized through two flexibility products: scheduled reprofiling product (SRP) and conditional reprofiling product (CRP). SRP is the obligation of the flexibility to modify the demand or generation at a given time to benefit flexibility buyers [3]. SRP price is the sum of flexibility reservation and activation. CRP, on the other hand, is described as when the flexibility seller must have the capacity to satisfy the traded flexibility with a specified demand or generation profile modification at a given period if the buyer requests it in real-time [3]. CRP price, therefore, has two elements: capacity reservation and activation [4]. In a predictive timeframe, two main functions are performed: congestion prediction and CM planning. Congestion prediction provides input for CM planning. Based on predicted grid states, CM planning decides if market-based flexibility is required and what flexibility mechanisms (e.g., CRP or SRP) are necessary to prevent congestion in the coming day or hours. Similar to the predictive one, two main functions are performed in the real-time timeframe: state monitoring and CM decision-making. State monitoring, in fact, provides inputs for real-time CM decision-making, which coordinates grid-side and market-based flexibility measures (e.g., CRP) and finally decides what actions are required if congestion occurs in real-time. Four main functions, two predictive and two real-time, are presented in the following. Predictive timeframe (will be simulated)

1. Congestion prediction The DSO performs congestion prediction to foresee any potential grid congestion that might appear in the future (e.g., the day ahead). The functionality includes grid state forecasting, which performs a predictive power flow based on forecasted load and generation across the grid. 2. CM planning (if required) Once the state of the grid is forecasted in step 1, if congestion is foreseen, the DSO plans a CM solution to remove congestion. The DSO, at this stage, needs to decide between three options: • Utilization of grid-side flexibility. This requires the DSO to have information about the status of components in the grid. This information helps the DSO to make full use of its controllable grid components. The information could include the component's characteristics (e.g., the ampacity of lines), information about the availability of components (scheduled maintenance), etc. Advanced voltage and reactive power control solutions fully accessed by DSO may enhance HC by modifying the voltage profile in the grid. • Utilization of market-based flexibility (demand-side, generation-side). This requires the DSO to access flexibility either through a market (e.g., local flexibility market (LFM)) or based on a bilateral contract with the FSP (e.g., a non-firm contract). • Utilization of both market-based and grid-side flexibility. This requires the DSO to combine market-based and grid-side flexibility to remove congestion more efficiently and effectively. This solution is more complex than the first two. It requires the DSO to optimize the use of market-based flexibility provided by FSPs and grid-side flexibility initiated from grid components. If the market-based solution is used, the DSO might need to participate in the market (e.g., local flexibility market (LFM)) or inform the grid customer about potential flexibility needs in case of utilizing non-firm capacity contracts. In any case, since a market-based solution requires the involvement of a party other than DSO for the activation of flexibility, communication with the FSP is required. Real-time timeframe (will be piloted) 1. State monitoring State monitoring aims to observe the state of the grid in terms of state variables of the power flow condition of a grid, for example, voltages and currents, in real time. This requires it to perform two main functions: estimation of the grid's operational limits and state estimation of the power flow in the grid. Estimating the limits within which the grid can be operated includes finding the ampacity of the grid component in real time since ampacity is dependent on weather and power flow conditions. Once the grid operational limits are known, the DSO will estimate the grid's state using the network model, online measurements (voltages, currents, and power flows), switch statuses, and load and generation estimates pseudo measurements. By comparing the grid limits with the output of state estimation (i.e., voltage and current), the DSO can assess whether there is any congestion case in the grid. 2. Activation of flexibility (if required) The information from Step 1 concerning the state of the grid is used. If congestion is observed, the DSO will use the flexibility provided by FSPs and/or grid-side flexibility to remove/alleviate the congestion.

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
The BUC is based on the following assumption: • There is market-based and/or grid-side flexibility available for the DSO.

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• Availability of market-based flexibility has been ensured by, for example, bilateral contracts between DSO and connected customers.
Prerequisites
• The DSO already has CM needs. • Flexibility utilization is cheaper and quicker to be realized compared to grid reinforcement in short to medium-term time scale (e.g., up to 5 years). • Connecting a new customer or upgrading the capacity of an existing customer is required to take less than 24 months, but the reinforcement of the grid will take several times longer.

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Level of depth
Prioritisation
Generic, regional or national relation
Nature of the use case
Business use case.
Further keywords for classification
DSO, LFMO, distribution grid, CM.

1.8 General Remarks

General Remarks

2 Diagrams of use case

Diagram(s) of use case
Figure 1 illustrates a diagram for the UC, which includes both the predictive and real-time time frames. Starting from the top of the diagram, the DSO predicts a potential congestion problem in its grid for the next day and plans a solution in advance. The process starts with the DSO initiating congestion prediction and performing a forecast of the grid state. After the forecast is performed, the congestion prediction compares forecasted values (e.g., voltage and current) with grid limitations (e.g., voltage and ampacity of grid components). If a potential congestion problem is detected, CM planning is triggered. CM planning can select either a market-based solution, grid-side flexibility, or both. The selections of CM planning are forwarded to the control room operator, and they can be seen as recommendations to the operator in the control room. The control room operator must make a decision based on the recommend solutions and take an action if required. If a market-based solution is chosen, CM planning creates a bid/s request (i.e., SRP or CRP) and sends it to the market platform, which then the nominated electricity market operator (NEMO) shares the requests with FSPs. FSPs respond with bids, which the market forwards to operator. The operator selects bids based on its internal cost function or any other criteria that might be important to consider and informs the market, which then notifies the FSPs of accepted bids, obligating them to deliver future flexibility to solve the congestion problem. If control room operator selects grid-side flexibility based on the recommended settings of controllable grid assets (e.g., tap changer control, reactive power control, etc), the operator stores those data concerning that recommended action (e.g., change of grid component settings). If the

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predicted congestion is realized in real-time, the control room operator can utilize the recommended settings to remove/alleviate congestion.
In real-time, the DSO aims to identify and address any congestion problems as they occur. The process begins with the DSO initiating state monitoring, which performs state estimation function. After the estimation is calculated, the grid's current state (e.g., voltage, current, angle) becomes evident. Next, state monitoring performs a function that calculate the grid's operational limits, which are influenced by the operating conditions of grid assets (e.g., weather). State monitoring can detect congestion by comparing the grid state variables with the operational limits. The congestion-related data (e.g., location, intensity) is sent to the CM decision-making function if congestion is found. The CM decision-making can select market-based, or grid-side flexibility based on available options and make recommendations based on those to the control room operator. The chosen CM alternative and their attributes are sent to the control room operator, in a same manner than it was for the predictive timeframe. If the operator selects market-based flexibility in the form of CRP, the required control signals are sent to the party responsible for activating the flexibility, for example, FSP. If grid-side flexibility is selected, the control signals are sent to the appropriate controllable component in the grid.

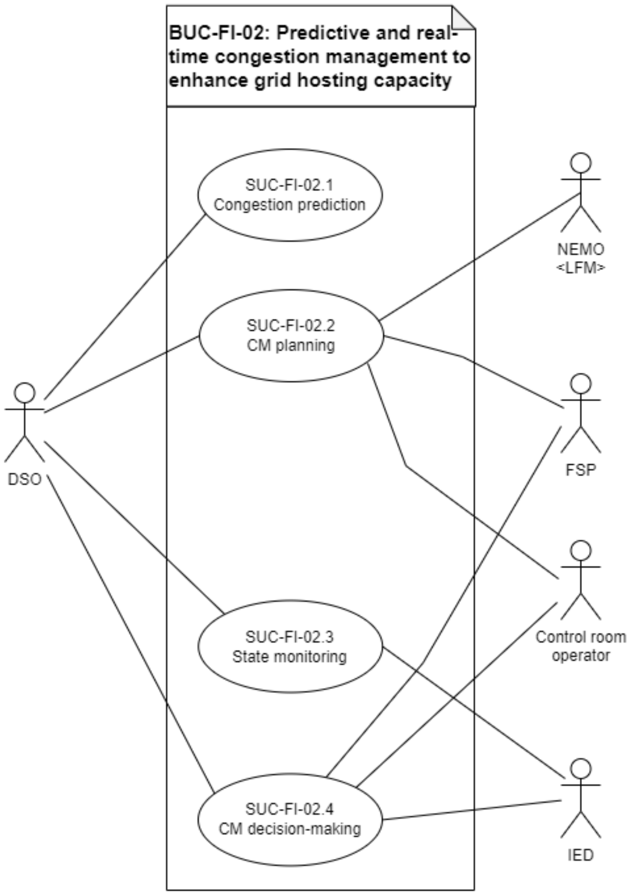

FIGURE 5- BUC-FI-02 DIAGRAM.

3 Technical details

3.1 Actors

Actors			
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***

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DSO	Operator	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity.	
FSP	Operator	A party that aggregates resources for usage by a service provider for market services.	
Control room operator	Operator	A human operator in the control room is responsible for monitoring the system and applying control decisions in real-time.	
Nominated electricity market operator (NEMO)	Operator	A party that provides a service whereby the offers to sell flexibility/electricity are matched with bids to buy flexibility/electricity.	The market could be, for example, a local flexibility market (LFM).
Intelligent electronic device (IED)	Logical actor	A device that acts as a measurement device. It can also receive control signals and apply them to the controllable resource.	

3.2 References

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4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc. 1	Congestion prediction	This scenario is realized every day because the DSO aims to know the state of its grid for the next day. Congestion prediction predicts a potential	DSO	Every day after DA market results (electricity price) are published.	The DSO must have input data, such as weather forecast data, grid data, load data, and generation data, to perform a predictive power flow.	

		congestion case in the future.				
Sc. 2	CM planning	The CM planning selects a solution among the available CM solutions (i.e., market-based flexibility, grid-side flexibility)	DSO	The scenario is triggered when congestion is predicted to happen in the grid according to Sc. 1.	At least one alternative (e.g., market-based, grid-side) should be available for CM.	
Sc. 3	Market participation	In this scenario, the DSO participates in a flexibility market.	DSO	This scenario is triggered when the DSO chooses a market-based solution for its congestion problem, according to Sc. 2.	A market-based flexibility solution, such as an LFM or non-firm capacity connection with controllable customers, should be available.	
Sc. 4	Grid-side flexibility planning	In this scenario, the DSO stores the recommended control settings of Sc. 2.	DSO	This scenario is triggered when the DSO chooses a grid-side solution for its congestion problem, according to Sc. 2.	At least one grid-side flexibility solution, such as reactive power control or tap changer setting control should be available.	
Sc. 5	State monitoring	This scenario is realized by the DSO to know the state of its grid in real time. It enhances the DSO's observability over its grid.	DSO	This scenario is always running (e.g., once in 5 minutes)	The DSO must have the data necessary for state monitoring, such as real-time measurements from across its grid, in addition to load and generation profiles.	
Sc. 6	CM decision making	The decision-making team selects the CM solution among available alternatives.	DSO	The scenario is triggered when congestion is observed in the grid, according to Sc. 4.	The decision-maker needs to have at least one CM alternative to use.	
Sc. 7	Market-based flexibility activation	This scenario includes activating a previously procured flexibility (e.g., CRP) to alleviate the congestion problem.	DSO	The scenario is triggered when a market-based solution for the congestion problem is selected according to Sc. 6.	There should be at least one market-based flexibility available to be controlled.	
Sc. 8	Grid-side flexibility activation	This scenario is realized when the DSO wants to use grid-side flexibility for the congestion problem.	DSO	The scenario is triggered when a grid-side flexibility solution for the problem is selected according to Sc. 6.	There should be at least one grid-side flexibility available to be controlled.	

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4.2 Steps – Scenarios

Scenario								
Scenario name:		Sc. 1: Congestion prediction						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St.1	Time	Initiate the process	Initiating the prediction function	Create	DSO	Congestion prediction	Inf.1	
St. 2	Initialization	Congestion prediction calculation	The congestion prediction predicts the state of the grid.	Execute	Congestion prediction	Congestion prediction		

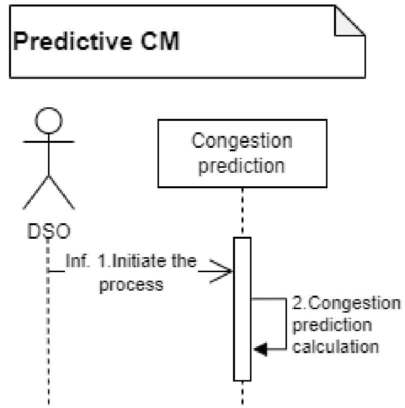

FIGURE 6- SEQUENCE DIAGRAM OF CONGESTION PREDICTION.

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Scenario								
Scenario name:	Sc. 2: CM planning							
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St.1	Congestion expected in Sc. 1	Data of congestion case	The congestion prediction reports the congestion information for CM planning.	Report	Congestion prediction	CM planning	Inf. 3	
St. 2	Congestion information received	CM decision-making	The CM planner selects a decision on the use of an alternative for CM.	execute	CM planning	CM planner	4	
St. 3	CM planning completed	Control recommendation/s	The CM planner reports the decision-making outcomes to the control room operator	Report	CM planning	Control room operator	Inf. 5	
St. 4	Control recommendations received	CM solution selection	The control room operator selects a CM alternative based on the control recommendations and possibly other sources of information.	Execute	Control room operator	Control room operator	6	

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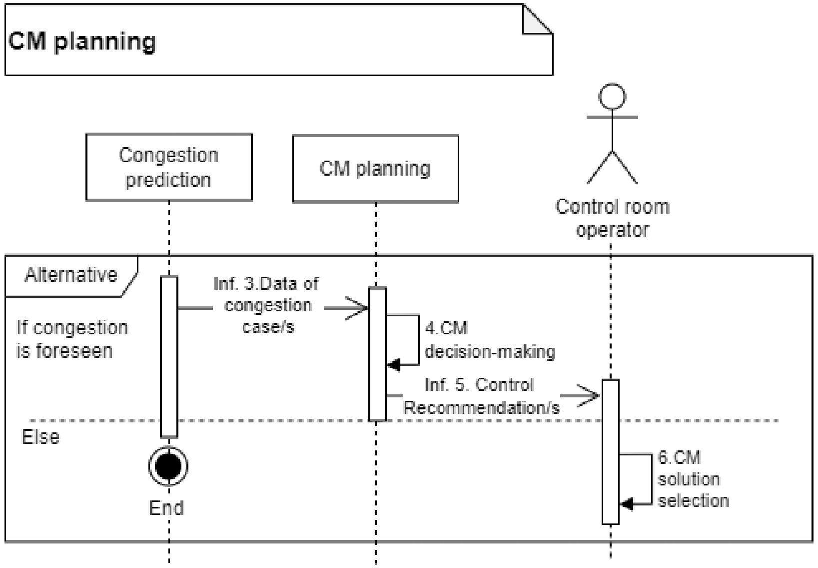

FIGURE 7- SEQUENCE DIAGRAM OF CM PLANNING

Scenario								
Scenario name:		Sc. 3: Market participation						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St.1	The market-based solution is selected in Sc. 2	Bid/s request	CM planning requests bid/s from the Market	Request	CM planning	NEMO	Inf. 7	
St. 2	Bid/s request	Bid/s	Market requests from FSPs to	Request	NEMO	FSP	Inf. 8	

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	received	request	bid/s in response to CM planner's request					
St. 3	Bid/s request received	Bid/s	The FSP responds to the bid request	Report	FSP	NEMO	Inf. 9	
St. 4	Bid/s received	Bid/s	The market reports the bid/s to the CM planning	Report	NEMO	Control room operator	Inf. 10	
St. 5	Bid/s received	Bid selection	The CM planning selects from the bids	Execute	Control room operator	Control room operator	11	
St. 6	Bid selection calculation completed	Selected bid/s	The CM planning reports the selected bid/s to the market	Report	Control room operator	NEMO	Inf. 12	
St. 7	Selected bid/s received	Selected bid/s	The market informs the FSPs about selected bids	Report	NEMO	FSP	Inf. 13	

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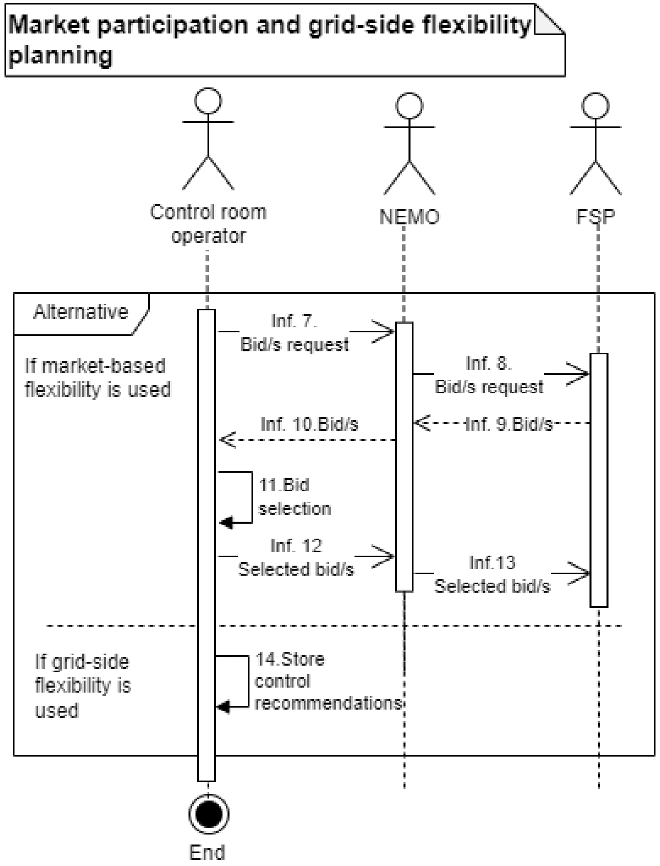

FIGURE 8- SEQUENCE DIAGRAM OF MARKET PARTICIPATION AND GRID-SIDE FLEXIBILITY PLANNING

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Scenario								
Scenario name:		Sc. 4: Grid-side flexibility planning						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St.1	The grid-side flexibility solution is selected in Sc. 2.	Store control recommendations	The DSO stores the control recommendation settings so that those settings can be taken into use if congestion happens in the future.	Execute	Control room operator	Control room operator	14, according to Fig. 4	

Scenario								
Scenario name:		Sc. 5: State monitoring						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St.1	Time/event (grid operational state violation)	Initiate the process	Initiating the state monitoring process	Create	DSO	State monitoring	Inf. 15	
St. 2	Time/event (grid operational state violation)	Measurement data	The IED forwards the measurement data	Report	IED	State monitoring	Inf. 16	
St. 3	Initialization and receiving the measurement data	Grid state analysis	The state monitoring compares the grid state with the grid's operational limits	Execute	State monitoring	State monitoring	17	

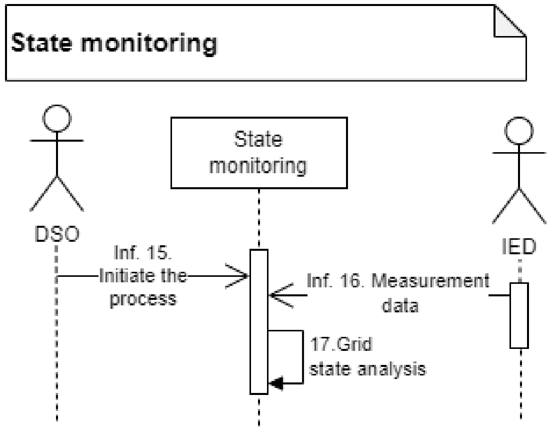

FIGURE 9- SEQUENCE DIAGRAM OF STATE MONITORING

Scenario								
Scenario name:		Sc. 6: CM decision-making						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St.1	Congestion observed in Sc. 5	Data of congestion case	The state monitoring reports the congestion-related data	Report	State monitoring	CM decision-making	Inf. 18	
St. 2	Congestion-related data received	Decision making	The real-time CM decision-making, according to the available control alternatives and congestion-related data, decides on CM alternative/s.	Execute	CM decision-making	CM decision-making	19	
St. 3	Calculation ready	Control recommend	The real-time CM decision-making reports the	Report	CM decision-making	Control room operator	Inf. 20	

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		ation/s	(recommended) control decisions to the control room operator.					
St. 4	Control recommendation/s received	CM solution selection	The control room operator selects from the recommended control solutions.	Execute	Control room operator	Control room operator	21	

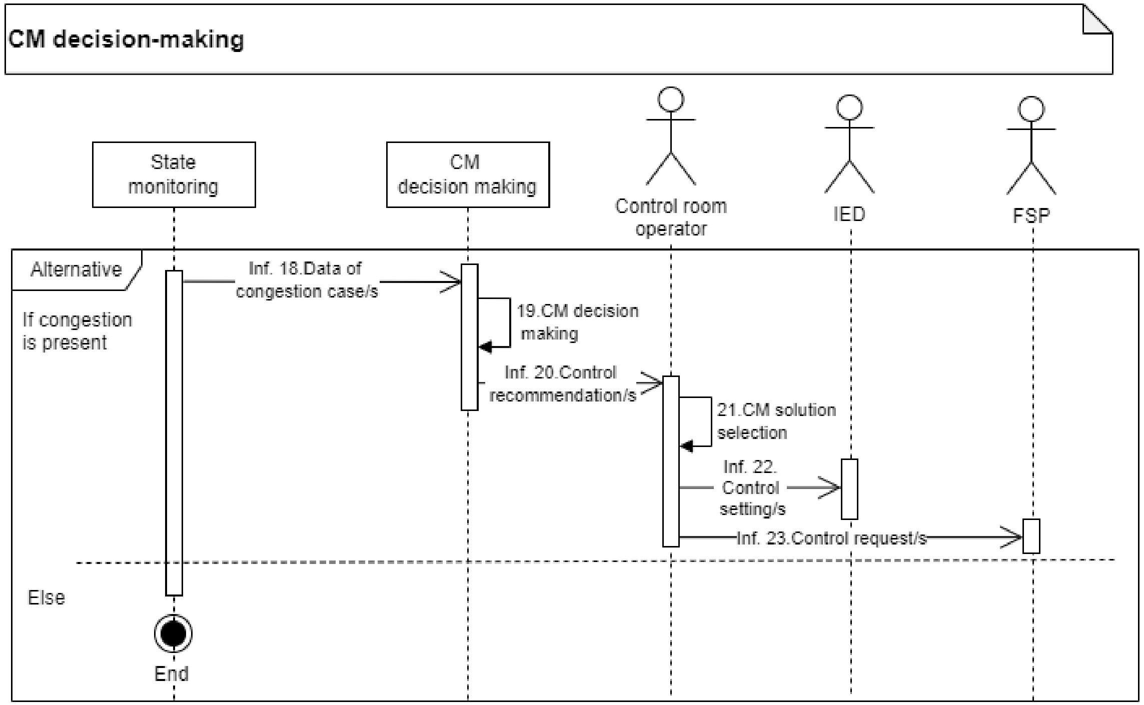

FIGURE 10- SEQUENCE DIAGRAM OF CM DECISION-MAKING

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Scenario								
Scenario name:		Sc. 6: Market-based flexibility activation						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St.1	The control room operator has selected market-based flexibility activation according to Sc. 6	Control request/s	The control room operator informs the FSP about the chosen control decision.	Report	Control room operator	FSP	Inf. 22, according to Fig. 6	

Scenario								
Scenario name:		Sc. 7: Grid-side flexibility activation						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St.1	The control room operator has selected grid-side flexibility activation according to Sc. 6	Control setting/s	The control room operator informs the control decision by sending the required control commands.	Report	Control room operator	IED	Inf. 23, according to Fig. 6.	

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5 Information exchanged

Information exchanged			
Information exchanged (ID)	**Name of information**	**Description of information exchanged**	**Requirement, R-IDs**
Inf. 1, Inf. 15	Initiate the process	It is a time-triggered message indicating a need to perform congestion prediction functionality. The triggering can also be based on an event, such as a violation of grid operational limits in real time. The data indicate a need for the receiver to start a functionality.	R.3, R.6, R.7
Inf. 3	Data of congestion case	The data include congestion time, duration, intensity, location, and congestion ID.	R.3, R.4, R.6, R.7, R.8
Inf. 5			
Inf. 7, Inf. 8	Bid/s request	Activation time, volume, location, duration, direction (up/down), congestion Id	R.3, R.4, R.5, R.6, R.7
Inf. 9, Inf. 10	Bid/s	Activation time, volume, location, duration, direction, price, congestion ID, bid ID	R.3, R.4, R.5, R.6, R.7, R.8
Inf. 12, Inf. 13	Selected bid/s	Bid ID/s	R.3, R.4, R.5, R.6, R.7
Inf. 16	Measurement data	The data include measurement values from IEDs across the grid	R.1, R.2, R.3, R.4, R.5, R.6, R.7, R.8
Inf. 18	Data of congestion case	The data include the intensity and location of the congestion.	R.3, R.4, R.6, R.7, R.8
Inf. 20, Inf 5	Control recommendation/s	The data indicate whether flexibility from the market, grid, or both should be used. For each recommended solution, the message includes settings and required actions to realize the required control action/s.	R.R.3, R.4, R.5, R.6, R.7, R.8
Inf. 22	Control setting/s	The setting of grid controllable components (e.g., reactive power compensator)	R.4, R.6, R.7, R.8
Inf. 23	Control request/s	The message includes the need for the activation of market-based flexibility, activation time and required volume.	R.4, R.6, R.7, R.8

6 Requirements

Requirements		
Requirement R-ID	**Requirement name**	**Requirement description**
R.1	Real-time data collection	The metering data platform must be able to collect the data from the smart meter in real-time. The measurement data must be collected from sensors in real-time (e.g., temperature, voltage, current)
R.2	Customer consent	The customer must provide her/his consent for the data to be exchanged.
R.3	Frequency of data exchange	Quality of Service (QoS) Issues Possible values: • Essentially continuous • Every few milliseconds • Every few seconds • Periodicity greater than a few seconds • Upon event • Upon request • Random • Sparse • Other

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R.4	Usefulness of source data	Data Management Issues Possible values: • Source data is always correct (e.g., by definition) • Source data is usually correct • Source data is often not correct (incorrectly entered, out of date, not available) • Source data is rarely correct • Correctness of source data is not relevant • Data is always from all locations and sensors available • Data is complete
R.5	Management of data across organizational boundaries	Data Management Issues Possible values: • Data exchanges go across organizational boundaries • Data exchanges go across departmental boundaries • Data exchanges go across boundaries between systems developed by different vendors • Data exchanges are within one vendor's system • Not relevant • Other
R.6	Authentication: Ensuring that data comes from the stated source or goes to an authenticated receiver	Security Issues Possible values: • Crucial • Quite important • Not particularly important • Detection that a security violation was attempted is crucial • Other
R.7	This data exchange has the following requirements with respect to proof of conformance and/or non-repudiation with contractual agreements.	Security issues Possible values: • Logging of all information exchanged during this interaction is required • Logging of only key information is required • Logging of the source, destination, requesting application, and requesting user of information exchanges is required, but not the data itself • Other
R. 8	Confidentiality of data	Possible values: Sharable to public Sharable within organizational boundaries Shareable between organizations under mutual agreements Non-sharable

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
DSO	Distribution system operator
FSP	Flexibility service provider
CM	Congestion management
HC	Hosting capacity
DER	Distributed energy resources
UC	Use case
SRP	Scheduled reprofiling product
CRP	Conditional reprofiling product
LFM	Local flexibility market
NEMO	Nominated electricity market operator
ID	Identification

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HEDGE-IoT
Holistic Approach towards Empowerment of the Digitalization of the Energy Ecosystem through adoption of IoT solutions

BUC-GR-01 FLEXIBILITY MANAGEMENT THROUGH ACTIVE PROSUMERS/CONSUMERS ENGAGEMENT

1 Description of the use case

1.1 Name of the use case

ID	***Area / Domain(s) / Zones(s)***	***Name of Use Case***
BUC-GR-01	Flexibility procurement	Flexibility management through active prosumers/consumers engagement

1.2 Version management

Version Management			
Version No.	***Date***	***Name of Author(s)***	***Changes***
0.1	19.03.2024	ICCS	First draft version
0.2	22.03.2024	HENEX	Comments and editing
0.3	02.04.2024	HENEX	Draft changes
0.4	05.04.204	ICCS	Consolidation
0.5	25.04.2024	HEDNO	Refinement
0.6	12.06.2024	ICCS	Finalizing missing parts

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Prosumers can actively participate in a flexibility market using easy to operate and user-friendly GUIs. The key point is to focus on empowering prosumers to manage their energy consumption and production dynamically, thereby contributing to grid stability and reliability while potentially earning incentives for their flexibility.
Objective(s)	The main objectives are: • To enhance the participation of prosumers and consumers to a flexibility market. • To enhance the penetration of RES into the grid operation • To advise consumers/prosumers on their energy usage habits and their environmental impact.
Related business case(s)	BUC-GR-02: Leveraging data exchange and AI edge algorithms for energy forecasting and optimal grid disaggregation BUC-GR-03: Flexibility trading for mitigating problems of the T&D networks

1.4 Narrative of use case

Narrative of Use Case
Short description
The Aggregator can leverage flexibility markets by strategically utilizing real-time data and market signals to optimize grid operations, balance supply and demand, integrate renewable energy sources efficiently, and incentivize demand response programs among consumers to enhance grid stability and reliability while minimizing costs. By utilizing mobile applications and dashboards powered by edge-collected data, the Aggregator can incentivize prosumers and consumers to actively participate in the flexibility market.
Complete description
The aim of this use case is to foster flexibility procurement by empowering and incentivising the Aggregator's consumers/prosumers to respond to market signals. The AI/ML algorithms will propose whether the Aggregator

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should offer incentives to its customers to respond to the LFM's product. As of today, consumers have not been afforded the opportunity to actively engage in the flexibility market, potentially limiting their ability to contribute to and benefit from its offerings. Several steps are necessary within this use case to attain flexibility procurement. Multiple subservices will be developed, and edge IoT devices will be deployed to monitor flexibility assets. The residential energy consumption and overall energy related information will be monitored to extract valuable insights from consumers' behaviour. Tasks such as energy disaggregation and demand and production forecasting will be carried out to better identify the ability to offer flexibility in residential level. By disaggregating energy usage data, it becomes easier to identify the energy consumption patterns of individual devices within a household or building, enabling more effective energy management strategies. Users will be able to identify energy-intensive appliances and optimize their usage, leading to potential cost savings on energy bills and support both the Aggregator to find the optimal flexibility distribution and the consumers to identify acceptable flexibility actions. The Aggregator can leverage these insights of monitoring the flexibility assets and results of demand and production forecasting, to run optimization methods and eventually decide whether it makes sense to bid for each flexibility product available in the Local Flexibility Market. This decision will be based on profit margins that the Aggregator sets as threshold, the constant fluctuations of the electricity price and the probability of the customers to accept to respond to the LFM's product at each specific time of the day, taking into consideration the relevant constraints (e.g., demand should always be satisfied, consumers always have the right to opt out or reject a flexibility offer, etc.). Modelling customers' behaviour on this kind of requests is also part of this use case taking into consideration several qualitative and quantitative customer characteristics such as time of the day, general partners, smart devices existence and readiness, etc. Customers with solar PVs would also be modelled and participate in the demand response program, supporting the system during the time periods when the production is sufficient or by utilizing storage systems. Based on the analysis on their data, the Aggregator could provide incentives to encourage customer participation in the flexibility market and identify the form these incentives should take. A dedicated UI will be also provided to the customers to be able to respond to flexibility offers coming from the aggregator. They will be able accept or not each flexibility offer, and directly be aware of the economic incentives they will receive. The BUC includes the following steps. 1. Data collection from IoT devices. 2. Storing and analysing historical data. 3. Aggregation of flexibility services. 4. Incentivise the request of flexibility. 5. Offer customized insights on energy consumption to consumers.

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
• Availability and installation of Edge IoT Devices in households • Near real time monitoring and access to consumers' behaviour • Data Quality and Accessibility/Availability • Regulatory and Compliance Requirements • Consumers/Prosumers Participation and Consent • Access to billing smart metering data for quality of measurement, settlement, and billing purposes
Prerequisites
• Consumers/Prosumers should possess IoT devices at selected homes and buildings. • Weather conditions and forecasts should be available (forecasting electricity demand and PV forecast for prosumers) • Prosumers/consumers are willing/agree to provide the data from the IoT devices through the energy supplier

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• Adequate flexibility offers from the Local Flexibility Market (BUC-GR-03) are available (through the system operators) to perform the experiment

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Linked to BUC-GR-02: • Providing forecasts (demand and production) to identify grid issues. Linked to BUC-GR-03: • Flexibility offer is available for the ESCO in order to decide to bid or not. • Activation of flexibility (if the bid is accepted) and resulting settlement.
Level of depth
General
Prioritisation
Medium
Generic, regional or national relation
National
Nature of the use case
Business use case: Information sharing between the Consumers/Prosumers, the ESCO and the Energy Supplier to optimise consumer behaviour in response to flexibility offers from market events
Further keywords for classification
Flexibility management, demand forecasting, production forecasting, optimisation algorithms, Machine Learning, Deep Learning, Optimisation algorithms

1.8 General Remarks

General Remarks

2 Diagrams of use case

Diagram(s) of use case

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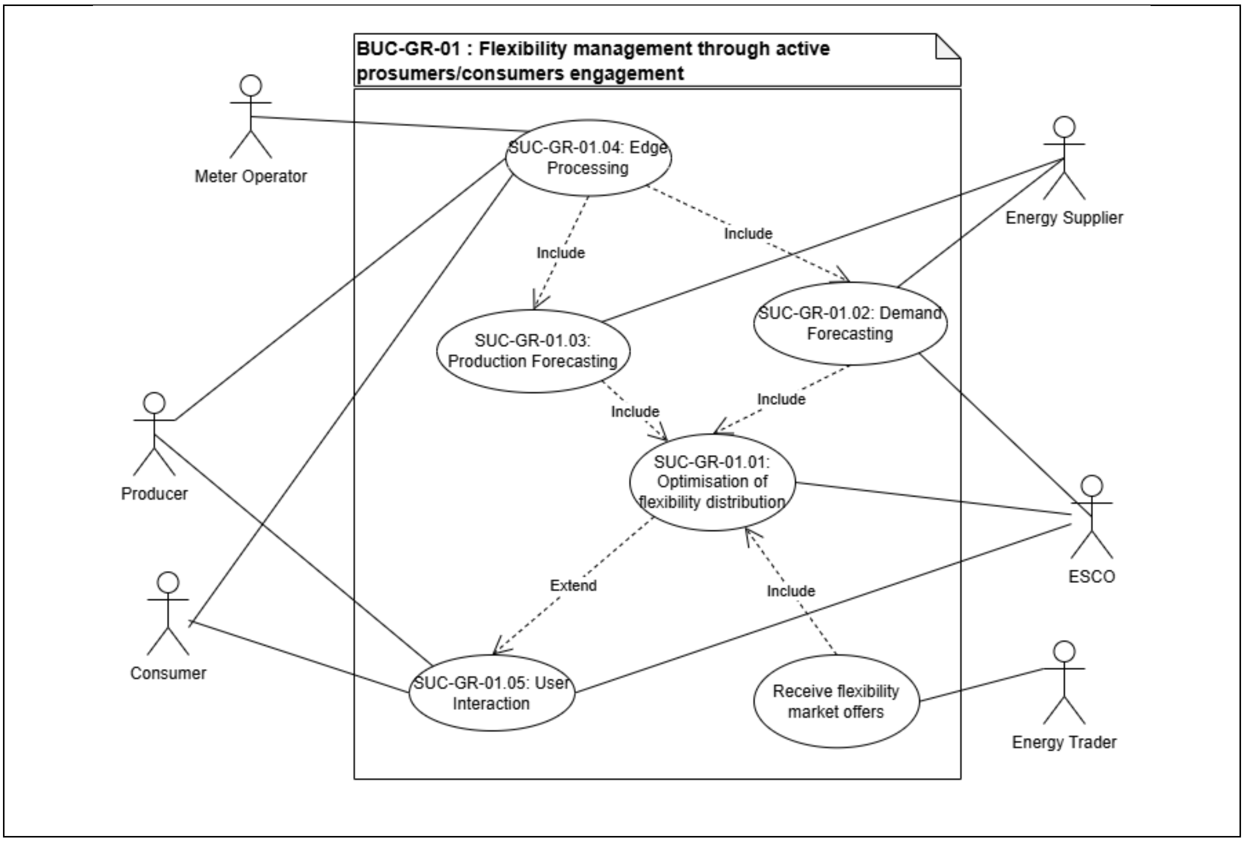

3 Technical details

3.1 Actors

Actors				
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***
Consumers	Business Actor	Consumers who possess IoT devices monitoring their consumption.	Residential Consumers/PPC Customers
Producers	Business Actor	Small residential PV owners, promoting self-consumption (mostly under net-metering schemes	Residential Consumers/PPC Customers
Meter Operator	Logical Actor	An entity providing IoT submetering devices (smart plugs, smart meters, gateways, etc.)	PPC, ICCS
ESCO	Business Actor	An entity processing, analysing and monitoring energy consumption/production data, operating the AI algorithms for demand/production forecasts, and performing the optimisation algorithms for the flexibility offers	PPC, ICCS
Energy Supplier	Business Actor	Collects consumer and prosumers data and is responsible for invoicing the consumers.	PPC
Energy Trader	Business Actor	The energy trader receives a flexibility offer from the LFM and decides to bid or not, based on the available flexibility resources available in the aggregator,	PPC

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3.2 References

References						
No.	***Reference Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc.1	Flexibility offer assessment	Demand side flexibility actions are determined through AI optimisation techniques on an aggregated scale	Consumer, producer, meter operator, ESCO	A flexibility offer for the aggregator is available in the LFM	Consumer/Producer has installed IoT and submetering devices, weather data are available, behavioural patterns are designed, GUI/dashboards to inform consumers and offer incentives is available	ESCO (aggregator) provide the results of the assessment to the energy trader to decide to bid or not

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4.2 Steps – Scenarios

Scenario								
Scenario name:		Sc. 1 - Flexibility offer assessment						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St. 1	ESCO is informed that a flexibility offer is available in the LFM	Flexibility offer availability	The ESCO receives a request to analyse the flexibility offer	REPORT	Energy Trader	ESCO	Inf.1	R10, R8, R9, R1, R11
St. 2	ESCO access residential data	Historical and real-time data availability	The ESCO requests the energy supplier to access historical and real-time data from consumers/producers to perform the analysis	GET	Energy Supplier	ESCO	Inf.2	R1, R2, R5, R7, R10, R11
St. 3	Energy Supplier request real-time data	IoT data and historical data access	The energy supplier requests from the meter operator access in real time data	GET	Meter Operator	Energy Supplier	Inf.3, Inf.4	R1, R6, R7, R8, R9, R10, R2, R11
St. 4	ESCO receives data	Historical and real-time energy consumption/production data are available	ESCO receives the data from the energy supplier	GET	ESCO	Energy Supplier	Inf.5	R1, R6, R2, R7, R8, R9, R10, R2, R11
St. 5	Optimisation algorithms for flexibility assessment	Analysing the potential flexibility of consumers/ producers	The ESCO proceeds with the analysis of the data and the flexibility offer (St. 1) to assess the potential actions by the consumers.	EXECUTE	ESCO	-	6	R4, R7
St. 6	Results of optimisation	Report of the	ESCO reports to the energy trader the flexibility analysis	REPORT	ESCO	Energy Trader	Inf.7	R1, R11, R2, R4, R8, R10

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	algorithms	potential flexibility actions of consumers	optimisation					
St. 7	Flexibility offer bid decision	Decision to bid for the flexibility offer	Energy Trader decides whether to bid on the flexibility offer based on the analysis	CREATE	Energy Trader	-	8	R4, R7, R12
St. 8	Bid for flexibility offer accepted	The Energy Trader decides that they will bid for the flexibility offer	Energy Trader informs that it will bid for the flexibility offer based on the St. 6 analysis and consumers/prosumers must be informed	REPORT	Energy Trader	ESCO	Inf.9	R1, R11, R2, R4, R8, R10
St. 9	Consumers/Producers are made aware of potential flexibility actions	ESCO provide the incentives to consumers in order to accept the flexibility offer	ESCO informs the consumers for incentives available if they accept the flexibility offer	REPORT	ESCO	Consumers, producers	Inf.10	R2, R3, R4
St. 10	Consumers/Producers decide if they accept the flexibility action	Flexibility action accepted by consumers/producers	ESCO receives the decision by consumers/producers and aggregates the results	REPORT	Consumer, producers	ESCO	11, Inf.12, 13	R1, R3, R4, R8, R9, R10, R11
St. 11	Inform of consumers/producers' decision	Flexibility actions inform	ESCO reports on the actual flexibility actions that will be made by consumers/producers	REPORT	ESCO	Energy Supplier, Energy Trader	Inf.14	R1, R3, R4, R8, R9, R10, R11
St. 12	Activate flexibility	Flexibility actions	Consumers/producers perform the flexibility actions and	EXECUTE	Consumers, producers,	-	15	R4

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	actions	activated	receives the incentives		ESCO, Energy Supplier, Energy Trader			
St. 13	Bid for flexibility offer rejected	The Energy Trader decides that they will not bid for the flexibility offer	Energy Trader informs that it will not bid for the flexibility offer based on the St. 6 analysis	CANCEL	Energy Trader	ESCO	Inf.16	R4, R12

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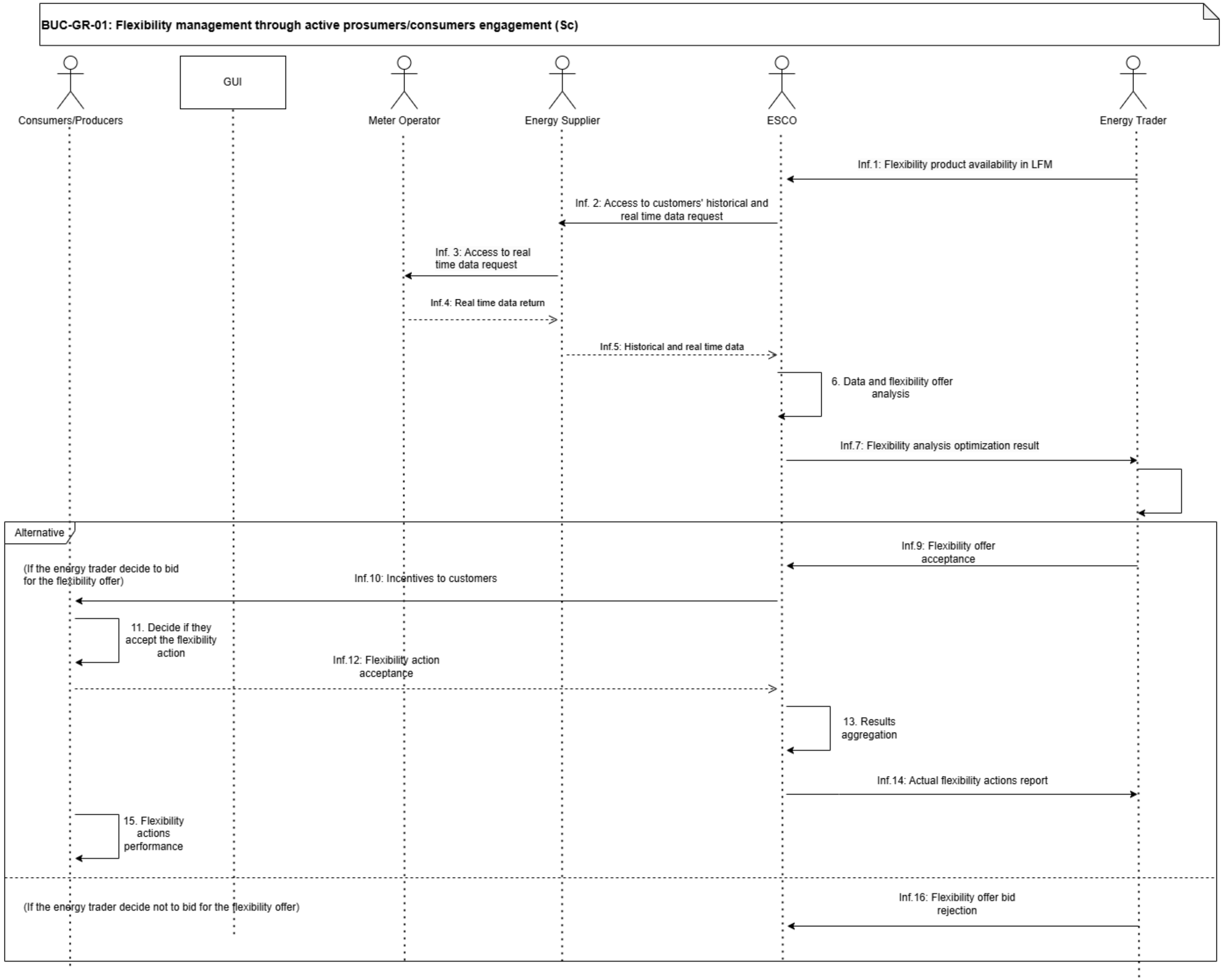

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5 Information exchanged

Information exchanged			
Information exchanged (ID)	**Name of information**	**Description of information exchanged**	**Requirement, R-IDs**
Inf.1	Flexibility offer availability	ESCO is informed that a flexibility offer is available in the LFM. This information includes the capacity requested plus the price of the flexibility offer	R10, R8, R9, R1, R11
Inf.2	Historical and Real-time data access request	The ESCO requests the energy supplier to access historical and real-time data from consumers/producers to perform the analysis	R1, R2, R5, R7, R10, R11
Inf.3	Access to real time data request	The energy supplier requests from the meter operator access in real time data	R1, R2, R3, R5
Inf.4	Real time data return	The Meter Operator returns the real time data to the energy supplier	R1
Inf.5	Historical and real time data return	The ESCO receives the data from the energy supplier	R1
6	[process] Data and flexibility offer analysis	Analysis of the data and the flexibility offer to assess the potential actions by the consumers	R4, R7
Inf.7	Flexibility analysis optimization result	The result of the flexibility analysis optimization which includes potential flexibility actions on the customer side	R1, R11, R2, R4, R8, R10
8	[process] Flexibility offer bid decision	The aggregator decides whether it takes the bid to the flexibility offer or not	R4, R7, R12
Inf.9	Flexibility offer bid acceptance	The aggregator decides that it bids for the flexibility offer using optimization algorithms	R4, R7, R12
Inf.10	Incentives to customers	Financial incentives to customers so it makes sense to them to accept the flexibility offer sent by the aggregator	R2, R3, R4, R12
11	[process] Flexibility action decision	The consumers/producers decide whether they accept the offer to perform specific flexibility actions	R3, R4
Inf.12	Flexibility action acceptance	The consumers/producers decide to accept the offer to perform specific flexibility actions	R3, R4
13	[process] Results aggregation	The ESCO receives the decision by consumers/producers and aggregates the results	R1, R2, R3, R7
Inf. 14	Actual flexibility actions report	ESCO reports on the actual flexibility actions that will be made by consumers/producers	R1, R2, R3, R5, R7, R10
15	[process] Flexibility action implementation	The consumers/producers perform the flexibility action they accept to receive financial incentives.	R4
Inf.16	Flexibility offer bid rejection	The aggregator decides that it doesn't bid for the flexibility offer using optimization algorithms	R4, R12

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6 Requirements

Requirements		
Requirement R-ID	**Requirement name**	**Requirement description**
R1	Interoperability	The interoperability is important for the communication of the different elements of the system.
R2	Privacy and data protection	All the customer's data should be protected and handled according to the GDPR regulations.
R3	Customer's consent	Customers need to provide their consent to deploy IoT devices in their houses and monitor their consumption
R4	User preferences	Respect the electricity needs of the customers at each time and not cause any inconvenience
R5	Ensuring that data cannot be resent by any unauthorized source	The data needs to follow the outlined flow and not used or resent by any unauthorized party
R6	Real time data collection	The metering data platform must be able to collect data in real time from the smart meters
R7	Correctness of data	All the data gathered need to be correct
R8	Management of data across organizational boundaries	Data exchanges go across organizational boundaries
R9	Management of data formats in data exchanges	The same data exchanges need to have the same format
R10	Communication access services requirements	Request-response
R11	Frequency of data exchanges	Established time window for data exchanges
R12	Established profit margin	The aggregator needs to establish a profit margin that is crucial in the decision on whether to bid for the flexibility offer or not

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
ESCO	Energy Service Company

BUC-GR-02 LEVERAGING DATA EXCHANGE AND AI EDGE ALGORITHMS FOR ENERGY FORECASTING AND PREVENTION OF CRITICAL GRID EVENTS

1 Description of the use case

1.1 Name of the use case

ID	*Area / Domain(s) / Zones(s)*	*Name of Use Case*
BUC-GR-02	Flexibility procurement	BUC-GR-02: Leveraging data exchange and AI edge algorithms for energy forecasting and prevention of critical grid events

1.2 Version management

Version Management			
Version No.	*Date*	*Name of Author(s)*	*Changes*
0.1	19.03.2024	ICCS	First draft version

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0.2	25.04.2024	HEDNO	Detailed description of BUC
0.3	15.05.2024	HEDNO	Drafting paragraphs 2 to 4

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	AI-IoT Edge-Cloud data exchange for assessing current and future grid security through consumption forecasting and the identification of optimal disaggregation and DR scenarios
Objective(s)	The main objectives are: • To collect and process data from IoT devices • To forecast long-term and day-ahead localized energy demand • For the SOs to analyse and assess the grid status and identify the possibility of critical events • To form flexibility requests for avoiding critical events and maintain grid stability
Related business case(s)	BUC-GR-01 Flexibility management through active prosumers/consumers engagement BUC-GR-03 Flexibility trading for mitigating problems of the T&D networks

1.4 Narrative of use case

Narrative of Use Case
Short description
Data collected by edge IoT devices can play a crucial role in ensuring grid stability by forecasting future energy demands and identifying potential critical events on the grid. AI-based services, utilizing Federated Learning to uphold data privacy and sovereignty, will be instrumental in analysing edge data from Energy suppliers, Aggregators and SOs. This analysis will strategically optimize grid operations, balancing supply and demand while efficiently integrating renewable energy sources.
Complete description
The data collected by edge IoT devices plays a crucial role in ensuring the stability and efficiency of the grid infrastructure. By leveraging this data, operators can forecast future energy demands with greater accuracy, anticipate critical events such as voltage fluctuations and congestions. In addition to data collection, the integration of AI-based services, particularly through techniques like Federated Learning, further enhances the capabilities of grid management systems. Federated Learning allows for the training of AI models on decentralized data sources, ensuring data privacy and sovereignty while still enabling valuable insights to be derived. This analysis of data collected from various stakeholders such as consumers and prosumers can provide a comprehensive understanding of grid dynamics, consumer behavior, and energy consumption patterns. Energy forecasts and insights on future energy behaviors by consumers, as well as predictions on energy production, allow the System Operators to identify future and near-future grid issues. Using this analysis, grid operators can also strategically optimize grid operations to balance supply and demand in real-time. This optimization involves efficient energy distribution and integration of renewable energy sources into the grid. In summary, the combination of edge IoT devices, AI-based analytics, and data-driven insights plays a pivotal role in ensuring the stability, efficiency, and sustainability of grid infrastructure. Through proactive monitoring, predictive analytics, and strategic optimization, grid operators can effectively address challenges and capitalize on opportunities in a flexibility market. The BUC includes the following steps. 6. Agreement between Consumers/Producers and the Energy supplier for data sharing (Consumers/Producers, Energy Supplier) 7. Data collection: Consumers/Producers IoT devices (Metered Data Administrator) 8. Energy forecasting based on collected data (ESCO) 9. Energy forecast aggregation for specified location (Energy Supplier) 10. Grid analysis based on energy forecasts at specified location (SO)

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11.	Grid issues identification (SO)
12.	Calculation of required flexibility (SO)

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
• Availability and installation of Edge IoT Devices • Data Quality and Accessibility/Availability • Regulatory and Compliance Requirements • Consumers/Producers Participation and Consent • Scalability and Flexibility of the BUC to different regions-cases
Prerequisites
• Consumers/Producers should possess IoT devices at selected homes and buildings. • Consumers/Producers are willing/agree to provide the data from the IoT devices. • Data collected to be useful to forecast grid issues. • The participation of a satisfying percentage of consumers for accurate energy forecast.

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Linked to BUC-GR-01: • Data collection from IoT devices. Linked to BUC-GR-03: • Platform for the execution of flexibility services. • Submission of flexibility request by the SO to Market Operator.
Level of depth
General
Prioritisation
High
Generic, regional or national relation
Regional
Nature of the use case
Business use case: Information sharing between the Consumers/Producers, the ESCO, the Energy Supplier and the SOs to predict and prevent grid critical events
Further keywords for classification
Energy forecasting, grid analysis, grid issues forecasting, IoT devices, flexibility services

1.8 General Remarks

General Remarks

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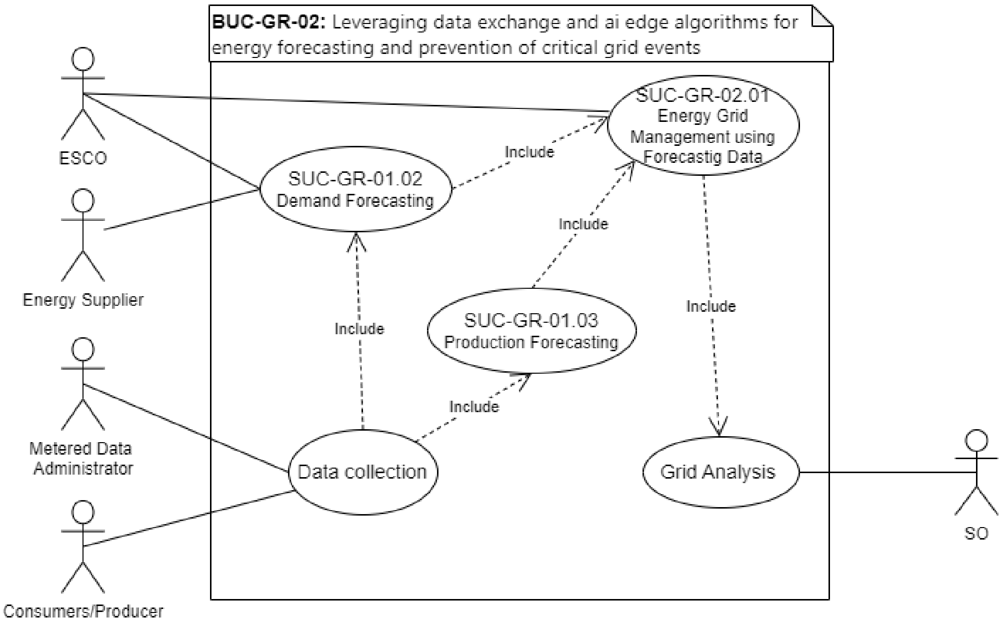
2 Diagrams of use case

Diagram(s) of use case


3 Technical details

3.1 Actors

Actors			
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***
Energy supplier	Business actor	An Energy Supplier supplies electricity to or takes electricity from a Party Connected to the Grid at an Accounting Point. Additional information: An Accounting Point can only have one Energy Supplier. When additional suppliers are needed the Energy Supplier delivers/takes the difference between established (e.g. measured or calculated) production/consumption and the (accumulated) contracts with other suppliers.	PPC

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System Operator	Business actor	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution or transmission of electricity.	HEDNO, IPTO
Consumer/Producer	Business actor	A party that consumes energy and that generates electricity. Additional information: This is a type of Party Connected to the Grid	
Energy Service Company	Business actor	A party offering energy-related services to the Party Connected to Grid, but not directly active in the energy value chain or the physical infrastructure itself. The Energy Service Company (ESCO) may provide insight services as well as energy management services.	ICCS
Metered Data Administrator	Operator	A party responsible for storing and distributing validated measured data.	

3.2 References

References						
No.	***Reference Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc. 1	Preparation for Consumer/Producer registration	Registration of the Consumer/Producers to share their data	Energy supplier	Consumer/Producer contacts Energy Supplier for registration	Consumer/Producer has installed IoT and submetering devices	The Consumer/Producer is informed on the processes and type of data they are required to share.
Sc. 2	Grid analysis for forecasting grid issues and calculation of required flexibility to avoid grid critical events.	By utilizing data collected from edge IoT devices and employing AI-based analytics, the Energy Supplier offers SO the possibility to identify future and near-future critical events.	System Operator	SO requests to perform grid analysis to assess future grid state.	1) Edge-IoT devices and AI-based analytics systems are operational and collecting data. 2) Availability of grid model for simulations and grid analysis.	1) SO to be able to perform accurate grid analysis based on highly reliable energy forecast. 2) SO to be able to accurately calculate required flexibility to prevent critical events.

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4.2 Steps – Scenarios

Scenario								
Scenario name:		Sc.1 - Preparation for Consumer/Producer registration						
St. No	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St.1	Consumer/Producer contacts Energy supplier to register	Send request for data access and collection	The Energy Supplier informs Consumer/Producer of their rights according to the GDPR policy and requests their consent to use their data	REPORT	Energy Supplier	Consumer/Producer	Inf.1	R.7, R.8, R.9, R.10, R.11, R.12, R.13, R.14
St.2-1	Consumer/Producer agrees to share data	Agree to participate	The consumer/producer sends a positive reply to Energy Supplier along with the participating assets.	GET	Consumer/Producer	Energy Supplier	Inf.2-1	GDPR.1, GDPR.2, GDPR.3, GDPR.4, R.2, R.3, R.4, R.5, R.9, R.11, R.12, R.14
St.3-1	Energy Supplier receives asset list	Register consumer/ producer	The Energy Supplier sends the Consumer/Producer assets to ESCO for registering them	GET	Energy Supplier	ESCO	Inf.3-1	GDPR.1, GDPR.2, GDPR.3, GDPR.4, R.2, R.3, R.4, R.5, R.9, R.11, R.12, R.14
St.2-2	Consumer/Producer does not agree to share data	Deny participation	The consumer/Producer sends a negative reply to Energy Supplier.	GET	Consumer/Producer	Energy Supplier	Inf.2-2	

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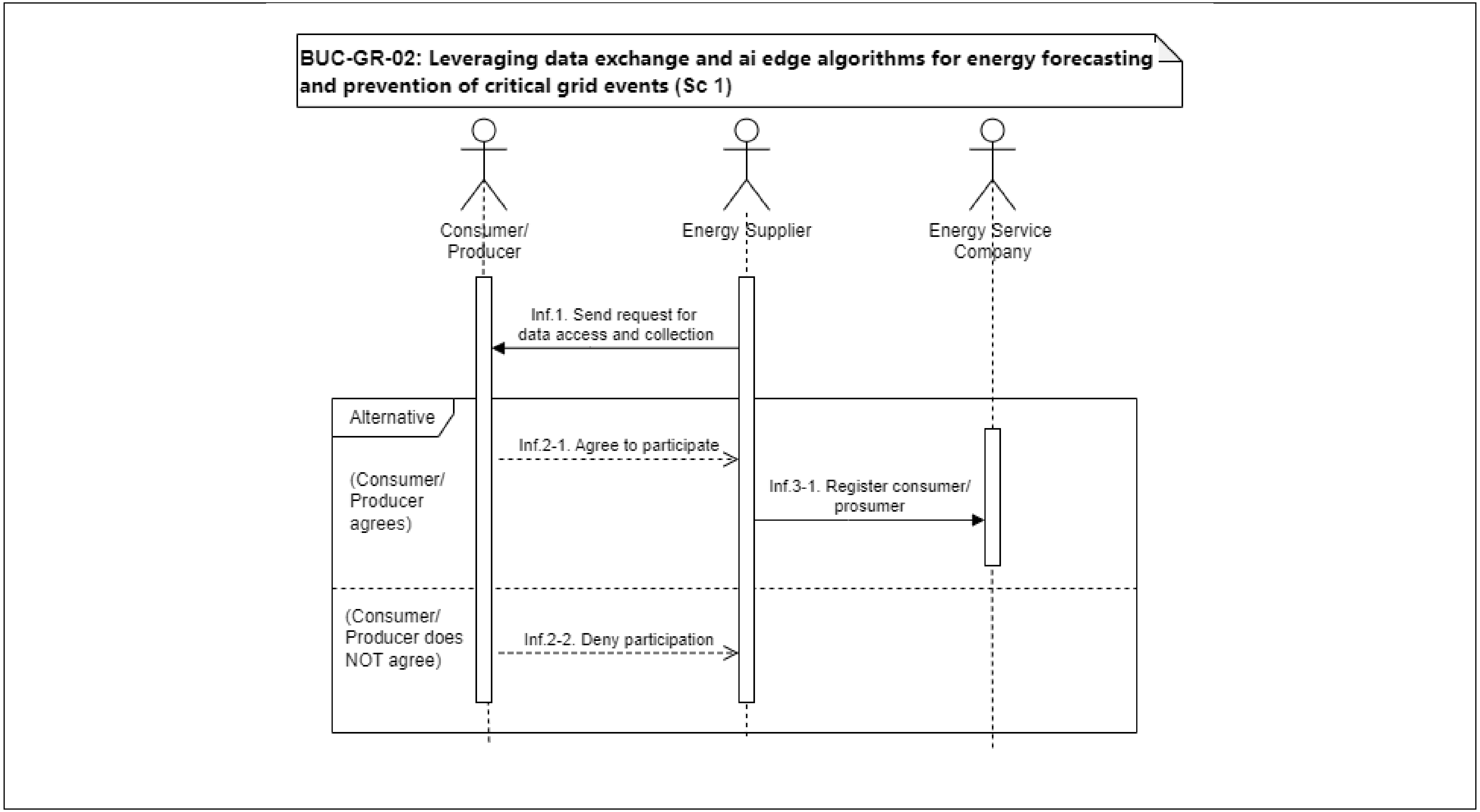

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Scenario								
Scenario name:		Sc.2 - Grid analysis for forecasting grid issues and calculation of required flexibility to avoid grid critical events						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St.4	Consumer/Producer consume/produce electric power	Create energy consumption/ production data	The consumption/production data are created and collected by the MDA	GET	Consumer/Producer	MDA	Inf.4	GDPR.1, GDPR.2, GDPR.3, GDPR.4, R.2, R.3, R.4, R.5, R.9, R.11, R.12, R.14
St.5	IoT devices data have been collected by the MDA	Send energy consumption/ production data	MDA shares the IoT devices collected data	GET	MDA	Energy Supplier	Inf.5	GDPR.1, GDPR.2, GDPR.3, GDPR.4, R.2, R.3, R.4, R.5, R.9, R.11, R.12, R.14
St.6	Energy Supplier collects the data from the IoT devices	Send energy consumption/production data	The Energy Supplier sends the IoT device data from the consumers/producers	GET	Energy Supplier	ESCO	Inf.6	GDPR.1, GDPR.2, GDPR.3, GDPR.4, R.2, R.3, R.4, R.5, R.9, R.11, R.12, R.14
St.7	SO requests energy forecast	Send request for energy forecast	The SO sends a request for energy forecast for specified location and time.	REPORT	SO	ESCO	Inf.7	R.7, R.8, R.9, R.10
St.8	ESCO receives a request for energy forecast	Energy Forecasting	The ESCO executes the algorithms to perform energy forecasting (demand and production)	EXECUTE	ESCO	ESCO	8	GDPR.1, GDPR.2, GDPR.3,

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								GDPR.4, R.6, R.15, R.17
St.9	ESCO performs forecast analysis (demand and production)	Send report of energy forecast	The ESCO sends the requested energy forecast report.	GET	ESCO	SO	Inf.9	R.7, R.8, R.9, R.10, R.11, R.12, R.13, R.14
St.10	SO receives energy forecast	Grid Analysis	The SO performs grid analysis to determine if one or more grid critical events will appear	EXECUTE	SO	SO	10	R.6, R.15, R.17
St.11-1	Grid issue identified	Calculation of required flexibility	The SO performs load optimization to define required flexibility for avoiding critical event	EXECUTE	SO	SO	11-1	R.6, R.15, R.17
St.12-2	Grid issue not identified	No flexibility is calculated	If no grid issue is identified, the SO does not take any further action	CANCEL	SO			

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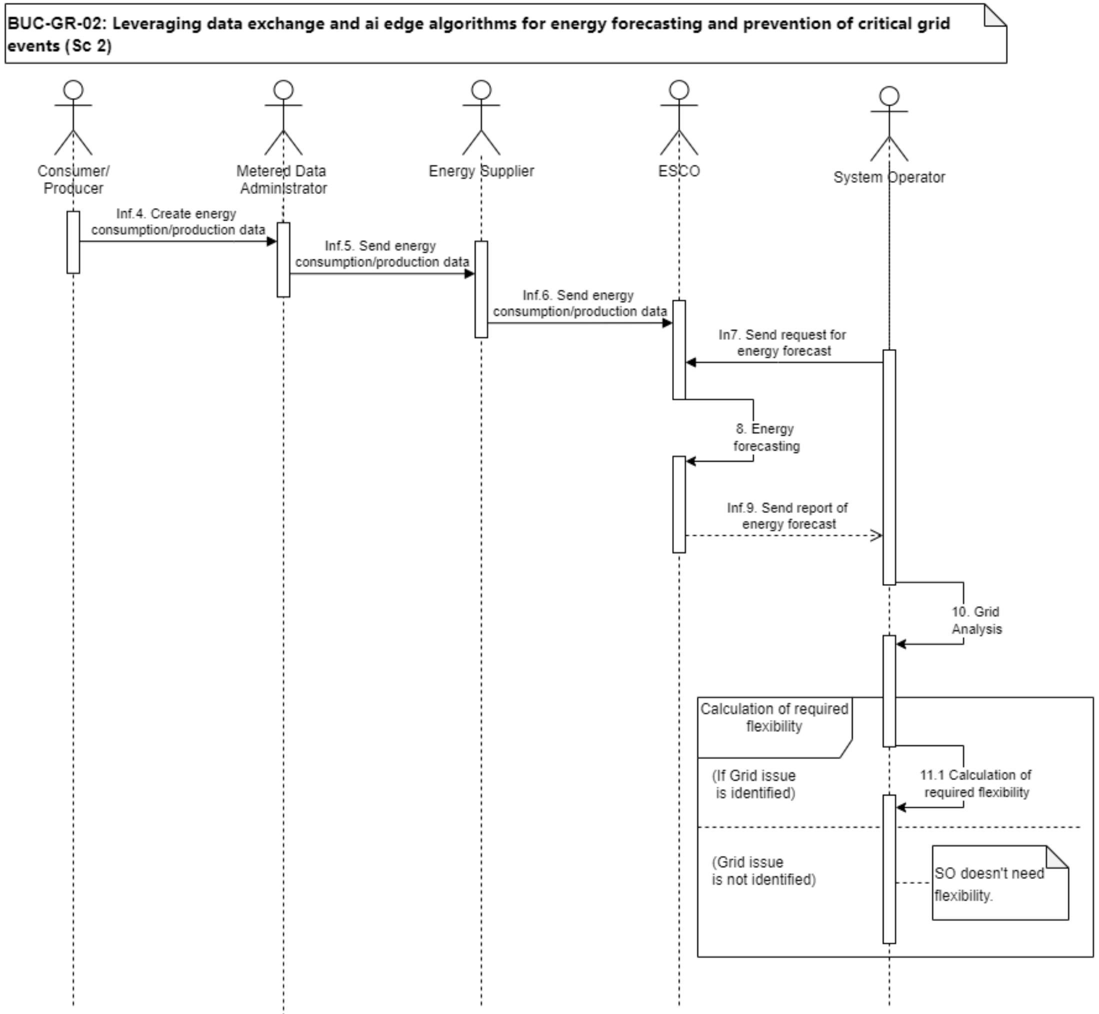

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5 Information exchanged

Information exchanged			
Information exchanged (ID)	**Name of information**	**Description of information exchanged**	**Requirement, R-IDs**
Inf.1	Data sharing request message	A message from the Energy supplier to the Consumer/Producer asking for the permission to use their data stating their rights according the GDPR policy.	
Inf.2-1	Agreement according to GDPR and asset list	A consent according to GDPR policy for accessing and processing data. The consumer/producer sends their assets info.	GDPR.1, GDPR.2, GDPR.3, GDPR.4
Inf.2-2	Message to deny participation	The consumer/producer denies permission to share data.	
Inf.3-1	Consumer/Producer asset list	The consumer's data and enlisted assets.	GDPR.1, GDPR.2, GDPR.3, GDPR.4
Inf.4, Inf. 5, Inf. 6	IoT device data	Energy consumption data as collected and stored by IoT devices connected to assets.	GDPR.1, GDPR.2, GDPR.3, GDPR.4, R.16
Inf.7	Request message for energy forecast	A message for requesting an energy forecast at • Specific location • Triggering Time • Duration	
Inf. 9	Energy demand/production report	A report on energy demand/supply forecast per asset for • Specific location • Triggering Time • Duration	R.6, R.17

6 Requirements

Requirements		
GDPR	Regulatory obligation related to privacy	General Data Protection Regulation
Requirement R-ID	**Requirement name**	**Requirement description**
GDPR.1	Data processing consent	Personal data may not be processes unless there is at least one legal basis to do so.
GDPR.2	Data retention policy	The time period specific sensitive data can be retained and the method of their disposal when the defined time period ends.
GDPR.3	Right to access, rectify, erasure, restriction	The data subject shall have right to obtain from the controller without undue delay the access/rectification/erasure/restriction of inaccurate personal data concerning them.
GDPR.4	Data transfer consent	Personal data may not be transferred to a third party if the data subject does not agree, and the third party provide appropriate safeguard.
R.1	Contractual timelines for exchanging data is required	Quality of Service (QoS) issues Possible values: • Within 1 second • Within 1 minute • Within 5 minutes • Within some longer time

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		• No specific contractual timeliness is required
R.2	Frequency of data exchanges	QoS Possible values: • Essentially continuous • Every few milliseconds • Every few seconds • Periodicity greater than a few seconds • Upon event • Upon request • Random • Sparse • Other
R.3	Interoperability	The interoperability is essential for the different elements of the system to be able to communicate. Interoperability is provided by the interoperability layer.
R.4	Report of user wills	The decision of the end user on the usage of his devices should be respected.
R.5	Ensuring that data cannot be resent by an unauthorized source	Security Ensuring that data cannot be resent by an unauthorized source Possible values : • Crucial • Quite important • Not particularly important • Detection that a security violation was attempted is crucial • Other__
R.6	Correctness of source data	Data Management Issues Possible values: • Source data is always correct (e.g. by definition) • Source data is usually correct • Source data is often not correct (incorrectly entered, out of date, not available) • Source data is rarely correct • Correctness of source data is not relevant • Other
R.7	Management of data across organizational boundaries	Data Management Issues Possible values: • Data exchanges go across organizational boundaries • Data exchanges go across departmental boundaries • Data exchanges go across boundaries between system developed by different vendors • Data exchanges are within one vendor's system • Not relevant • Other
R.8	Management of data formats in data exchanges	Data Management Issues Possible values: • The same data exchanged between different applications have the same formats • Conversion of data formats is automatically handled by each application. • Conversion of data formats is handled by Aggregator • Conversion of data formats is handled by DSO
R.9	Communication access services requirements	Configuration Issues Possible values: • Any or all

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		• Request-response • Periodic reporting • Report-by-exception • Control command • Select-before-operate • Set parameter values • Query for data by name • Subscribe • Broadcast • Multi-cast • Data discovery • Use of data sets • Query to find location of data • Query to determine what data is available (discovery) • Execute application • Establish and end association • Logging • Remote restart • Remote reconfiguration • Remote diagnosis • Other
R.10	Authentication: Masquerade and/or spoofing: Ensuring that data comes from the stated source or goes to authenticated receiver	Security Issues Possible values: • Crucial • Quite important • Not particularly important • Detection that a security violation was attempted is crucial • Other
R.11	Authentication and Access Control mechanisms commonly used with this data exchange	Security Issues Possible values • Private (secret) key encryption • Public key encryption (e.g. SSL/TLS) • Certificate • Shared secret • Access control through database security mechanisms • Bilateral data access control tables • Other
R.12	Validation of data exchanges	Data management issues Possible values • All data must be validated on each data exchange • Data must include quality codes to indicate its validity • Data from different sources must be validated against each other • Data mapping of data item names is required for data from different sources • Data can be assumed as valid (or validity checking is handled elsewhere) • Data is usually not validated • Validity of data is not relevant • Other
R.13	Management of accessing different types of data to be exchanged	Data management issues Possible values • Each data exchange could entail different types of data (e.g query a database)

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		• Numbers or types of data being exchanged are changed or updated every few minutes • Numbers or types of data being exchanged are changed or updated every few hours • Numbers or types of data being exchanged are changed or updated every few days or weeks • Numbers or types of data being exchanged are rarely changed or updated • Not relevant • Other ___
R.14	Replay Ensuring that data cannot be resent by an unauthorized source.	Security issues Possible values: • Quite important • Not particularly important • Detection that a security violation was attempted is crucial
R.15	Electric grid information	This information is confidential to DSO and will not be communicate to other stakeholders.
R.16	Historical data	Historical data are need from IoT devices and smart meters.
R.17	Accuracy of AI Edge Results	Enough raw data and participants to cover a large percentage of consumers at specified area.

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
DSO	Distribution System Operator
TSO	Transmission System Operator
ESCO	Energy Service Company
KPI	Key Performance Indicator
IoT	Internet of Things
GDPR	General Data Protection Regulation
MDA	Metered Data Administrator

BUC-GR-03 FLEXIBILITY TRADING PLATFORM FOR MITIGATING PROBLEMS OF THE T&D NETWORKS

1 Description of the use case

1.1 Name of the use case

ID	*Area / Domain(s) / Zones(s)*	*Name of Use Case*
BUC-GR-03	Flexibility procurement	Flexibility trading platform for mitigating problems of the T&D networks

1.2 Version management

Version Management			
Version No.	*Date*	*Name of Author(s)*	*Changes*
0.1	19.03.2024	ICCS	First draft version

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0.2	22.03.2024	HENEX	Comments and editing
0.3	01.04.2024	HENEX	Detailed description of BUC on Flexibility trading for mitigating problems of the Transmission and Distribution (T&D) networks
0.4	08.04.2024	ICCS	Draft changes
0.5	20.05.2024	HEDNO	Longer version
0.6	22,05,2024	HENEX	Contribution in diagrams & minor changes in text
0.7	11.06.2024	HENEX	Simplify use case, add different scenarios

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Enable trading of residential Distributed Energy Resources (DERs) flexibility in a cloud-based Local Flexibility Market (LFM) by deploying near real-time measurements from behind the meter IoT devices for flexibility settlements and associated transaction management.
Objective(s)	The goal of the UC is to build an independent marketplace to procure flexibility generated through federated-learning algorithms at consumer level with the objective to solve T&D grid issues. The LFM acts as a central hub for all market relevant processes, related to registration & prequalification, trading and post trading and facilitates coordinated IoT Cloud-Edge data exchange and interaction among market participants, respecting their business needs and data exchange limitations.
Related business case(s)	BUC-GR-01: Flexibility management through active prosumers/consumers engagement BUC-GR-02: Leveraging data exchange and AI edge algorithms for energy forecasting and prevention of critical grid events.

1.4 Narrative of use case

Narrative of Use Case
Short description

The UC implements a Local Flexibility Market Platform operated by the independent Market Operator (MO) to address T&D network issues. The System Operators (SOs) identify anticipated T&D network issues and request flexibility by submitting flexibility requests in terms of predefined flexibility energy products in the LFM. Qualified market participants - Flexibility Service Providers represent the local prosumers and offer flexibility to the LFM to match the SOs needs. The feasibility of the market outcome is assessed by the SOs by respecting TSO-DSO cooperation principles. Data from IoT devices are used for the settlement of transactions by the SOs. The LFM operations consist of the following:
 	
• Registration & Prequalification
    • Company Registration
    • Grid/Assets Prequalification
• Flexibility Trading
    • Grid Operators pre-announce flexibility needs
    • Flexibility service providers bids submission
• Settlement & Remuneration

Complete description
In this use case, the FSP, the System Operators (DSO & TSO), and the Market Operator will collaborate to enable the trading of flexibility to address issues of the T&D network. As described in BUC 1, the SOs will use their own tools and processes to monitor and forecast the grid status and determine grid issues. In case of a grid issue, the DSO/TSO will communicate their flexibility needs to the platform, operated by the MO, in terms of predefined market products. The FSP will evaluate the SOs flexibility requests based on AI/ML algorithms and related processes described in BUC-GR-01 and may opt to respond to the SOs needs and participate in the LFM by offering flexibility services. Platform interoperability holds paramount importance in facilitating smooth and efficient data

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exchange among stakeholders, ensuring seamless collaboration and integration across diverse systems and technologies. The BUC includes the following steps. 1. Registration & Prequalification Different flexible resources can qualify for the flexibility market. FSPs can request qualification when their assets meet market access requirements as defined by the SOs and the MO. If the prequalification is successful, the FSP becomes an approved FSP for the respective assets on the flexibility market. The FSP can now create offers on the flexibility market. If the prequalification is not successful, the FSP cannot register the assets nor create offers on the flexibility market. In this phase, it is also assumed that the SOs register on the market platform as buyers of flexibility. 2. Flexibility Trading In this phase, planning of grid utilisation and identifying potential grid issues is taking place. This implies that the SOs first need to forecast grid issues (BUC-GR-02), and then the available flexibility needs to be determined and pre-announced in the market platform. Only FSPs that are prequalified can submit bids to the LFM. Bids submission follows a predefined format. The FSP bidding strategies are defined through AI/ML algorithms in BUC-GR-01. The orders are evaluated based on the rule that grid issues should be resolved at the lowest possible cost. Furthermore, the grid operators coordinate with each other and prevent the market outcomes from causing or aggravating transport restrictions elsewhere in the grid. The market platform carries out the market clearing and informs the market parties involved and the grid operators of this fact. Dispatch instructions will be sent by the SOs after they have confirmed bid decisions. 3. Settlement & Remuneration Finally, when the services are delivered, based on respective baselines for the specific offers, and active metering systems, it is calculated how much the SOs need to pay to the FSP for flexibility delivery. As such, the delivered flexibility is remunerated.

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
Prerequisites

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Linked to BUC-GR-01: • Evaluates the SO's request through AI. • Decides whether to offer flexibility service

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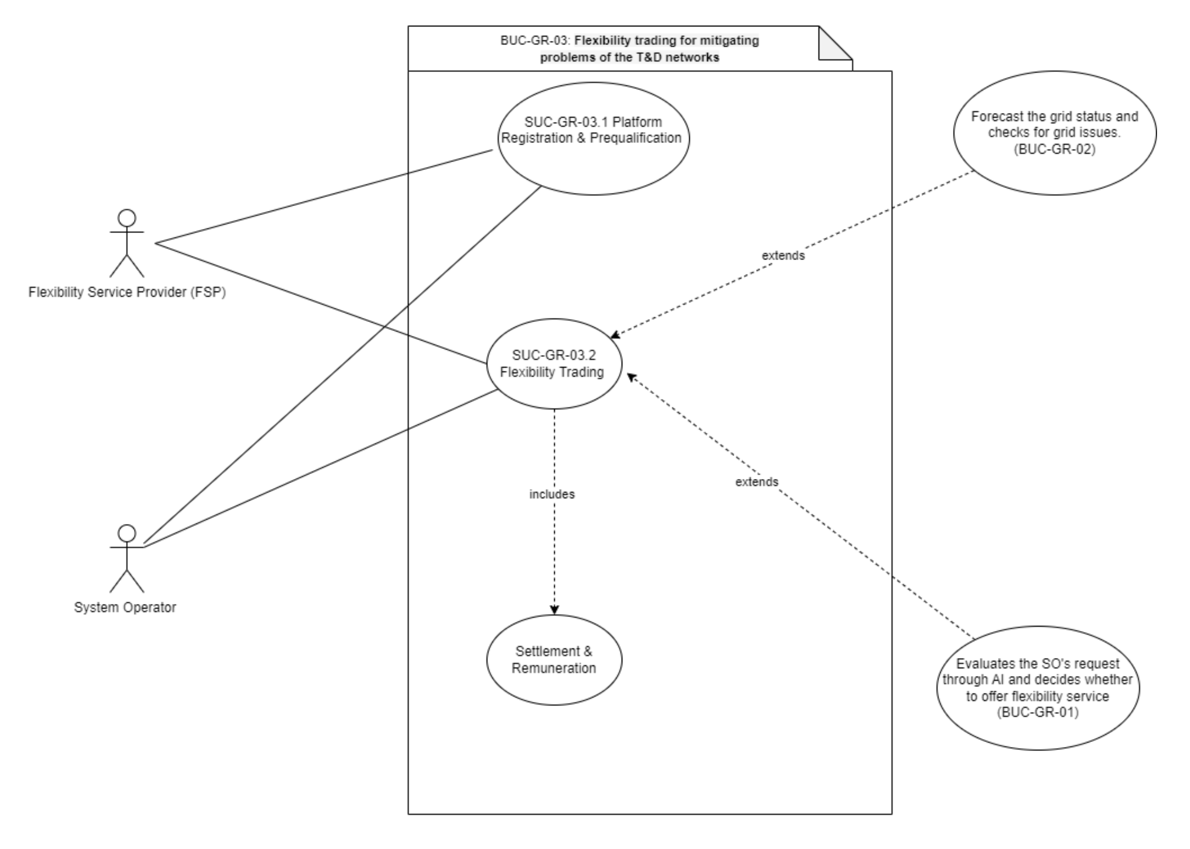
Linked to BUC-GR-02: • Performs grid analysis to identify grid issues. • Calculates required flexibility to mitigate grid issue.
Level of depth
General
Prioritisation
High
Generic, regional or national relation
Generic
Nature of the use case
Business Use Case: information sharing and referring information for flexibility transactions between actors
Further keywords for classification
Local flexibility market, market operator, flexibility trading

1.8 General Remarks

General Remarks

2 Diagrams of use case

Diagram(s) of use case



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3 Technical details

3.1 Actors

Actors			
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***
System Operator	Business Actor	System Operators join the local flexibility market to request and purchase flexibility from the flexibility providers.	
Flexibility Service Provider	Business Actor	Flexibility Service Provider joins the flexibility market and registers their clients (prosumers/consumers) assets to offer and sell flexibility.	
Registration Layer	Logical Actor	The service for prequalification of assets and participants	
Local Flexibility Market	Logical Actor	The market for flexibility trading	

3.2 References

References						
No.	***Reference Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc.1	Flexibility Service Provider participation on the LFM platform	In this scenario, we present the whole cycle of FSP participation in the LFM platform from registration to settlement	FSP	FSP visits platform's authorization page	The FSP is legal entity that serves the prequalification requirements of the LFM	The FSP has physically delivered the traded flexibility
Sc.2	System Operator participation on the LFM platform	In this scenario, we present the whole cycle of SOs participation in the LFM platform from registration to settlement	SO	SO visits platform's authorization page	The SO is a legal entity that serves the prequalification of the LFM	The SO has solved the identified grid issues

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4.2 Steps – Scenarios

Scenario								
Scenario name:		Sc. 1 - Flexibility Service Provider participation on the LFM platform						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St.1	FSP request registration for participating in the LFM	Send registration information	The FSP sends the company's information to register into the LFM	GET	FSP	Registration Layer	Inf.1	GDPR.1, GDPR.2, GDPR.3, GDPR.4, R.1, R.2, R.5, R.6, R.7, R.8 R.12 R.11
St.2	Registration Layer request prequalification	Request prequalification	The Registration layer request for further prequalification	REPORT	Registration Layer	FSP	Inf. 3	R.1, R.2, R.5, R.6, R.7, R.8, R.14 R.12
St.4	FSP send prequalification assets	Send assets information for prequalification	The FSP sends their assets information to be assessed for prequalification	GET	FSP	Registration Layer	Inf.4	GDPR.1, GDPR.2, GDPR.3, GDPR.4, R.1, R.2, R.5, R.6, R.7, R.8, R.14 R.12
St.5	Registration Layer forward FSP's assets data	Forward assets information for prequalification	The registration layer forwards the assets data of the FSP to SO in order to assess them	GET	Registration Layer	SO	Inf.4	GDPR.1, GDPR.2, GDPR.3, GDPR.4, R.1, R.2, R.5, R.6, R.7, R.8, R.14 R.12
St.6	SO, accesses FSP's assets	Sends response for assets' prequalification	SOs send their assessment on the FSP's assets to the Registration Layer	EXECUTE	SO	Registration Layer	Inf.5	R.1, R.2, R.5, R.6, R.7, R.8, R.14 R.12
St.7	Assets are approved by SOs for flexibility offers	Send success reply for prequalification	The Registration Layer notifies FSP on their successful prequalification	REPORT	Registration Layer	FSP	Inf.6	R.1, R.2, R.5, R.6, R.7, R.8, R.14
St.8	FSP partakes on LFM	FSP bids on a flex request	The FSP bids on flex request after evaluation	GET	FSP	LFM	Inf. 8	R.1, R.2, R.5, R.6, R.7, R.8, R.12, R.13, R.14

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St. 9	LFM trading	LFM Trading and return of market results	LFM executes trading algorithm and the returns the market results to FSP	EXECUTE	LFM	FSP	Inf. 9	R.1, R.2, R.5, R.6, R.7, R.8, R.12, R.13, R.14
St. 10	Settlement & Remuneration	LFM and SO execute settlement & remuneration process	LFM and SO calculating quantities and define prices for settlement	EXECUTE	LFM & SO	FSP	Inf.10	R.1, R.2, R.5, R.6, R.7, R.8, R.12, R.13, R.14

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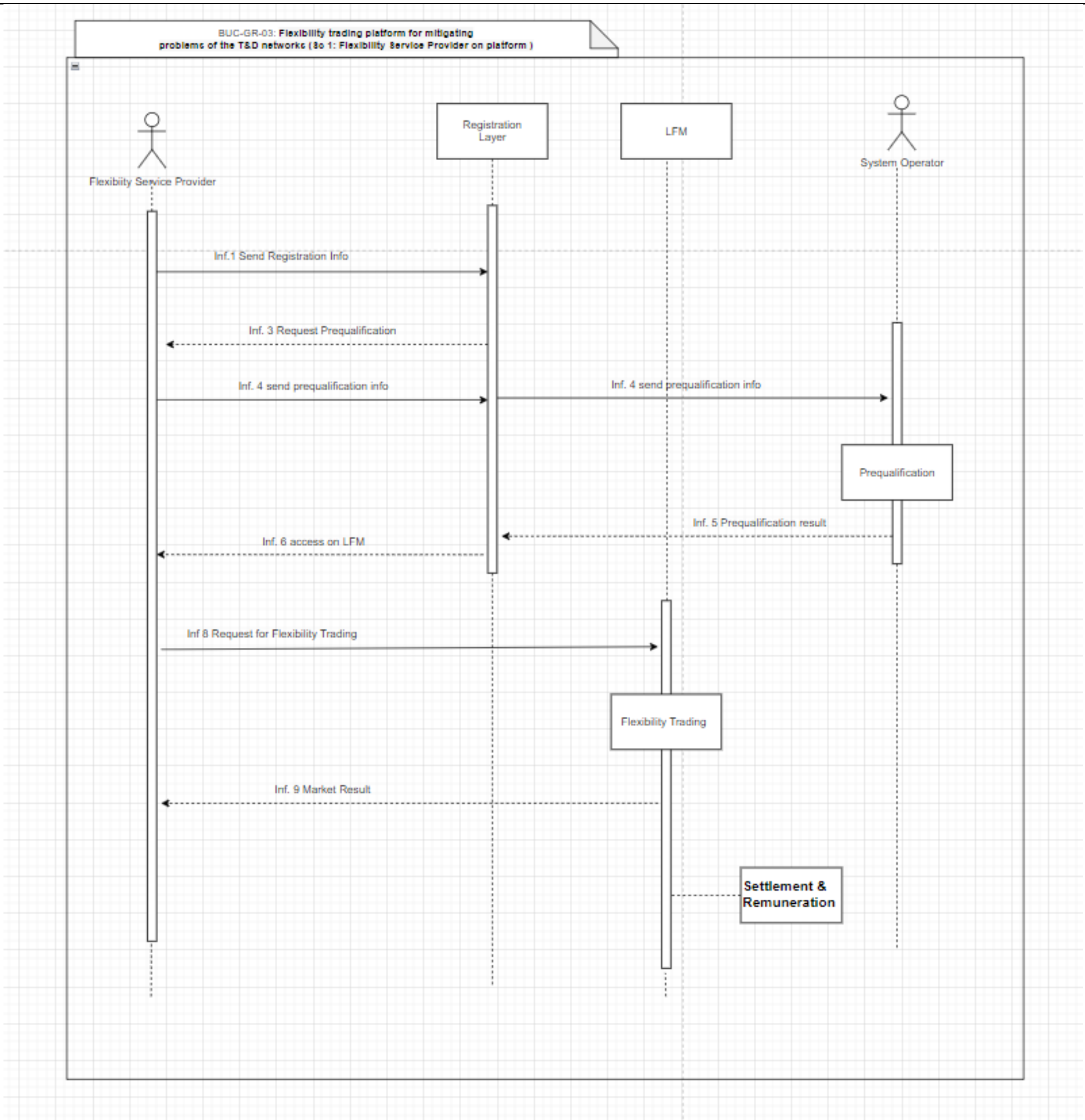

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Scenario								
Scenario name:		Sc. 2 - System Operator participation on the LFM platform						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St. 1	FSP request registration for participating in the LFM	Send registration information	The FSP sends the company's information to register into the LFM	GET	SO	Registration Layer	Inf.1	GDPR.1, GDPR.2, GDPR.3, GDPR.4, R.1, R.2, R.5, R.6, R.7, R.8 R.12 R.11
St.2	Registration Layer receives registration info by SO	Send Registration Approval	Registration layer receives information about SO and after evaluation sends approval	GET	Registration Layer	SO	Inf.2	R.1, R.2, R.5, R.6, R.7, R.8
St.3	SO request flexibility	Submit Flexibility Request	The SO after grid issue identification submits a flexibility request on the LFM	GET	SO	LFM	Inf. 7	R.1, R.2, R.5, R.6, R.7, R.8, R.12, R.13, R.14
St. 4	LFM trading	LFM Trading and return of market results	LFM executes trading algorithm and returns the market results to SO	EXECUTE	LFM	SO	Inf. 9	R.1, R.2, R.5, R.6, R.7, R.8, R.12, R.13, R.14
St. 5	Settlement & Remuneration	LFM and SO execute settlement & remuneration process	LFM and SO calculate quantities and define prices for settlement	EXECUTE	LFM & SO	FSP	Inf.10	R.1, R.2, R.5, R.6, R.7, R.8, R.12, R.13, R.14

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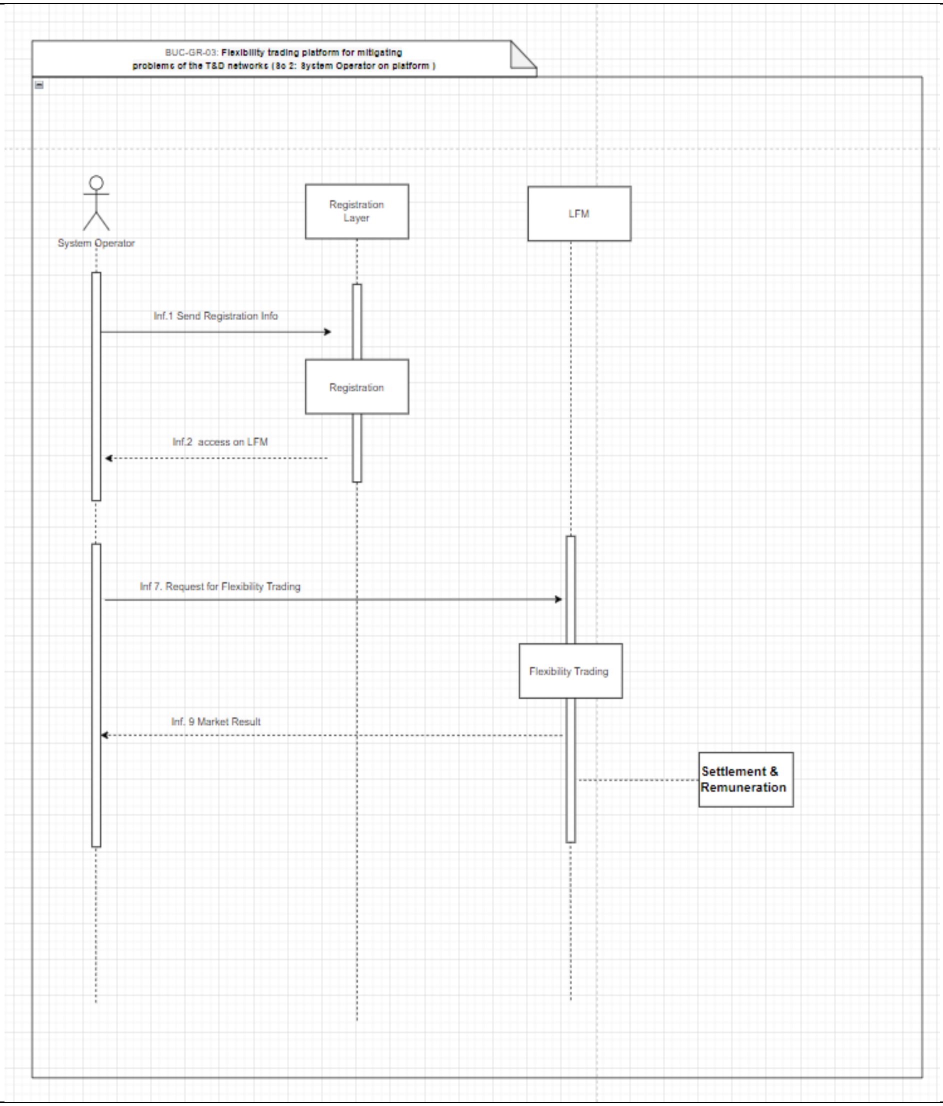

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5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
Inf. 1	Registration Information	Company's information and signature of online registration form	GDPR.1, GDPR.2, GDPR.3, GDPR.4, R.1, R.2, R.5, R.6, R.7, R.8 R.12 R.11
Inf.2	Registration approval message	Reply to a registration request (Inf.1) - a registration request will always be approved	R.1, R.2, R.5, R.6, R.7, R.8
Inf 3	Request for prequalification	Message declares the need for prequalification	R.1, R.2, R.5, R.6, R.7, R.8, R.14 R.12
Inf.4	Prequalification details	Technical information on assets	GDPR.1, GDPR.2, GDPR.3, GDPR.4, R.1, R.2, R.5, R.6, R.7, R.8, R.14 R.12
Inf.5	Result of the prequalification assessment	The results and details of the prequalification assessment	R.1, R.2, R.5, R.6, R.7, R.8, R.14 R.12
Inf.6	Successful prequalification notification	Positive notification to prequalification request	R.1, R.2, R.5, R.6, R.7, R.8, R.14
Inf. 7	Flexibility request	Bid submission by the SO	R.1, R.2, R.5, R.6, R.7, R.8, R.12, R.13, R.14
Inf. 8	Flexibility offer	Bid submission by the FSP	R.1, R.2, R.5, R.6, R.7, R.8, R.12, R.13, R.14
Inf. 9	Market Results	Trades details after flexibility trading	R.1, R.2, R.5, R.6, R.7, R.8, R.12, R.13, R.14
Inf. 10	Settlement & remuneration results	Details about settlement and remuneration	R.1, R.2, R.5, R.6, R.7, R.8, R.12, R.13, R.14

6 Requirements

Requirements		
Categories ID	**Category name for requirements**	**Category description**
GDPR	Regulatory obligation related to privacy	General Data Protection Regulation
Requirement R-ID	**Requirement name**	**Requirement description**
GDPR.1	Data processing consent	Personal data may not be processes unless there is at least one legal basis to do so.
GDPR.2	Data retention policy	The time period specific sensitive data can be retained and the method of their disposal when the defined time period ends.
GDPR.3	Right to access, rectify, erasure, restriction	The data subject shall have right to obtain from the controller without undue delay the access/rectification/erasure/restriction of inaccurate personal data concerning them.
GDPR.4	Data transfer consent	Personal data may not be transferred to a third party if the data subject does not agree, and the third party provide appropriate safeguard.
R.1	Contractual timelines for exchanging data is required	Quality of Service (QoS) issues Possible values: • Within 1 second • Within 1 minute

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		• Within 5 minutes • Within some longer time • No specific contractual timeliness is required
R.2	Frequency of data exchanges	QoS Possible values: • Essentially continuous • Every few milliseconds • Every few seconds • Periodicity greater than a few seconds • Upon event • Upon request • Random • Sparse • Other
R.3	Interoperability	The interoperability is essential for the different elements of the system to be able to communicate. Interoperability is provided by the interoperability layer.
R.4	Report of user wills	The decision of the end user on the usage of his devices should be respected.
R.5	Ensuring that data cannot be resent by an unauthorized source	Security Ensuring that data cannot be resent by an unauthorized source Possible values: • Crucial • Quite important • Not particularly important • Detection that a security violation was attempted is crucial • Other__
R.6	Correctness of source data	Data Management Issues Possible values: • Source data is always correct (e.g. by definition) • Source data is usually correct • Source data is often not correct (incorrectly entered, out of date, not available) • Source data is rarely correct • Correctness of source data is not relevant • Other
R.7	Management of data across organizational boundaries	Data Management Issues Possible values: • Data exchanges go across organizational boundaries • Data exchanges go across departmental boundaries • Data exchanges go across boundaries between system developed by different vendors • Data exchanges are within one vendor's system • Not relevant • Other
R.8	Management of data formats in data exchanges	Data Management Issues Possible values: • The same data exchanged between different applications have the same formats • Conversion of data formats is automatically handled by each application. • Conversion of data formats is handled by FSP • Conversion of data formats is handled by DSO • Conversion of data formats is handled by MO
R.9	Communication access services requirements	Configuration Issues Possible values:

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		• Any or all • Request-response • Periodic reporting • Report-by-exception • Control command • Select-before-operate • Set parameter values • Query for data by name • Subscribe • Broadcast • Multi-cast • Data discovery • Use of data sets • Query to find location of data • Query to determine what data is available (discovery) • Execute application • Establish and end association • Logging • Remote restart • Remote reconfiguration • Remote diagnosis • Other
R.10	Authentication: Masquerade and/or spoofing: Ensuring that data comes from the stated source or goes to authenticated receiver	Security Issues Possible values: • Crucial • Quite important • Not particularly important • Detection that a security violation was attempted is crucial • Other
R.11	Authentication and Access Control mechanisms commonly used with this data exchange	Security Issues Possible values • Private (secret) key encryption • Public key encryption (e.g. SSL/TLS) • Certificate • Shared secret • Access control through database security mechanisms • Bilateral data access control tables • Other
R.12	Validation of data exchanges	Data management issues Possible values • All data must be validated on each data exchange • Data must include quality codes to indicate its validity • Data from different sources must be validated against each other • Data mapping of data item names is required for data from different sources • Data can be assumed as valid (or validity checking is handled elsewhere) • Data is usually not validated • Validity of data is not relevant • Other
R.13	Management of accessing different types of data to be exchanged	Data management issues Possible values • Each data exchange could entail different types of data (e.g. query a database)

		• Numbers or types of data being exchanged are changed or updated every few minutes • Numbers or types of data being exchanged are changed or updated every few hours • Numbers or types of data being exchanged are changed or updated every few days or weeks • Numbers or types of data being exchanged are rarely changed or updated • Not relevant • Other ___
R.14	Replay Ensuring that data cannot be resent by an unauthorized source.	Security issues Possible values: • Quite important • Not particularly important • Detection that a security violation was attempted is crucial

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
FSP	Flexibility Service provider
SO	System Operator
LFM	Local Flexibility Market

BUC-IT-01 ENERGY FLOW OPTIMISATION WITH DYNAMIC GRID LIMITS

1 Description of the use case

1.1 Name of the use case

ID	*Area / Domain(s) / Zones(s)*	*Name of Use Case*
BUC-IT-01	Energy Community	Energy flow optimisation with dynamic grid limits

1.2 Version management

Version Management			
Version No.	*Date*	*Name of Author(s)*	*Changes*

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Optimize the real time energy flow in an Energy Communities considering the dynamic local grid constraints
Objective(s)	From the Energy Communities - Perform the tool for energy flow using the dynamic grid constraints. From the DSO – Detect the real time grid constraints.

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Related business case(s)	

1.4 Narrative of use case

Narrative of Use Case
Short description
The Energy Communities (ECs) maximize the self-consumption between producers and consumers located in a limited area of the distribution grid (e.g. primary substation). To optimize the energy sharing and the benefits of the participants, when the producers inject energy into the grid the consumers have to increase the loads. This coordination mechanism, unconsidered into traditional distribution grid design, could bring network capacity closer to the technical limits stressing the network. The ECs are a pillar of the European energy transition, so their huge spread, expected in the next years, will have a great impact on the local network, that will need to be managed. The solution aims to face cases where the participants joined in the EC are concentrated in a point of the grid (e.g. secondary substation, feeder low voltage, Low Voltage cabinet), and the coordination of the loads or the productions could achieve the network limit. To avoid these issues the DSO runs the grid simulation and detects the local grid constraints. The information is shared in real time with the EC manager, that optimizes the energy flows defining the set points in compliance with thresholds defining by DSO.
Complete description
The Use Case detects the real-time limits of the distribution grid and the timely communication them to the Energy Community Manager, in order to integrate this data in the optimization of energy flow in the community. The ECs, involved in the pilot, are connected to the urban distribution grid and are based on virtual model. The phases identified to implement the use case are: **Communication of the EC's users ➔** The EC manager sends to Flexibility Register the localization and characterization of the users involved in the EC. The dataset encompass: Point of Delivery (PoD) code, geographical coordinates, voltage level, consumer or producer, poverty condition, etc. These data will be updated upon event. **Users Localization ➔** The DSO acquires the data from the Flexibility Register and <u>localized the users on its network</u>. identifying their <u>concentration per electrical node</u> (e.g. secondary substation, LV feeder, counters). **Detect of the real time grid limits ➔** leveraging on updated grid topology, weather forecasts and measurements coming from sensors in the field, the DSO runs <u>the tools to foresee the productions and consumptions</u> in the short term, detecting possible network congestion. To avoid outages, the DSO runs the <u>OPF algorithm</u> and evaluates the grid limits per PODs fed by the portion of the network involved into the congestion. **Sending real time grid limits to the PGUI ➔**The DSO broads the grid limits to Power Grid User Interfaces (PGUIs), devices installed in the customer property interfaced with the DSO systems. The PGUI acquires the technical information (range and duration) and <u>sends it to the Energy Community Platform</u>. **Set point Optimization ➔** The Energy Community Platform receives the grid limits per PoD and defines the set-points to performs the energy exchange in the community. **Measurements and checking ➔**The Flexibility Register acquires from the PGUIs the real time measurements and real time grid limits, so it runs the <u>algorithms to test the persistency and the quality of the information</u> and finally sends the measurements to DSO that performs the checking, through a proper KPI.

1.5 Key performance indicators (KPI)

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ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
Prerequisites

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Level of depth
Prioritisation
Generic, regional or national relation
Nature of the use case
Further keywords for classification

1.8 General Remarks

General Remarks

2 Diagrams of use case

Diagram(s) of use case

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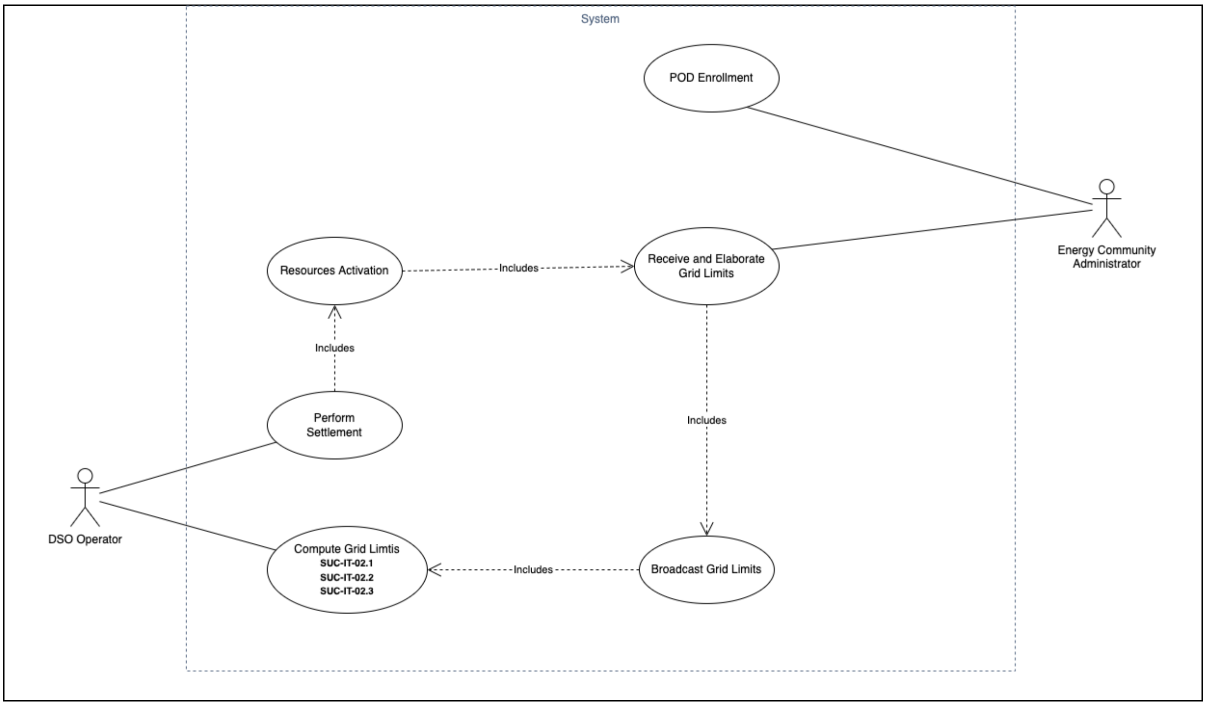

3 Technical details

3.1 Actors

Actors			
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***
DSO	Business Role (HEMRM)	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of energy	
Flexibility Register Operator	New	Administrator of all the information that is stored in the Flexibility Register. Responsible for allocating access rights to the various actors and controlling the level of access. Stores flexibility assets, results of qualification (both product and grid), stores market results, grid information, aggregates flexibility information and stores the results of the settlement. Forwards activation signals to flexibility assets upon request of the SOs. The Flexibility operator should be a trusted authority due to the sensitivity level of the information being handled	
Party Connected to the Grid	Business Role (HEMRM)	A party that contracts for the right to take out or feed in energy at a Point of Delivery (PoD).	
Consumer	Business Role (HEMRM)	A party that consumes energy.	
Producer	Business Role (HEMRM)	A party that generates electricity.	

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Energy Community Manager	New	A party offering energy management services to the Party Connected to Grid, but not directly active in the energy value chain or the physical infrastructure itself.	

3.2 References

References						
No.	***Reference Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc. 1	Enrolment	Enrolling Energy Community Resources in Local Flexibility Services	Energy community	Registration of resources to the local market	Willingness of customers in the energy community to participate in the market	Registration of resources in the market and notification to the DSO
Sc. 2	Dispatch Grid Limits	DSO identifies network limits and communicates them to flexible resources	DSO	Short-term network simulation	Regulating list of resources available for limitation	Dispatch of the set point on flexible community resources.
Sc. 3	DSO check	DSO verifies performance and measures	DSO	Receipt of the measure	Activation of the resource in the market	Verification of dispatched limits

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4.2 Steps – Scenarios

Scenario								
Scenario name:	Sc. 1 – Enrolment							
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St. 1	BSP Operator participate to the market	Resource Registration	BSP Operators register their customers on the Flexibility Register	CREATE	BSP Operator		Inf.1	
St. 2	FR Receives resources	Resources Propagation	Flexibility Register broadcasts information to the interested services	REPORT			Inf.1	
St. 3	ADMS receives resources	Resource Grid Pairing	The DSO platform pairs reported resources with its own resources	EXECUTE	DSO operator	DSO operator	Inf.1	

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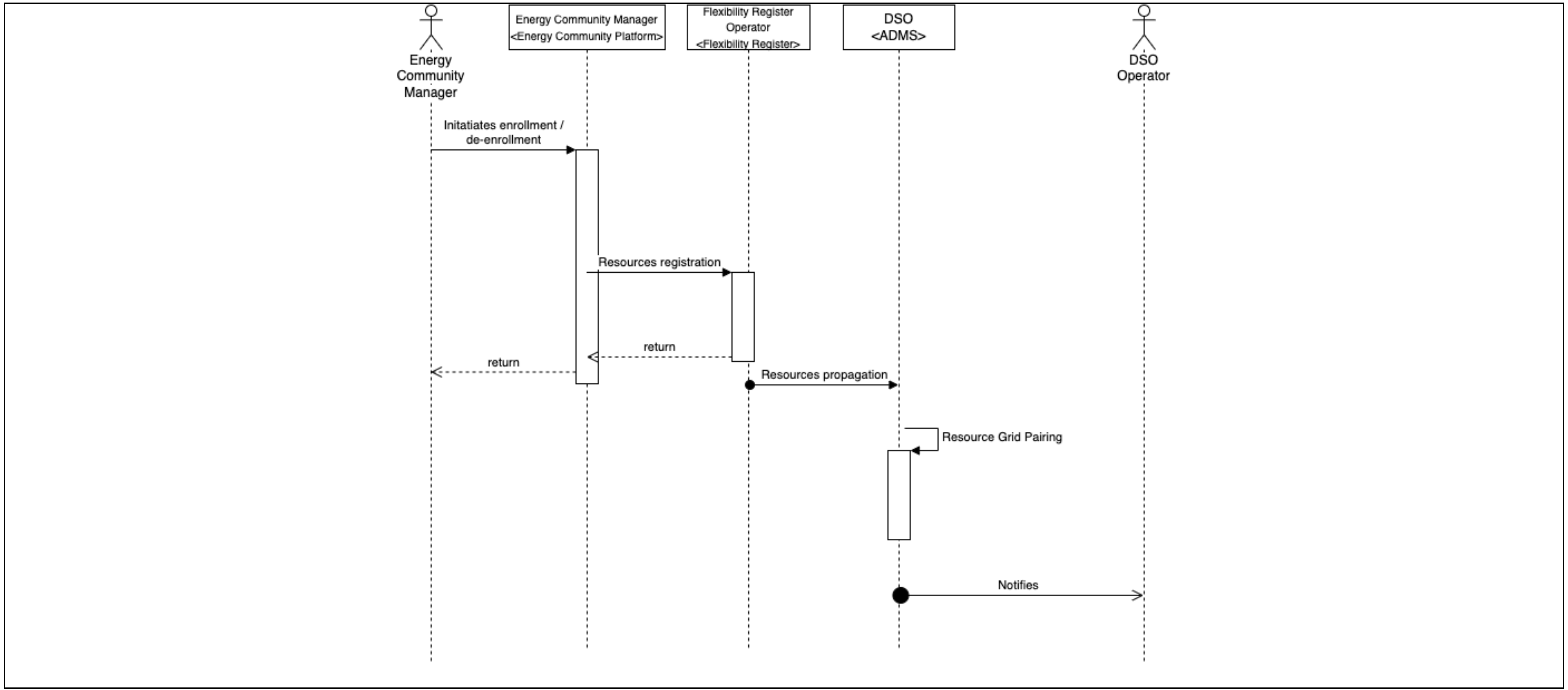

Scenario								
Scenario name:		Sc. 2 - Dispatch Grid Limits						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St. 1	Scheduled	Updates Grid topology	The DSO Platform updates its grid topology	GET	DSO operator	DSO operator	Inf.2	
St. 2	Scheduled	Receives	The DSO Platform updates its weather	GET	DSO operator	DSO operator	Inf.3	

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		Weather Forecasts	forecasts					
St. 3				REPEAT(1-3)				
St. 4	Scheduled	Performs Load and Production Forecasting	The DSO Platform updates its load and production forecasts	EXECUTE	DSO operator		Inf.2, Inf.3, Inf.6	
St. 5	Step 4 is completed	Grid Congestion computing	The DSO Platform computes potential Grid Congestions	EXECUTE	DSO operator		Inf.4	
St. 6	Step 5 detects grid congestion	Optimal power flow	The DSO Platform computes the optimal power flow	EXECUTE	DSO operator		Inf.4	
St. 7	Step 6 is completed	Computes Grid Limits	The DSO Platform computes the grid limits	EXECUTE	DSO operator		Inf.4	
St. 8	Steps 6 and 7 are completed	Updates Grid Limits	The DSO Platform computes the optimal power flow taking grid limits into account then shows the results to an operator for confirmation	REPORT	DSO operator		Inf.4	
St. 9	Step 8 is completed	Confirms Grid Limit	The DSO Operator confirms the Platforms' proposal and greenlight limit dispatching	CREATE	DSO operator		Inf.4	
St. 10	Step 9 is completed	Dispatches Grid Limits	The DSO Platform dispatches thw new grid limits to the Blockchain access layer (BAL), formalizing DSO's needs.	REPORT	DSO operator		Inf.4	
St. 11	Data from step 10 is received	Dispatch grid limits to PGUIs	The BAL dispatched the new grid limits to PGUIs	REPORT	DSO operator		Inf.4	
St. 12	Acknowledge from step 11 is received	Dispatch grid limits to EC PODs	The BAL dispatches grid limits to the Energy Community Platform(s)	REPORT	DSO Operator	EC Admin	Inf.4	
St. 13	Data from step 12 is received	Compute setpoints	The Energy Community Platform computes the setpoints to apply to its DERs to satisfy DSO's request	CREATE	EC Admin		Inf.5	
St. 14	Step 13 is completed	Dispatch setpoints	Setpoints are dispatched to DERs	REPORT	EC Admin	Party Connected to the Grid	Inf.5	
St.				REPEAT(4-15)				

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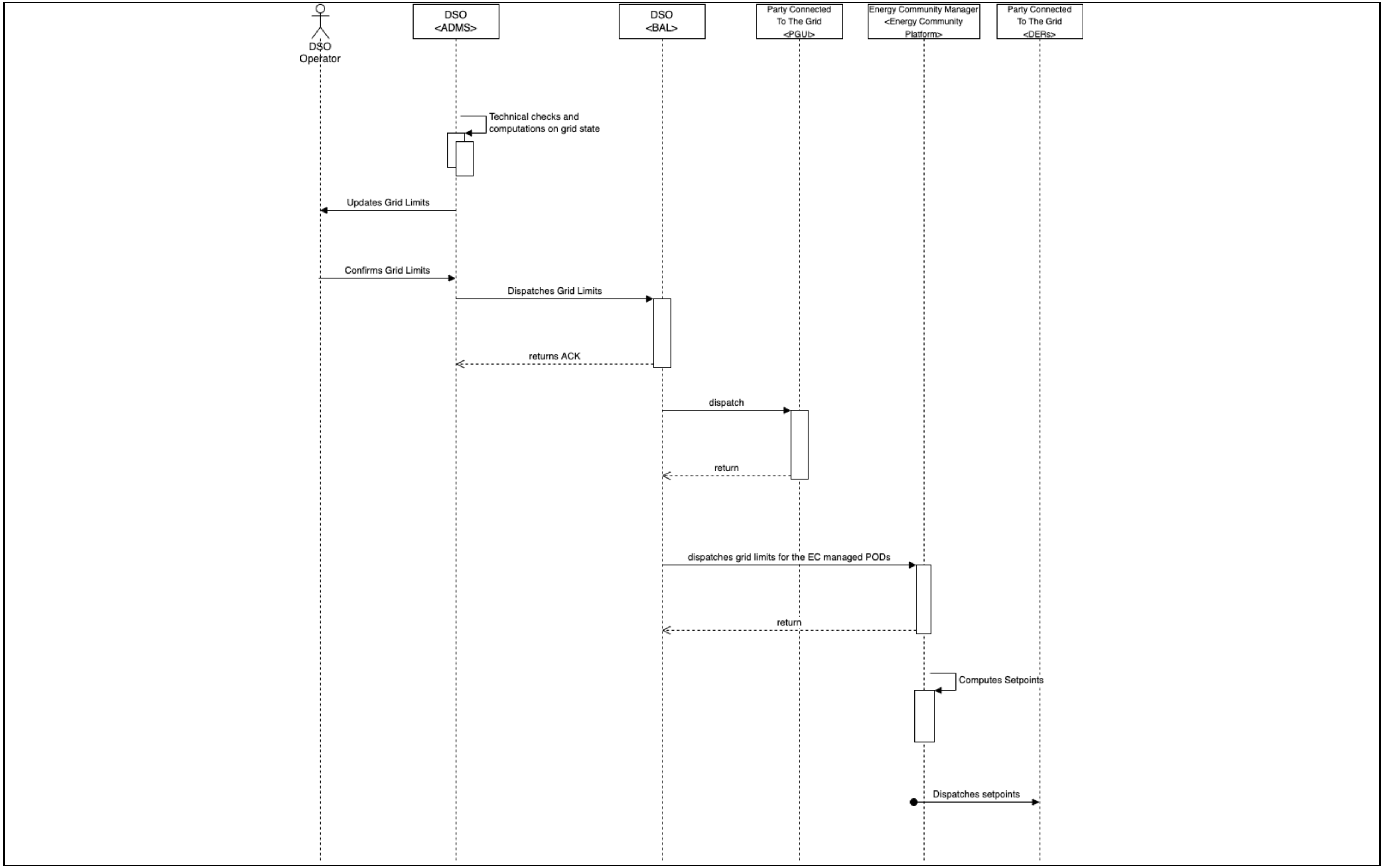
DSO Operator
DSO <ADMS>
DSO <BAL>
Party Connected To The Grid <PGU>
Energy Community Manager <Energy Community Platform>
Party Connected To The Grid <DERs>
Technical checks and computations on grid state
Updates Grid Limits
Confirms Grid Limits
Dispatches Grid Limits
returns ACK
dispatch
return
dispatches grid limits for the EC managed PODs
return
Computes Setpoints
Dispatches setpoints

Scenario								
Scenario name:		Sc. 3 - DSO Check						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St. 1	DSO Grid limits are applied	Sends signed measurements	PGUIs sends signed measurements to the Blockchain Access Layer (BAL) confirming that DSO Grid Limits are applied	REPORT	DSO Operator		Inf.6	
St. 2	Data from step 1 is received	Verifies signatures	The BAL verifies the signatures from the received measurements	EXECUTE	DSO Operator		Inf.6	
St. 3	Step 2 is completed	Notarized measurements	The BAL notarized the measurements via blockchain publication	EXECUTE	DSO Operator		Inf.6	
St. 4	Step 3 is completed	Dispatches measurements	The BAL notifies the measurements dispatching them to the Flexibility Register	REPORT	DSO Operator	Flexibility Register operator	Inf.6	
St. 5	Data from step 4 is received	Performs sanity checks	Flexibility Register Performs Data quality Checks	EXECUTE	Flexibility Register operator		Inf.6	
St. 6	Step 5 is completed	Dispatched measurements	The Flexibility Register dispatches the validated measurements to the DSO Platform	REPORT	Flexibility Register operator	DSO Operator	Inf.6	
St. 7	Data from step 6 is received	Verified dispatched limits	The DSO Platform verifies the received measures against the request created to avoid congestion	EXECUTE	DSO Operator		Inf.6, Inf.4	
St. 8	Step 7 is completed	Acknowledges dispatched limits	The DSO Platform presents measures reconciliation to the DSO operator for acknowledgement.	REPORT	DSO Operator		Inf.6, Inf.4	

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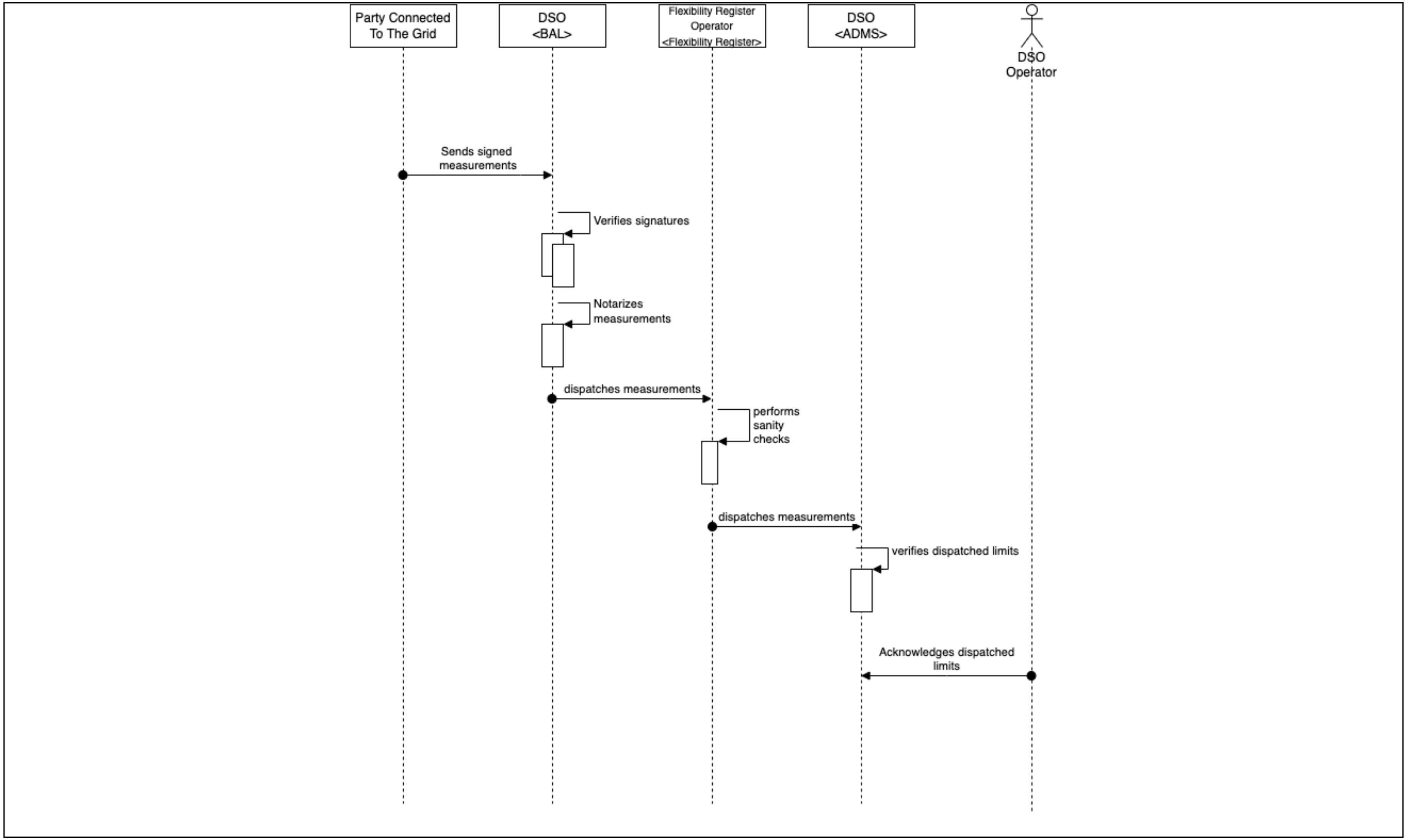

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5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
Inf.1	Resource Anagraphic	Information about the POD	
Inf.2	Grid topology	A subset of the entire grid topology, either as substations, lines, or asynchronous change notifications	
Inf.3	Weather forecast	Localized weather forecast with sufficient granularity to be able to predict generation from renewable DERs	
Inf.4	DSO Activation	Technical parameters (power)	
Inf.5	BSP Setpoint	Technical parameters (power)	
Inf.6	Measurements	Electrical measurements	

6 Requirements

Requirements		
Requirement R-ID	**Requirement name**	**Requirement description**

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
Setpoint	Target Power values for any Distributed Energy Resource

BUC-IT-02 FLEXIBILITY PROVIDED BY ENERGY COMMUNITY TO SOLVE A LOCAL CONGESTION

1 Description of the use case

1.1 Name of the use case

ID	***Area / Domain(s) / Zones(s)***	***Name of Use Case***
BUC-IT-02	Distribution Grid & Flexibility Service Provider Platform	Flexibility provided by Energy Community to solve a local congestion

1.2 Version management

Version Management			
Version No.	***Date***	***Name of Author(s)***	***Changes***
1	25.03.2024	Gabriele Fedele	First version of the draft
2	21.05.2024	Gianluca Nori	Review and update

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1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Solving a local congestion issue acquiring flexibility provided by Energy Communities, through market approach.
Objective(s)	Provide flexibility to DSO. Ensure an inclusive and non-discriminatory access to the market.
Related business case(s)	BUC-IT-01

1.4 Narrative of use case

Narrative of Use Case
Short description
The electrification of the transport and heating sectors pose a great challenge for DSOs. The switch to heat pumps, electric vehicle (EV) charging stations, photovoltaic (PV) systems and residential batteries significantly increases energy demand on the network. In this scenario, the local feeders could be temporarily overloaded and exposed to power outages, jeopardising security of supply. To avoid these issues, the DSO can acquire flexibility from the Distributed Energy Resources (DERs) connected to its grid through a market approach. Indeed, the local flexibility market implemented in the use case treats the short-term sessions and the phases of procurement, activation and settlement. However, the focus will be the flexibility provided by the Energy Communities (ECs), optimized by Flexibility Service Provider (FSP) platform, with attention of vulnerable users, focalizing on the despatching algorithm (till Behind the Meter devices) and on the value stacking.
Complete description
The Use Case describes the main steps to solve local congestion issue, exploiting flexibility provided by the ECs and implementing the market phases (procurement, activation and settlement) foreseen in the short-term market. The use case also foresees the possibility for vulnerable end-users to optimizes the energy position co-participating on EC and flexibility market. This process will be possible through the figure of the FSP or Energy Community manager. The phases identified to implement the use case are: **Communication of the EC's users:** The FSP (or Flexibility Service Provider FSP) or EC manager, qualified as Flexibility Provider, sends to Flexibility Register the localization and characterization of the users involved in the EC. The dataset encompass: Point of Delivery (PoD) code, geographical coordinates, voltage level, consumer or producer, poverty condition, etc. These data will be updated upon event; In this phase we will put the attention to identify vulnerable characteristics. **Users Localization and checking:** The DSO acquires the data from the Flexibility Register and localized the users on its network, identifying their concentration per electrical node (e.g. secondary substation, LV feeder, counters). Moreover, the DSO, for any resources, checks the data and shares the outcomes to Flexibility Register (validation check). **Enrolling of the EC in the flexibility market:** The Flexibility Register sends the DSO validation results per PODs and the baselines to FSP or Energy Community manager. **Detect of the local congestions:** Leveraging on updated grid topology, weather forecasts and measurements coming from sensors in the field, the DSO runs the tools to foresee the productions and consumptions in the short term, detecting possible network congestions. **Sending of flexibility requests to Market platform:** The DSO sends the flexibility requests to Market Platform, that opens the market session and forwards them to FSP or EC manager.

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Sending of flexibility offers to Market Platform: The FSP or EC manager, acquires the requests, performs the algorithms to optimize the dispatching and sends the flexibility offers to Market platform. Through a tool in FSP Platform, the FSP can perform an algorithm to maximize the value for a defined set of vulnerable end user in the Energy Community. In FSP platform is also performed the forecast of available flexibility, whit customers habits, weather forecast and flexible assets real time measurements. **Market clearing:** The Market Platform matches flexibility offers and requests and define a merit order list. The outcomes are shared with DSO and FSP or EC manager. **Local reserve building:** The DSO receives the awarded offers from the market and built a reserve for the activation phase. **Activation Order:** The DSO sends the activation order to the EC manager. **Set point Optimization**: As outcome of previous algorithm and flexibility request, FSP platform receive the activation orders, reaggregate them and defines the set-point (for PoDs and for behind the meter flexible assets) to performs the energy exchange in the community. **Sending of set-point to the PGUI**: The FSP or EC manager receives the activation order and sends the set-points to DSO that forwards them to Power Grid User Interfaces (PGUIs), devices installed in the customer property interfaced with the DSO systems. The PGUI acquires the set point (range and duration) and makes it available to the flexibility assets. **Measurements and Validation:** The Flexibility Register acquires from the PGUIs the real time measurements and activation orders, after runs the algorithms to test the persistency and the quality of the information. **Settlement: T**he Market Platform acquires the measurements from the Flexibility Register and calculates the difference with the baseline.

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
Prerequisites

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Level of depth
Prioritisation
Generic, regional or national relation

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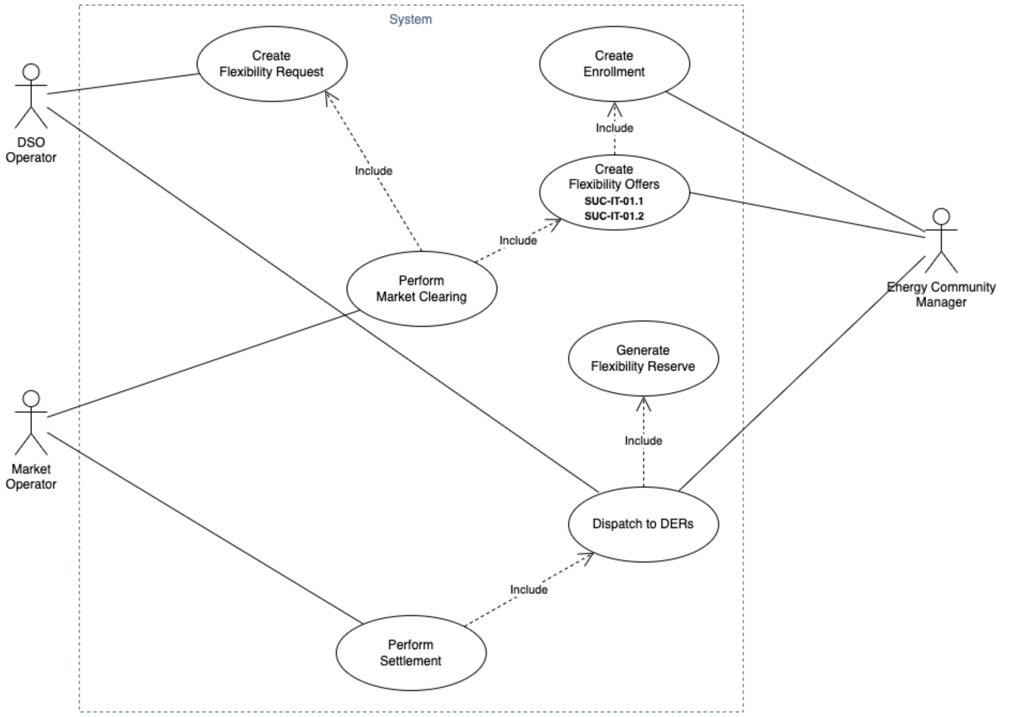
Nature of the use case
Further keywords for classification

1.8 General Remarks

General Remarks

2 Diagrams of use case

Diagram(s) of use case



3 Technical details

3.1 Actors

Actors			***Further information specific to this use case***
Actor Name	***Actor Type***	***Actor Description***	
DSO	Business Role (HEMRM)	A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term	

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		ability of the system to meet reasonable demands for the distribution of energy	
Flexibility Register Operator	New	Administrator of all the information that is stored in the Flexibility Register. Responsible for allocating access rights to the various actors and controlling the level of access. Stores flexibility assets, results of qualification (both product and grid), stores market results, grid information, aggregates flexibility information and stores the results of the settlement. Forwards activation signals to flexibility assets upon request of the SOs. The Flexibility operator should be a trusted authority due to the sensitivity level of the information being handled	
Flexibility Service Provider	Business Role (HEMRM)	A party that offers flexibility services based on acquired (aggregated) Resources.	
Market Operator	Business Role (HEMRM)	A party that provides a service whereby the offers to sell energy are matched with bids to buy energy.	
Party Connected to the Grid	Business Role (HEMRM)	A party that contracts for the right to take out or feed in energy at an Point of Delivery (PoD).	
Consumer	Business Role (HEMRM)	A party that consumes energy.	
Producer	Business Role (HEMRM)	A party that generates electricity.	
Energy Community Manager	New	A party offering energy management services to the Party Connected to Grid, but not directly active in the energy value chain or the physical infrastructure itself.	
Customer	Business Role (HEMRM)	A party enrolled by FSP to participate to Flexibility Market and/or Energy Community	
Balance Service Provider	Business Role (HEMRM)	A party with reserve-providing units or reserve-providing groups able to provide balancing services to one or more LFC Operators.	

3.2 References

References						
No.	***Reference Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**

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Sc. 1	Enrolment	Mechanism of resource involvement within the market	FSP	Flexibility Market Adhesion	Engagement of resources by the FSP	Shared and actionable resources between DSO and FSP
Sc. 2	Procurement	Procurement of flexible resources by the DSO, using a market approach through a forecast of technical operational parameters	DSO	Definition of flexibility requirements	Availability of resources and offering by FSP	Sharing the market result between DSO and FSP
Sc. 3	Activation	Activation and use of negotiated flexibility resources	FSP - DSO	Network conditions planning short casts	Availability of negotiated resources	Timely activation of resources
Sc. 4	Settlement	Control and enhancement of flexibility performance (energy moved and SLA)	Market Operator	Planning Definition	Availability of measures	Sharing market results

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4.2 Steps – Scenarios

Scenario								
Scenario name:	Sc. 1 - Enrolment							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St. 1	FSP Operator participate to the market	Resource Registration	FSP Operators register their customers on the Flexibility Register	CREATE	FSP Operator		Inf.1	
St. 2	FR Receives resources	Resources Propagation	Flexibility Register broadcasts information to the interested services	REPORT			Inf.1	
St. 3	ADMS receives resources	Resource Grid Pairing	The DSO platform pairs reported resources with its own resources	EXECUTE	DSO operator	DSO operator	Inf.1	

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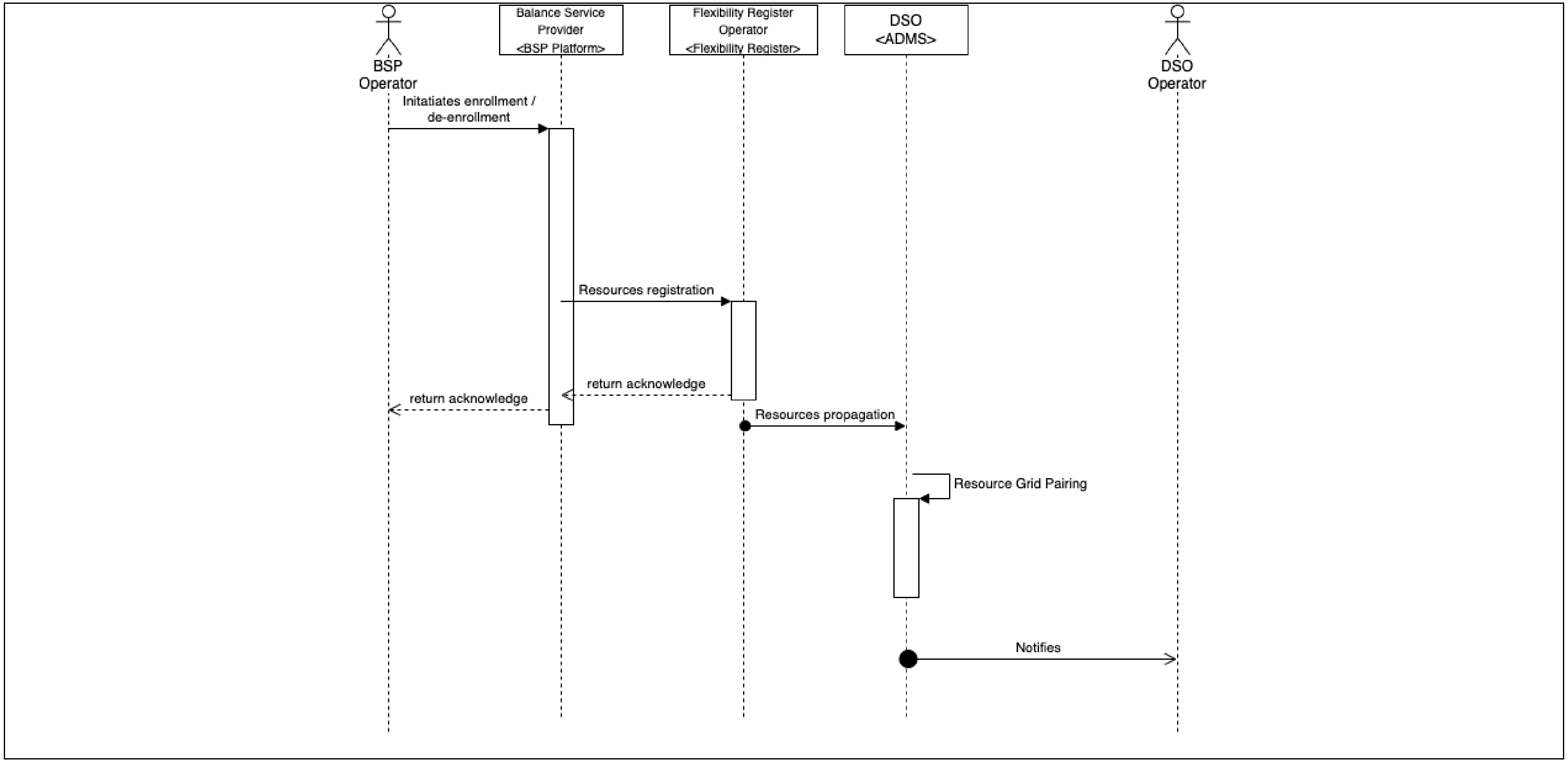

Scenario								
Scenario name:		Sc. 2 - Procurement						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**

St. 1	Scheduled	Grid Topology Update	The DSO Platform updates its grid topology	EXECUTE		DSO Operator		
St. 2	Scheduled	Weather Forecasts Computation	The DSO Platform updates its weather forecasts	EXECUTE		DSO Operator		
St. 3	Scheduled	Load And Production Forecasts Computation	The DSO Platform updates its load and production forecasts	EXECUTE		DSO Operator		
St. 4	Scheduled	Grid Congestion Computation	The DSO Platform computes potential Grid Congestions	EXECUTE		DSO Operator		
St. 5	Potential Grid Congestion are found	Flexibility Requirements Definition	The DSO Platform defines flexibility requirements to solve potential grid congestions	CREATE	DSO Operator		Inf.2	
St. 6	Grid congestions are computed	Flexibility requests publication	Publishes flexibility requests	REPORT	DSO Operator		Inf.2	
St. 7	Flexibility requests are defined	Flexibility Requests Propagation	Propagates flexibility requests	REPORT			Inf.2	
St. 8	FSP Platform received flexibility requests	Flexibility Offers Computation	The FSP Platform computes offers	CREATE			Inf.3	
St. 9	Flexibility offers are computed	Flexibility Offers Publication	The FSP Platform publishes offers on the Market Platform	REPORT	FSP Operator		Inf.3	
St. 10	Scheduled	Market Clearing	The Market Operator performs market clearing	CREATE	Market Operator		Inf.4	
St. 11	Scheduled	Market Outcome dispatch	The Market Operator publishes market outcome to actors	REPORT	Market Operator	DSO Operator FSP Operator	Inf.4	

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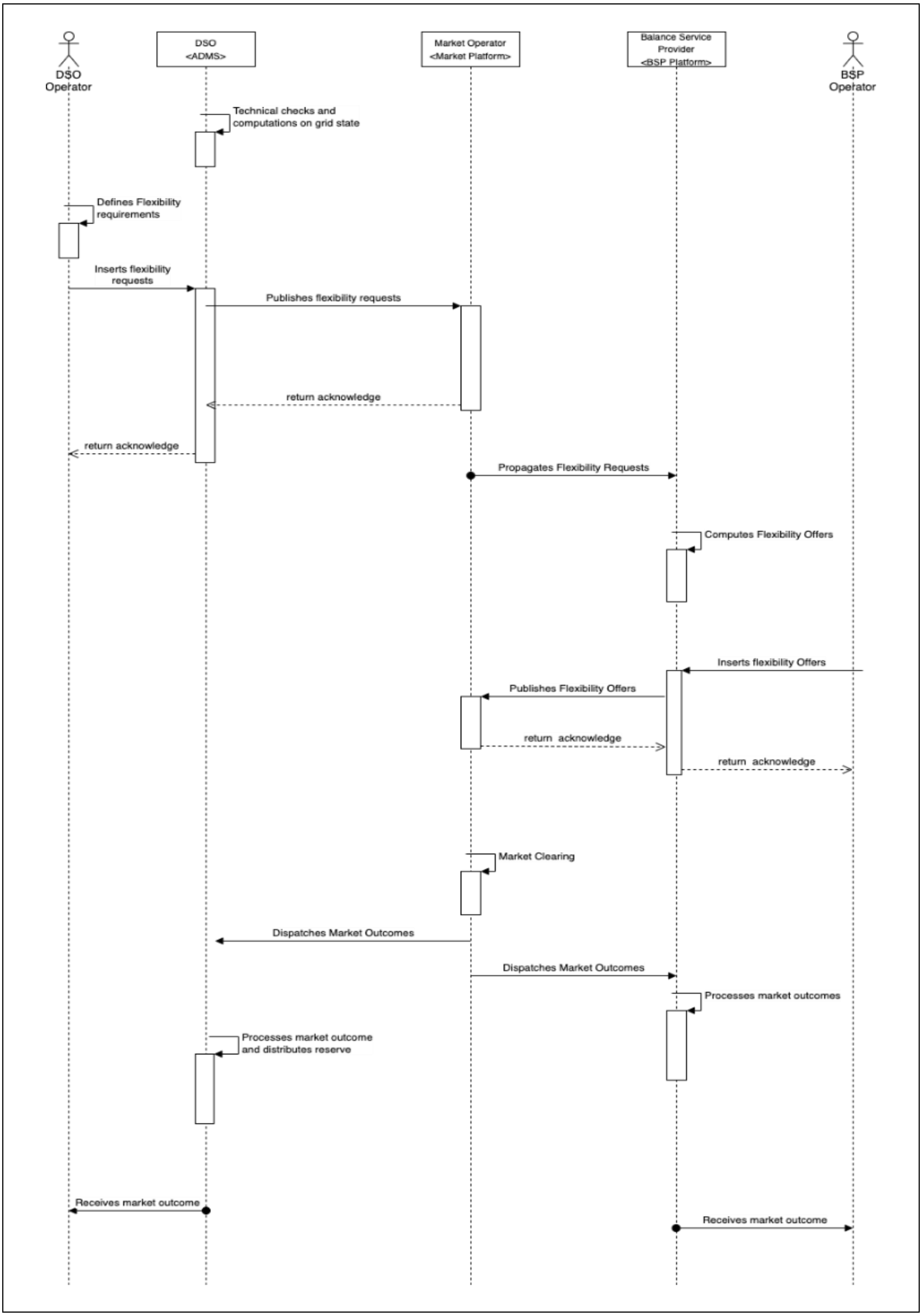
DSO Operator
DSO <ADMS>
Market Operator <Market Platform>
Balance Service Provider <BSP Platform>
BSP Operator
Technical checks and computations on grid state
Defines Flexibility requirements
Inserts flexibility requests
Publishes flexibility requests
return acknowledge
return acknowledge
Propagates Flexibility Requests
Computes Flexibility Offers
Inserts flexibility Offers
Publishes Flexibility Offers
return acknowledge
return acknowledge
Market Clearing
Dispatches Market Outcomes
Dispatches Market Outcomes
Processes market outcomes
Processes market outcome and distributes reserve
Receives market outcome
Receives market outcome

Scenario								
Scenario name:	Sc. 3 - Activation							
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St. 1	Scheduled	Grid Topology Update	The DSO Platform updates its grid topology	EXECUTE		DSO Operator		
St. 2	Scheduled	Weather Forecasts Computation	The DSO Platform updates its weather forecasts	EXECUTE		DSO Operator		
St. 3	Scheduled	Load And Production Forecasts Computation	The DSO Platform updates its load and production forecasts	EXECUTE		DSO Operator		
St. 4	Scheduled	Grid Congestion Computation	The DSO Platform computes potential Grid Congestions	EXECUTE		DSO Operator		
St. 5	Grid Congestion are found	Activation Order Computation	The DSO Platform computes the actual activations to perform	CREATE	DSO Operator		Inf.5	
St. 6		Activation Order Dispatch	The DSO Platform dispatched activation orders to the FSP platform	REPORT			Inf.5	
St. 7		Setpoint Computation	The FSP Platform computes setpoints	CREATE			Inf.6	
St. 8		Setpoint Dispatch	The FSP Platform dispatches setpoints	REPORT	FSP Operator	Party Connected to the Grid	Inf.6	

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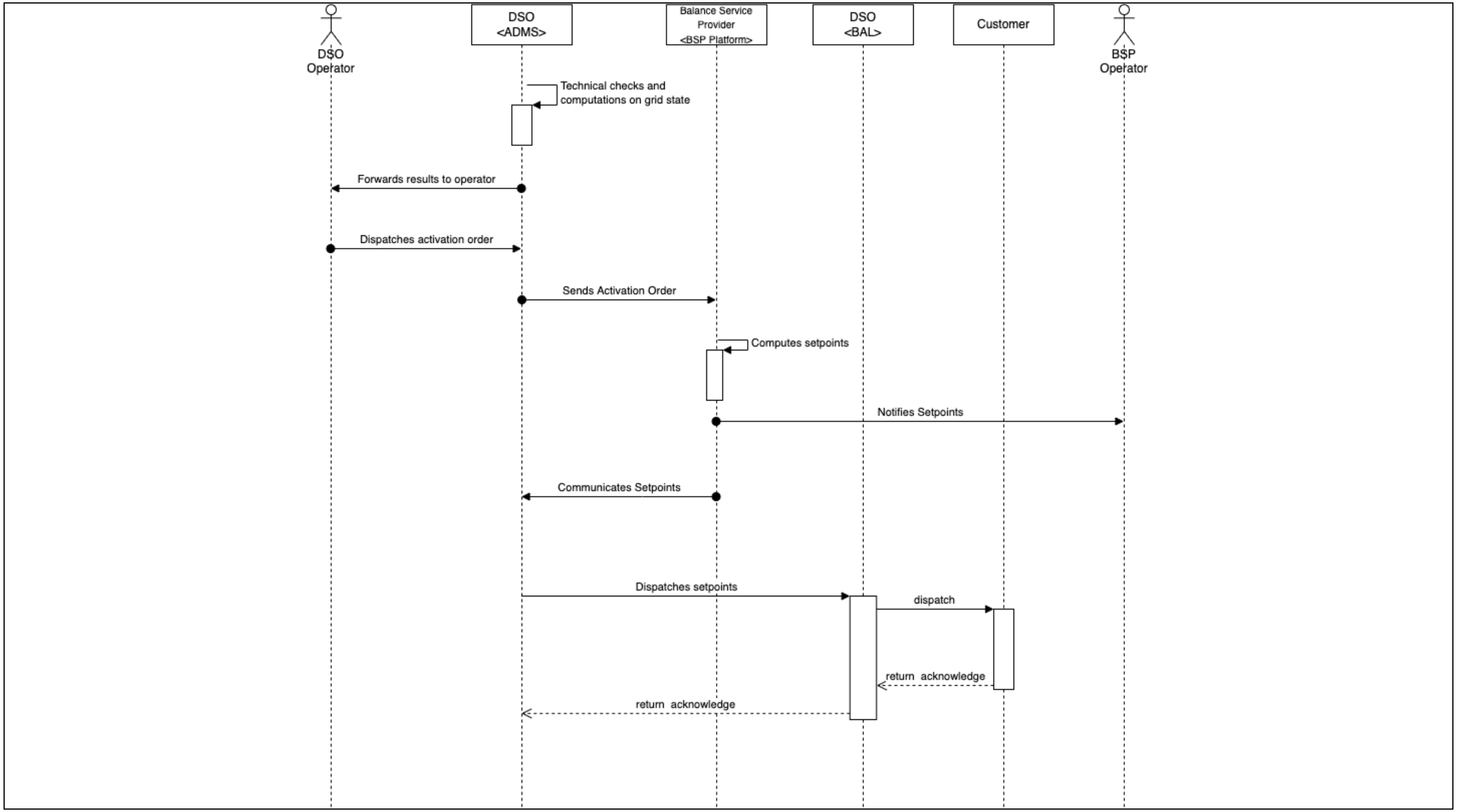

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Scenario								
Scenario name:		Sc. 4 - Settlement						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St. 1	Scheduled	Measurements Publication	PGUI Publishes measurements	CREATE			Inf.7	
St. 2	Measurements received from field	Measurements signature verification	BAL Verifies signatures on measurements	EXECUTE			Inf.7	
St. 3	Measurements are verified	Measurements Notarization	BAL Notarizes measurements on Blockchain	EXECUTE			Inf.7	
St. 4	Scheduled	Notarized Measurements Propagation	BAL propagates notarized measurements to Flexibility Register	REPORT			Inf.7	
St. 5		Data Quality Checks	Flexibility Register Performs Data Quality Checks	EXECUTE			Inf.7	
St. 6	Measurements passed checks	Verified measurements Propagation	Flexibility Register Propagates Measurements to Market	REPORT			Inf.7	
St. 7	Measurements received	Settlement	Measurements are checked against flexibility requests and offers	EXECUTE			Inf.8	
St. 8	Settlement is available	Settlement Dispatch	Settlement results are dispatched to FSP and DSO	REPORT	Market Operator	DSO Operator FSP Operator	Inf.8	

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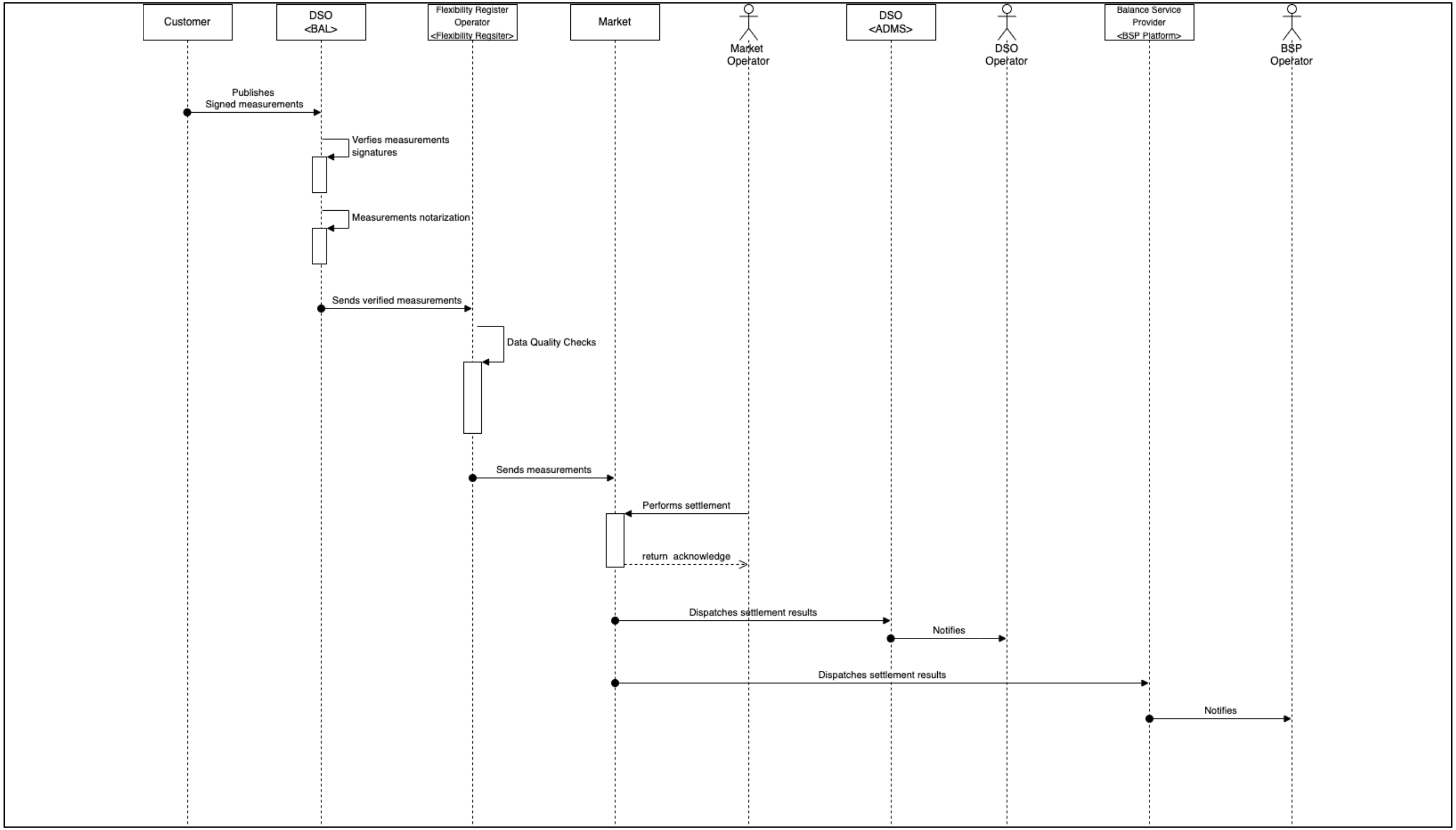

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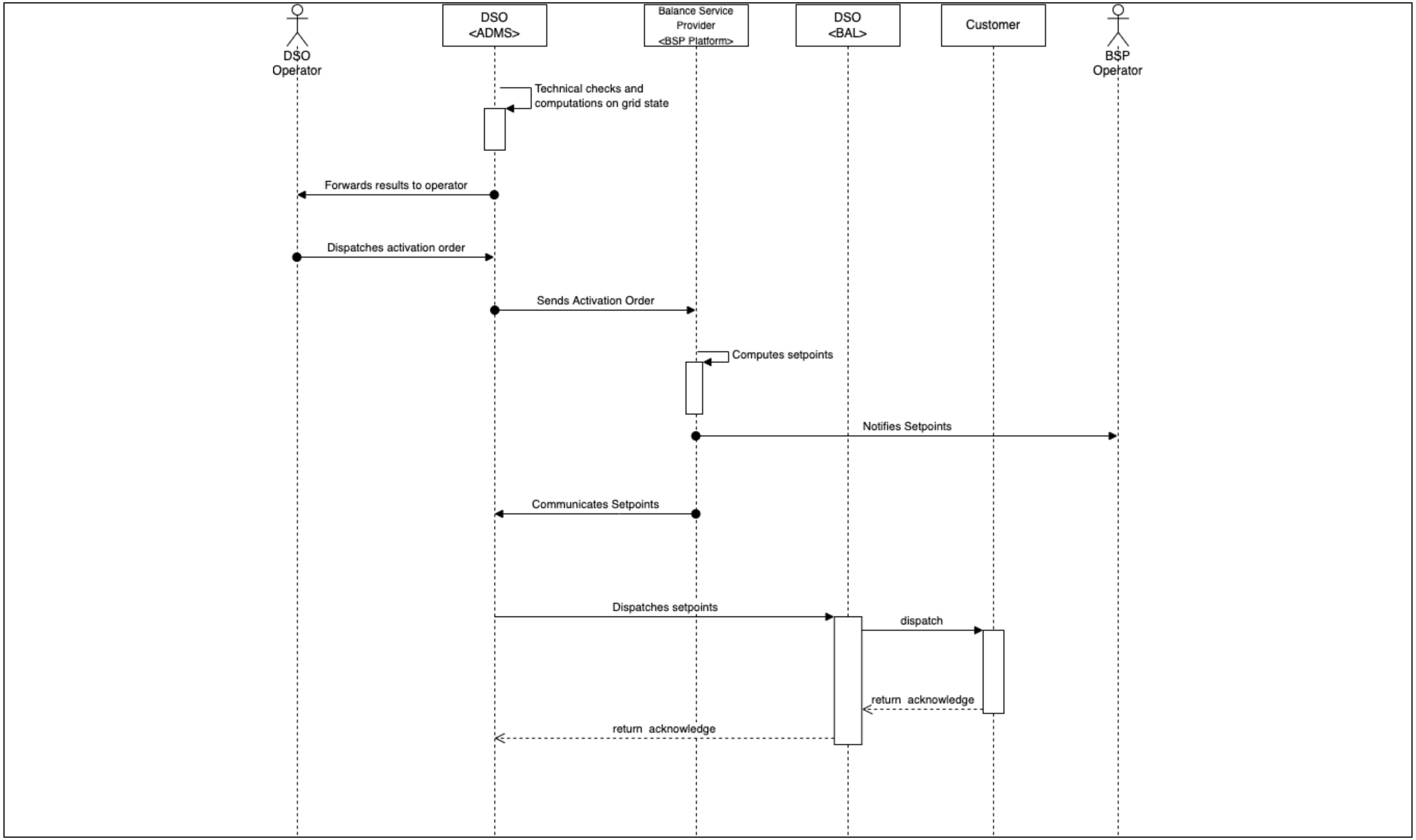

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5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
Inf.1	Resource Anagraphic	Information about the POD	
Inf.2	DSO Flexibility Requirements	Information about the grid localization and technical parameters (power)	
Inf.3	FSP Flexibility Offers	Information about resources and technical parameters (power)	
Inf.4	Market Outcome	Economic and Technical information about the matched offers and requests	
Inf.5	DSO Activation	Technical parameters (power)	
Inf.6	FSP Setpoint	Technical parameters (power)	
Inf.7	Measurements	Electrical measurements	
Inf.8	Settlement	Economic and Technical information	

6 Requirements

Requirements		
Requirement R-ID	**Requirement name**	**Requirement description**

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
Setpoint	Target Power values for any Distributed Energy Resource

BUC-NL-01 OPTIMAL FLEXIBILITY MANAGEMENT OF A DECENTRAL ENERGY GRID

1 Description of the use case

1.1 Name of the use case

ID	*Area / Domain(s) / Zones(s)*	*Name of Use Case*
BUC-NL-01	Energy flexibility at business park	Gaining insight into the flexibility of the decentral energy grid (i.e., the Arnhems Buiten electricity campus) with connected energy nodes (including buildings) to optimally manage this flexibility through a platform (Energy Management System), thereby enabling the growth of users, adding more energy nodes and increase the sustainability of real estate.

1.2 Version management

Version Management			
Version No.	***Date***	***Name of Author(s)***	***Changes***
1	02-04-2024	AB	Draft outline of use case

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2	03-04-2024	AB	Focus points
3	03-04-2024	AB, TNO	Adjustments RTO
4	2-5-2024	AB, TNO	Adding UML
5	21-5-2024	AB, TNO	Adding Sequence diagrams
6	23-5-2024	TNO	Added scenarios
7	2-6-2024	AB, TNO	Addes KPI's and use case conditions
8	13-6-2024	VU	Overall proofread and editorial changes
9	14-6-2024	C. Bouter and L.Daniele (TNO)	Updated UML use case diagrams
10	21-6-2024	C. Bouter, W. van der Berg, L. Daniele (TNO)	Updated UML sequence diagrams
11	24-06-2024	L.Daniele (TNO) & W.Belen (AB)	Finalized UML diagrams (UC and SD)
12	28-06-2024	L. Daniele (TNO)	Scenarios, requirements and info exchange
13	05-07-2024	TNO & AB	BUC update based on SUC1 and SUC2 development

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Allow for expansion of business activities and residences with a limited grid connection
Objective(s)	- Maximizing the amount of energy consumption and production of the grid of Arnhems Buiten within the real-time grid constraints of the DSO. - Remuneration and/or added value for the end-user and/or asset owners that provide energy flexibility. - Creating insights (and potential calculation models) into the various configurations possible in an electricity grid and the nodes and the advantages and disadvantages they offer in terms of energy flexibility.
Related business case(s)	

1.4 Narrative of use case

Narrative of Use Case
Short description
The goal is to enable further expansion of end users and support decarbonization of the energy consumption at the Electricity Campus Arnhems Buiten while consumption and production of energy is restricted cause of limited grid capacity. This use case entails optimal real-time balance and control of energy flexibility of the decentral grid. To make this possible (new) energy nodes (e.g., PV, Batteries, Heat pumps) will be added and/or (old) nodes will be integrated into the energy management platform. Monitoring and analysis of (real-time) data of the grid usage of the business park should lead to (automated) insight on energy flexibility during across the year. To harness and optimize the grid flexibility end users will be offered remuneration and/or added value for the end-user and/or asset owners that provide energy flexibility.
Complete description
Electricity Campus Arnhems Buiten envisions a (near) future where energy production and consumption can be optimized to not only meet the growing demand but also attract and facilitate new businesses to the area. Thus, they will embark on a journey to transform their district into a beacon of sustainability and energy efficiency. The Electricity Campus has its own decentral grid which connects buildings, renewable energy sources, batteries, and EV chargers. This grid will be expanded and enriched with additional systems (like V2G and heat pumps) to facilitate

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the needed improved sustainability of buildings and the growth in the number of tenants at the park. Specifically for EV and V2G, since it is in early adaptation stage learnings of acceptance and usages could be relevant. However, the current grid connection is not able to facilitate any more growth of energy production and consumption because of a congested DSO grid. Rather than relying solely on a centralized power grid, a network of renewable energy generators and storage across the district needs be added to be able to harness energy flexibility. Special attention needs to be paid to the year-round capacity of these generators, consumers, and available storage, due to the seasonal imbalance between PV production and consumption of heat pumps. To be able to harness the energy flexibility, real-time monitoring and control of existing and new assets is needed. Arnhems Buiten wants to have insight in, and forecast (and learnings/analysis) of, energy production and consumption of the decentral grid these forecasts will be used to control the decentral grid. For example, to what extent can charging of cars be limited or even switch over to discharge. Or to what extent can a building system be cooled/heated earlier or later (via heat pumps and/or air conditioners) or by shifting large/peak consumption of machines or, for example, data processing (server capacity) in time. **Preparation phase:** The first step is to analyse the interface used by the aggregator and DSO to assess potential starting points and how an EMS could be interacting. In parallel the transformation of the park is an ongoing process in which buildings, chargers, heat pumps, PV all need to be able to be monitored and controlled. Therefore, a list of protocols needs to be created. The protocols on the list need to be supported by the aggregator. Support of the aggregator is needed to align monitoring and control data flows. **Implementation:** Hardware such as smart meters, V2G and heat pumps will be installed early in the project. To be able to collect valuable insights even when not fully used (by occupied buildings). This will make relevant analysis possible to see how big the impact is of more/new (end)users. When selecting solutions focus is on the interoperability of these solutions to integrate them to the Decentral Grid Energy Management system. **Measurement phase:** The measurement phase already starts early in the project. Currently, there is no real-time monitoring of buildings and grid connections at the Electricity Campus. It is crucial to be able to define the impact of adding more electricity producers and/or storage to a decentral grid. These analyses with learnings are crucial for upscaling solutions to other business parks. Potentially the created insights will lead into a calculating model for analysing grid configurations (for other business parks).

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
- The electricity consumption profiles of the buildings are such that the electricity can be delivered from the energy flexibility that is applied to not exceed the grid connection capacity. - Data clearance (granted permission) of all energy nodes. - The ability to detect relevant measurements across the grid, and therefore have a stable and real-time flow of data and analysis of data. - Availability of V2G stations that function with interoperable control system.

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- Flexibility of energy nodes is/will become available.
Prerequisites
- Metering infrastructure in place - Energy nodes have proper protocols to allow for third-party control

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Level of depth
Prioritisation
Generic, regional or national relation
Nature of the use case
Flexibility optimization
Further keywords for classification
Smart grid, electric vehicles, loading of vehicles, electricity metering, storage, load-balancing, V2G stations

1.8 General Remarks

General Remarks

2 Diagrams of use case

Diagram(s) of use case

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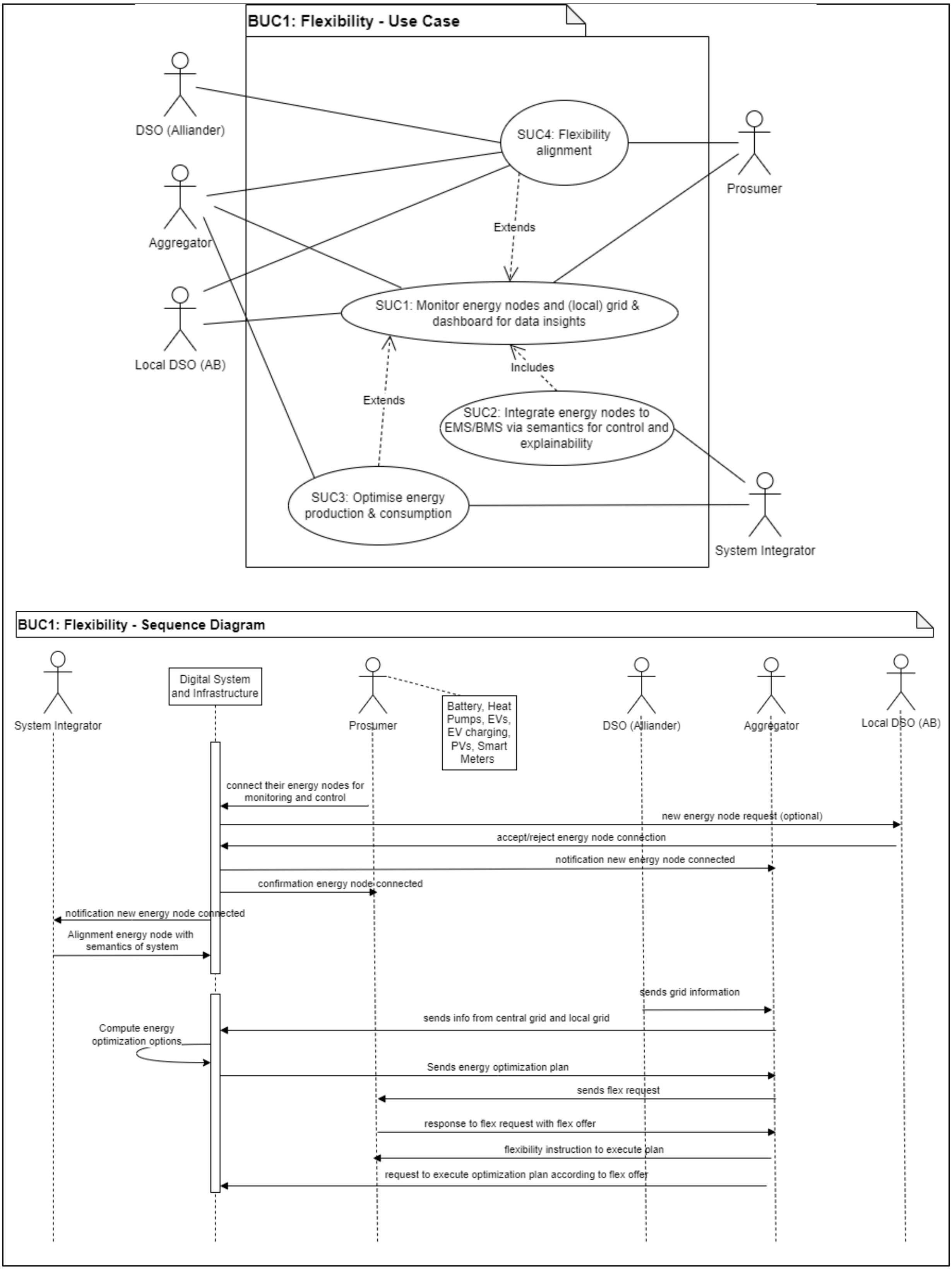

3 Technical details

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3.1 Actors

Actors			
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***
Prosumer	Business actor	The combination of: - Visitor or tenant, paying (in)direct, via Grid operator) energy bill for using energy for charging EV, or using office (facilities). - Owner of buildings and (e.g. connected) PV, charging stations and batteries)	Visiting EV User connection car to grid (V2G or normal charging), tenants of office space and/or Arnhems Buiten as Building owner
Local DSO	Operator	Local/decentral DSO Owner of the Mid and Low voltage grid	Arnhems Buiten
DSO – central	Operator	Central grid owner and operator.	Alliander. Exact role (probably in relation to demand respond) to be defined. And contractual input.
Aggregator	Business actor	Responsible for EMS	To be defined, possibly Edmij
System integrator	Operator	Responsible for semantic integration and explainability	Initially data scientists from TNO/VU-A

3.2 References

References						
No.	***Reference Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc. 1	Monitoring and dashboards	The energy nodes of the prosumer (i.e., batteries, Heat Pumps, EVs, EV charging, PVs, Smart Meters) get connected to the local grid and can provide real-time data to the digital system in place for the Dutch pilot, so that these energy nodes can be monitored to optimise energy production & consumption (Sc.3), but also to	Prosumer	Prosumer connecting a new energy node and afterwards the monitoring is a continuously running process)	No energy nodes to monitor yet.	All types of energy nodes are connected (batteries, Heat Pumps, EVs, EV charging, PVs, Smart Meters) and can be monitored. Data insights can be offered via dashboards.

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		detect anomalies in the local grid (Sc.4). A dashboard is available to provide insights on energy nodes data.				
Sc. 2	Integrate energy nodes via semantics for control and explainabilit y	Once the energy nodes are connected to the local grid, a process takes place to enhance the data exchanged by the nodes with formal semantics and integrate them with the EMS/BMS (i.e., making mappings into the SAREF ontology and creating semantic adapters). Energy nodes can now also be controlled via the EMS/BMS. Because of semantics, explanations on certain decisions/ optimizations/ controls can be offered to the involved actors (i.e., prosumer, local DSO, aggregator).	System Integrator	Notification of new energy node connected to the local grid	Energy nodes and EMS/BMS are not integrated with each other and provide only raw data.	Energy nodes integrated with EMS/BMS. Energy nodes can now be controlled. Raw data from energy nodes and EMS/BMS is enhanced with semantics. Data is SAREFized and can be exchanged using semantic adapters. Explainability can be offered based on semantics.
Sc. 3	Optimise energy production & consumptio n	The digital system, using the EMS connected to the energy nodes and grid information/signa ls from the central DSO, optimises energy production & consumption by computing the most suitable flexibility options for prosumers and local DSO	Aggregato r	Continuously running process (once the energy nodes are connected to the local grid and integrated with the EMS)	Energy nodes are connected for monitoring and control	Energy nodes are optimised on their consumption and production by the aggregator
Sc. 4	Flexibility alignment	Based on grid information from the central DSO but also the local grid, the	Aggregato r	Info from central and local grid sent to the digital system	Energy nodes producing and consuming without use of flexible tariffs	Flex offer agreed between aggregator and prosumer can be executed

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		aggregator aligns with the prosumers on flexibility profiles and corresponding tariffs, until a final plan can be executed according to the selected flex offer				

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4.2 Steps – Scenarios

Scenario								
Scenario name:	Sc. 1 - Monitoring and dashboards (also used in BUC-NL-02)							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St.1	Initialization energy nodes in the grid	Energy node connection request	An energy node (e.g., Battery, Heat Pumps, EVs, EV charging, PVs, Smart Meters) is registered by the prosumer in the digital system	CREATE	Prosumer	Digital System and Infrastructure	Inf1, Inf2	R1, R2
St. 2	Energy node connection request	New energy node connection request	A new energy node requests to be registered into the local grid by the DSO. This request is optional based on the typology of the node	CREATE	Digital System and Infrastructure	Local DSO	Inf1, Inf2	R1, R2
St. 3	New energy node connection request	Response energy node connection	Local DSO accepts or rejects the request from the Digital System to connect a new energy node	GET	Local DSO	Digital System and Infrastructure	Inf1, Inf2	R1, R2
St. 4	Response energy node connection	Notification new energy node connection	Notification from the digital system that a new energy node is successfully connected to the local grid	GET	Digital System and Infrastructure	Aggregator	Inf1, Inf2	R1, R2
St. 5	Energy node connection request	Confirmation energy node connected	Confirmation to the prosumer that the energy node is successfully connected	GET	Digital System and Infrastructure	Prosumer	Inf1, Inf2	R1, R2
St. 6	Confirmation energy node connected	Monitoring and control process	Monitoring and control of the energy node can start in the digital system	EXECUTE	Digital System and Infrastructure		Inf1, Inf2	R1, R2
St.7	Confirmation energy node connected	Notification new energy	Notification from the digital system to the system integrator that a new energy node is	GET	Digital System and Infrastructure	System Integrator	Inf1, Inf2	R1, R2

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		node connection	successfully connected to the local grid					

Scenario								
Scenario name:	Sc. 2 - Integrate energy nodes via semantics for control and explainability (also used in BUC-NL-02)							
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St.1	Confirmation energy node connected	Notification new energy node connection	Notification from the digital system to the system integrator that a new energy node is successfully connected to the local grid	GET	Digital System and Infrastructure	System Integrator	Inf1, Inf2	R1, R2
St. 2	Notification new energy node connection	Integration and semantic alignment energy nodes	Alignment energy node to enhance their data with formal semantics and integrate them with the EMS/BMS (i.e., making mappings into the SAREF ontology and creating semantic adapters)	CREATE	System Integrator	Digital System and Infrastructure	Inf3	R4
St. 3	Integration and semantic alignment energy nodes	Control	Energy nodes can be controlled via the EMS/BMS.	EXECUTE	Digital System and Infrastructure	Digital System and Infrastructure	Inf1, Inf3	R3, R4, R6
St. 4	Integration and semantic alignment energy nodes	Explainability	Because of semantics, explanations on certain decisions/ optimizations/ controls can be offered to the involved actors (i.e., prosumer, local DSO, aggregator).	GET	Digital System and Infrastructure	Prosumer, local DSO, or aggregator	Inf3	R3, R4

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Scenario								
Scenario name:	Sc. 3 - Optimise energy production & consumption							
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St. 1	Initialize central Grid information	Central Grid information collection	The central DSO sends grid information such as capacity, signals, curtailing, etc. to the aggregator	GET	DSO	Aggregator	Inf3	R3, R4
St. 2	Central Grid information collection	Central and local Grid information collection	The aggregator sends info collected from the local and central grid to the Digital System and Infrastructure that can use it for optimizing energy	GET	Aggregator	Digital System and Infrastructure	Inf4	R3, R4
St. 3	Central and local Grid information collection & “monitoring and control” scenario	Compute energy optimization options	The Digital System and Infrastructure, using the EMS connected to the energy nodes and info collected from the local and central grids, computes the most suitable flexibility options for prosumers and local DSO	EXECUTE	Digital System and Infrastructure	Aggregator	Inf1, Inf2, Inf3, Inf4	R2, R3

Scenario								
Scenario name:	Sc. 4 - Flexibility alignment							
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St. 1	Compute energy optimization options	Optimization plan	The Digital System and Infrastructure sends energy optimization plan to the Aggregator	GET	Digital System and Infrastructure	Aggregator	Inf5	R3, R4
St. 2	Optimization plan	Flex request	Flexibility request message can be sent by a EMS (of the aggregator) to an energy node to inquire for the flexibility it can offer	GET	Aggregator	Prosumer	Inf6	R3, R5

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St. 3	Flex request	Flex offer	Flexibility offer message can be sent by an energy node (of the prosumer) to the EMS (of the aggregator) as a response to a Flexibility Request, indicating the energy node flexibility potential	GET	Prosumer	Aggregator	Inf7	R3, R5
St. 4	Flex offer	Flexibility instruction	Flexibility instruction, which is a request that an EMS (of the aggregator) sends to an energy node (of the prosumer) about how it should operate according to the EMS optimization plan	GET	Aggregator	Prosumer	Inf8	R3, R5
St. 5	Optimization plan	Optimizatio n plan execution	The request sent by the Aggregator to the Digital System and Infrastructure to execute the optimization plan according to Flex offer	EXECUTE	Aggregator	Digital System and Infrastructure	Inf5	R3, R5

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5 Information exchanged

Information exchanged			
Information exchanged (ID)	**Name of information**	**Description of information exchanged**	**Requirement, R-IDs**
Inf1	Registration data	Energy node registration data such as device type, manufacturer, specs, etc.	R1, R2
Inf2	Connection data	Energy node connection data such as ID, endpoint)	R1, R2
Inf3	Semantic data	Semantically enriched (SAREFized) data	R4
Inf4	Grid data	Central grid and local grid information (capacity, signals, unavailability, etc.)	R2
Inf5	Energy optimization plan	Energy optimization plan of energy nodes sent to the Aggregator by the digital system	R2, R3
Inf6	Flex request	Flexibility request, message can be sent by an EMS (of the aggregator) to an energy node to inquire for the flexibility it can offer	R3, R5
Inf7	Flex offer	Flexibility offer, sent by an energy node (of the prosumer) to the EMS (of the aggregator) as a response to a Flexibility Request, indicating the energy node flexibility potential	R3, R5
Inf8	Flex instruction	Flexibility instruction, which is a request that an EMS (of the aggregator) sends to an energy node (of the prosumer) about how it should operate according to the EMS optimization plan	R3, R5

6 Requirements

Requirements		
Requirement R-ID	**Requirement name**	**Requirement description**
R1.1	Prosumer consent for data exchange	The prosumer must provide consent for their energy node data to be exchanged (monitoring purpose)
R1.2	Prosumer consent for control	The prosumer must provide consent for their energy node to be controlled by a logical function for energy optimization (such as EMS)
R2	Data availability	Data must be available from energy nodes (batteries, Heat Pumps, EVs, EV charging, PVs, Smart Meters) to the digital system, but also data from the central grid DSO
R3	Logical function for energy optimization	For computation of optimization of consumption and production, a logical function (EMS) must be available to the digital system
R4	Semantic enrichment	To offer proper explainability data and advanced insights, data must be semantically enriched

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
Energy nodes	Hardware such as batteries, heat pumps, PVs, EV-chargers, smart meters, and other energy (flexibility) assets with interoperable interface/connection and owned by the Prosumer
EMS	Energy Management System
BMS	Building Management System
EV	Electric Vehicle
PV	Photo Voltaic

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HP	Heat Pump

BUC-NL-02 ANOMALY DETECTION IN A DECENTRALIZED ELECTRICITY GRID TO OPTIMIZE GRID AVAILABILITY AND GRID RESILIENCE

1 Description of the use case

1.1 Name of the use case

ID	***Area / Domain(s) / Zones(s)***	***Name of Use Case***
BUC-NL-02	Electricity Campus business park anomaly detection	Detecting anomalies in a decentralized electricity grid (i.e., the Arnhems Buiten electricity campus) to identify technical deviations such as, e.g., power quality issues and data (transmission) faults. The system monitors real-time data from various energy nodes in the grid, using (e.g. advanced ML) analytics and semantic reasoning to spot irregularities in voltage, frequency, and data flow. This provides the basis for a platform (hardware and software) to optimize grid availability and grid resilience.

1.2 Version management

Version Management			
Version No.	***Date***	***Name of Author(s)***	***Changes***
1	03-04-2024	W. Beelen	Draft outline of use case
2	10-4-2024	W. Beelen	Expanding scope definition
3	2-5-2024	W. Beelen and others	Redefinition and UML diagram added
4	21-5-2024	W. Beelen and others	Adding of Sequence diagrams
5	23-5-2024	S. Lathouwers	Added scenarios
6	2-6-2024	W. Beelen AB	Adjustments, adding KPI's and use case conditions
7	13-6-2024	R. Siebes (VU Amsterdam)	Proofread, editorial changes and additions
8	14-6-2024	C. Bouter and L.Daniele (TNO)	Updated UML use case diagrams
9	19-6-2024	W.Beelen AB	Refinement and specification of BUC scope
10	21-6-2024	C. Bouter, W. van der Berg, L. Daniele (TNO)	Updated UML sequence diagrams
11	24-06-2024	L.Daniele (TNO) & W.Beelen (AB)	Finalized UML diagrams (UC and SD)
12	28-06-2024	L. Daniele (TNO)	Scenarios, requirements and info exchange
13	05-07-2024	TNO & AB	BUC update based on SUC1 and SUC2 development

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Within the grid of the Electricity Campus realizing an open platform (hardware, software and ecosystem) and process to make the operation of the grid and its connected energy assets (i.e., nodes) robust and more resilient.

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Objective(s)	Strengthen the grid's ability to withstand and recover from technical faults and external disruptions by implementing advanced anomaly detection and automated response mechanisms, thereby enhancing overall system stability and reliability.
Related business case(s)	BUC-NL-01

1.4 Narrative of use case

Narrative of Use Case
Short description
To stimulate and concretize the ambition of "excellence" in the Electricity Campus at Arnhems Buiten, an open and robust platform (hardware, software, and ecosystem) is going to be realised. The platform must supervise the functioning of the grid and quickly detects (technical) anomalies with the grid (and/or between energy nodes) to overcome or in best case prevent failure of (parts/nodes of) the system.
Complete description
Technology developments (especially in the IoT) go very vast. Many new products are developed and are being connected to the grid. However not all new technology is safe, secure, and reliable (also with respect to power and data quality and stability). The Electricity Campus at Arnhems Buiten is dedicated to fostering excellence in the field of electricity innovation. To further this ambition, an open platform encompassing hardware, software, and an ecosystem is wanted. Next to hardware also focus will be on Energy Management Systems (EMS). These systems swiftly can detect changes and anomalies, such as the addition or removal of nodes or faults in the operation of assets and take immediate corrective actions. The integration of such EMS is a crucial ingredient to achieve self-organized and smart electricity grids. **Context and Objectives:** The Electricity Innovation Campus is committed to advancing the forefront of electrical innovation. However, achieving excellence requires a robust infrastructure. The proposed open platform aims to fulfill this need by providing a collaborative space where researchers, developers, and industry experts can come together to experiment and innovate. Key objectives include: • Prioritizing safety and security in solution development. • Empowering EMS to efficiently manage the electricity system and to respond to system anomalies and hereby potentially enabling a self-organized (mesh) grid. Scope and Components of the Platform: The open platform will comprise several interconnected components, including: • Hardware Infrastructure: State-of-the-art equipment and devices necessary for testing IoT solutions and simulating real-world scenarios. • Software Framework: A flexible and scalable software framework to support diverse experimentation needs, including data analytics, security protocols, and integration with existing systems. • Ecosystem Integration: Collaboration with industry partners, academic institutions, and technology providers to foster a vibrant ecosystem of innovation and knowledge exchange. • Monitoring and Control Systems: Tools and protocols for real-time monitoring of system health, anomaly detection, and automated response mechanisms. Key Features and Functionalities: • Emphasis on Safety and Security: Stringent protocols and testing procedures will be implemented to ensure that solutions developed on the platform adhere to the highest standards of safety and security. • Real-time Anomaly Detection and Response: Advanced monitoring and control systems will enable detection of anomalies, such as node additions/removals or faults, in real-time and take immediate corrective actions to maintain system integrity. Business Benefits:

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• Innovation Leadership: By providing a cutting-edge platform for experimentation, the Electricity Innovation Campus will solidify its reputation as a leader in electrical innovation, attracting top talent and fostering collaborations with industry stakeholders. • Enhanced Safety and Reliability: By prioritizing safety and security in solution development, the platform will contribute to the overall improvement of electrical systems' safety and reliability, reducing the risk of accidents and downtime. • Cost Savings: Early detection and mitigation of system anomalies will help minimize operational costs associated with maintenance, repairs, and downtime. Implementation Plan: Phase 1: Infrastructure Setup - Procurement and installation of hardware and software components. Phase 2: Platform Development - Development and integration of software frameworks, establishment of testing protocols, and ecosystem partnerships. Phase 3: Pilot Testing - Conducting pilot tests with select partners to validate the platform's functionality and gather feedback for further refinement. Phase 4: Preparation for upscaling – Create conditions to be able to widespread the use of the platform by researchers, developers, and industry stakeholders. The proposed open platform for innovation at the Electricity Campus represents a significant step forward in advancing excellence in electrical innovation. To have an advanced anomaly detection system is crucial to optimize grid operations from Electricity campus and/but at the same time it's crucial to be able scale up the solutions to other (business) areas.

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
• Data clearance (granted permission) of all energy nodes. • The ability to detect relevant measurements across the grid, and therefore have a stable and real-time flow of data and analysis of data.
Prerequisites
- Provision of information and connection possibility to a (to be developed) Distributed Energy Resource Management Systems (DERMS): Systems to manage and optimize the integration of distributed energy resources, which can be critical for detecting anomalies related to renewable energy sources. - Personnel is skilled in data science, machine learning and analysis. - Real time monitoring and alarming systems available. - Integration (based on interoperable standards) between EMS and Energy Nodes. - Data/cybersecurity. - Compliance with regulations of (a not formal) decentralised grid.

1.7 Further Information to the use case for classification / mapping

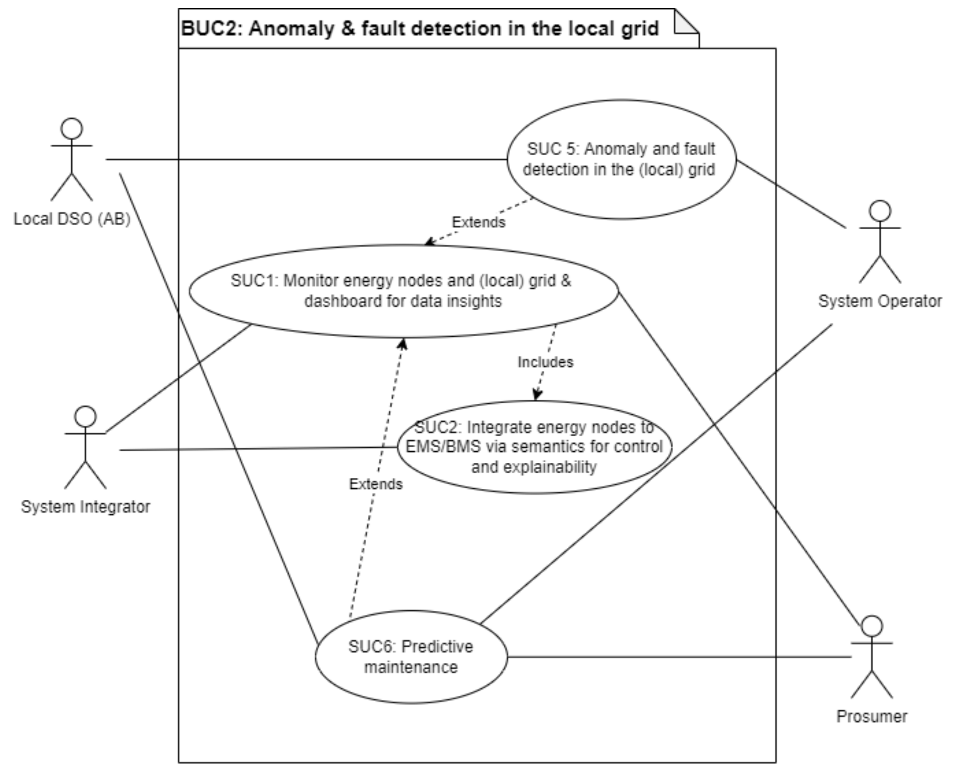
Classification Information
Relation to other use cases
Level of depth

Prioritisation
Generic, regional or national relation
Generic to scale up regional and (inter)national
Nature of the use case
Technical business use case
Further keywords for classification
Smart grid, electric vehicles, loading of vehicles, sensors, experimental equipment, electricity metering, storage.

1.8 General Remarks

General Remarks

2 Diagrams of use case

Diagram(s) of use case


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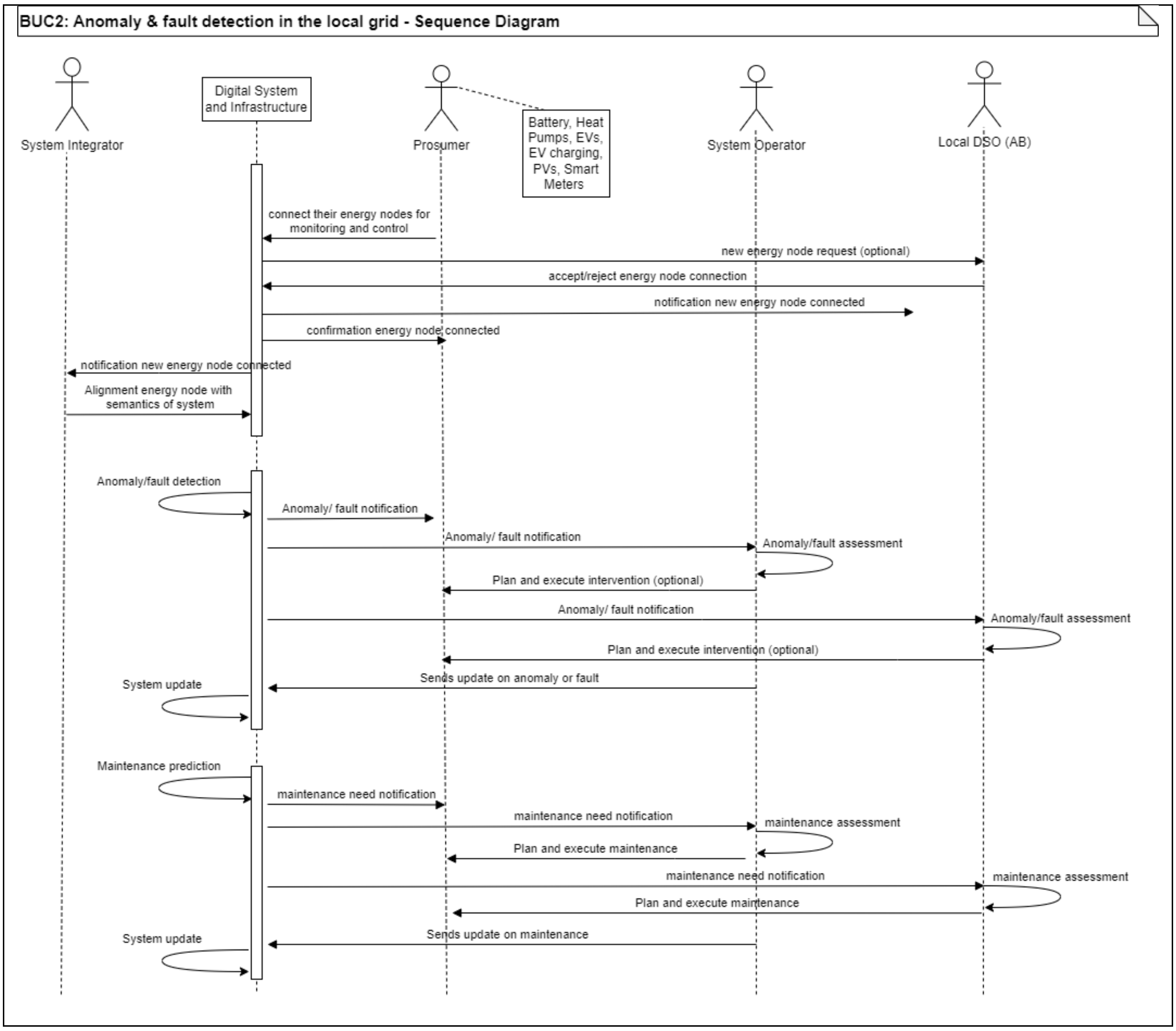

3 Technical details

3.1 Actors

Actors			
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***
Prosumer	Business actor	The combination of: - Visitor or tenant, paying (in)direct, via Grid operator) energy bill for using energy for charging EV, or using office (facilities). - Owner of buildings and (e.g., connected) PV, charging stations and batteries)	Visiting EV User connection car to grid (V2G or normal charging), tenants of office space and/or Arnhems Buiten as Building owner
Local DSO	Operator	Local/decentral DSO Owner of the Mid and Low voltage grid	Arnhems Buiten
System operator	Operator	Responsible for operating, ensuring the maintenance of and, if necessary, developing the decentral grid/system	
System integrator	Operator		Initially data scientists from TNO/VU-A

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Digital system and Infrastructure	Logical actor	The Digital system and Infrastructure is a general-purpose logical function used in the BUCs that facilitates communication among energy nodes and other software components, allowing their automatic discovery. It also contains the intelligence for monitor and control, compute flexibility optimization options, detect anomalies and predict maintenance	

3.2 References

References						
No.	***Reference Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc. 1	Monitoring and dashboards	The energy nodes of the prosumer (i.e., batteries, Heat Pumps, EVs, EV charging, PVs, Smart Meters) get connected to the local grid and can provide real-time data to the digital system in place for the Dutch pilot, so that these energy nodes can be monitored to optimise energy production & consumption (Sc.3), but also to detect anomalies in the local grid (Sc.4). A dashboard is available to provide insights on energy nodes data.	Prosumer	Prosumer connecting a new energy node and afterwards the monitoring is a continuously running process)	No energy nodes to monitor yet.	All types of energy nodes are connected (batteries, Heat Pumps, EVs, EV charging, PVs, Smart Meters) and can be monitored. Data insights can be offered via dashboards.
Sc. 2	Integrate energy nodes via semantics for control	Once the energy nodes are connected to the local grid, a process takes	System Integrator	Notification of new energy node connected to the local grid	Energy nodes and EMS/BMS are not integrated with each	Energy nodes integrated with EMS/BMS. Energy nodes

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	and explainability	place to enhance the data exchanged by the nodes with formal semantics and integrate them with the EMS/BMS (i.e., making mappings into the SAREF ontology and creating semantic adapters). Energy nodes can now also be controlled via the EMS/BMS. Because of semantics, explanations on certain decisions/ optimizations/ controls can be offered to the involved actors (i.e., prosumer, local DSO, aggregator).			other and provide only raw data.	can now be controlled. Raw data from energy nodes and EMS/BMS is enhanced with semantics. Data is SAREFized and can be exchanged using semantic adapters. Explainability can be offered based on semantics.
Sc. 3	Anomaly and fault detection	The digital system has detected an anomaly or fault in the grid. The System Operator and/or the local DSO perform an assessment, and, if needed, plan and execute an intervention at the Prosumer's premises (e.g., at the building owner or energy asset owner)	Digital System and Infrastructure	Continuously running process (once the energy nodes are connected to the local grid and integrated with the EMS/BMS)	Energy nodes are connected for monitoring and control	Anomaly and/or fault in the grid are fixed, system updated, and energy nodes connected for monitoring and control
Sc. 4	Predictive maintenance	The digital system has predicted that maintenance needs to be executed. The System Operator performs this maintenance at the Prosumer's premises (e.g., at the building owner or energy asset owner)	Digital System and Infrastructure	Continuously running process (once the energy nodes are connected to the local grid and integrated with the EMS/BMS)	Energy nodes are connected for monitoring and control	Maintenance executed (or not), system updated, and energy nodes connected for monitoring and control

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4.2 Steps – Scenarios

Scenario								
Scenario name:	Sc.1 - Monitoring and dashboards (also used in BUC-NL-01)							
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St. 1	Initialization energy nodes in the grid	Energy node connection request	An energy node (e.g., Battery, Heat Pumps, EVs, EV charging, PVs, Smart Meters) is registered by the prosumer in the digital system	CREATE	Prosumer	Digital System and Infrastructure	Inf1, Inf2	R1, R2
St. 2	Energy node connection request	New energy node connection request	A new energy node requests to be registered into the local grid by the DSO. This request is optional based on the typology of the node	CREATE	Digital System and Infrastructure	Local DSO	Inf1, Inf2	R1, R2
St. 3	New energy node connection request	Response energy node connection	Local DSO accepts or rejects the request from the Digital System to connect a new energy node	GET	Local DSO	Digital System and Infrastructure	Inf1, Inf2	R1, R2
St. 4	Response energy node connection	Notification new energy node connection	Notification from the digital system that a new energy node is successfully connected to the local grid	GET	Digital System and Infrastructure	Aggregator	Inf1, Inf2	R1, R2
St. 5	Energy node connection request	Confirmation energy node connected	Confirmation to the prosumer that the energy node is successfully connected	GET	Digital System and Infrastructure	Prosumer	Inf1, Inf2	R1, R2
St. 6	Confirmation energy node connected	Monitoring and control process	Monitoring and control of the energy node can start in the digital system	EXECUTE	Digital System and Infrastructure		Inf1, Inf2	R1, R2
St. 7	Confirmation energy node connected	Notification new energy node connection	Notification from the digital system to the system integrator that a new energy node is successfully connected to the local grid	GET	Digital System and Infrastructure	System Integrator	Inf1, Inf2	R1, R2

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Scenario								
Scenario name:	Sc. 2 - Integrate energy nodes via semantics for control and explainability (also used in BUC-NL-01)							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St.1	Confirmation energy node connected	Notification new energy node connection	Notification from the digital system to the system integrator that a new energy node is successfully connected to the local grid	GET	Digital System and Infrastructure	System Integrator	Inf1, Inf2	R1, R2
St. 2	Notification new energy node connection	Integration and semantic alignment energy nodes	Alignment energy node to enhance their data with formal semantics and integrate them with the EMS/BMS (i.e., making mappings into the SAREF ontology and creating semantic adapters)	CREATE	System Integrator	Digital System and Infrastructure	Inf3	R4
St. 3	Integration and semantic alignment energy nodes	Control	Energy nodes can be controlled via the EMS/BMS.	EXECUTE	Digital System and Infrastructure	Digital System and Infrastructure	Inf1, Inf3	R3, R4, R6
St. 4	Integration and semantic alignment energy nodes	Explainability	Because of semantics, explanations on certain decisions/ optimizations/ controls can be offered to the involved actors (i.e., prosumer, local DSO, aggregator).	GET	Digital System and Infrastructure	Prosumer, local DSO, or aggregator	Inf3	R3, R4

Scenario								
Scenario name:	Sc. 3 - Anomaly and fault detection							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**

St. 1	Enabled by "Monitoring & Control" scenario and "Semantic alignment energy nodes" scenario	Anomaly/Fault detection	The Digital System and Infrastructure uses several algorithms to detect anomalies or faults in the energy grid based on historical & current energy usage data of the grid.	EXECUTE	Digital System and Infrastructure	Digital System and Infrastructure	Inf1, Inf2, Inf3, Inf9	R1, R2, R3, R4
St. 2	Anomaly/Fault detection	Anomaly/Fault notification	The Digital System and Infrastructure notifies the Prosumer about an anomaly/fault in (one of) their energy nodes (e.g., Battery, Heat Pumps, EVs, EV charging, PVs, Smart Meters) or in their building.	GET	Digital System and Infrastructure	Prosumer	Inf1, Inf2, Inf9	R6
St. 3	Anomaly/Fault detection	Anomaly/Fault notification	The Digital System and Infrastructure notifies the System Operator about an anomaly/fault in the grid	GET	Digital System and Infrastructure	System Operator	Inf1, Inf2, Inf9	R2
St. 4	Anomaly/Fault notification	Anomaly/Fault assessment	The System Operator makes an assessment about the anomaly/fault in the grid signalled by the Digital System and Infrastructure	EXECUTE	System Operator	System Operator	Inf1, Inf2, Inf9	R2
St. 5	Anomaly/Fault assessment	Plan & Execute intervention	As a result of the assessment, if needed to fix the anomaly/fault, the System Operator plans and executes an intervention at the Prosumer's premises (e.g., at the building owner or energy asset owner)	EXECUTE	System Operator	Prosumer	Inf1, Inf2, Inf9	R6
St. 6	Anomaly/Fault detection	Anomaly/Fault notification	The Digital System and Infrastructure notifies the Local DSO about an anomaly/fault in the grid	GET	Digital System and Infrastructure	Local DSO	Inf1, Inf2, Inf9	R2
St. 7	Anomaly/Fault notification	Anomaly/Fault assessment	The Local DSO makes an assessment about the anomaly/fault in the grid signalled by the Digital System and Infrastructure	EXECUTE	Local DSO	Local DSO	Inf1, Inf2, Inf9	R2
St. 8	Anomaly/Fault assessment	Plan & Execute	As a result of the assessment, if needed to fix the anomaly or fix the fault, the Local DSO plans and executes	EXECUTE	Local DSO	Prosumer	Inf1, Inf2, Inf9	R6

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		intervention	an intervention at the Prosumer's premises (e.g., at the building owner or energy asset owner)					
St. 9	Plan & Execute intervention OR Anomaly/Fault assessment	Anomaly/Fault status update	Once the anomaly is handled and the eventual fault fixed, the System Operator sends a status update to the Digital System and Infrastructure	GET	System Operator	Digital System and Infrastructure	Inf9	R2
St. 10	Anomaly/Fault status update	System update	The Digital System and Infrastructure is updated	EXECUTE	Digital System and Infrastructure	Digital System and Infrastructure	Inf9	R2

Scenario								
Scenario name:	Sc. 4 - Predictive maintenance							
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St. 1	Enabled by "Monitoring & Control" scenario and "Semantic alignment energy nodes" scenario	Maintenance prediction	The Digital System and Infrastructure uses several algorithms to predict whether maintenance is needed in the energy grid based on historical & current energy usage data of the grid.	EXECUTE	Digital System and Infrastructure	Digital System and Infrastructure	Inf1, Inf2, Inf3, Inf10	R1, R2, R3, R4
St. 2	Maintenance prediction	Maintenance need notification	The Digital System and Infrastructure notifies the Prosumer about the need for maintenance in (one of) their energy nodes (e.g., Battery, Heat Pumps, EVs, EV charging, PVs, Smart Meters) or in their building.	GET	Digital System and Infrastructure	Prosumer	Inf1, Inf2, Inf10	R6
St. 3	Maintenance prediction	Maintenance need notification	The Digital System and Infrastructure notifies the System Operator about the	GET	Digital System and Infrastructure	System Operator	Inf1, Inf2, Inf10	R2

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			need for maintenance in a node of the grid					
St. 4	Maintenance need notification	Maintenance assessment	The System Operator makes an assessment about the need for maintenance in the grid signalled by the Digital System and Infrastructure	EXECUTE	System Operator	System Operator	Inf1, Inf2, Inf10	R2
St. 5	Maintenance assessment	Plan & Execute Maintenance	As a result of the assessment, the System Operator plans and executes the maintenance at the Prosumer's premises (e.g., at the building owner or energy asset owner)	EXECUTE	System Operator	Prosumer	Inf1, Inf2, Inf10	R6
St. 6	Maintenance prediction	Maintenance need notification	The Digital System and Infrastructure notifies the Local DSO about the need for maintenance in a node of the grid	GET	Digital System and Infrastructure	Local DSO	Inf1, Inf2, Inf10	R2
St. 7	Maintenance need notification	Maintenance assessment	The Local DSO makes an assessment about the need for maintenance in the grid signalled by the Digital System and Infrastructure	EXECUTE	Local DSO	Local DSO	Inf1, Inf2, Inf10	R2
St. 8	Maintenance assessment	Plan & Execute Maintenance	As a result of the assessment, the Local DSO plans and executes the maintenance at the Prosumer's premises (e.g., at the building owner or energy asset owner)	EXECUTE	Local DSO	Prosumer	Inf1, Inf2, Inf10	R6
St. 9	Plan & Execute Maintenance	Maintenance status update	Once the maintenance is handled, the System Operator sends a status update to the Digital System and Infrastructure	GET	System Operator	Digital System and Infrastructure	Inf10	R2
St. 10	Maintenance status update	System update	The Digital System and Infrastructure is updated with the latest maintenance information	EXECUTE	Digital System and Infrastructure	Digital System and Infrastructure	Inf10	R2

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5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
Inf1	Registration data	Energy node registration data such as device type, manufacturer, specs, etc.	R1.1, R1.2, R2
Inf2	Connection data	Energy node connection data such as ID, endpoint)	R1.1, R1.2, R2
Inf3	Semantic data	Semantically enriched (SAREFized) data	R4
Inf4	Grid data	Central grid and local grid information (capacity, signals, unavailability, etc.)	R2
Inf5*	Energy optimization plan	Energy optimization plan of energy nodes sent to the Aggregator by the digital system	R1.2, R2, R3
Inf6*	Flex request	Flexibility request, message can be sent by a EMS (of the aggregator) to an energy node to inquire for the flexibility it can offer	R3, R5
Inf7*	Flex offer	Flexibility offer, sent by an energy node (of the prosumer) to the EMS (of the aggregator) as a response to a Flexibility Request, indicating the energy node flexibility potential	R3, R5
Inf8*	Flex instruction	Flexibility instruction, which is a request that an EMS (of the aggregator) sends to an energy node (of the prosumer) about how it should operate according to the EMS optimization plan	R3, R5
Inf9	Anomaly/Fault data	Data about a possible anomaly/fault detected by the system for notification and status updates	R2, R6
Inf10	Maintenance data	Data about maintenance predicted by the system for notification and status updates	R2, R6
*Inf5, Inf6, Inf7, Inf8 not used here but only in BUC1 "Flexibility"			

6 Requirements

Requirements		
Requirement R-ID	**Requirement name**	**Requirement description**
R1.1	Prosumer consent for data exchange	The prosumer must provide consent for their energy node data to be exchanged (monitoring purpose)
R1.2	Prosumer consent for control	The prosumer must provide consent for their energy node to be controlled by a logical function for energy optimization (such as EMS)
R2	Data availability	Data must be available from energy nodes (batteries, Heat Pumps, EVs, EV charging, PVs, Smart Meters) to the digital system, but also data from the central grid DSO
R3	Logical function for energy optimization	For computation of optimization of consumption and production, a logical function (EMS) must be available to the digital system
R4	Semantic enrichment	To offer proper explainability data and advanced insights, data must be semantically enriched
R5*	Dynamic tariffs	To experiment with flexible offers dynamic tariffs must be in use
R6	Prosumer availability	The prosumer must provide availability for an intervention to be scheduled and performed (e.g., anomaly/fault fixing or maintenance execution) on their energy node(s)
*R5 not used here but only in BUC1 "Flexibility"		

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7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
Energy nodes	Hardware such as batteries, heat pumps, PVs, EV-chargers, smart meters and other energy (flexibility) assets with interoperable interface/connection and owned by the Prosumer
EMS	Energy Management System
BMS	Building Management System. A system consisting of several decentralized controllers and a (de)centralized management system to monitor and control the systems responsible for heating, electricity, indoor climate and comfort and other facilities within a building.
EV	Electric Vehicle
PV	Photo Voltaic
HP	Heat Pump
EMS	Energy Management System
DSO	Distribution System Operator
IoT	Internet of things

BUC-PT-01 GREENVALE: HARNESSING THE POTENTIAL OF ENERGY COMMUNITIES BY LEVERAGING FEDERATED LEARNING STRATEGIES

1 Description of the use case

1.1 Name of the use case

ID	*Area / Domain(s) / Zones(s)*	*Name of Use Case*
BUC-PT-01	Energy Flexibility	GreenVale: Harnessing the potential of energy communities by leveraging Federated Learning strategies.

1.2 Version management

Version Management			
Version No.	*Date*	*Name of Author(s)*	*Changes*
1.0	16.04.2024	David Rua (INESC TEC) Fábio Coelho (INESC TEC) Vasco Campos (INESC TEC)	Initial version of the BUC
1.1	19.04.2024	David Rua (INESC TEC) Fábio Coelho (INESC TEC) Vasco Campos (INESC TEC)	Deeper explanation of the SUC
1.2	03.06.2024	David Rua (INESC TEC) Fábio Coelho (INESC TEC) Vasco Campos (INESC TEC)	Final consolidation
1.3	17.06.2024	David Rua (INESC TEC) Fábio Coelho (INESC TEC) Vasco Campos (INESC TEC)	Review corrections
1.4	03.07.2024	David Rua (INESC TEC) Fábio Coelho (INESC TEC) Vasco Campos (INESC TEC)	Final version

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1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Explore the energy flexibility of communities of citizens toward the creation of energy and non-energy services.
Objective(s)	The goals that the use case is expected to achieve: • Valorization of the existing flexibility (generation and load). • Use Federated Learning strategies to foster local optimization. • Enable Community-based renewable generation (investment/operational plan). • Enabling the flexibility on the community participants (new technologies) through the DPP's flexibility value chain. • Support the ongoing living lab. • Foster interoperability and the integration with data spaces (multi-domain).
Related business case(s)	BUC-PT-02: Participation of industrial and residential energy communities in ancillary services market for the TSO BUC-PT-03: Flexibility aggregation at tertiary buildings

1.4 Narrative of use case

Narrative of Use Case
Short description
The valorization of the flexibility assets within a community of citizens is the fundamental goal of this use-case, which allows the community to become naturally an energy community. The use-case will focus on the market conditions that allow the creation of such a community, with the identification of the most relevant assets to be controlled. It will also focus on the dynamic operation of the energy community using federated learning strategies that allow the optimization of the different assets and fulfilling the differentiated objectives set by the community participants. The use of interoperability enablers will expedite the integration and will ensure the fast opt-in of new assets and data. The processes are included in a flexibility-centric energy value-chain that supports the exploration of data value and services.
Complete description
1. Link flexibility stakeholders to participate in the DPP's flexibility value chain. [Flexibility Enablement] Prosumers (with or without flexible assets) and providers of services with business cases exploiting flexibility are engaged in the value-chain to exploit all available flexibility potential. Service providers exploit business models to install flexible assets in candidate consumers in exchange for their participation while providing them incentives. Contractual relationships between stakeholders are handled and recorded. Service subscriptions benefit from the integrated cash-flow. **System Use Case called by the step** SUC-PT-01.1 – Connect flexibility providers across the DPP flexibility value chain **2. Integrate flexible assets and services in the flexibility value chain. [Integration/Enablement]** Service providers integrate their operational platforms with the Digital Platform Provider (DPP) to collect the flexibility potential from prosumers. Prosumers integrate their flexibility capacity with the value-chain enabler (Energy Community). **3. Enable cross-domain community data. [Integration/Enablement]** Data sources are equipped with data exchange mechanisms that are aligned with interoperability standards and initiatives such as the data spaces to ease, expedite access to data, while imposing data sovereignty and control checks. Data sources such as: Metering, Forecasting (weather, and energy), asset's metadata, GIS data, stakeholder's data (where applicable), flexibility representations and/or biding structures will adopt this strategy. **System Use Case called by the step** SUC-PT-01.2 -Enable Data Exchange via Data Spaces

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4. **Aggregate flexibility potential. [Aggregation]**
This step considers an upstream and downstream stage, respectively covering preparations to market operation and the results from market operation or based on a bilateral agreement.
A renewable energy community manager embodying the role of aggregator, or an aggregator creates and pre-qualifies a flexibility bid that will be submitted to market negotiation during the upstream stage. In the downstream stage, the renewable energy community manager disaggregates the flexibility bids that were selected for activation and settles the process. Service providers with subscribed prosumers or capacitated prosumers are expected to activate the flexible loads.

5. **Optimize and prepare flexibility bids and take them to Market. [Negotiation]**
Flexibility needs are established considering the flexibility zones. The optimization of the flexibility participation is defined by the Aggregator/Community Manager. Flexibility bids are prepared by the Aggregator/Community Manager. The TSO pre-qualifies the bids with the expectation that they are activated during the activation and settlement stage after market clearing.

5a. Optimize and define the conditions for the bilateral agreement
A contract among aggregating entities is set with the technical and commercial conditions to define the use of flexibility of a third party.

6. **Operate Market and select flexibility bids. [Market Operation]**
The Flexibility Market Operator via its market digital platform allows flexibility bids to be selected. Contractual agreements are validated or established to fulfil the procurement of flexibility between stakeholders.

System Use Case called by the step
SUC-PT-01.3 – Mobilizing Energy Flexibility

7. **Enable the TSO to dispatch flexibility in an interoperable way. [Activation & Settlement]**
During the downstream stage, the TSO dispatches the activation of flexibility to aggregators or to the Renewable Energy Community Manager, with the expectation that aggregators disaggregate the activation to prosumers. The interoperable interface allows linking with several aggregator interfaces, with the expectation of no barriers or interface lockdowns. Most importantly it pushes for prosumers to directly collect the activation signals from TSOs. Compensations as part of the flexibility cash-flow and the settlement process is handled and billing is triggered directly in the Digital Platform Provider (DPP).

7a. Activation of the bilateral agreement
The bilateral agreement may be activated to either ensure a more comprehensive participation or as a form to reduce risk and uncertainties of a larger portfolio.

System Use Case called by the step
SUC-PT-01.4 – Activation of Energy Flexibility

1.6 Use case conditions

Use case conditions
Assumptions
There are assumptions to be considered within this BUC: • Ability to mobilize a minimum amount of flexibility power (100kW) in steps of 10kW. • Prosumers grant control of their assets over to the aggregators or the Renewable Energy Community Manager. • Aggregator/Community manager defined and developed a downstream flexibility optimization algorithm.

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Prerequisites
The following prerequisites should be observed: • Ability to collect data in an automated way (e.g., DMS: consumption, voltage profiles, etc.) • Quantification of dispatchable flexibility (e.g., which loads, existing / needed, will be used) • Strategies for the valorization of flexibility established (e.g., definition of incentives) • Data availability to fulfil ML/AI strategies for the community (e.g., federated learning, ...) • Settlement strategies defined (e.g., metering resolution, prices, revenue, ...)

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
BUC-PT-02, BUC-PT-03.
Level of depth
Prioritisation
High
Generic, regional or national relation
Regional
Nature of the use case
Business Use Case
Further keywords for classification
Energy Community, Flexibility Services, Interoperability, Data Spaces

2 Diagrams of use case

Diagram(s) of use case

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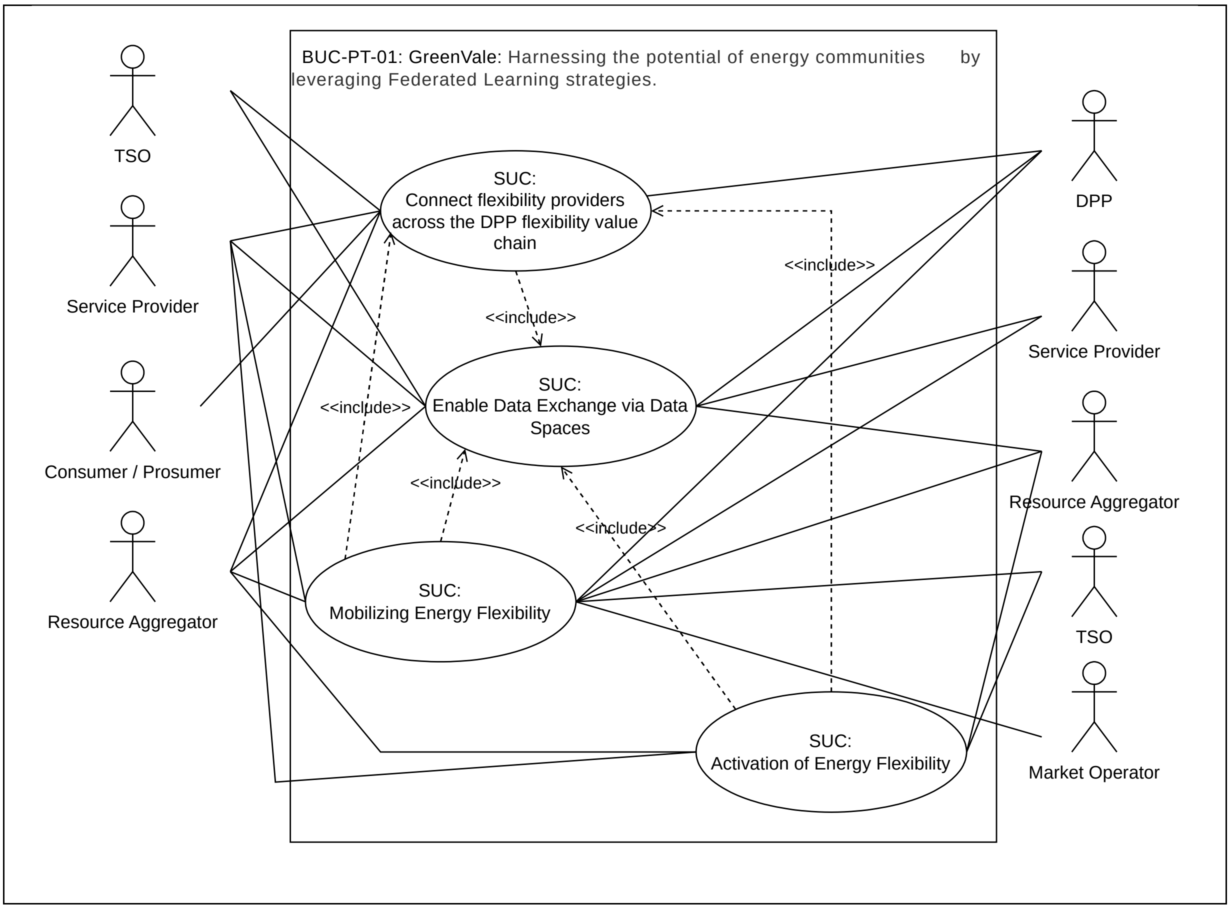

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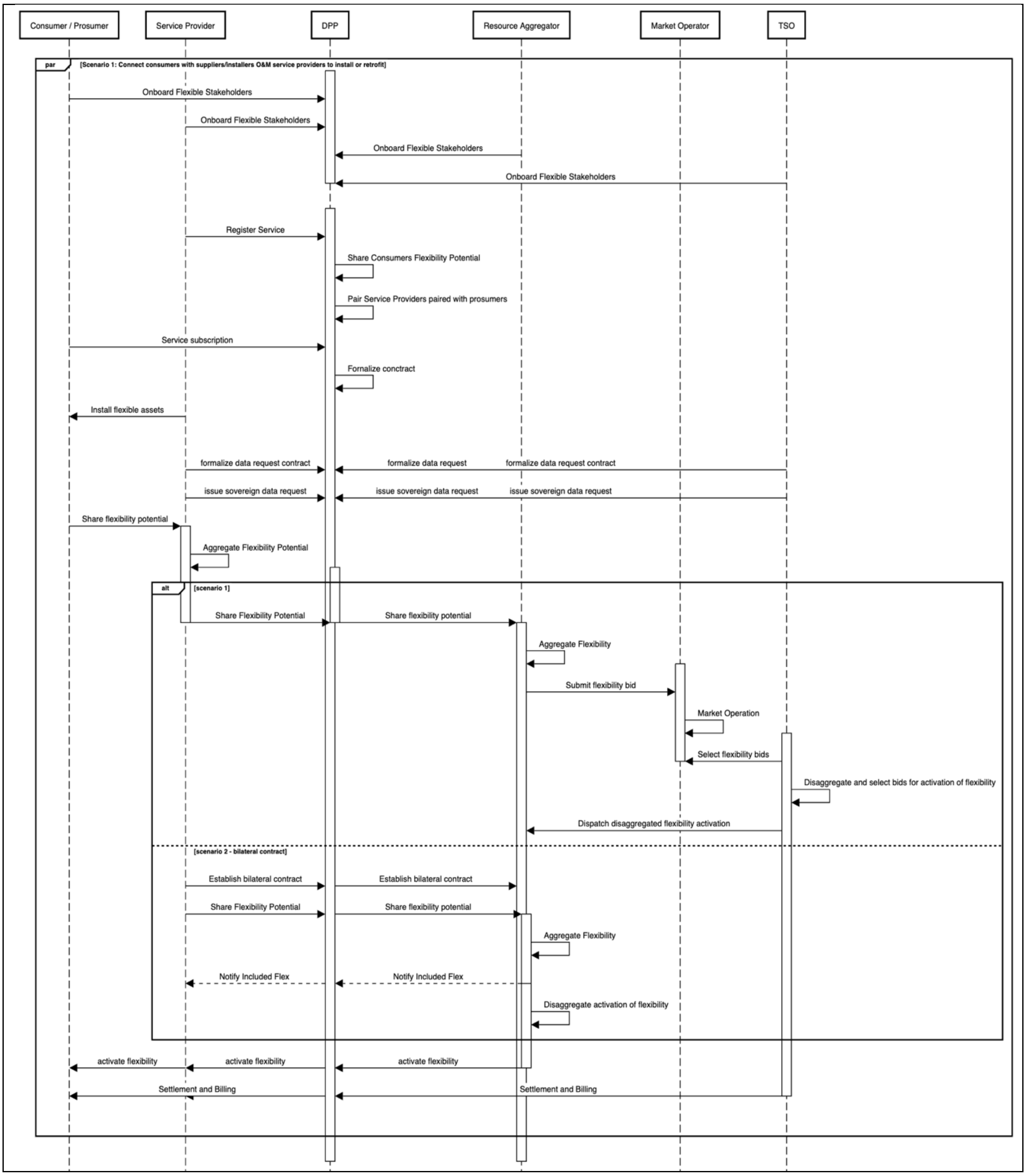

3 Technical details

3.1 Actors

Actors			
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***
Resource Aggregator (HEMRM)	Operator	A party that aggregates resources for usage by a service provider for energy market services.	Responsible for managing business activities within an Energy Community.

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			In this BUC the ECM is rather and actor that also performs the role of aggregator.
Consumer /Prosumer (HEMRM)	Business Actor	The Prosumer is a Consumer who can also produce electricity. In HEDGE-IoT role model (T1.3) it is assumed that a prosumer also adopts an active role in the energy chain, by, for example, be willing to joint self-consumption structures or provide flexibility (sometimes Flexumer is also used). The EC members are assumed to be prosumers.	
Data Hub Operator (HEMRM)	Business Actor	(The ICT/SW/DP Provider) Supports other entities with ICT (Information and Communications Technology), Software (SW) or Digital Platforms (DP).	In this BUC we designate it as Digital Platform Provider (DPP)
Flexibility Service Provider (HEMRM)	Business Actor	Offers energy related services. Can provide insights and energy management services as well as implementing energy efficiency and renewable energy projects.	In this BUC and in the DPP, we generally identify it as Service Provider (SP).
TSO (HEMRM)	Business Actor	Responsible for security of supply and reliability of a transmission network and real time operation and monitoring, building, expanding, and maintaining the transmission system. In this BUC the TSO is the main procurer of flexibility.	
Market Operator (HEMRM)	Business Actor	Provides a service whereby the offers to sell electricity are matched with the bids to buy it.	In this case this actor could manage the TSO flexibility market where the ECM negotiates the EC aggregated flexibility.

3.2 References

References						
No.	***References Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***
[1]	Technical Report	Harmonized Electricity Market Role Model (HEMRM)	Public	Role Model	BRIDGE	https://energy.ec.europa.eu/system/files/2021-06/bridge_wg_regulation_eu_bridge_hemrm_report_2020-2021_0.pdf

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc. 1	Explore consumers flexibility potential and take it to market via a flexibility DPP	Explore DER flexibility through the DPP, linking consumers with flexibility service providers that explore their	Digital Platform Provider (DPP)	Consumers and Flexibility Service Providers explore the available flexibility potential and	Services with a business model to subscribes services with a monthly fee to in return of installed DER assets;	Consumers contribute with flexibility towards the value-chain and collect incentives when

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		flexibility potential in the market.		take it to market for later activation.	consumers onboarded in the DPP.	activating procured flexibility.
Sc.2	Explore consumers flexibility potential via a bilateral agreement	Explore DER flexibility through the DPP, linking consumers with flexibility service providers that explore their flexibility potential in bilateral agreement.	Digital Platform Provider (DPP)	Market participation is not viable (i.e., minimum flexibility amount not reachable) and a bilateral contract can be use	Bilateral agreement conditions are set for flexibility provisioning and activation	The resource aggregator is informed of the activated flexibility within the bound or conditions of the bilateral agreement

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4.2 Steps – Scenarios

Scenario								
Scenario name:	Sc. 1 – Explore consumers flexibility potential and take it to market via a flexibility value-chain enabler.							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs**	**Requirement, R-IDs**
St. 1	Stakeholders onboard the DPP	Onboard Flexible Stakeholders	Registered stakeholders are onboarded on the DPP by going through the Flex enablement stage of the flexibility platform Consumers and their underlying flexible assets become discoverable.	CREATE	Consumer, Service Provider, TSO, Resource Aggregator	DPP	Inf. [1-4], Inf. 8	GDPR-[1-4],SOC-2
St. 2	Service provider registers service	Register Service	Service Provider registers service offering in the DPP.	CREATE	Service Provider	DPP	Inf. 5, Inf. [7-9]	GDPR-[1-4],SOC-3
St. 3	Occurs periodically (daily/hourly)	Share consumers flexibility potential	The flexibility potential available on behalf of consumers is made available to be explored by service providers.	CREATE	DPP	Service Provider	Inf. [1-3], Inf. [5-7]	GDPR-[1-4]
St. 4	Occurs periodically (daily/hourly)	Pair Service Providers paired with consumers	Service recommendations are delivered to consumers suggesting the subscription of services from the available service catalogue. Paring is done via the availability of given classes of flexible assets, suggesting their upgrade or retrofit, or in the case of absence of flexible resources, suggesting installation.	EXECUTE	DPP	Consumer	Inf. [1-4], Inf. 8	GDPR-[1-4], SOC-2
St. 5	Consumer subscribes a service	Service subscription	Consumer subscribes a service from a given service provider, accepts consent management.	EXECUTE	Consumer	DPP	Inf. 1, Inf. 2, Inf. 5, Inf. 8, Inf. 9	GDPR-[1-4]. SOC-3
St. 6	Contract agreement	Formalize contract	Service subscription establishes a contract between consumer and service provider which the DPP records and tracks.	EXECUTE	Consumer, Service Provider	DPP	Inf. 1, Inf. 2, Inf. 14	GDPR-[1-4], SOC-3

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St. 7	Occurs periodically (on consumer or provider request)	Install / association flexible assets	Service providers equip or link existing controllable flexible assets according to service constraints. This maps to the Integration/Enablement stage of the flexibility platform.	REPEAT	Service Providers (installers and O&Ms)	Consumer	Inf. 1, Inf. 2, Inf. 5, Inf. 8	GDPR-[1-4], SOC-1, SOC-3
St. 8	Request data sharing contract with data provider	Formalize data request contract	Data consumer requests a data sharing contract with a provider party.	GET	Service Provider	DPP	Inf. 13	GDPR-[1-4], SOC-3
St. 9	Request data sharing contract with data provider	Formalize data request contract	Data consumer requests a data sharing contract with a provider party.	GET	Resource Aggregator	DPP	Inf. 13	GDPR-[1-4], SOC-3
St. 10	Request data sharing contract with data provider	Formalize data request contract	Data consumer requests a data sharing contract with a provider party.	GET	TSO	DPP	Inf. 13	GDPR-[1-4], SOC-3
St. 11	Request data to be transferred scoping the signed contract.	Issue Sovereign data request	Data consumer uses the signed smart contract to request data to be transferred.	GET	Service Provider	DPP	Inf. 13	GDPR-4
St. 12	Request data to be transferred scoping the signed contract.	Issue Sovereign data request	Data consumer uses the signed smart contract to request data to be transferred.	GET	Resource Aggregator	DPP	Inf.8, Inf.13	GDPR-4
St. 13	Request data to be transferred scoping the signed contract.	Issue Sovereign data request	Data consumer uses the signed smart contract to request data to be transferred.	GET	TSO	DPP	Inf.13	GDPR-4
St. 14	Occurs periodically	Share flexibility	Shares flexibility potential of consumer with energy and non-energy services,	GET	Consumer, Service Providers	DPP	Inf. [1-3], Inf. 6	GDPR-[1-4],SOC-2

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	(daily/hourly)	potential	particularly those from the service provider / installer.					
St. 15	Occurs periodically (daily/hourly)	Aggregate flexibility	Service provider aggregates the flexibility potential of consumers that subscribed its services.	CREATE	Service Providers	Resource Aggregator	Inf. [1-3], Inf. 6	GDPR-[1-4],SOC-2
St. 16	Occurs periodically (daily/hourly)	Submit flexibility bid	Computed flexibility is communicated to the Resource aggregator as a bid.	CREATE	Service Providers	Resource Aggregator	Inf. [1-3], Inf. 6, Inf.10	GDPR-[1-4],SOC-2,RCR-1
St. 17	Occurs periodically (daily)	Market Operation	Flexibility Market operation	EXECUTE	Market Operator	TSO	Inf. 10, Inf. 11	GDPR-[1-4], RCR-1
St. 18	Occurs periodically (daily)	Select flexibility bids	Select flexibility bids that will be activated. TSO operational platform validates chosen bids	CREATE	TSO	TSO	Inf. 4, Inf. [10-12]	GDPR-[1-4], RCR-1
St. 19	Occurs periodically (daily)	Disaggregate activation of flexibility	Disaggregate flexibility activation requests per resource aggregator	EXECUTE	TSO	TSO	Inf. 3, Inf. 4, Inf. [10-12]	GDPR-[1-4], RCR-1
St. 20	Occurs periodically (daily)	Dispatch disaggregated flexibility	Sets selected flexibility bids for dispatch. Makes use of the interoperable data formats.	CREATE	TSO	DPP	Inf. 3, Inf. 4, Inf. [10-12]	GDPR-[1-4], SOC-3, RCR-1
St. 21	Occurs periodically (daily)	Activate flexibility	Dispatches the activation of disaggregated flexibility bids.	EXECUTE	DPP	Resource Aggregator, Service Provider, Consumer	Inf. 3, Inf. 4, Inf. [10-12]	GDPR-[1-4], RCR-1
St. 22	Occurs periodically (daily/monthly)	Settlement and Billing	Cash flow management is performed from the computed incentives and service subscription fees	EXECUTE	DPP	Consumer	Inf. [11-13]	GDPR-[1-4]

Scenario								
Scenario name:	Sc. 2 – Explore consumers flexibility potential via a bilateral agreement.							
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs***	***Requirement, R-IDs***
St. 1	Stakeholders onboard the DPP	Onboard Flexible Stakeholders	Registered stakeholders are onboarded on the DPP by going through the Flex enablement stage of the flexibility platform Consumers and their	CREATE	Consumer, Service Provider, TSO, Resource Aggregator	DPP	Inf. [1-4], Inf. 8	GDPR-[1-4], SOC-2

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			underlying flexible assets become discoverable.					
St. 2	Service provider registers service	Register Service	Service Provider registers service offering in the DPP.	CREATE	Service Provider	DPP	Inf. 5, Inf. [7-9]	GDPR-[1-4], SOC-3
St. 3	Occurs periodically (daily/hourly)	Share consumers flexibility potential	The flexibility potential available on behalf of consumers is made available to be explored by service providers.	CREATE	DPP	Service Provider	Inf. [1-3], Inf. [5-7]	GDPR-[1-4]
St. 4	Occurs periodically (daily/hourly)	Pair Service Providers with consumers	Service recommendations are delivered to consumers suggesting the subscription of services from the available service catalogue. Paring is done via the availability of given classes of flexible assets, suggesting their upgrade or retrofit, or in the case of absence of flexible resources, suggesting installation.	EXECUTE	DPP	Consumer	Inf. [1-4], Inf. 8	GDPR-[1-4],SOC-2
St. 5	Occurs on-demand flexibility is procured via a bilateral agreement	Service subscription	Consumer subscribes a service from a given service provider, accepts consent management.	EXECUTE	Consumer	DPP	Inf. 1, Inf. 2, Inf. 5, Inf. 8, Inf. 9	GDPR-[1-4], SOC-3
St. 6	Contract agreement	Formalize contract	Service subscription establishes a contract between flexibility procurer and service provider (flexibility provider) which the DPP records and tracks.	EXECUTE	Consumer, Service Provider	DPP	Inf. 1, Inf. 2, Inf. 14	GDPR-[1-4], SOC-3
St. 7	Request data sharing contract with data provider	Formalize data request contract	Data consumer requests a data sharing contract with a provider party.	GET	Service Provider	DPP	Inf. 13	GDPR-[1-4], SOC-3
St. 8	Request data sharing contract with data provider	Formalize data request contract	Data consumer requests a data sharing contract with a provider party.	GET	Resource Aggregator	DPP	Inf. 13	GDPR-[1-4], SOC-3

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St. 9	Request data sharing contract with data provider	Formalize data request contract	Data consumer requests a data sharing contract with a provider party.	GET	Flexibility Procurer/Resource Aggregator	DPP	Inf. 13	GDPR-[1-4], SOC-3
St. 10	Request data to be transferred scoping the signed contract.	Issue Sovereign data request	Data consumer uses the signed smart contract to request data to be transferred.	GET	Service Provider	DPP	Inf.13	GDPR-[1-4], SOC-3
St. 11	Request data to be transferred scoping the signed contract.	Issue Sovereign data request	Data consumer uses the signed smart contract (bilateral agreement) to request data to be transferred.	GET	Resource Aggregator	DPP	Inf. 13	GDPR-[1-4], SOC-3
St. 12	Request data to be transferred scoping the signed contract.	Issue Sovereign data request	Data consumer uses the signed smart contract to request data to be transferred.	GET	Flexibility Procurer/Resource Aggregator	DPP	Inf. 13	GDPR-[1-4], SOC-3
St. 13	Request bilateral contract	Establish bilateral contract	Service Provider and Resource Aggregator establish bilateral contract via the DPP	CREATE	Service Provider, Resource Aggregator	DPP	Inf. 13	GDPR-[1-4], SOC-3,
St. 14	Occurs periodically (daily/hourly)	Share flexibility potential	Shares flexibility potential of consumer with energy and non-energy services, particularly those from the service provider / installer.	GET	Consumer, Service Providers	DPP	Inf. [1-3], Inf. 6	GDPR-[1-4]
St. 15	Occurs periodically (daily/hourly)	Aggregate flexibility	Service provider aggregates the flexibility potential of consumers that subscribed its services.	CREATE	Service Providers	Resource Aggregator	Inf. [1-3], Inf. 6	GDPR-[1-4], RCR-1
St. 16	Occurs periodically (daily/hourly)	Notify Included Flexibility	Resource Aggregator informs Service Provide that its flexibility will be considered	CREATE	Resource Aggregator	Service Provider	Inf. 6	GDPR-[1-4], RCR-1
St. 17	Occurs periodically	Disaggregat e activation	Disaggregate flexibility activation requests per resource aggregator	EXECUTE	Flexibility Procurer	Flexibility Procurer	Inf. 3, Inf. 4, Inf. [10-12]	GDPR-[1-4], RCR-1

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	(daily)	of flexibility						
St. 18	Occurs periodically (daily)	Dispatch disaggregated flexibility	Sets selected flexibility bids for dispatch. Makes use of the interoperable data formats.	CREATE	Flexibility Procurer	DPP	Inf. 3, Inf. 4, Inf. [10-12]	GDPR-[1-4], RCR-1
St. 19	Occurs periodically (daily)	Activate flexibility	Dispatches the activation of disaggregated flexibility bids.	EXECUTE	DPP	Resource Aggregator, Service Provider, Consumer	Inf. 3, Inf. 4, Inf. [10-12]	GDPR-[1-4], RCR-1
St. 20	Occurs periodically (daily/monthly)	Settlement and Billing	Cash flow management is performed from the computed incentives and service subscription fees	EXECUTE	DPP	Consumer	Inf. [11-13]	GDPR-[1-4]

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5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
Inf. 1	Consumer profile	Data and metadata about a consumer.	
Inf. 2	Service provider profile	Data and metadata about a service provider	
Inf. 3	Resource Aggregator profile	Data and metadata about a resource aggregator profile	
Inf. 4	DSO profile	Data and metadata about a DS profile	
Inf. 5	Service offering	Data that describes a service	
Inf. 6	Flexibility potential	Flexibility potential of a stakeholder. Also represented as an aggregated shape.	
Inf. 7	Consent	Consent for data usage	GDPR-[1-4]
Inf. 8	Asset	Description of a flexible asset	
Inf. 9	Business model	Business model description	
Inf. 10	Flexibility bid	A flexibility bid	
Inf. 11	Flexibility activation	Flexibility activation request. Also considers the disaggregated version	
Inf. 12	Energy Settlement	Settlement detail on Energy exchange	
Inf. 13	Contract	Contract between stakeholders	GDPR-[1-4]

6 Requirements

Requirements		
Categories ID	**Category name for requirements**	**Category description**
GDPR	Regulatory obligation related to privacy	2016/679 (General Data Protection Regulation)
Requirement R-ID	**Requirement name**	**Requirement description**
GDPR-1	Data processing consent	Personal data may not be processed unless there is at least one legal basis to do so.
GDPR-2	Data retention policy	Data retention policy outlines the time period specific sensitive data can be retained, plus how it will be disposed of when the time to do so comes.
GDPR-3	Right to access, rectify, erasure, restriction	The data subject shall have the right to obtain from the controller without undue delay the access/rectification/erasure/restriction of inaccurate personal data concerning him or her.
GDPR-4	Data transfer consent	Personal data may not be transferred to a third-party if the data subject did not agree and the third party provide appropriate safeguard.
GDPR-X	All GDPR constraints also apply to this BUC.	e.g., proportional measures of protection, communication of data breach, among others
Categories ID	**Category name for requirements**	**Category description**
SOC	Social requirements for value addition and engagement	Inputs from 2.1 and 2.2
Requirement R-ID	**Requirement name**	**Requirement description**
SOC-1	Flexible assets installation	Economic constraints exist from user's side as the economic benefit from their efficiency is not high.
SOC-2	Incentives provision for participation	The actual economic incentive is not enough for users to participate in flexibility mechanisms.

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		Incentives must be interesting and not only economics.
SOC-3	Non-energy services	Services are available namely for Information (traffic, weather), health (air quality) and comfort are some of the non-energy services most expressed by users.
Categories ID	**Category name for requirements**	**Category description**
RCR	Regulations on aggregators to be fully developed	Draft Proposal for Network Code on Demand Response
Requirement R-ID	**Requirement name**	**Requirement description**
RCR-1	Regulations on aggregators may outline boundaries for the aggregation and market participation practices.	National regulations prescribe for aggregation activities rules concerning data exchange and confidentiality, market access and compensation for aggregated entities. Moreover, the relation with the retailer considering unbalance responsibility and transfer of energy requires bilateral agreements whether not regulated.

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
DER	Distributed Energy Resources
DMS	Distribution Management Service
DPP	Digital Platform Provider
DSO	Distributed System Operator
ID	Identifier
O&M	Operations and Maintenance
RCR	Regulation Category Requirement
SOC	Social (Category Requirement)
TSO	Transmission System Operator

BUC-PT-02 PARTICIPATION OF INDUSTRIAL AND RESIDENTIAL ENERGY COMMUNITIES IN ANCILLARY SERVICES MARKET FOR THE TSO

1 Description of the use case

1.1 Name of the use case

ID	***Area / Domain(s) / Zones(s)***	***Name of Use Case***
BUC-PT-02	Energy Markets	Participation of industrial and residential energy communities in ancillary services market for the TSO

1.2 Version management

Version Management			
Version No.	***Date***	***Name of Author(s)***	***Changes***
0.1	26.03.2024	RDN	1.1, 1.2, 1.3, 1.4, 3.1

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0.2	26.04.2024	RDN	1.5, 1.6, 1.7, 2
0.3	17.05.2024	RDN	4, 5, 6
0.4	31.05.2024	RDN	Revision of all sections
0.5	03.06.2024	RDN	Harmonization and diagrams update
1.0	14.06.2024	RDN	Harmonization and diagrams update
2.0	14.06.2024	RDN	Harmonization and diagrams update
2.1	19.06.2024	RDN	Diagrams update
2.2	23.06.2024	RDN	Diagrams update
2.3	24.06.2024	RDN	Harmonization and diagrams update
2.4	28.06.2024	RND	Requirements update

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	The scope of this BUC involves the assessment of industrial and residential Energy communities (ECs) with regard to their potential to offer ancillary services to TSOs, specifically in terms of Automatic Frequency Restoration Reserve (aFRR) and Manual Frequency Restoration Reserve (mFRR).
Objective(s)	• Evaluate the ability of ECs to provide ancillary service through a pre-qualification process, supported by hardware-in-the-loop real-time simulation. • Support the bidding strategy development by the BSP within the aFRR/mFRR service market participation. • Assess the performance of the aFRR/mFRR services provision by the ECs according to the MPGGS and TSO's rules. • Assess the economic viability of EC participation in ancillary services markets. • Evaluate the technical performance of supply and communication systems. • Explore the role of ECs in promoting the integration of renewable energies and grid flexibility.
Related business case(s)	

1.4 Narrative of use case

Narrative of Use Case
Short description
The use case presents a techno-economic analysis of the performance of industrial and residential energy communities in the provision of ancillary services, namely through automatic frequency restoration reserve (aFRR) and manual frequency restoration reserve (mFRR). The framework relies on a real-time hardware-in-the-loop (HIL) configuration to simulate the dynamic interaction between these energy communities and the system operator (SO) in order to exploit the flexibility and distributed resources within the energy communities to provide rapid response and regulation services, thereby improving grid resilience and reducing dependence on traditional centralized generation sources.
Complete description
The integration of distributed energy resources (DER) throughout the grid, coupled with their proactive power control capabilities, has fundamentally transformed the way that system operators (SOs) operate and manage the grid. Traditional generation technologies, once dominated by large fossil-fuel utilities with dispatchable units, have given way to decentralized intermittent units based on renewable energies.

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Moreover, the integration of connected loads, such as electric vehicles and storage units, has considerably diversified the grid landscape, necessitating an evolved operational approach. As the grid evolves, operators are increasingly compelled to extract more flexibility from all available system resources in order to effectively manage the growing complexity. This imperative underscore the essential role of demand flexibility, particularly at the end-user level, in mitigating system unpredictability. By harnessing the capacity of DER, demand-side flexibility enables these resources to be reallocated to ancillary services, thereby enhancing system support and resilience. This strategic shift towards harnessing DER for ancillary services not only improves grid stability, but also fosters a more dynamic and responsive energy ecosystem. Energy communities (ECs) play a key role in this scenario, as they aggregate small-scale resources and enable their participation in such services. Through a single market agent, ECs can consolidate and offer their combined flexibility to the market, streamlining their participation in the provision of ancillary services.

This use case assesses the ability of ECs, made up of industrial and residential users with DERs, to provide ancillary services to the TSO over a given period to support the system. The aggregator (RA) leverages a platform developed by the technology provider to manage energy assets within the energy community (EC). The available load and generation energy assets of the ECs are aggregated to submit bids to the market. These energy assets mainly include small loads such as electric heaters, HVAC systems, refrigerators, and small production and storage units such as photovoltaic panels, batteries, and electric vehicles. Each community member specifies the periods and conditions during which they agree to let the EC to control (switch on/off, change setpoint, discharge) their specific energy assets. The BSP flexibility platform will forecast and aggregate all demands and available energy assets for the next day, with constant updating if triggered by a change in condition. Specifically, during specific timeframes with respect to the market bidding deadline for restoration reserves, the BSP flexibility platform employs an optimization algorithm to forecast the combined capacities of assets. This assessment aims to determine whether there is available flexibility to offer in terms of active power and time horizon. If such flexibility exists, a bid is prepared for submission during the market session. The BSP flexibility platform precisely identifies and records the specific loads assigned to control, detailing control methods (e.g., on/off, pulsed) and designated time slots. This sequence of control actions is stored as an executable operation if the RA deems it necessary. If the conditions of the offer are met, the RA retains the option, subject to contractual obligations, of sending notifications via the BSP flexibility platform to each member of the community whose assets are concerned. These notifications specify the asset concerned, the method of control and the expected time of implementation. The notification will provide an estimate of the payment the community member will receive for the activity. A time-limited opt-out option will also be provided via the BSP flexibility platform. Opt-in is assumed unless a member expressly opts-out. Once the opt-out period has elapsed, the BSP flexibility platform reanalyses the community's aggregated demand and generation profiles. If the required active power profiles are still met, the RA will have the opportunity to submit an offer to the SO before the gate closes. If the offer is accepted, the SO will instruct the RA to provide the service. The RA will instruct the BSP flexibility platform to perform the actions on the backed-up energy assets (turning on/off the specified energy assets as agreed). The BSP flexibility platform performs the reprogramming and sets the new setpoints for the energy assets. The imbalance resolver will then pay for the volume of flexibility delivered and issue a charge for any volume of imbalance. The BSP flexibility platform will record payments/micropayments due to each community member who has provided the service (or charges, for example if a member disconnects an asset at the last moment).

The use case will focus on two different ancillary services, namely automatic frequency restoration reserves (aFRR) and manual frequency restoration reserves (mFRR), both of which are of the utmost importance for the smooth operation of power systems. The use case will adopt the product parameter requirements defined by the Portuguese Global System Management Procedure Manual (MPGGS 2023[2]), which follows the European Grid Code and the guidelines on power system operation ((EU) 2017/1485 of 2 August 2017[3]) and the European guideline on electricity balancing ((EU) 2017/2195 of 23 November 2017[4]). The objective of the simulation is to evaluate the effectiveness of ECs in providing flexibility services to the system through aFRR and mFRR. This evaluation aims to validate the EC's ability to meet the system's operational demands in this area. It will also seek to quantify the technical and economic feasibility of the process, and endeavours to provide information on the potential benefits and challenges associated with EC participation in the provision of ancillary services, thereby informing decision-making and strategic planning for EC operators and system stakeholders.

[22] ERSE, Manual de Procedimentos de Gestão de Sistema, 2023. Available on: https://www.erse.pt/media/3bqhdcjq/diretiva-19_2023-mpggs.pdf

[3] https://eur-lex.europa.eu/eli/reg/2017/1485/oj

[4] https://eur-lex.europa.eu/eli/reg/2017/2195/oj

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The service provision will be described in four stages: 1. Prequalification phase The pre-qualification phase serves as a registration procedure, wherein providers must meet specific criteria in order to qualify and commit themselves as reserve providers. During the registration process, specific prerequisites are established on the basis of local requirements defined by the relevant SO. The balancing service provider (BSP) and reserve supply units (or groups) must meet all stipulated requirements, including electrical and system control capabilities, as well as availability, in order to qualify. 2. Bidding phase & Selection During the bidding phase/ selection, the qualified providers submit their offers to supply aFRR / mFRR based on market conditions and system requirements. This involves determining the quantity of reserves they can offer, as well as the price at which they are willing to supply them. System operators or market platforms evaluate these offers and select those best suited to meet system needs while guaranteeing profitability. 3. Delivery Once selected, suppliers are responsible for delivering the agreed quantity of aFRR / mFRR within a specific timeframe, in accordance with the network operator's instructions. This involves constantly monitoring the network frequency and reacting quickly to deviations by adjusting the production of their resources or activating reserve capacity if necessary. Suppliers must remain ready to respond to dispatching instructions throughout the delivery phase to support network stability. 4. Settlement After the delivery phase, the settlement process occurs, during which providers are compensated for the ancillary services they have provided. This involves reconciling actual performance with contractual obligations and determining payments or penalties accordingly. Settlement procedures ensure that providers are fairly compensated for their contribution to maintaining grid stability and provide an incentive for reliable performance in future market interactions.

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
• The resource aggregator (RA) collects a variety of customer loads or locally generated electricity in the energy community (EC), facilitating their bidding on the electricity market. • The ancillary services market is open to demand-side bids from aggregators. • Internal processes within the aggregated physical unit are regarded as inputs for the simulation and are consequently outside the scope of the use case (UC). • The cloud-based service, which encompasses the market simulator and manages communication among the involved actors, will operate automatically and in real-time throughout the duration of the simulation for the use case (UC). • The economic evaluation will rely on the outcomes of the simulation as well as on actual historical data from ancillary markets. EC members are incentivized to grant the RA control over their energy assets for both economic and social reasons. Economically, they benefit from reduced electricity expenses and potential access to cheaper tariffs, as well as the opportunity to earn monetary rewards for grid services. Socially, membership promotes renewable energy usage, offers an engaging way to interact with the energy market, and contributes to network resilience.
Prerequisites

- The demand scheduler, flexibility availability, baseline schedule, and bidding strategy of the aggregated and storage physical units, along with any relevant local market outcomes.
- Quantification of the available flexibility in the EC by the BSP.
- Automated execution of energy asset actions for aFRR
- Historical Portuguese market data for aFRR and mFRR, e.g., bids, activated power, clearing price.
- Metering capability of the power delivery from EC (consumption or generation), either real or synthetized and communication between BSP and TSO/MO.
- The insurances and securities necessary for market participation, including insurance coverage and other financial instruments.

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Level of depth
General
Prioritisation
Generic, regional or national relation
National
Nature of the use case
Business use case
Further keywords for classification
Ancillary Services, Electricity Markets, Energy Communities, Reserve Flexibility Services.

1.8 General Remarks

General Remarks

2 Diagrams of use case

Diagram(s) of use case

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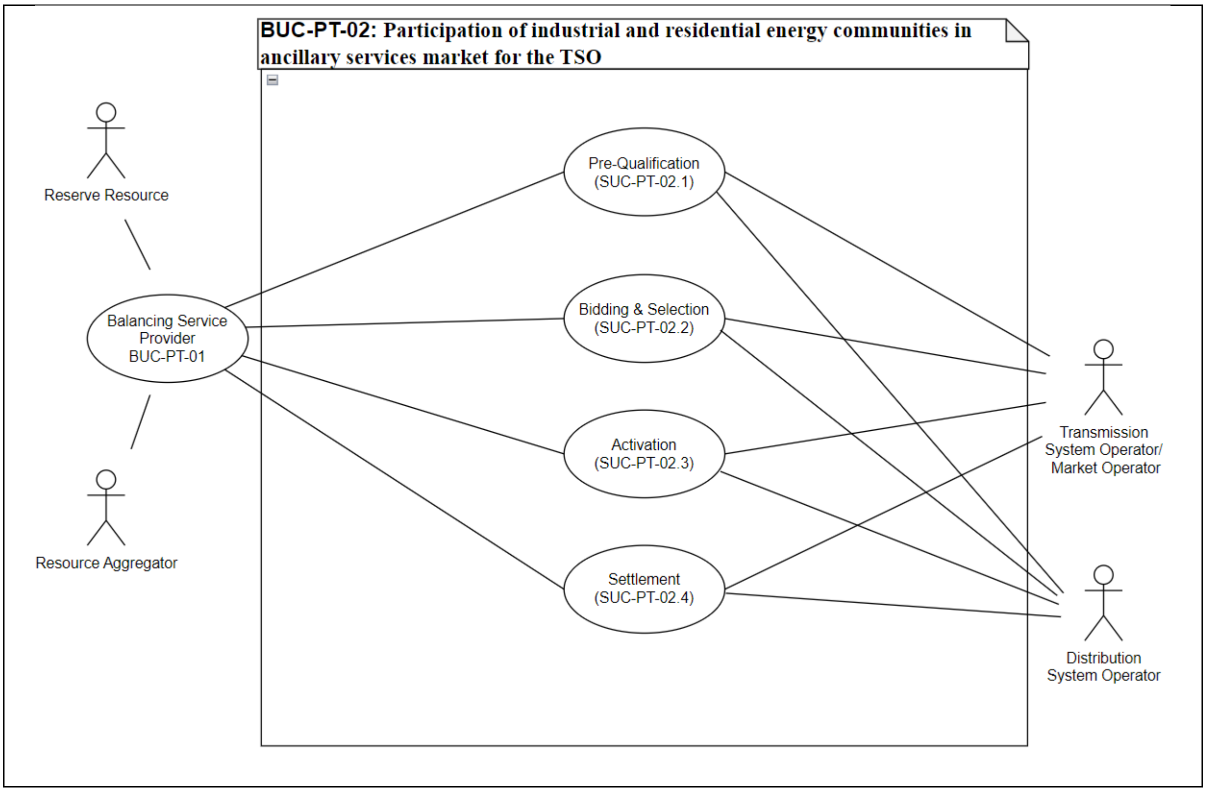

3 Technical details

3.1 Actors

Actors			
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***
Resource Aggregator (RA)	Business actor	The Resource Aggregator (RA) is an energy flexibility manager and aggregator that uses a flexibility management platform to deploy business models inside the energy community that monetize their customers' flexibility in order to deliver system services to the grid. It serves as a source of balancing resources for the Balancing Service Provider (BSP) from the grid/SO standpoint by submitting aFRR/mFRR bids to the TSO. Internally, starting with the Flexibility Platform, the RA oversees the entire procedure. In addition to promoting member engagement and community recruitment, it involves choosing the desired energy mix and carefully recruiting segmented customers. It also guarantees the proper operation and maintenance of the energy community through the installation of IoT equipment, regular site maintenance visits, and handling of member complaints and concerns.	
Reserve Resource (RR)	Business actor	A resource technically pre-qualified using a uniform set of standards to supply reserve capabilities to a System Operator and is associated with one or more tele measuring	

		devices. It generates, consumes, distributes, and uses electricity with the intention of benefiting the local community on an economic, social, and environmental level. This can include producers, consumers, and prosumers. The RR flexibility will be utilized in this use-case to provide aFRR/mFRR services, a type of ancillary service, to Transmission System Operators (TSOs).	
System Operator (SO)	Operator	A system operator is responsible for ensuring the reliable and efficient operation of a power grid. Their primary role involves monitoring, controlling, and optimizing the flow of electricity across the grid to meet demand while maintaining system stability and reliability.	This BUC incorporates both TSO and DSO.
Market Operator (MO)	Operator	A party that provides a service of collecting offers to sell and bids to buy electricity and matching these offers and bids in order to determine a market price at the clearing point. This activity can be conducted in the forward, days-ahead and/or intraday timeframes, and can be combined with transmission capacity allocation in the context of market coupling. Organization in charge of calculating and delivering ancillary services' market results, as well as giving the Flexibility Platform instructions on service delivery and specifications.	In this BUC, the TSO will perform the actions of the Market Operator.
Reserve Allocator (RA)	Role	Informs the market of reserve requirements, receives bids against the requirements and in compliance with the prequalification criteria, determines which bids meet requirements and assigns bids.	Part of the market simulation platform of the TSO/MO. The real-time reserve market simulator is in charge of: • Coordinating real-time processes. • Modelling reserve market behaviour in accordance with regulations from Portugal. • Get inputs (bids and metering data) for the computation of market results. • Determine market clearing and settlement. • Communication back and forth via a web-API with the Flexibility Platform used by the BSP
Merit Order List Responsible (MOLR)	Role	Responsible for the management of the available tenders for all Acquiring LFC Operators to establish the order of the reserve capacity that can be activated.	Part of the market simulation platform of the TSO/MO. The real-time reserve market simulator is in charge of: • Coordinating real-time processes.

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			• Modelling reserve market behaviour in accordance with regulations from Portugal. • Get inputs (bids and metering data) for the computation of market results. • Determine market clearing and settlement. • Communication back and forth via a web-API with the Flexibility Platform used by the BSP
Reconciliation Responsible	Role	A party that is responsible for reconciling, within a Metering Grid Area, the volumes used in the imbalance settlement process for profiled Accounting Points and the actual measured quantities.	In this use case this role is responsibility of the TSO/MO
Imbalance Settlement Responsible	Role	A party that is responsible for settlement of the difference between the contracted quantities with physical delivery and the established quantities of energy products for the Balance Responsible Parties in a Scheduling Area.	In this use case this role is responsibility of the TSO/MO
Balancing Service Provider (BSP)	Role	A party with reserve-providing units or reserve-providing groups able to provide balancing services to one or more LFC Operators (i.e. System Operators). Digital platform run by the BSP that serves as an autonomous link between the balancing markets and Reserve Resources.	

3.2 References

References						
No.	***Reference Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***
1	Directive	MPGGS_Directive19/2023 from ERSE	Active	Rules for aFRR/mFRR RR services	Portuguese TSO / ERSE	https://diariodarepublica.pt/dr/detalhe/diretiva/19-2023-835663384

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc.1	aFRR	The market platform simulation will	RR RA BSP	Bid submission	Pre-qualification approved	Saved results of the

		emulate the aFRR market of Portugal. HIL simulation for technical KPI evaluation. Simulation of the whole system for technical performance evaluation.	TSO/MO DSO			simulation regarding: - Bidding history -Scheduling - EC metering - Settlement
Sc.2	mFRR	The market platform simulation will emulate the mFRR market of Portugal. HIL simulation for technical KPI evaluation. Simulation of the whole system for technical performance evaluation.	RR RA BSP TSO/MO DSO	Bid submission	Pre-qualification approved	Saved results of the simulation regarding: - Bidding history -Scheduling - EC metering - Settlement

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4.2 Steps – Scenarios

Scenario								
Scenario name:		Technical assessment						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information Receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St.1	Pre-Qualification form submission	BSP Pre-Qualification Form	The BSP submits the pre-qualification form to the TSO/MO		BSP	TSO/MO	Inf.1	R1, R2, R5
St.2	Validation of Pre-Qualification Requirements	Validates Pre-Qualification Requirements	The TSO/MO validates the pre-qualification requirements of the BSP		TSO/MO	BSP	Inf.2	R1, R2, R5
St.3	Pre-Qualification Notification	Pre-Qualification Notification	The TSO/MO notifies the DSO on the pre-qualification process result of the BSP located in its network.		TSO/MO	DSO	Inf.3	R1, R2, R5
St.4	Energy Market Clearing Schedule	Baseline Energy Market Clearing Schedule	The energy market clearing schedule for the current market hour, set as a power baseline upon which the bids for FRR from the RR/RA are applied.		TSO/MO Locally saved historical data.		Inf.4	R1, R2, R3 or R4, R5
St.5	RR/RA send reserve availability	RR/RA Flexibility	The RR/RA communicate the available flexibility for FRR to the BSP.		RR/RA	BSP	Inf.5	R1, R2, R3 or R4, R5
St.6	BSP submits FRR bids	Bidding	The BSP submits the FRR bids to the TSO/MO (according to the internal procedures defined by the RR and RA).		BSP	TSO/MO	Inf.6	R1, R2, R3 or R4, R5
St.7	TSO/MO bid validation	Bidding Validation Message	Message accepting or rejecting FRR bids.		TSO/MO	BSP	Inf.7	R1, R2, R3 or R4, R5
St.8	TSO/MO computes market clearing	Market Clearing	The TSO/MO computes market clearing.		TSO/MO		Inf.8	R1, R2, R3 or R4, R5

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St.9	TSO/MO sends scheduling signal	Scheduling Message	The TSO/MO sends scheduling Message to BSP.		TSO/MO	BSP	Inf.9	R1, R2, R3 or R4, R5
St.10	Scheduling Validation Message	Scheduling Validation Message	The BSP confirms reception of scheduling signal to TSO/MO.		BSP	TSO/MO	Inf.10	R1, R2, R3 or R4, R5
St.11	DSO Scheduling Notification	Scheduling Notification	The TSO/MO notifies the DSO on the scheduling of the BSP located in its network.		TSO/MO	DSO	Inf.11	R1, R2, R3 or R4, R5
St.12	BSP assets scheduling	Scheduling Assets Message	BSP schedules assets from RR/RA members		BSP	RR/RA	Inf.12	R1, R2, R3 or R4, R5
St.13	RR/RA scheduling confirmation	Scheduling Assets Validation Message	The RR/RA confirms and validates scheduling with message to BSP, if there are assets.		RR/RA	BSP	Inf.13	R1, R2, R3 or R4, R5
St.14-1	BSP activation	Activation	The TSO/MO activates aFRR from BSP.		TSO/MO	BSP	Inf.14-1	R1, R2, R3 or R4, R5
St.15-1	BSP activation confirmation	Activation validation message	BSP confirms and validates activation message.		BSP	TSO/MO	Inf.15-1	R1, R2, R3 or R4, R5
St.14-2	BSP activation	Activation	The TSO/MO activates mFRR from BSP.		TSO/MO	BSP	Inf.14-2	R1, R2, R3 or R4, R5
St.15-2	BSP activation confirmation	Activation validation message	BSP confirms and validates activation message.		BSP	TSO/MO	Inf.15-2	R1, R2, R3 or R4, R5
St.16	DSO Activation Notification	Activation Notification	The TSO/MO notifies the DSO on the scheduling of the BSP located in its network.		TSO/MO	DSO	Inf.16	R1, R2, R3 or R4, R5
St.17	BSP activates RR/RA assets	Activation Signals	The BSP activates the assets from RR/RA members.		BSP	RR/RA	Inf.17	R1, R2, R3 or R4, R5

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St.18	RR/RA activation confirmation	Activation Validation Message	The RR/RA validates the activation to BSP.		RR/RA	BSP	Inf.18	R1, R2, R3 or R4, R5
St.19-1	DSO provides metering data to TSO/MO	Metering Data	The DSO sends the disaggregated metering data from the RR/RA assets related to the BSP to the TSO/MO		DSO	TSO/MO	Inf.19-1	R1, R2, R3 or R4, R5
St.19-2	BSP provides metering data to TSO/MO	Metering Data	The BSP sends the disaggregated metering data from the RR/RA assets to the TSO/MO		BSP	TSO/MO	Inf.19-2	R1, R2, R3 or R4, R5
St.20	TSO/MO computes settlement	Settlement	The TSO/MO computes the payments or penalties after reviewing the metering data from BSP against the activation orders.		TSO/MO		Inf.20	R1, R2, R3 or R4, R5
St.21	TSO/MO delivers settlement to BSP	Payments/ Penalties	The TSO/MO sends the payments/penalties to BSP		TSO/MO	BSP	Inf.21	R1, R2, R3 or R4, R5
St.22	BSP applies settlement to RR/RA	Payments/ Penalties (RR/RA)	The BSP applies the disaggregated payments/ penalties to RR/RA members.		BSP	RR/RA	Inf.22	R1, R2, R3 or R4, R5

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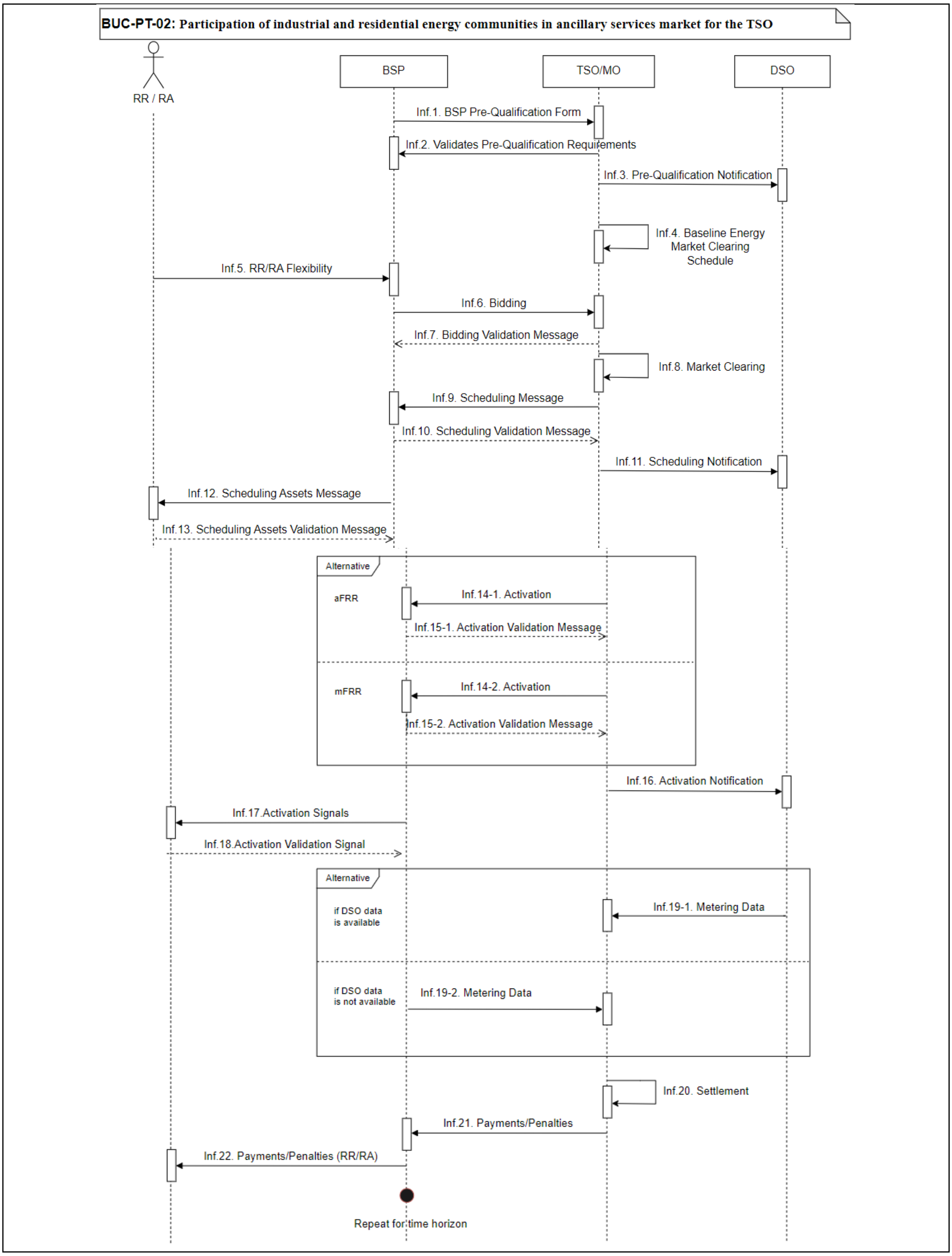

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5 Information exchanged

Information exchanged			
Information exchanged (ID)	**Name of information**	**Description of information exchanged**	**Requirement, R-IDs**
Inf.1	BSP Pre-Qualification Form	BSP sends the Pre-Qualification form to the TSO/MO about their capabilities and their communication system (e.g., SCADA)	R1, R2, R5
Inf.2	Validates Pre-Qualification Requirements	The TSO/MO validates the pre-qualification requirements of the BSP and sends a message to the BSP.	R1, R2, R5
Inf.3	Pre-Qualification Notification	The TSO/MO notifies the DSO about the pre-qualification results of the BSP sending a message to the DSO.	R1, R2, R5
Inf.4	Baseline Energy Market Clearing Schedule	Energy market clearing schedule for the current market hour, set as a power baseline upon which the bids for FRR from the RR/RA are applied. The market clearing schedule are shared between the MO and the TSO (internal information).	R1, R2, R3 or R4, R5
Inf.5	RR/RA Flexibility > BSP	Members of the energy community (RR/RA) provide a forecast of available flexibility based on estimation and/or agreed flexibility settings (contracts). This request identifies an asset, a period, and an estimate of the flexibility and corresponding monetary benefit.	R1, R2, R3 or R4, R5
Inf.6	Bids submission from BSP to TSO/MO	Using the reserve bid market model (XML file)	R1, R2, R3 or R4, R5
Inf.7	TSO/MO Bidding Validation message	Using the reserve bid market model (XML file)	R1, R2, R3 or R4, R5
Inf.8	Market Clearing Results	The market clearing results are shared between the MO and the TSO (internal information).	R1, R2, R3 or R4, R5
Inf.9	Scheduling Message from TSO/MO to BSP	Using the reserve bid market model (XML file)	R1, R2, R3 or R4, R5
Inf.10	BSP to TSO/MO schedule validation message	Using the reserve bid market model	R1, R2, R3 or R4, R5
Inf.11	Scheduling Notification	The TSO/MO notifies the DSO about the scheduling of the BSP sending a message to the DSO with the scheduling forecast.	R1, R2, R5
Inf.12	BSP to RR/RA Scheduling Assets Message	The schedule message for each asset includes an id, an activation time, a period, and a setpoint. This schedule is sent prior to the activation time.	R1, R2, R3 or R4, R5
Inf.13	RR/RA to BSP Scheduling Assets Validation Message	A confirmation message is received by the BSP when a scheduled signal is executed.	R1, R2, R3 or R4, R5
Inf.14-1	TSO/MO to BSP aFRR Activation to BSP	Using the reserve bid market model (using SCADA)	R1, R2, R3 or R4, R5
Inf.15-1	BSP to TSO/MO aFRR Activation Validation Message	Using the reserve bid market model (using SCADA)	R1, R2, R3 or R4, R5
Inf.14-2	TSO/MO to BSP mFRR Activation to BSP	Using the reserve bid market model (XML file)	R1, R2, R3 or R4, R5
Inf.15-2	BSP to TSO/MO mFRR Activation Validation Message	Using the reserve bid market model (XML file)	R1, R2, R3 or R4, R5
Inf.16	Activation Notification	The TSO/MO notifies the DSO about the activation of the BSP sending a message to the DSO.	R1, R2, R5
Inf.17	BSP to RR/RA Activation signals	The activation signal for each asset includes an id, an activation time, a period, and a setpoint.	R1, R2, R3 or R4, R5

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Inf.18	RR/RA to BSP Activation Validation Signals	A confirmation message is received by the BSP when a activation signal is executed.	R1, R2, R3 or R4, R5
Inf.19-1	DSO to TSO/MO metering data	Metering data from the RR/RA assets is collected by the DSO and made available to the TSO/MO for Settlement purposes.	R1, R2, R3 or R4, R5
Inf.19-2	BSP to TSO/MO metering data	Metering data from the RR/RA assets is collected by the BSP and made available to the TSO/MO for Settlement purposes.	R1, R2, R3 or R4, R5
Inf.20	Settlement	The settlement results are shared between the MO and the TSO (internal information).	R1, R2, R3 or R4, R5
Inf.21	TSO/MO to BSP Payments/Penalties	Payments/Penalties information is sent by the TSO/MO to the BSP through an XML file using the reserve bid market model	R1, R2, R3 or R4, R5
Inf.22	BSP to RR/RA Payments/Penalties	Payments/Penalties information is sent by the BSP to the RR/RA through an XML file using the reserve bid market model	R1, R2, R3 or R4, R5

6 Requirements

Requirements		
Requirement R-ID	**Requirement name**	**Requirement description**
R1	Pre-qualification requirements	Any market agent willing to participate in the ancillary services market, as a Balancing Service Provider (BSP) must comply with the following requirements (MPGGS[2]): a) Ensure the continuous compliance with the technical and operational requirements necessary to participate in the market; b) Acquire, install and maintain in proper working conditions the equipment with the characteristics indicated by GGS and needed infrastructure for the participation in the ancillary services market; c) Bear the costs associated with the acquisition, conservation and maintenance of the equipment and infrastructure indicated in the previous point; d) Report to the GGS any irregularities that could jeopardize their participation in ancillary services market; e) Be technically capable of complying with the power instructions issued by the GGS; f) Comply with dispatch instructions and power limitation instructions issued by the GGS; g) Pay the penalties owed to the GGS when applicable; h) Pay the obligations resulting from the ancillary services contracted within this market; i) Be able to exchange operational communications, namely, the submission of bids and the reception of the results of its participation in the market; j) Install and maintain in good operation conditions the equipment and communication channels that ensure observability and controllability by the GGS and compliance with the network code related to emergency and restoration states in electricity networks, where applicable; k) Be able to exchange communications with the IT system of the settlement department, for the communication of information needed for carrying out the settlement processes of the market and receiving the associated results.

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R2	Metering and communication requirements	Any physical unit acting as BSP must make available a local real-time monitoring and control infrastructure connected to the GGS's SCADA systems. This service includes the mandatory installation of a Remote Terminal Unit (RTU) communicating with the SCADA using the IEC 60870-5-104 standard[5]. The technical requirements for the different types of connections to the GGS's SCADA are available in[6], which is published in the GGS's website. Real-time communications between the physical units enabled to participate in the ancillary services market and the SCADA of the GGS are established through redundant channels, one to the National Dispatch Centre (Sacavém) and other to the Operational Centre (Vermoim), and should present a yearly availability rate higher than 96.7%. This means a maximum of 289.08 hours (12.05 days) of unavailability[2,6]. For production units, such communication network must present a yearly availability rate higher that 99.9%, i.e., a maximum of 8.76 hours of unavailability[6]. The electric and physical parameters to be reported to the GGS are the following[6]: a) Analog channels: i. Active power consumed (MW), ii. Reactive power consumed (Mvar), iii. Voltage (kV), iv. Frequency measurement (Hz); b) Digital channels (sent with a timestamp): i. OPEN/CLOSED state of the disconnection device from the connected grid, ii. Unblocked frequency load-shedding function, iii. Activation of frequency load-shedding function, iv. Blocking of active load replacement, v. Malfunction of the frequency load-shedding relay (equipment watchdog – one signal for each relay installed), vi. Malfunction of the time service (equipment watchdog), vii. Cyclic sending (every 15 minutes) of the message C_CS_NA_1 (date and time of the RTU's internal clock). The information related to the analogic channels must be sent periodically every 4 seconds, with a resolution of 1 kW, 1 kvar, 1 kV, and 10 mHz, respectively. The establishing and preserving of the operating equipment and communication channels used for this service is always responsibility of the BSP[6]. For the sake ensuring the feasibility of this use case with the existing demand-side assets, the following requirements were relaxed: • Connection to GGS's SCADA systems: no need to ensure SCADA connection, as long as alternative infrastructure allows real-time information exchange in terms of metering and control (activation signals)
R3	aFRR product requirements	The starting of the provision of secondary regulation (aFRR) should not take more than 30 seconds and its activation should be concluded, in the case of loss of one important generation installation, pumping or storage, no later than 5 minutes[2]. The physical units that can provide this service must have a total regulation capacity (up or down) equal or higher than 1 MW and have the corresponding qualification from the GGS (procedure 11 of MPGGS[2]).

[5] NGS, D3.1 – Definition of TSO and DSO market requirements for balancing and ancillary services, 2024.
[6] REN, Requisitos Técnicos para Ligação ao SCADA da REN, 2022. Available on: https://mercado.ren.pt/PT/Electr/AcessoRedes/AcessoRNT/LigacoesRede/BibScadaPT/Requisitos%20T%C3%A9c%20Lig%20ao%20SCADA%20REN,%20Rev10.2%20(Vers%C3%A3o%20P%C3%9ABLICA).pdf

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		The market agents that want to qualify a physical unit, should ask the GGS, with at least five working days in advance, the carrying out of tests to assess the technical and operational capacity. These tests assess the following aspects: a) The communication capacity with the central regulator; b) Real generation or consumption in fixed load regime; c) Variation gradient of the generation or consumption and the conservation of this value; d) Response to requests for random variation in generation or consumption, including reversing the direction of the request. The response of the generator in the test is always assessed according to the type of group in question, considering the experience with groups with the same type of response. The power-generating modules must comply with the requirements on the basis of the voltage level of their connection point and their maximum capacity according to their category. For the sake ensuring the feasibility of this use case with the existing demand-side assets, the following requirements were relaxed: • Minimum bid size: 0.1MW • Bid granularity: 0.01MW
R4	mFRR product requirements	In Portugal, BSP can participate in the mFRR market, remunerated in terms of activated energy, and the mFRR band market, remunerated in terms of capacity. Additionally, in the mFRR market, BSPs can provide a standard product or a specific product of rapid mFRR[5]. The characteristics of the standard mFRR service are stated in the following table (procedure 12 of MPGSS[2]), and include the following requirements: a) Activation mode: manual b) Time unit of the mFRR market: 15 min c) Activation moment: i. Direct activation: Between the publishing of the results of the scheduled activation and the beginning of the next process ii. Scheduled activation: 12.5 min before the delivery period d) Full activation time: 12.5 min e) Minimum bid: 1 MW f) Maximum bid: 9999 MW g) Bid granularity: 1MW h) Minimum duration of delivery period: 5 min i) Price of the bid: €/MWh, with resolution of 0.01 €/MWh j) Preparation period: 2.5 min (included in the full activation time) k) Ramping period: 10 min (included in the full activation time) l) Deactivation period: up to 10 min m) Aggregation level of the bids: Bidding area n) Delivery period: i. Direct Activation: between 6 and 19 min, according to the activation point ii. Scheduled activation: 5 min To be able to provide mFRR services, the physical units should get the qualification with the GGS, by demonstrating that they fulfil the technical and operational requirements, namely the ones referred above. The enabled physical units should have an offer capacity over 1 MW[2]. The participation of aggregated physical units with a bidding capacity below 1 MW is allowed, as long as the aggregated capacity exceeds 1 MW, they are aggregated in the same bidding area and are associated with the programming units of a single Balancing Responsible Party (BRP)[2]. To qualify a physical unit, the respective BSP should ask the GGS to carry out tests to assess the unit's technical and operational capacity. The following requirements must be checked (procedure 12 of MPGSS[2]): a) The connection of the physical unit to the remote metering system;

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		b) The correct operation of real time communications between the physical unit and the SCADA of the GGS; c) The correct operation of voice communications between the dispatch and the command rooms of the physical unit; d) The quality of the real time measurements of the physical unit; e) The correct operation of the equipment to receive the instructions from the dispatch centre and limitations to production or consumption; f) The capacity to receive and reply to instructions of the dispatch from the command room of the physical unit; g) The capacity of the command room of the physical unit to communicate changes to its available power; h) The existence of means for the compliance of the instructions of the dispatch in case of total failure in the command room of the physical unit, including the test of the contingency plans established. The specific product of rapid mFRR is used when the available balancing products do not permit to solve a given constraint that is threatening the stability of the electric system. The characteristics of this product demands for a faster response time in comparison with the standard product. The additional requirements of this product are stated below: a) Activation mode: Manual b) Full activation time: From 1 to 10 min c) Bid granularity: 1 MW d) Minimum duration of delivery period: 1 min e) Maximum duration of delivery period: 12.5 min f) Direction: a. Positive (upwards regulation) or b. Negative (downwards regulation) According to procedure 15 of MPGGS[2], mFRR band is defined as the power variation margin in which the bidding area can be mobilized to go up, through scheduled activation, in less than 12.5 minutes, starting from its current operation point. The entities or installations that want to deliver band mFRR services must fulfil the following requirements (procedure 15 of MPGGS[2]): a) Be connected to Extra-High Voltage (EHV), High Voltage (HV) or Medium Voltage (MV) and be: i. A physical unit associated to a power consumption installation; or ii. A physical unit associated to a power generation installation that is not obliged to participate in the mFRR market; iii. A physical unit associated to a storage installation; b) Be a market agent qualified to provide mFRR service; c) If the consuming installation is a cogeneration plant, it needs to prove it has the capacity to reduce consumption without loss of generation; d) If it is a production unit for self-consumption (does not use the public power grid), the measurement of the provision of the service will use as reference the net value between consumption and production in interconnection point with the grid e) Each physical unit should have an eligible power equal or higher than 1 MW; f) Install the real-time measurement devices, according to the requirements published by GGS; g) Ensure the correct operation of the real-time communications between the physical units and the SCADA from GGS; h) Do not have any unsettled overdue debt with the GGS; i) Provision of guarantees to the Integrated Guarantee Manager (GIG, "*Gestor Integrado de Garantias*", in Portuguese), under the risk and guarantee management regime in the national electricity system, whenever applicable;

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		j) Comply with the requirements to participate in the mFRR market (stated above). For the sake ensuring the feasibility of this use case with the existing demand-side assets, the following requirements were relaxed: • Minimum bid size: 0.1MW • Bid granularity: 0.01MW
R5	GDPR	Compliance with the EU General Data Protection Regulation (GDPR).

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
aFRR	Automatic Frequency Restauration Reserve
BRP	Balancing Responsible Party
BSP	Balancing Service Provider
DER	Distributed Energy Resources
DSO	Distribution System Operator
GGS	Global System Management (from the System Operator)
GIG	Integrated Guarantees Manager
HIL	Hardware-In-the-Loop
HVAC	Heating, Ventilation, and Air Conditioning
mFRR	Manual Frequency Restauration Reserve
MO	Market Operator
MPGGS	Portuguese Global System Management Procedures Manual for the electricity sector
MSP	Market Simulation Platform
NPV	Net Present Value
RA	Resource Aggregator
RR	Reserve Resource
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SO	System Operator
TSO	Transmission System Operator

BUC-PT-03 FLEXIBILITY AGGREGATION AT TERTIARY BUILDINGS

1 Description of the use case

1.1 Name of the use case

ID	*Area / Domain(s)*	*Name of Use Case*
BUC-PT-03	Flexibility aggregation	Flexibility aggregation at tertiary buildings

1.2 Version management

Version Management			
Version No.	*Date*	*Name of Author(s)*	*Changes*
1.0	15.04.2024	Amândio Ferreira	First draft version
1.1	05.06.2024	Amândio Ferreira	Improvement of BUCs scope
1.2	15.06.2024	Amândio Ferreira	Final consolidation
1.3	26.06.2024	Amândio Ferreira	Harmonization with pilot partners

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1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Flexibility aggregation for commercial applications
Objective(s)	Creation of services based on flexibility management Benchmark valorisation of different flexibility scenarios Demonstrate business case from aggregator / BSP perspective
Related business case(s)	BUC-PT-01 BUC-PT-02

1.4 Narrative of use case

Narrative of Use Case
Short description
The flexibility aggregator / BSP needs to be able to manage a heterogeneous pool of flexible assets. End users and assets owners want to monetize their flexibility. Flexibility aggregator / BSP aims to develop a set of services that can deliver benefits to assets owners. With current and projected RES penetration market prices volatility opens a number of opportunities to arbitrage solutions driven either by energy price, CO2 footprint or grid operator incentives. To maximize assets monetization different activation scenarios, need to be analysed before dispatch through an orchestration tool. The BUC includes the following steps. 1. Integration of different assets from commercial buildings 2. Creation of a tool for flexibility forecast and associated valorization for each asset 3. Aggregation of flexibility at building level 4. Aggregation of flexibility at aggregator level and associated valorization 5. Orchestration and decision on flexibility scenarios to be dispatched
Complete description
1. Integration of different flexible assets from commercial buildings Commercial buildings have a multitude of assets from different manufacturers using different protocols, commands and operation modes. Aggregation of these assets requires a demanding work of integration and harmonization for both data collection and control enablement. A BEMS (Building Energy Management System) will act as a gateway to the exterior, exposing local assets data to the flexibility management platform, DPP. **System Use Case called by the step:** SUC-PT-04.1 – Integrate flexible assets from commercial buildings **2. Creation of default valorization scenario based on price edging** Flexible asset owners seek for the best possible monetization for flexibility activation. The participation of prosumers (domestic or commercial/industrial) in flexibility markets for provision of flexibility to grid operators will only become a reality if prosumers / assets owners get the right incentives to do so. Such incentives will necessarily be compared to other possibilities, namely through price edging scenarios which can be considered a default valorization. For commercial buildings 3 types of assets will be considered in the pilot demonstrations (cooling / HVAC and storage). Creation of this default valorization scenario requires the simulation and optimization of flexibility activation schedule for each asset within the building based on price edging.

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System Use Case called by the step
SUC-PT-04.2 – Default valorization scenario based on price edging

3. Aggregate of flexibility potential

In this stage flexibility of different buildings is aggregated to provide flexibility to the grid operator [linked to BUC-PT-02]. Flexibility aggregator of commercial buildings can also integrate additional assets in its offer to the grid operator. These assets can be integrated in the aggregator offer via bilateral agreement with other aggregators [linked to BUC-PT-01].

System Use Case called by the step
SUC-PT-04.3 – Aggregation of flexibility

4. Scenarios comparison

At this stage both scenarios are compared for decision on flexibility activation. The tool will proceed with the scenario that maximizes the value for the prosumer / asset owner.

System Use Case called by the step
SUC-PT-04.4 – Scenarios comparison

5. Flexibility activation

At this stage the schedule is dispatched to the BEMS for asset activation.

System Use Case called by the step
SUC-PT-04.5 – 5. Flexibility activation

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
In the BUC it is assumed that • Grid operator will provide incentives to aggregator for flexibility activation through flexibility market mechanisms • Threshold for provision of flexibility to the grid operator of 100 kW (through aggregation) with steps of 10 kW. • Aggregator can establish bilateral contracts with other aggregators to complement its offer to the market operator • Prosumers (domestic or commercial / industrial) grant control over their assets to the aggregators
Prerequisites
• Ability to collect and share data in an automated way • Strategies for the valorization of flexibility established (e.g., definition of incentives) • Data availability to fulfil ML/AI strategies • Access to energy contract details of each building for price edging optimization • Range of operation of each asset well defined

1.7 Further Information to the use case for classification / mapping

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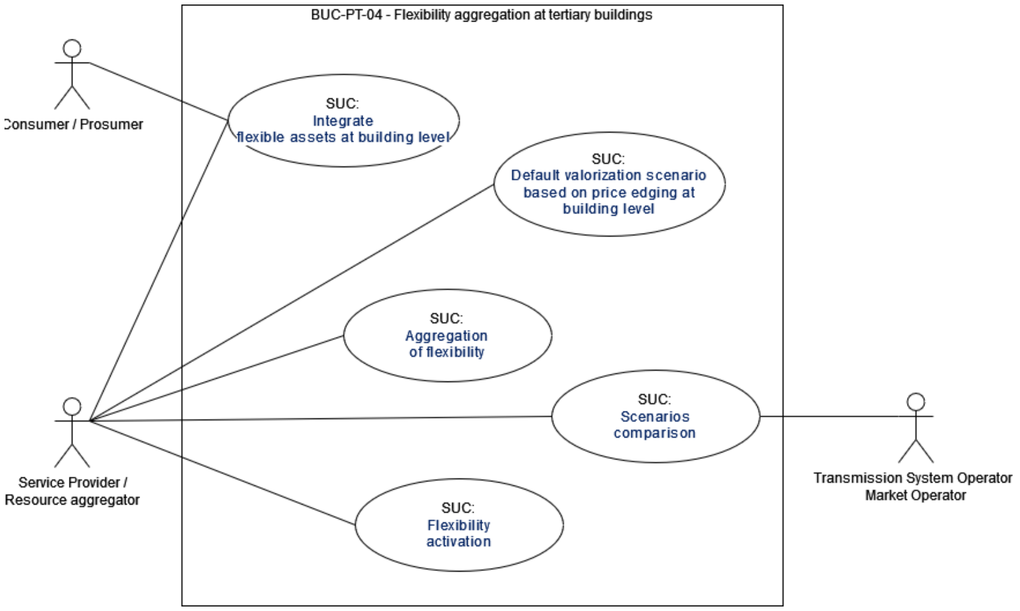
Classification Information
Relation to other use cases
BUC-PT-01, BUC-PT-02
Level of depth
Business use case (BUC) use case which describes a general requirement, idea or concept independently from a specific technical realization like an architectural solution
Prioritisation
High
Generic, regional or national relation
National
Nature of the use case
Business Use Case
Further keyword for classification
Flexibility Aggregator, Flexibility Service Provider, Flexibility Services, Interoperability, Grid Operator

1.8 General Remarks

General Remarks

2 Diagrams of use case

Diagram(s) of use case



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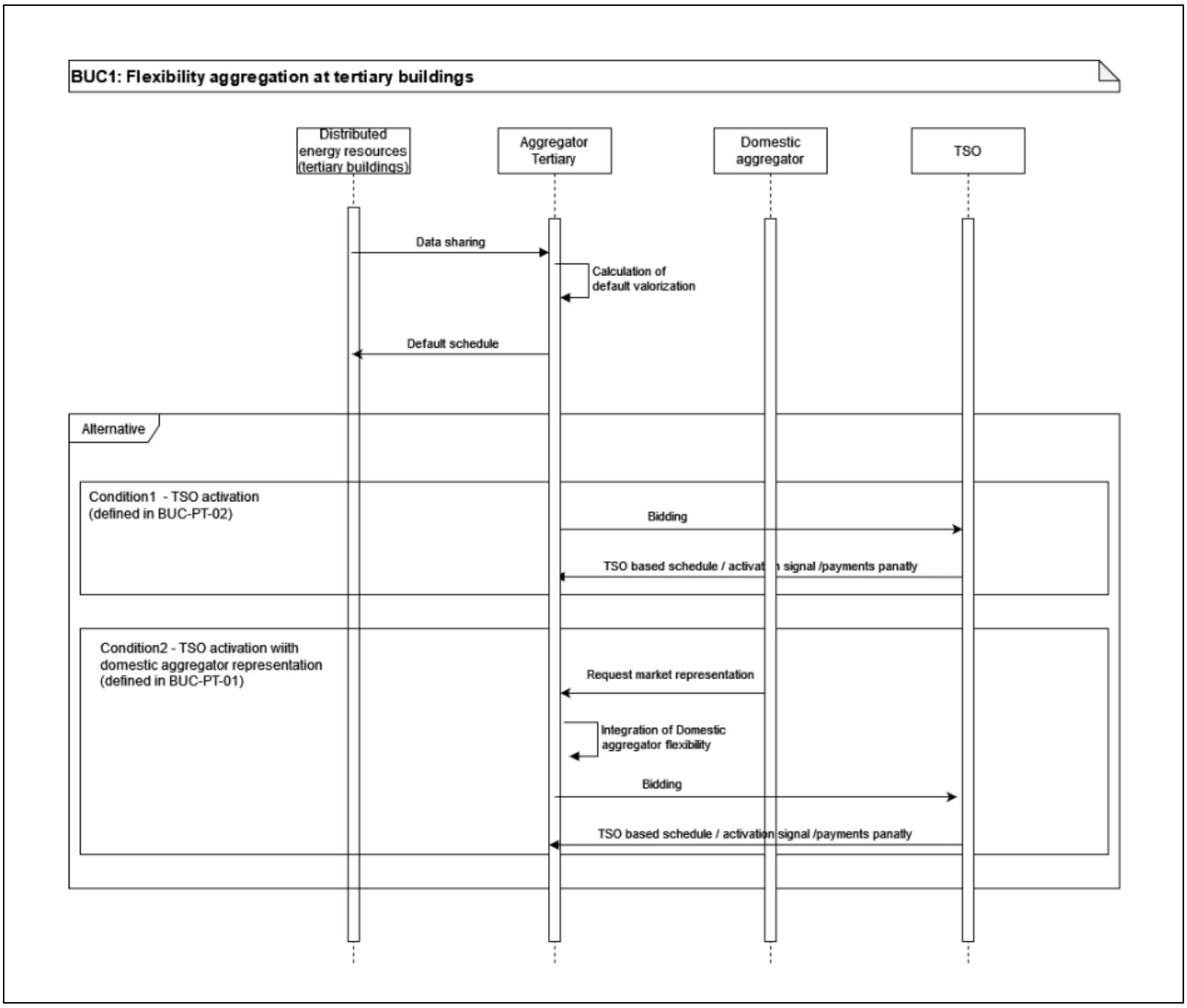

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3 Technical details

3.1 Actors

Actors		
Actor Name	**Actor Type**	**Actor Description**
Resource Aggregator (RA)	Role	The Resource Aggregator (RA) is an energy flexibility manager and aggregator that uses a flexibility management platform to deploy business models inside the energy community that monetize their customers' flexibility in order to deliver system services to the grid. It serves as a source of balancing resources for the Balancing Service Provider (BSP) from the grid/SO standpoint by submitting aFRR/mFRR bids to the TSO. Internally, starting with the Flexibility Platform, the RA oversees the entire procedure. In addition to promoting member engagement and community recruitment, it involves choosing the desired energy mix and carefully recruiting segmented customers. It also guarantees the proper operation and maintenance of the energy community through the installation of IoT equipment, regular site maintenance visits, and handling of member complaints and concerns.
Reserve Resource (RR)	Resource	A resource technically pre-qualified using a uniform set of standards to supply reserve capabilities to a System Operator and is associated with one or more tele measuring devices. It generates, consumes, distributes, and uses electricity with the intention of benefiting the local community on an economic, social, and environmental level. This can include producers, consumers, and prosumers. The RR flexibility will be utilized in this use-case to provide aFRR/mFRR services, a type of ancillary service, to Transmission System Operators (TSOs).
System Operator (SO)	Role	A system operator is responsible for ensuring the reliable and efficient operation of a power grid. Their primary role involves monitoring, controlling, and optimizing the flow of electricity across the grid to meet demand while maintaining system stability and reliability.
Balancing Service Provider (BSP)	Role	A party with reserve-providing units or reserve-providing groups able to provide balancing services to one or more LFC Operators (i.e. System Operators). Digital platform run by the BSP that serves as an autonomous link between the balancing markets and Reserve Resources.
Prosumer	Business Actor	The Prosumer is a Consumer who can also produce electricity. In HEDGE-IoT role model (T1.3) it is assumed that a prosumer also adopts an active role in the energy chain, by, for example, being willing to join self-consumption structures or provide flexibility (sometimes Flexumer is also used). The EC members are assumed to be prosumers.

3.2 References

References						
No.	**References Type**	**Reference**	**Status**	**Impact on use case**	**Originator / organisation**	**Link**

4 Step by step analysis of use case

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4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc. 1	Tertiary building aggregation only	Tertiary aggregator runs optimizes flexibility management only considering its own assets	Resource aggregator (tertiary buildings)	-	Control over tertiary buildings flexible assets	-
Sc. 2	Tertiary building & green vale aggregation	Tertiary aggregator represents green vale aggregator assets	Resource aggregator (domestic)	Request to aggregate green vale assets	Bilateral agreement between Tertiary aggregator and Green Vale aggregator and control over flexible assets.	-
Sc. 3	Default price edging activation	Default price edging activation	Resource aggregator	-	Control over tertiary buildings flexible assets. Bid to provide flexibility to the TSO was not accepted	-

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4.2 Steps – Scenarios

Scenario								
Scenario name:		Sc. 1 - Tertiary aggregator only						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St. 1	Continuous retrieval	Data monitoring	Continuous monitoring of flexible assets / energy price / PV generation	GET	Prosumers assets & energy markets	Tertiary aggregator	Inf.01 Inf.02	-
St. 1.2	Default valorization	Default valorization calculation	Based in price edging a default asset schedule is created	EXECUTE	Tertiary aggregator	-	-	-
St. 1.3	Activate default schedule	Default valorization schedule	Tertiary aggregator sets assets with the default valorization schedule	POST	Tertiary aggregator	Prosumers assets & energy markets	Inf.03	
St. 1.4	TSO bid	Create bid to TSO	Creation of bid to submit to the TSO	CREATE	Tertiary aggregator	-	-	
St. 1.5	Bidding	TSO bidding	Send bid to the TSO	POST	Tertiary aggregator	TSO	Inf.04	
St. 1.6	TSO activation	TSO activation confirmation	Confirmation from the TSO that flexibility will be activated	POST	TSO	Tertiary aggregator	Inf.05	
St. 1.7	Activate TSO schedule	TSO valorization schedule	Tertiary aggregator updates assets schedules with the TSO based schedule	POST	Tertiary aggregator	Prosumers assets & energy markets	Inf.06	

Scenario								
Scenario name:		Sc. 2 - Aggregation tertiary & green vale						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St. 1.1	Continuous retrieval	Data monitoring	Continuous monitoring of flexible assets / energy price / PV generation	GET	Prosumers assets & energy markets	Tertiary aggregator	Inf.01 Inf.02	-
St. 1.2	Default valorization	Default valorization calculation	Based in price edging a default asset schedule is created	EXECUTE	Tertiary aggregator	-	-	-
St.	Activate	Default	Tertiary aggregator sets assets with	POST	Tertiary	Prosumers assets	Inf.03	

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1.3	default schedule	valorization schedule	the default valorization schedule		aggregator	& energy markets		
St. 1.4	Request from Green Vale	Request from Green Vale	Request from Green Vale to aggregate its assets	GET	Green Vale aggregator	Tertiary aggregator	Inf.07	
St. 1.5	Integration of green vale flexibility	Integration of green vale flexibility	Integration of green vale flexibility with the tertiary buildings' flexibility	EXECUTE	Tertiary aggregator	-	-	
St. 1.6	TSO bid	Create bid to TSO	Creation of bid to submit to the TSO	CREATE	Tertiary aggregator	-	-	
St. 1.7	Bidding	TSO bidding	Send bid to the TSO	POST	Tertiary aggregator	TSO	Inf.04	
St. 1.8	TSO activation	TSO activation confirmation	Confirmation from the TSO that flexibility will be activated	POST	TSO	Tertiary aggregator	Inf.05	
St. 1.9	Green Vale activation	Green Vale activation	Share with Green Vale aggregator the activation confirmation	POST	Tertiary aggregator	Green Vale aggregator	Inf.0.8	
St. 2.0	Activate TSO schedule	TSO valorization schedule	Tertiary aggregator updates assets schedules with the TSO based schedule	POST	Tertiary aggregator	Prosumers assets	Inf.06	
St. 2.1	Monitor flexibility activation	Monitor flexibility activation	Monitor flexibility activation follows the expected schedule	GET	Tertiary aggregator	Prosumers assets	Inf.01	

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5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
Inf.01	Assets data	Energy metering data consumption, operational modes, …	Communication and data integration
Inf.02	Market data	Contract information, market price data,	Access to contract data
Inf.03	Default schedule	Operation schedule for each asset based on default valorization	-
Inf.04	Bidding to TSO	Offer to the TSO	-
Inf.05	TSO activation confirmation	TSO activation confirmation that the bid was accepted	-
Inf.06	TSO schedule	Operation schedule for each asset based on TSO valorization	-
Inf.07	Green vale request	Request from green vale and flexibility information	Integration with Green Vale
Inf.08	TSO aggregated activation	Confirmation of TSO aggregated activation to green vale	-

6 Requirements

Requirements		
Categories ID	**Category name for requirements**	**Category description**
GDPR	Regulatory obligation related to privacy	2016/679 (General Data Protection Regulation)
Requirement R-ID	**Requirement name**	**Requirement description**
GDPR-2	Data retention policy	Data retention policy outlines the time period specific sensitive data can be retained, plus how it will be disposed of when the time to do so comes.
GDPR-3	Data transfer consent	Personal data may not be transferred to a third-party if the data subject did not agree and the third party provide appropriate safeguard.
GDPR-X	All GDPR constraints also apply to this BUC.	e.g., proportional measures of protection, communication of data breach, among others

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
RA	Resource Aggregator
RR	Reserve Resource
SO	System Operator
TSO	Transmission System Operator
HVAC	Heating, Ventilation, and Air Conditioning
DER	Distributed Energy Resources
BRP	Balancing Responsible Party
BSP	Balancing Service Provider

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BUC-SI-01 MAXIMIZING ASSET CAPACITY FOR INCREASED LIFETIME OF DSO AND TSO EQUIPMENT

1 Description of the use case

1.1 Name of the use case

ID	Area / Domain(s) / Zones(s)	Name of Use Case
BUC-SL-01	Grid-centred-optimal load	Maximizing asset capacity for increased lifetime of DSO and TSO equipment

1.2 Version management

Version Management			
Version No.	**Date**	**Name of Author(s)**	**Changes**
0.1	14.03.2024	Lenart Ribnikar, Elektro Gorenjska d.d.	First draft version of BUC-SL-01 for Demo 6
0.2	17.05.2024	Lenart Ribnikar Elektro Gorenjska d.d.	Full completion of BUC-SL-01for Demo 6 of Hedge-IoT project
0.3	11.06.2024	Lenart Ribnikar, Elektro Gorenjska, d.d.	Fixed some parts based on feedback from T2.2 leader.

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Real time Dynamic thermal rating (DTR) calculation for distribution transformers in secondary transformer substations and dynamic line rating (DLR) calculations for transmission power lines that will take place on edge IoT devices.
Objective(s)	The objective of this Business Use Case (BUC) is to enhance the efficiency and reliability of energy assets by developing and deploying real-time dynamic thermal rating (DTR) and dynamic line rating (DLR) calculations on edge IoT devices for distribution transformers and power lines. These real-time calculations will provide accurate data on thermal load capacity, helping to prevent overheating and overloading of critical infrastructure or ensuring a safe overload if the weather is ideal. Understanding dynamic ratings allows for optimal asset utilization, extending their lifespan, improving grid reliability, and reducing maintenance costs, thereby enhancing overall operational efficiency and customer service. The DLR calculations will be initially implemented in a pilot program with the Slovenian Transmission System Operator (TSO), ELES. Meanwhile, DTR calculation will be introduced and evaluated within the Slovenian Distribution System Operator (DSO), EG.
Related business case(s)	BUC-SL-02: Enhanced Network Manageability and Observability

1.4 Narrative of use case

Narrative of Use Case
Short description
The growing electrification of transport, heating and overall increased consumption of electrical energy is directly impacting the load on transmission and distribution electric grid and respectably to DSO and TSOs. More and more

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distribution transformers are loaded near or over their rated power. The problem also stands for transmission power lines.

This poses a problem for TSO and DSO with more and more needs for new investments for stable grid capable of handling bigger loads. Dynamic rating (DR) provides critical insights into the actual potential loads of transformers and power lines, incorporating environmental factors like outside temperature. For instance, during colder winter days, it becomes feasible to load transformers beyond their rated capacity without compromising their integrity. This principle also applies to power lines.

The BUC includes the following steps.

1. DTR and DLR edge calculation made for specific asset types
2. Implementation of the IoT device to TSO and DSO grid
    2.1. Grid pre-qualification

Complete description

The BUC will implement the real-time DTR of distribution transformers, utilizing local telemetry data from transformers and local weather conditions calculated using different algorithms. Similarly, it will include dynamic line rating (DLR) calculations for transmission lines. DLR assessments leverage similar data sources to optimize the operational capacity of power lines, factoring in environmental conditions.

Transformers are one of the most important assets in the distribution power network; in the case of their overload, their lifespan significantly deteriorates due to insulation damage. In the case of underload, however, transformers are not optimally utilized. In recent years, due to the rise of micro power plants (such as solar power plants on the roofs of individuals) and the increase in electricity consumption due to heating and the electrification of transport, there has been an increase in electricity consumption. Increased electricity consumption has a direct impact on the load of distribution networks, where overloads of certain transformers can occur, thereby necessitating investment in a new network. Currently, the load of a transformer is monitored through its rated power, but rated power is not a correct indicator of transformer overload. DTR allows the calculation of the optimal load of the transformer based on its temperature. Thus, in wintertime, a transformer can be overloaded up to 100% without affecting its lifespan.

Likewise, the deployment of DLR offers a sophisticated method for regulating the capacity of transmission lines across diverse environmental conditions, optimizing performance while enhancing the longevity of the infrastructure. Like transformers and DTR calculations, power lines can be loaded beyond their rated capacities under favourable weather conditions, ensuring efficient utilization.

Using the DTR and DLR information allows for the targeted allocation of investment funds to the most heavily loaded transformers and power lines, thereby ensuring optimal use of available resources that can't cover all the current overloaded and aged transformers and power lines.

BUC-SL-01 introduces a ground-breaking solution for calculating DTR and DLR at the network's edge, offering real-time processing essential for dynamic transformer and line protection. By performing calculations on IoT devices located at the network's edge, the system gains independence from server and cloud communication, ensuring robustness even in communication failure scenarios. Moreover, this edge-based computation promises enhanced accuracy and speed due to superior computing power, marking a significant advance in managing and optimizing power network operations.

1. **DTR and DLR edge calculation made for specific asset types**
   First step of BUC will be the adapting of edge IoT devices for DR calculations. In previous pilot project EG and ELES have already implemented first versions of DTR and DLR that lack computing power and speed. The existing cloud-based algorithms will be upgraded and deployed to edge IoT devices. The edge implementation will enable faster calculations due to direct connections to power quality meters.
   First step and BUC in general will be split to 2 scenarios.
   First scenario named Maximizing DSO MV/LV capacity using DTR. The scenario will focus on DSO secondary substation transformers
   Second scenario named Maximizing power lines capacity using DLR, will focus on TSO power lines.
   This is the major step in the BUC. The DLR and DTR on edge calculation will provide the necessary data for better grid observability.

2. **Implementation of the IoT devices to TSO and DSO grid**

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After the development of IoT devices the next step will be to implement the devices to electric grids. During the Hedge-IoT project the BUC will be implemented in Slovenian TSO ELES (DLR) and DSO Elektro Gorenjska (DTR). With this step the IoT device will be tested directly on the grid.

a. Grid pre-qualification

One of the important steps in implementing IoT devices for TSO and DSO is the pre-qualification of the energy network. In this step, TSO and DSO will identify locations in a pilot project that would benefit from the introduction of DTR and DLR calculations at the edge of the network. It will be necessary to identify overloaded transformers (especially during the winter time) and loaded power lines. This will determine the locations where the IoT device needs to be implemented. It is important that these locations also have a measurement centre, as it provides input data for the DR calculation algorithm.

3. Validation and measurement phase

The final phase of BUC encompasses the measurement stage. Once the IoT devices have been integrated into the TSO and DSO grids, data pertaining to calculated DTR will be collected in the SUMO cloud, making it accessible for subsequent ML/AI algorithm analyses presented in BUC-SL-02. This setup lays the groundwork for future enhancements, including the refinement of DTR/DLR calculations with dynamic protection and the incorporation of additional flexibility algorithms.

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
In this BUC it is assumed that • DSO has overloaded transformers with sufficient data • TSO has overloaded power lines with sufficient data • Cloud provider has experience with SO companies • Transformer and power lines dynamic protection (influenced by DTR and DLR) is a cost-effective solution (in respect to network replacement), at least in the short-term
Prerequisites
• DSO has secondary transformer stations with PQ meters • TSO has power lines with PQ meters • Transformers are overloaded • Power lines are overloaded

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Hedge-IoT project: BUC-SL-02: Enhanced Network Manageability and Observability Connected to SUC of Hedge-IoT Demo 6
Level of depth
Business use case (BUC) use case which describes a general requirement, idea or concept independently from a specific technical realization like an architectural solution

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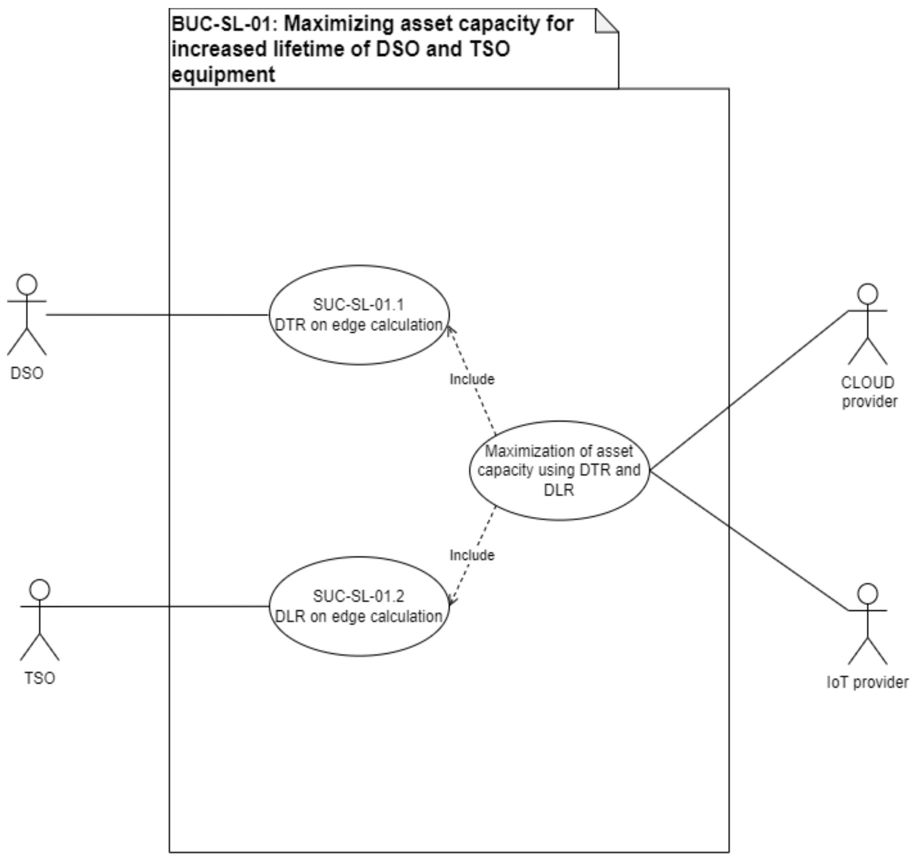
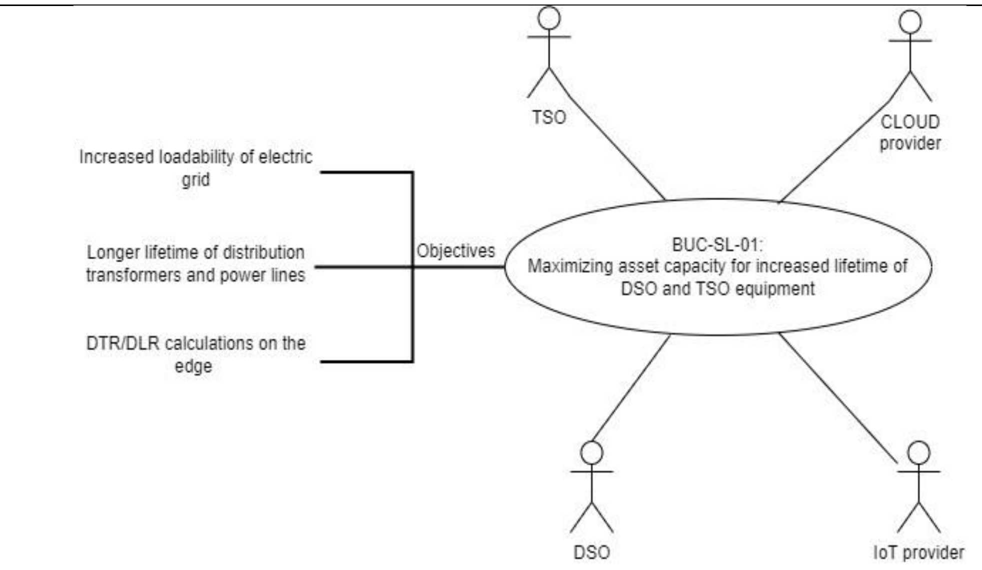
Prioritisation
To be demonstrated in Slovenia (pilot 6)
Generic, regional or national relation
Generic / regional
Nature of the use case
Business Use Case
Further keywords for classification
Dynamic Thermal Rating, Dynamic Line Rating, Optimal Load, Distribution energy grid, Transmission energy grid, observability, cloud, IoT, DSO, TSO

1.8 General Remarks

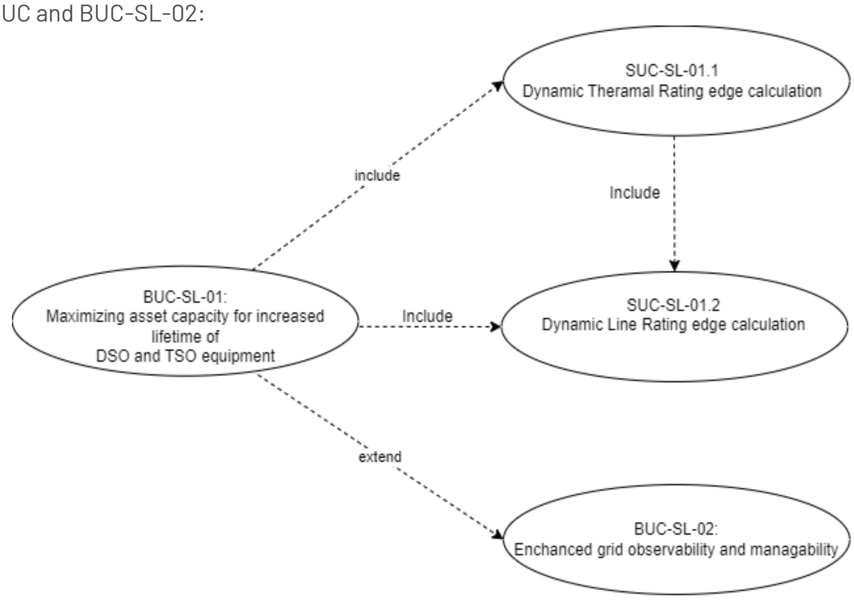
General Remarks

2 Diagrams of use case

Diagram(s) of use case




Connection to SUC and BUC-SL-02:



3 Technical details

3.1 Actors

Actors			
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***
Distribution System Operator (DSO	Operator	A party who will use DTR calculation on distribution transformers. DSO is responsible for determining locations, where the DTR device will be implemented and for providing the specific PQ data for transformers.	ELEKTRO GORENJSKA
Transmission System Operator (TSO)	Operator	A party who will use DLR calculation on transmission power lines. TSO is responsible for determining	ELES

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		locations, where the DLR device will be implemented and for providing the specific PQ data for power lines.	
Cloud service provider	Business actor	Company that provides cloud service for saving DTR and DLR data, where the data exchange and additional ML/AL algorithms can be applied.	OPERATO
IoT provider	Business actor	A party responsible for the development of the IoT device and the deployment of code for DTR/DLR to IoT device	IJS

3.2 References

References						
No.	***Reference Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc. 1	Maximizing DSO MV/LV transformer capacity using DTR	DTR edge calculation made for secondary transformers (DSO)	IoT provider, Cloud provider, DSO	The need of optimal load of SO grid, better insight, and digitalization of electric grid	Overloaded DSO grid based on rated power. Grid must contain PQ meters	Optimal load of transformer and power lines based on their thermal specification. This can extend assets lifetime and prevent unnecessary outage
Sc. 2	Maximizing TSO power lines capacity using DLR	DLR edge calculation made for power lines in Transmission system operator grid	IoT provider, Cloud provider, TSO	The need of optimal load of SO grid, better insight, and digitalization of electric grid	Overloaded TSO grid based on rated power and limitations.	Optimal load of transformer and power lines based on their thermal specification. This can extend assets lifetime and prevent unnecessary outage

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4.2 Steps – Scenarios

Scenario								
Scenario name:		Sc. 1 - Maximizing DSO MV/LV transformer capacity using DTR						
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information Exchanged (IDs)***	***Requirement, R-IDs***
St. 1	Transformer DTR request	DTR request	IoT device requests DTR calculation from DTR calculation program (locally on edge)	CREATE	IoT device	DTR edge calculation	Inf.1	R1, R2, R3, R5, R6, R7, R8
St. 2	DTR calculation	DTR calculation	DTR on edge calculation code gathers request and data from IoT device to perform on edge DTR calculation	EXECUTE	DTR on edge	DTR on edge		R4, R7
St. 3	DTR value	DTR value is send to IoT device	Calculated DTR is stored to IoT device	REPORT	DTR on edge	IoT device	Inf.2	R1, R2, R3, R5, R6, R7, R8
St. 4	Transformer capacity information	Sending DTR data to cloud	Calculated DTR values are sent from edge IoT device to Cloud	EXECUTE	IoT device	SUMO Cloud	Inf.3	R2, R3, R5, R6
St. 5	Transformer capacity information request	Transformer capacity information request	DSO requests information of transformer load capacity based on Dynamic Thermal Rating	CREATE	DSO	SUMO cloud	Inf.4	R3, R7, R8
St. 6	Transformer capacity information	Transformer capacity information	DSO gathers DTR data from SUMO cloud for optimal maintenance	REPORT	SUMO cloud	DSO	Inf.5	R3, R6, R7, R8

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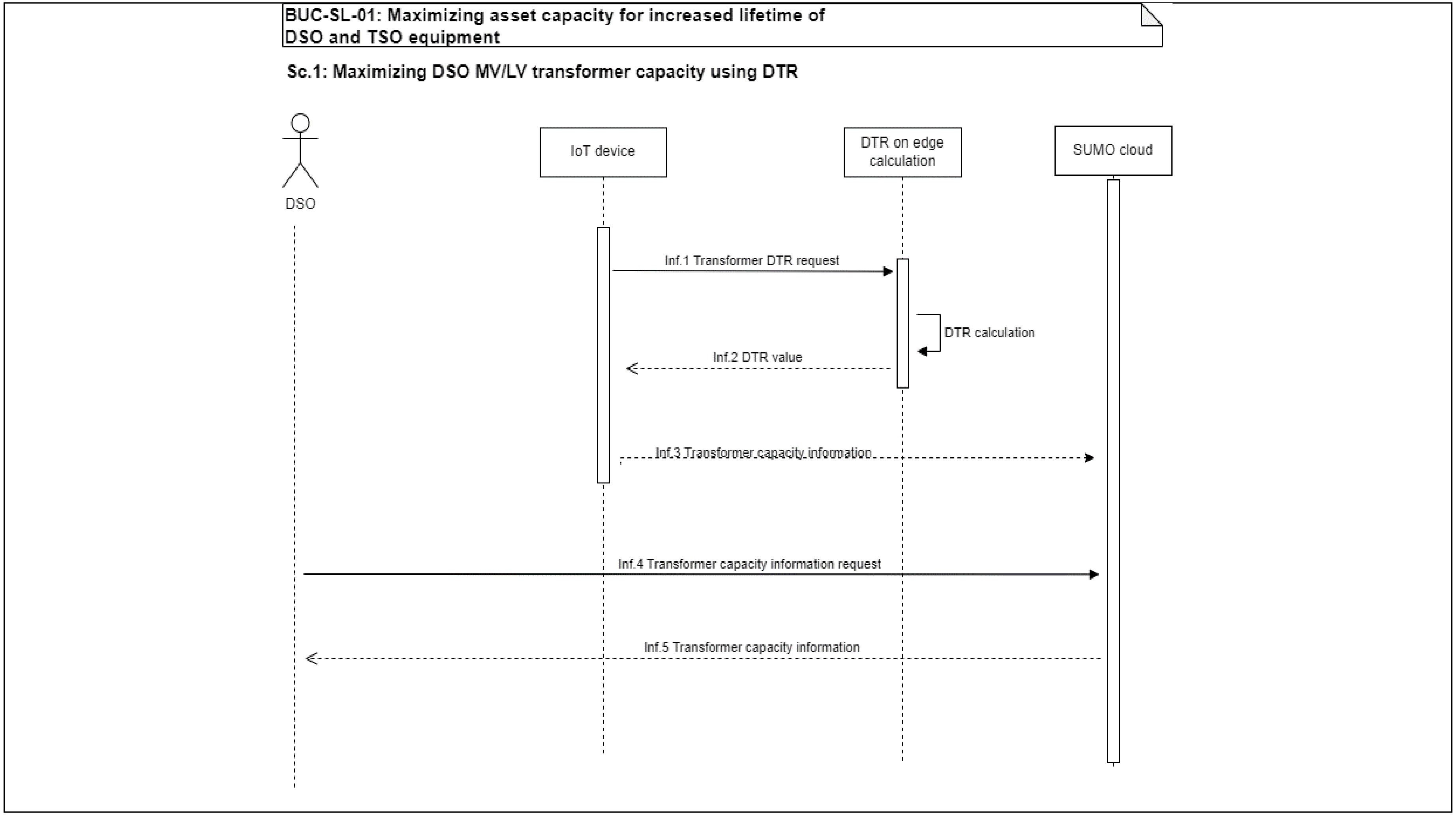

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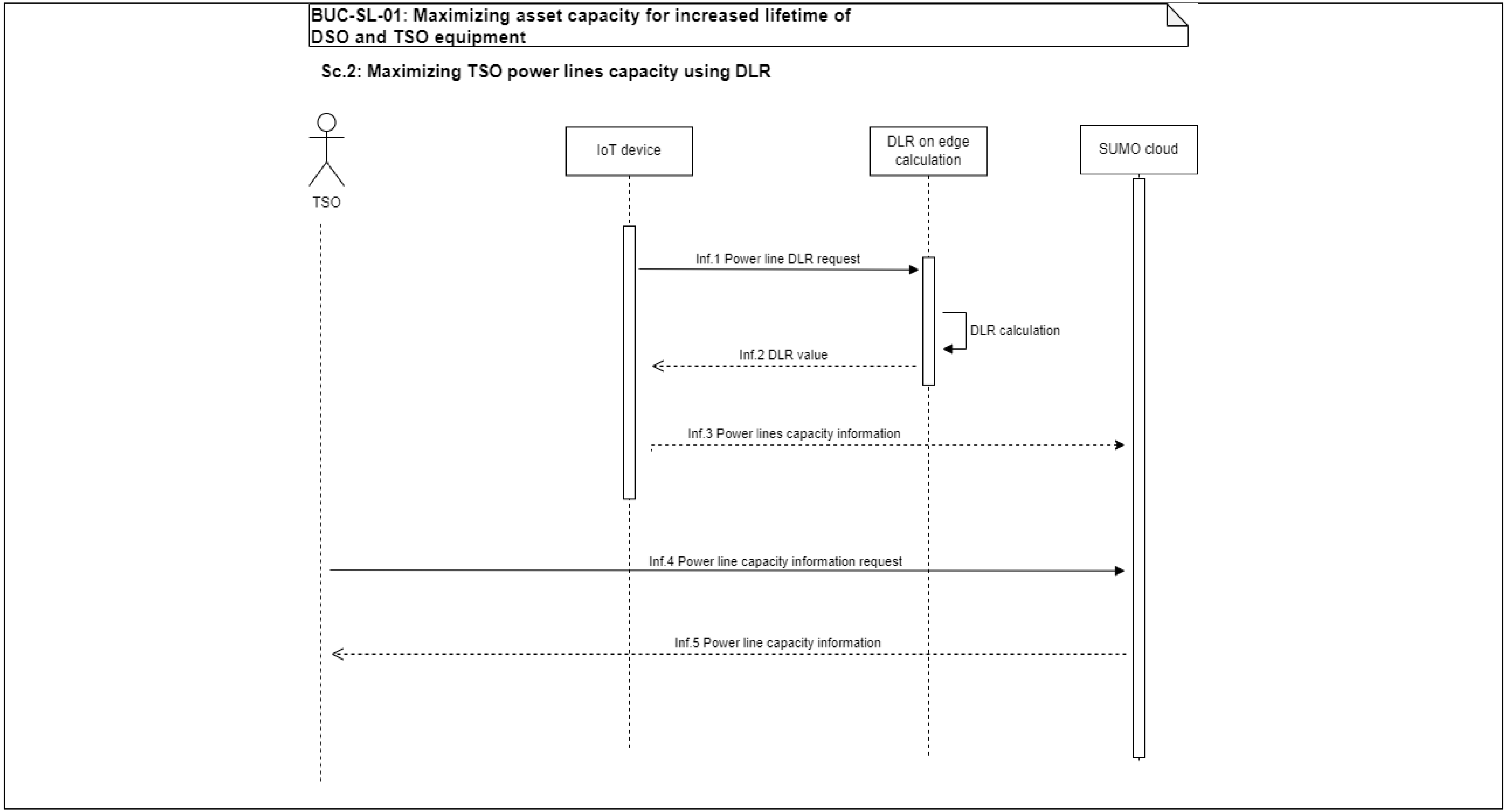
Scenario								
Scenario name:	Sc. 2 - Maximizing TSO power lines capacity using DLR							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St. 1	Power lines DLR request	DLR request	IoT device requests DLR calculation from DLR calculation program (locally on edge)	CREATE	IoT device	DLR edge calculation	Inf.1	R1, R2, R3, R5, R6, R7, R8
St. 2	DLR calculation	DLR calculation	DLR on edge calculation code gathers request and data from IoT device to perform on edge DLR calculation	EXECUTE	DLR on edge	DLR on edge		R4, R7
St. 3	DLR value	DLR value is send to IoT device	Calculated DLR is stored to IoT device	REPORT	DLR on edge	IoT device	Inf.2	R1, R2, R3, R5, R6, R7, R8
St. 4	Power lines capacity information	Sending DLR data to cloud	Calculated DLR values are sent from edge IoT device to Cloud	EXECUTE	IoT device	SUMO Cloud	Inf.3	R2, R3, R5, R6
St. 5	Power lines capacity information request	Power lines capacity information request	TSO requests information of power line load capacity based on Dynamic Line Rating	CREATE	TSO	SUMO cloud	Inf.4	R3, R7, R8
St. 6	Power lines capacity information	Power lines capacity information	TSO gathers DLR data from SUMO cloud for optimal maintenance	REPORT	SUMO cloud	TSO	Inf.5	R3, R6, R7, R8



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5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
Inf.1	Dynamic rating request	The request for the dynamic rating of an energy asset	R1, R2, R3, R5, R6, R7, R8
Inf.2	Dynamic rating value	The calculated dynamic rating value for energy asset	R4, R7
Inf.3	Asset Capacity Information	The request for the capacity information of the energy asset is stored on IoT	R1, R2, R3, R5, R6, R7, R8
Inf.4	Asset capacity information	The capacity information of the energy asset based on dynamic rating calculation	R2, R3, R5, R6
Inf.6	Asset dynamic rating information request	SO requests the dynamic rating information from SUMO cloud, where the data is stored	R3, R7, R8
Inf.7	Asset capacity information	The capacity information of the energy asset based on dynamic rating is sent from cloud to SO.	R3, R6, R7, R8

6 Requirements

Requirements		
Requirement R-ID	**Requirement name**	**Requirement description**
R1	Real-time data collection	The IoT device must be able to collect data in real time (from smart meters and weather provider)
R2	IoT Device Specifications	Define the technical specifications for IoT devices, including processor capabilities, memory, sensor types and connectivity options to ensure efficient edge computing.
R3	System Integration	Ensure IoT devices are compatible and seamlessly integrate with existing DSO and TSO grid infrastructure, including power quality meters and communication systems.
R4	DTR and DLR Accuracy	Ensure that the DTR calculation have mean absolute error of less than +/- 2°C and DLR calculation are accurate in predicting the optimal load of power lines.
R5	IoT Device Uptime	Maintain a minimum uptime of 99.5% for IoT devices ensure continuous data collection and processing.
R6	Data Encryption	Implement encryption for data transmitted between IoT devices and the cloud to ensure data security and integrity.
R7	Compliance with Standards	Ensure that all deployed IoT devices and associated software comply with relevant national and international standards and regulations for data security, privacy, and grid security.
R8	Support and Troubleshooting	Provide ongoing technical support and troubleshooting services to access any issues with IoT device performance and data accuracy

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
DTR	Dynamic Thermal Rating
DLR	Dynamic Line Rating
TSO	Transmission System Operator
DSO	Distribution System Operator
BUC	Business use case
ML	Machine Learning
AI	Artificial Intelligence

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SO	System Operator
PQ	Power Quality

BUC-SI-02 ENHANCED NETWORK MANAGEABILITY AND OBSERVABILITY

1 Description of the use case

1.1 Name of the use case

ID	Area / Domain(s) / Zones(s)	Name of Use Case
BUC-SL-02	Distribution network planning and management	Enhanced Network Manageability and Observability

1.2 Version management

Version Management			
Version No.	Date	Name of Author(s)	Changes
0.1	11.04.2024	Josipa Stegić, Leila Luttenberger Marić	First draft version of BUC-SI-02.
0.2	17.05.2024.	Josipa Stegić, Leila Luttenberger Marić, Tomislav Antić	Second version with new chapters filled in.
0.3	25.5.2024.	Josipa Stegić, Leila Luttenberger Marić, Tomislav Antić	Updated version.
0.4	11.06.2024.	Josipa Stegić, Leila Luttenberger Marić, Tomislav Antić	Final version.

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Gathering and utilizing data for further improvement of network operations management and planning, thereby increasing system observability.
Objective(s)	• Increasing the observability of the distribution network at the substation level. • Enhancement of network management and planning processes at the distribution level. • Resolving interoperability issues within a distribution system
Related business case(s)	

1.4 Narrative of use case

Narrative of Use Case
Short description
The complexity of the system at the distribution network level requires the implementation of various solutions to optimize the network management process and facilitate long-term network planning. Integrating a variety of machine learning (ML) algorithms and Semantic model of the substation solution is positioned to enhance the efficiency of existing asset management and grid analysis practices, leverage the potential of data collected from various systems and Internet of Things (IoT) devices, increase sub system interoperability and facilitate semantic data aggregation as well as standardized exchange with different stakeholders. Furthermore, these implementations will tackle the barriers associated with the integration of

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distributed energy resources (DER) and enhance the observability and capacity assessment of distribution networks.
Complete description
As data is collected from various systems and in different formats, information about the data remains trapped, hindering its further utilization in network analyses. Beyond addressing the challenge of system interoperability and data aggregation, it is imperative to eliminate the barrier of data interpretation. To enable their use in further distribution-level calculations and AI/ML algorithms, data must be identified to facilitate interpretation for network users, thereby improving the algorithms trained on specific datasets. A unified semantic model, output from SUC-SI-02.1, will aggregate data from different sub-systems using the PowerCIM solution. The substation model will serve as the foundation for further analysis and management of the distribution network. This approach aims to resolve system interoperability issues at the distribution network level and the aggregation of semantic data. Furthermore, the semantic substation model will be utilized by various stakeholders to facilitate complex data management, provide unified identification through cross-referencing, and offer an information model about measurements for further data processing. Ultimately, implementing this approach of a unified model will enable better monitoring and management of the distribution network. Once PowerCIM is fully utilized within the demo site, collection of electrical data in a unique way enables the development of new algorithmic solutions and analyses of distribution networks needed for a DSO to plan and operate the system in the most efficient and reliable way. Due to the large number of collected measurements, the requirement for the developed solutions is the efficiency in the big data analytics. ML algorithms have shown great potential in handling large number of measurements. Even though the large number of IoT devices and measurements increases the observability of the network, it also creates challenges in their exploitation in defining and conducting relevant distribution network analyses. If properly used, data can be of a great help to a DSO and enable less complex planning and operation of distribution networks. Distribution networks are facing changes related to energy transition and adoption of DERs, i.e., the continuous increase in the share of PV power plants, heat pumps, EV charging stations and other technologies. Despite their environmental and economic benefits, their uncoordinated integration often creates challenges in the planning and operation for DSOs. The limited observability of distribution networks presents an additional problem in analysing the impact of DER integration. Installing IoT devices and advanced metering infrastructure in every node of a network is inefficient and expensive and the satisfactory network's observability can be reached by the limited set of measurements. One of the goals that tend to be reached with the development of ML algorithms is to provide DSOs the better insight into distribution network conditions by enabling the identification of installed DERs using only collected electrical and weather data and forecasting the values of technical parameters relevant for the safe and reliable planning and operation of distribution networks. • Long-term planning: In addition to resolving challenges associated with data interpretation and system interoperability, our proposed BUC aims to enhance asset management and network planning within the distribution network. Leveraging the capabilities of PowerCIM, we envision empowering distribution network operators with a comprehensive toolset for data collection, analysis, and decision-making. PowerCIM serves as a pivotal solution enabling the collection of diverse data streams, including sensor data, transformer performance data etc. By combining this wealth of information into a unified semantic model, operators gain novel insights into the health and condition of network assets. Utilizing advanced algorithms and machine learning techniques, such as calculating equipment health indices, operators can proactively identify potential issues, prioritize maintenance activities, and optimize asset utilization. Moreover, the bitemporal representation of data and models facilitated by PowerCIM enables operators to conduct network planning exercises with unparalleled accuracy and foresight. By comparing planned network configurations with real-time models, operators can perform scenario analyses, forecast future network demands, and assess the financial implications of various investment strategies. This capability not

only enhances the reliability and resilience of the distribution network but also optimizes resource allocation and capital expenditure. In summary, the implementation of a unified semantic model empowered by PowerCIM enhances asset management and network planning paradigms within the distribution network. By seamlessly integrating data interpretation, asset health monitoring, and predictive analytics, operators can ensure the efficient operation and sustainable growth of the network, ultimately benefiting consumers and stakeholders alike.

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives

1.6 Use case conditions

Use case conditions
Assumptions
• Difficulties related to interpretation of data. • Request for system interoperability. • Request for increased network observability. • Insufficient utilization of data gathered from IoT devices.
Prerequisites
• Installed systems with network models ready for further implementation. • IoT devices installed to gather measurements of the electrical network. • Availability of weather data for the region surrounding the substation. • The DSO aims to enhance network management operations and planning processes.

1.7 Further Information to the use case for classification / mapping

Classification Information
Relation to other use cases
Linked to SUC-SI-02.1, SUC-SI-02.2
Level of depth
General
Prioritisation
High
Generic, regional or national relation
Generic
Nature of the use case
Business use case
Further keywords for classification
Network observability, network planning, IEC CIM, system interoperability, data exchange, standardization

1.8 General Remarks

General Remarks

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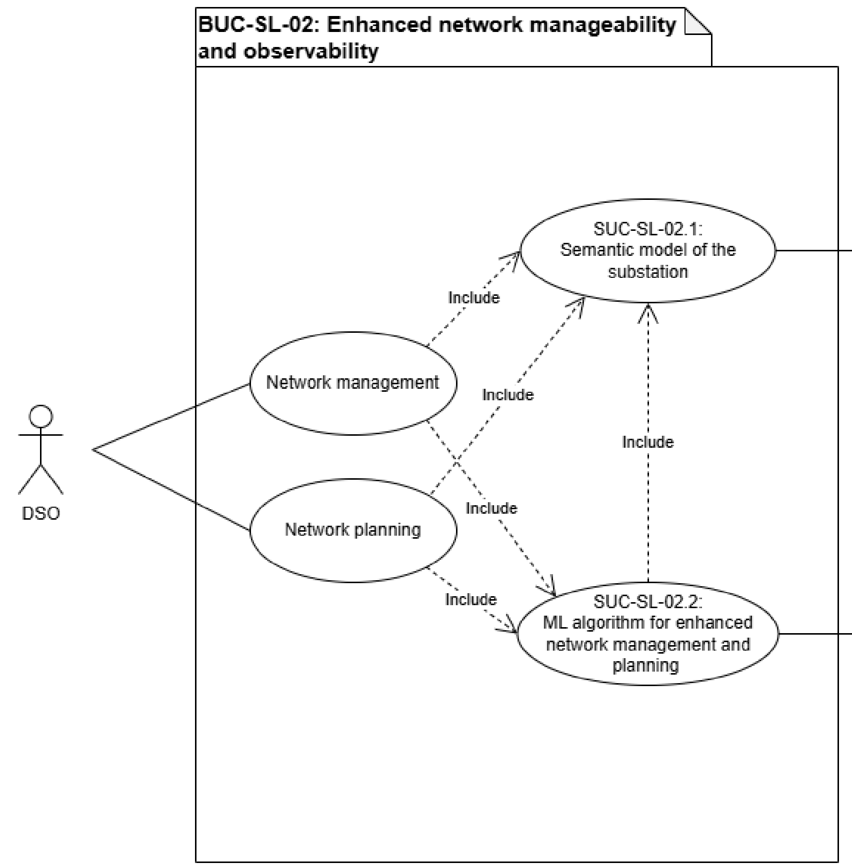
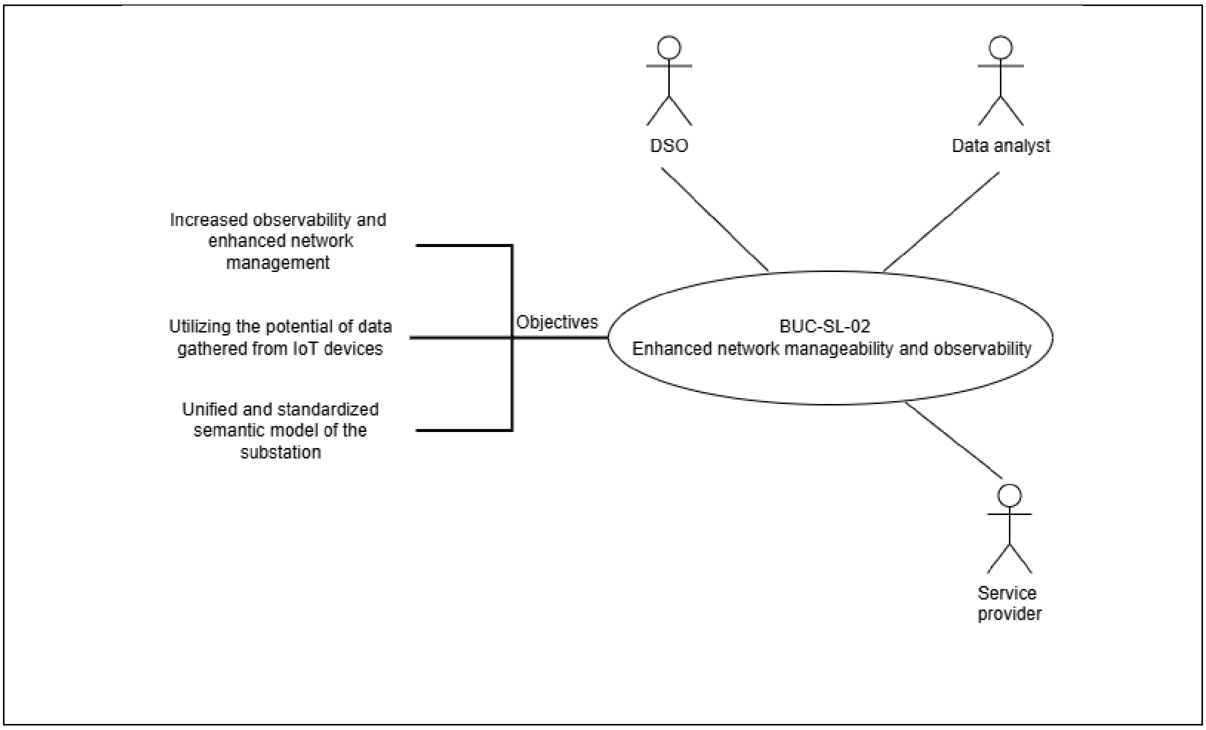
2 Diagrams of use case

Diagram(s) of use case




3 Technical details

3.1 Actors

Actors			
Actor Name	***Actor Type***	***Actor Description***	***Further information specific to this use case***
DSO	Business actor	Distribution System Operator (DSO) utilize the enhanced network manageability and observability by using IoT/edge measurement devices for better monitoring and planning of the distribution network.	Elektro Gorenjska
Data Analyst	Business actor	Responsible for interpreting and deriving insights from the aggregated data for decision-making purposes and for developing the algorithms enhancing the planning and operation of a network.	Faculty of electrical engineering and computing, Zagreb
Service provider	Business actor	Provides appropriate tools for both DSOs and Data Analysts enabling unified data identification and semantic interpretation within distribution level.	KONČAR

3.2 References

References						
No.	***Reference Type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***

4 Step by step analysis of use case

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4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
Sc.1	Network analysis	The DSO aims to conduct network analysis to enhance planning. DSO compares planned configuration models with the actual network configuration, deriving conclusions based on these comparisons.	DSO	The DSO is requesting models in the PowerCIM.	Models are stored in separate systems within the distribution management system.	Network planning and analysis are being enhanced based on accessing various models from separate systems.
Sc.2	Asset management	The DSO wants to enhance asset management by gathering diverse data related to specific components of the distribution network, stored across independent systems.	DSO	The DSO is requesting data in the PowerCIM.	The existence of data within independent systems that do not exchange information with each other.	Improving asset management, enabling predictive management, accessing information from separate systems.
Sc. 3	Application of ML algorithms	The DSO uses the ML tools in order to increase the network's observability and increase the insight into the conditions in distribution networks. The application of algorithms enables network's easier and safer planning and operation.	DSO	The DSO is requesting improvement of management and planning processes.	The continuous access to the measurement and the results of the calculations.	Increasing network's observability, enabling future analyses, widening the knowledge on distribution systems.

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4.2 Steps – Scenarios

Scenario								
Scenario name:		Sc.1- Network Analysis						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St.1	The DSO seeks access to data for network planning and analysis.	Planned configuration model request	The DSO requests the network configuration planned for a specific period.	GET	DSO/Data analyst	Service provider	Inf.1	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
St.2	Unified model export requested.	Requested model retrieval	PowerCIM solution serves the unified and validated model from the parent system with bitemporal tagging.	EXECUTE	Service provider	DSO/Data analyst	Inf.2	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
St.3	The DSO wants to obtain a verified network model in standard form.	Real-state model request	The DSO requests the actual network configuration for a specific time period.	GET	DSO/Data analyst	Service provider	Inf.1	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
St.4	Unified model export requested.	Real-state model retrieval	The PowerCIM solution integrates the model with bitemporal tagging from the parent system where data is inputted.	EXECUTE	Service provider	DSO/Data analyst	Inf.2	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
St.5	The data analyst/DSO possesses all the necessary models for conducting network analysis.	Network analysis	The DSO analyzes by comparing the planned and actual network configuration, deriving insights to improve system planning.	REPORT	DSO/Data analyst	DSO	Inf.7	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8

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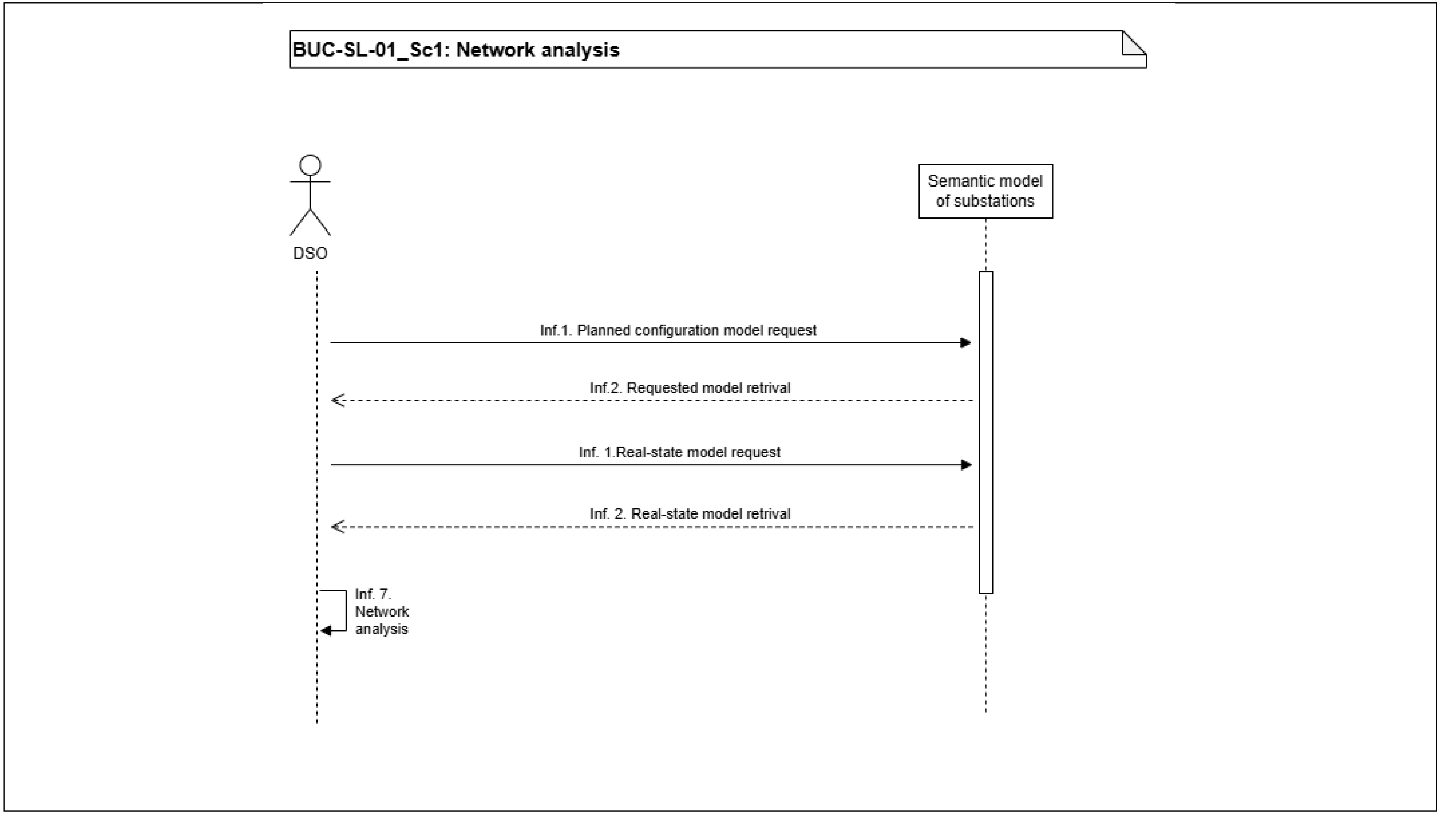

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Scenario								
Scenario name:		Sc.2 - Asset management						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St.1	The DSO seeks access to data for predictive asset management.	Switchgear data request	The DSO requests the switchgear technical parameters from different separated systems.	GET	DSO/Data analyst	Service provider	Inf.3	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
St.2	Switchgear data requested	Data retrieval	PowerCIM serves the requested data for selected switchgears from the parent system.	EXECUTE	Service provider	DSO/Data analyst	Inf.4	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
St.3	DSO wants to access data for asset management	Transformer data request	The DSO requests the transformer technical parameters from different separated system.	GET	DSO/Data analyst	Service provider	Inf.5	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
St.4	Transformer data requested	Data retrieval	PowerCIM serves validated data.	EXECUTE	Service provider	DSO/Data analyst	Inf.6	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
St.5	The DSO requires measurement data for predictive management purposes.	Measurement data request	DSO requests measurements related to the operational mode of the substation.	GET	DSO/Data analyst	Service provider	Inf.15	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
St.6	Measurement data requested	Data retrieval	PowerCIM serves validated measurement data.	EXECUTE	Service provider	DSO/Data analyst	Inf.16	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
St.7	DSO gets access to data from different systems.	Asset management report	Based on the analysis, the DSO draws conclusions to make predictions regarding system maintenance and efficiency improvements.	REPORT	DSO/Data analyst	DSO	Inf.8	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8

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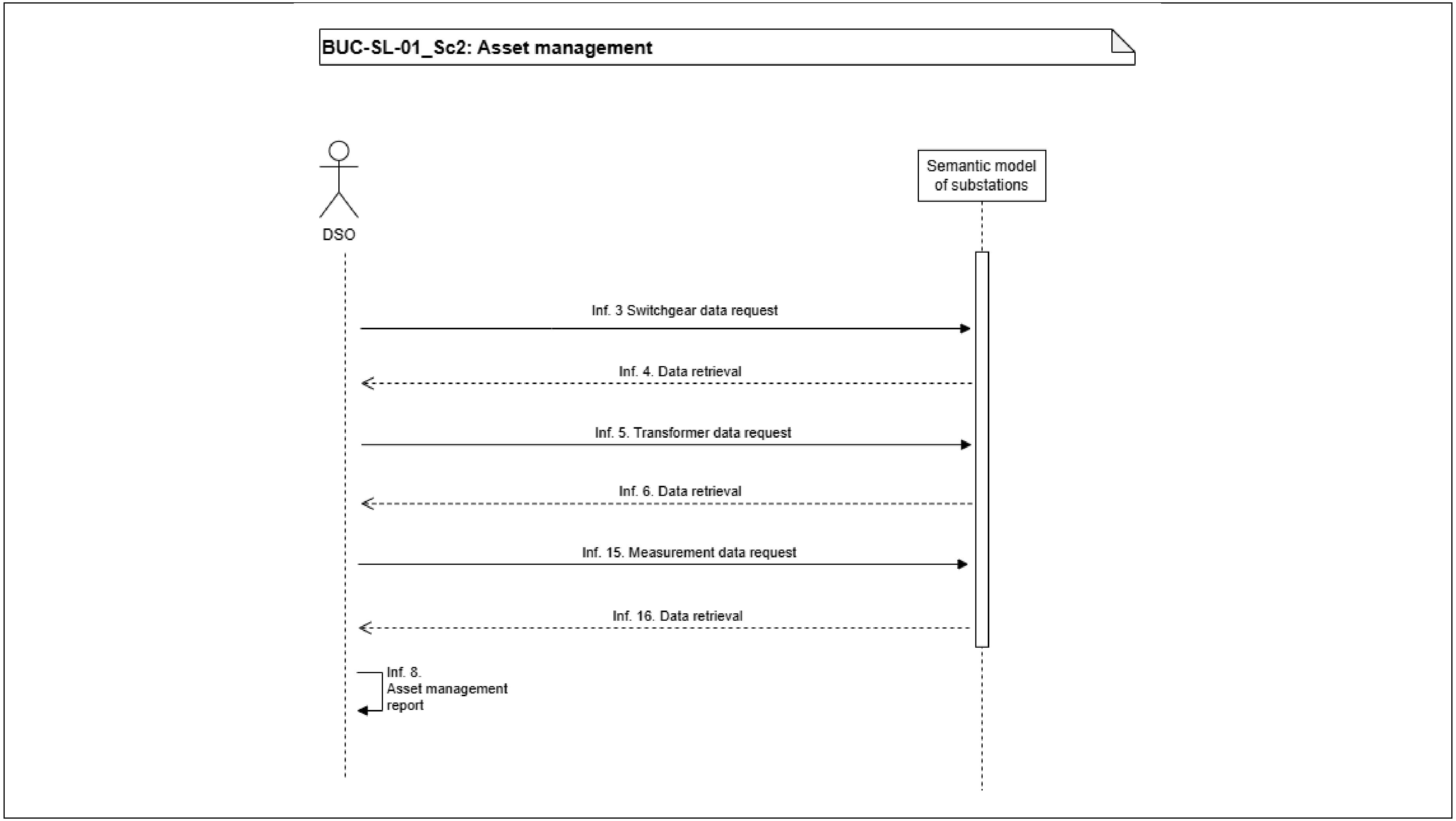

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Scenario								
Scenario name:		Sc.3 - Application of ML algorithms						
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information Exchanged (IDs)**	**Requirement, R-IDs**
St.1	DSO wants to maximize the utilization of data from IoT devices with the aim of reducing CAPEX.	Enhancement network analysis & planning request	DSO sends a request to the Data Analyst to develop algorithms that will improve existing network management and planning processes.	CREATE	DSO	Data Analyst	Inf.9	
St.2	Data Analyst requests data	Data access request	The Data Analyst sends the request to access the data	CREATE	Data Analyst	DSO	Inf.10	
St.3	Data provider receives request	Data retrieval	Data provider receives the request and enables the access	EXECUTE	DSO	Data Analyst	Inf.14	
St.4	Data Analyst requests data	Data access request	Data analyst requests unified substation or network model using the REST JSON or XML export APIs. The data includes unified and validated CIM network, environment and measurement models.	CREATE	Data Analyst	Service provider	Inf.10	
St.5	The Data Analyst requires a semantic model for accurate data interpretation, component	Data retrieval	Data analyst requests unified substation or network model using the REST JSON or XML export APIs. The data includes unified and validated CIM network, environment and measurement models.	EXECUTE	Service provider	Data Analyst	Inf.12, Inf.13	

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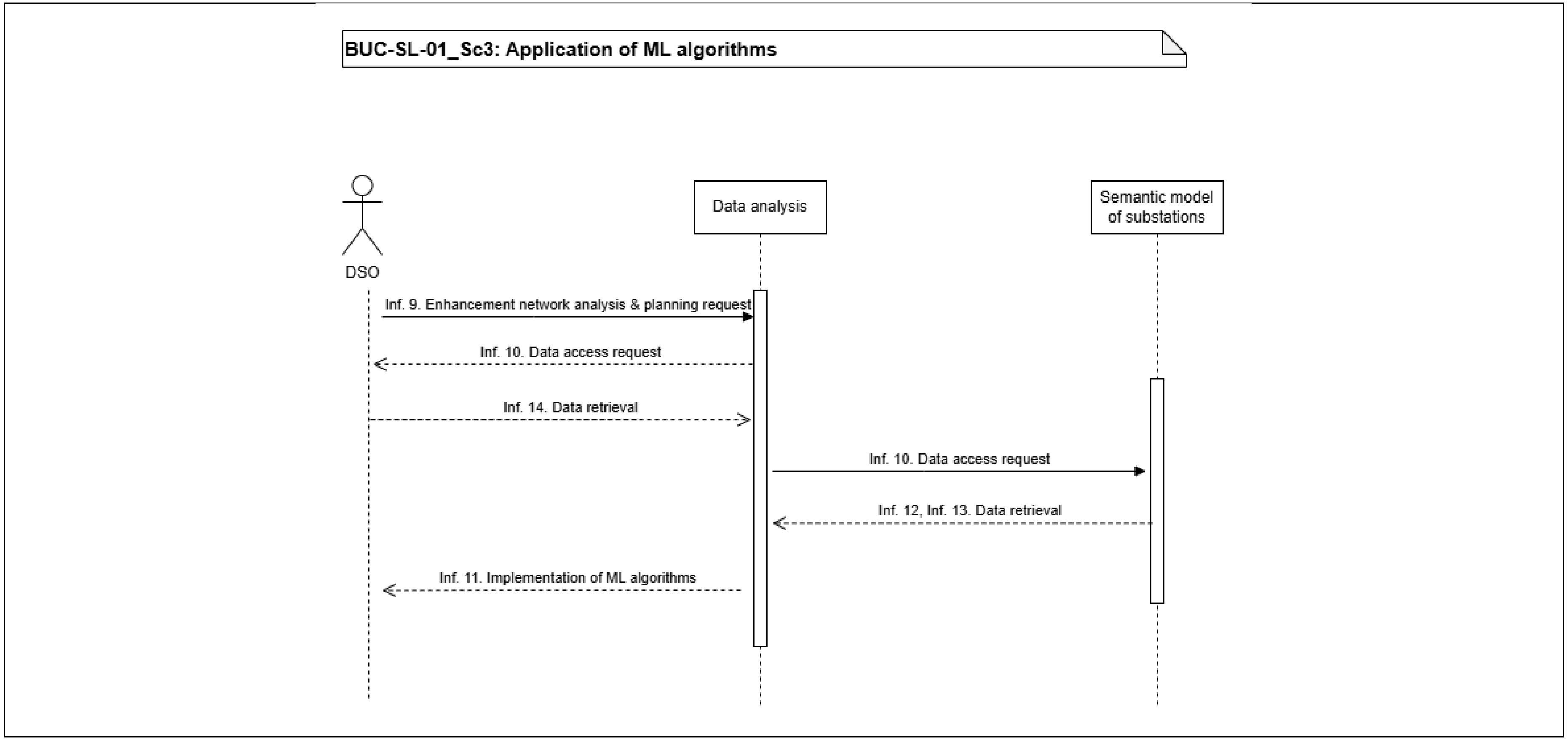
	identification, and accessing data from the CIM model							
St.6	The Data Analyst develops ML algorithm using data and models from DSO & Technology provider to solve the given problem	Results retrieval	The Data Analyst sends the results and the model that improves existing network management and planning.	EXECUTE	Data Analyst	DSO	Inf.11	



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5 Information exchanged

Information exchanged			
Information exchanged (ID)	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
Inf.1	Request message for validated network model.	Request for validated network model in standardized format for export.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
Inf.2	Unified CIM model	Unified and validated CIM substation and network model (1+2+3)	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
Inf.3	Request message for validated switchgear data.	Request for validated switchgear data with an associated identifier tag.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
Inf.4	Switchgear data	Validated and unified transformer data.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
Inf.5	Request message for validated transformer data	Request for validated transformer data with an associated identifier tag.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
Inf.6	Transformer data	Validated and unified transformer data.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
Inf.7	Network analysis report	Novel insights and reports derived from data and models obtained through PowerCIM. Related to network analysis and planning.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
Inf.8	Asset management report	Novel insights and reports derived from data and models obtained through PowerCIM. Related to predictive asset management.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
Inf.9	Request for ML solution	Request for enhancement of network management and planning.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8, R. 9, R. 10, R.11, R. 12
Inf.10	Data request	Request for access to telemetry data.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8, R. 9, R. 10, R.11, R. 12
Inf.11	ML algorithms report	Novel insights and reports derived from the results of calculations using developed ML algorithms.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8, R. 9, R. 10, R.11, R. 12
Inf.12	Substation telemetry	Substation telemetry from EDGE DTR, metering, environment sensors, substation SCADA etc... systems	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8, R. 9, R. 10, R.11, R. 12
Inf.13	DTR parameters	EDGE DTR system parameters	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8, R. 9, R. 10, R.11, R. 12
Inf.14	Data access enabled	Enabled access to telemetry data collected in the distribution network.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
Inf.15	Measurement data request	Request for access to measurement data.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8
Inf.16	Measurement data	Measurements related to the operational mode of the substation necessary for predictive asset management.	R. 1, R. 2, R. 3, R. 4, R. 5, R. 6, R. 7, R. 8

6 Requirements

Requirements		
Categories ID	**Category name for requirements**	**Category description**

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Requirement R-ID	Requirement name	Requirement description
R.1	Management of accessing different types of data to be exchanged	Data Management Issues Possible values: • Each data exchange could entail different types of data (e.g. query a database) • Data and models are exchanged every few minutes • Data and models are exchanged every few hours • Data and models are exchanged every few days or weeks • Data and models are rarely being exchanged
R.2	Management of data across organizational boundaries	Data Management Issues Possible values: • Data is previously stored across organizational boundaries • Data is previously stored across organizational departmental boundaries • Data is previously stored across boundaries between system developed by different vendors
R.3	Naming of data items	Data Management Issues Components should have a unique identifier.
R.4	Validation of data exchanges	Data Management Issues Data and models should be validated.
R.5	Management of large volumes of data that are being exchanged	Data Management Issues The solution facilitates the utilization and management of large models along with their dependencies.
R.6	Correctness of source data	Data Management Issues The solution enables data accuracy verification.
R.7	Type of source data	Data Management Issues The solution supports the utilization of multiple data types.
R. 8	Data privacy	It is necessary to ensure secure data exchange.
R. 9	Up-to-date management	Data Management Issues • Received data must be up-to-date within seconds of source data changing • Received data must be up-to-date within minutes of source data changing • Received data must be up-to-date within hours of source data changing
R. 10	Elapsed time response requirements for exchanging data	Quality of Service (QoS) Issues: • 1-4 milliseconds • 4-10 milliseconds • Less than 1 second • 1-2 seconds • 10 seconds • More than 10 seconds • No specific response requirements
R. 11	Availability of information flows	Quality of Service (QoS) Issues: • 99.9999% + availability - Allowed outage: 1/2 second per year

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		• 99.999% + availability - Allowed outage: 5 minutes per year • 99.99% + availability - Allowed outage: 1 hour per year • 99.9% + availability - Allowed outage: 9 hours per year • 99% + availability -Allowed outage: 3.5 days per year • 90% + availability - Allowed outage: 1 month per year • Less than 90% • Continuous availability not required so long as downtime is scheduled • Continuous availability not required but must be available at specific times or under specific conditions
R. 12	Frequency of data exchanges	Quality of Service (QOS) Issues: • Essentially continuous • Every few milliseconds • Every few seconds • Periodicity greater than a few seconds • Upon event • Upon request • Random • Sparse

7 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
DSO	Distribution system operator
DER	Distributed Energy Resources
ML	Machine Learning
EV	Electric vehicle

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HEDGE-IoT