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D1.2 Functional and operational requirements

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Abstract

The work documented in this report aims to deduce the requirements of the cyber-physical framework of FEVER solution, analyse stakeholders' needs with regards to their interaction with the flexibility solutions and devise metrics for assessing the technology impact at the pilots' validation phase. Functional and non-functional requirements were documented from different viewpoints: business, end-user and systemic.

Keyword list

requirements, flexibility, trading, network congestion, voltage compensation, flexibility markets, energy community, p2p trading, microgrid, grid islanding, dynamic prices

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Executive summary

The main objective of this report is to describe the functional and non-functional requirements of the components that comprise the cyber-physical framework (hardware and software) of the FEVER project. Its contribution also lays in the documentation of metrics for assessing the technology impact at the pilots' validation phase.

The work documented in this report, continues the analysis of task T1.1, fine graining the requirements from a business to a systemic level, aiming to guide the definition of the architecture of FEVER and the detailed technical specifications of each of the constituting components of this framework, which will take place in the context of the subsequent tasks of the project.

The work focuses on different type of requirements: those describing the functions or tasks to be performed by the system (functional), qualitative characteristics and properties of the system (non-functional) as well as how a system is required to interact (interface) with external systems, with humans or with regards to components inside the system. However, requirement may vary depending the stakeholder's view they represent. Within FEVER different categories of concerns were addressed (i.e. privacy/security, scalability, performance, integration/connectivity, compliance with standards, interoperability, regulations, functionality, and usability) and different viewpoints were identified for collecting requirements, ranging from the acquirers of the systems (e.g. BRP, DSO), the end-users as well as developers/technology providers. The following main categories of requirements were used:

- *Business Requirements*: Provide the description of the procedures of business activities and possible system interfaces, aiming at presenting why the system is needed, what it should support and in which context.
- *User Requirements*: Capture the perspective of the human-machine interface answering to the question on what do end users need the system to do.
- *System Requirements*: Concern the requirements of the system from a technical perspective, answering to the question on what do the system needs to do.

Business functional requirements were derived from the analysis of T1.1 and were documented in D1.1 in the form of use cases, whilst non-functional business requirements and the rest of the categories are documented in this report.

The approach utilized for capturing *user requirements* follows the agile concept of user stories, capturing usability requirements for the human machine interactions for a set of users within the interest of the project (e.g. operator of the control center of DSO/Microgrid Operator, manager of the portfolio of the Aggregator, prosumer).

On the other hand, *system requirements* are captured in the form of use cases, following an adjusted template of the IEC 62559-2 standard. In contrary to the use cases documented in D1.1, use cases presented in this report cover a technical aspect and capture a finer level of detail, whilst key performance indicators and individual requirements are also analysed. To facilitate conceptual representation of the different subsystem, three main functions were identified for grouping the systemic use cases:

- Monitoring and automated control of the distribution grid: Relates to the toolbox offering for DSO for advanced monitoring and controllability of the distribution grid.
- Flexibility management & trading: Relates to the flexibility measures and flexibility-based electricity grid services.
- Market mechanisms: Relates to the market mechanisms supporting and incentivizing flexibility services at the level of wholesale & balancing markets.

During the analysis process, concerns were raised regarding the necessary parameters for characterizing flexibility in order to create effective services at the level of the distribution grid for the various stakeholders in the electricity market. In this regard, some crucial characteristics of flexibility are analysed in this report with regards to spatial and time dimension and type of provided flexibility which need to be considered in the design phase.

The documentation of the requirement analysis follows different levels of granularity, since on one hand the components of the solution have different maturity levels involving both existing implementations

that will be evolved and tailored to the needs of the project and newly developed ones, as well as "production" level solutions vs. solutions that will be tested only in simulation environment. The same applies for the business processes envisioned to be offered by FEVER since established business processes should be taken into account, as well as others which are currently at a more conceptual level seeking for establishing a concrete business framework.

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1 Introduction

FEVER project is a response to the call *LC-SC3-ES-1-2019, entitled "Flexible Energy Production, Demand and Storage-based Virtual Power Plants for Electricity Markets and Resilient DSO Operation"*, of the Horizon 2020 program. The FEVER's project objectives lie on three keys axes:

1. To implement flexibility measures and comprehensive flexibility aggregation, management and trading solutions, in order to provide electricity grid services, such as congestion management and overvoltage avoidance, at the distribution grid.

2. To implement enhanced monitoring and automated control of the distribution grid, by developing an innovative toolbox and implementing advanced technology that leverages flexibility form distributed resources towards providing ancillary services.

3. To implement market mechanisms and tools that support and incentivize flexibility services. These mechanisms concern different market structures and time-horizons (day-ahead and continuous trading of flexibility services, centralized and local/regional markets).

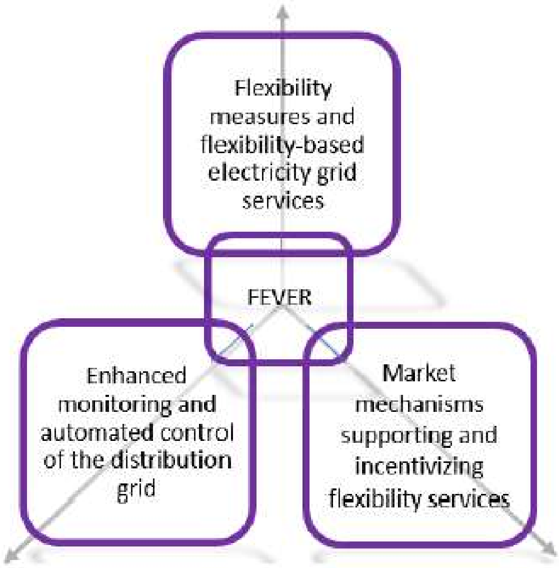


Figure 1 FEVER's high-level scope.

In order to demonstrate the real-world applicability of the innovation concepts and to create a strong impact of the results, FEVER includes three real-world pilots in different countries, namely Cyprus, Germany and Spain. In addition to that, the project includes the design of a simulation testbed, to simulate the operation of electricity markets that incorporate novel flexibility-related services. In each demo activity, different specific objectives are set, overall contributing to the accomplishment of FEVER's high-level objectives.

1.1 Task 1.2

The preparation of this report took place under the activities of T1.2. The objective of the task was to deduce requirements related to the cyber-physical framework based on work of use case analysis – documented in D1.1 [1], analyse stakeholders' needs on their interaction with the flexibility energy solutions and devise metrics for assessing the technology impact at the pilots' validation phase.

1.2 Objectives of the work reported in this deliverable

The main objective of this report is to describe the functional and non-functional requirements of the components that comprise the cyber-physical framework (hardware and software) of FEVER project. It aims at facilitating the technical partners and solution' providers of the project in the definition of detailed technical specifications of each of the constituting components of this framework, in the context of the subsequent tasks of the project. Furthermore, given the public nature of this report, a secondary objective is to provide a comprehensive description of the aforementioned requirements to a broader audience, interested in the specification of flexibility-driven solutions in the distribution grid domain.

1.3 Outline of the deliverable

The document is structured as follows:

- Section 1 provides an introduction to the report.
- Section 2 describes the methodology followed to capture and document the requirements within the activities reported in this work, differentiating them in different viewpoint: business, end-user and systemic.
- Section 3 presents business stakeholders, their main concerns and a high level view of FEVER framework.
- Section 4 documents the requirements from a business perspective, summarizing part of the work of D1.1 and presenting the non-functional requirements tackling the concerns of the business stakeholders as well as requirements that arose from the technical discussions related to flexibility characteristics.
- Section 5 documents the end-user perspective, covering the concerns of usability of FEVER solution, whilst it also documents best practices for the design of the user interfaces.
- Section 6 documents the systemic requirements of the solution in the form of use cases, following the established paradigm of analysis in the domain.
- Section 7 concludes the work of this report, with experiences gathered and next steps.

1.4 How to read this document

The content of this report is of interest for technical staff (e.g. software architects, requirements' engineers), providing input on the functional and non-functional requirements of the technical solution of the project. It should be read following / in combination with D1.1 as a requirements' specification documentation.

2 Methodology

Requirements analysis is a highly demanding activity, requiring interdisciplinary skills, given that it mediates between the domains of an acquirer/user and a supplier of a system, aiming at establishing a common understanding of what the system should do and specific qualities it must comply with. This chapter presents the methodology followed in order to transform the stakeholders' needs to a formal documentation for the system of interest as well as the main concepts utilized.

The methodology for the description of the systems' functionalities and qualitative characteristics is based on international standards (ISO/IEC 15288:2008, ISO/IEC 29148:2011), adapted to the needs of the project.

2.1 Requirement types

Requirements are statements which translate or express needs, their associated constraints and conditions (i.e. measurable qualitative or quantitative attribute). Requirements can vary in type, depending on the stakeholder's viewpoint they represent, as well as based on the kinds of properties they address.

A viewpoint provides the perspective of a stakeholder with an interest in the system e.g. end-user, acquirer, supplier etc. A minimum set of viewpoints consists of users and acquirers as well as the organization(s) developing, maintaining, or operating the system or software. Within FEVER different viewpoints were identified and requirements were collected, initiating from the acquirers of the systems (e.g. BRP, DSO), the end-users and developers/technology providers (TP).

Requirements can be categorised in terms of intent:

- *Business Requirements*: Provide the description of the procedures of business activities and possible system interfaces, aiming at presenting why the system is needed, what it should support and in which context. Business objectives and concerns are identified as a driving activity for requirements elicitation, following a goal oriented approach, aiming at describing as closely as possible the envisioned solution.
- *User Requirements:* Capture the aspect of human-machine interface answering to the question on what do end users need the system to do. Elaborate user / operator characteristics and usability of the system.
- *System Requirements*: Concern the requirements of the system from a technical perspective, answering to the question on what does the system need to do. Following the elicitation of the business requirements, the technical requirements for the selected systems of interest are identified, based on the draft architectural design, transforming the stakeholders' requirements into a technical view required for documenting the systems, defining the boundaries of the system/subsystem in terms of the behaviour and properties to be provided.

Requirements can be also differentiated in terms of what kind of properties they represent:

- *Functional*: Describe the functions or tasks to be performed by the system
- *Non-Functional*: Provide the qualitative characteristics and properties of the system
- *Interface*: Define how a system is required to interact with external systems (external interface), or how individual elements of a system (including humans) interact with other elements within the system (internal interface).

2.2 Requirements elicitation and elaboration

Consistent practice has shown that the process of analysing requirements requires iterative steps in order to elaborate high-level requirements to lower-level ones, group them and allocate them to system elements. The later action is part of the architectural design process which needs to proceed in parallel with the definition of requirements (recursive process). There is a feedback loop from the architectural design process to the requirement definition one, since some requirements may not be able to be derived until some portion of the architecture or design evolves. Via the activities of task T1.2 the high level business requirements elicited in task T1.1 are transformed into systemic requirements for the system-of-interest, whilst the design activities of task T1.3 elaborate the architectural elements that will be analysed in the context of task T1.2. The interdependencies among the different tasks is presented in the next figure.

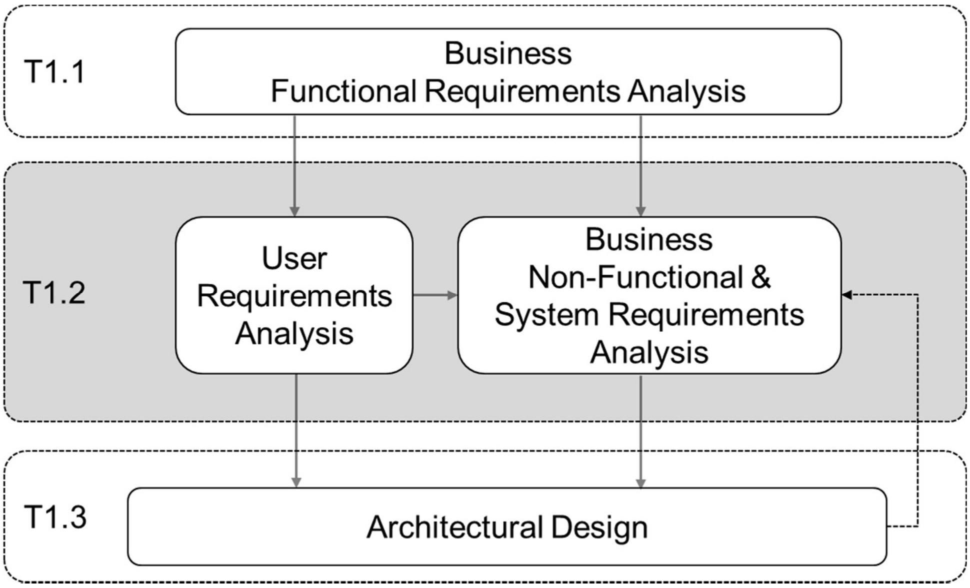


Figure 2 Requirement and design analysis process in FEVER

On the basis of the above analysis framework and prior work of T1.1, the different stakeholders and their concerns were identified (presented in Chapter 3); responsibilities for analysis were allocated according to the role(s) of each partner. Via focused discussions and reusing experience from prior projects in the same domain (e.g. RESOLVD, GOFLEX) the requirements were elicited, elaborated and documented, using templates tailored to the needs of each category type.

2.2.1 Business requirements

Business functional requirements were derived from the analysis of T1.1 and were documented in D1.1 [1] in the form of Use Cases (UCs); Business Use Cases (BUCs) and High Level Use Cases (HLUCs).

Business requirements are presented in Chapter 4; a summary of functional requirements is presented in 4.2, whilst non-functional requirements are documented in Section 4.3, capturing the different concerns presented in Section 3.1. Section 4.1 provides a description of characterization of flexibility tackling concerns that were raised during the analysis regarding the necessary parameters for characterizing flexibility in order to create effective services.

2.2.2 User requirements

The approach utilized for capturing User requirements follows the concept of User Stories. User Stories are short natural language sentences of the intended functionality of a software system, written in the language of the user or stakeholder of the system. User stories can be developed through discussion with stakeholders or simply made up. User stories differ from use cases in the sense that the latter have a formal structure and cover significantly more details, such as preconditions, detailed steps of scenarios, multiple actors.

In FEVER a simple template was used to capture user stories, containing the following information:

- ID: Unique identifier of the story.
- Title: A short description of the story.
- Related business requirement: Relevant BUC or HLUC.
- Description: The narrative of the story, providing the role / actor issuing the requirement the rationale behind the requirement.

User requirements are presented in chapter 5.

2.2.3 System requirements

System requirements were captured in the form of use cases following an adjusted template of the IEC 62559-2 standard [2], as presented in D1.1 [1]. In contrary to the use cases documented in D1.1, the ones documented in this report will also capture requirements related to key performance indicators, as non-functional requirements. An initial system use cases list was already identified in T1.1, documenting a short narrative of Primary Use Cases – PUCs (main functions) and Secondary Use Cases – SUCs (reusable functions). During the current analysis the system UC list was refined.

System requirements are presented in Chapter 6.

3 FEVER Ecosystem

This chapter presents the business stakeholders, their main concerns and a high level design of the solution proposed by FEVER project.

3.1 Business stakeholders and concerns

The following table provides a list of the stakeholder categories of FEVER project.

Name	Abbr.	Description
Distribution System Operator	DSO	Entity responsible for: distribution network planning and development; safe & secure network operation; data management associated with the utilization of the distribution grid; procurement of flexibility services
Flexibility Aggregator	AGG	A party that aggregates flexibility offered by a Flexibility Service Provider. It offers flexibility aggregation and management services to Flexibility Service Providers.
Balance Responsible Party	BRP	A party that has a contract proving financial security and identifying balance responsibility with the Imbalance Settlement Responsible of the Scheduling Area entitling the party to operate in the market. This is the only role allowing a party to nominate energy on a wholesale level.
Microgrid Responsible	MgR	An entity responsible for the monitoring and management of a microgrid as well as for representing microgrid members in the market negotiations
Generic Market Operator	GMO	Generalization of Market Operator overarching the role of Market Operator at different electricity grid domains (generation, transmission, distribution, sub-distribution). It is a party that provides a service whereby the offers to sell electricity are matched with bids to buy electricity. This usually is an energy/power exchange or platform.
Flexible Prosumer	FP	A prosumer that owns and manages dispatchable DER generation/ consumption/ storage asset(s)
Energy Community Member	ECM	Member of an Energy Community
Energy Community Responsible	ECR	A party responsible for representing an Energy Community in the market negotiations
Technology Providers	TP	Providers of technology. In the context of this report the solution providers of FEVER consortium.

Table 1 Stakeholder categories

The following table presents different categories of concerns investigated in the requirements analysis of the project.

Concern Categories	Abbr.	Description
Privacy and Security	P&S	Requirements on access control are relevant restrictions related to the integrity and availability of data, as well as to privacy of proprietary or sensitive/personal information
Scalability	SCA	Specifies requirements of a system to handle a growing amount of work by adding resources to the system
Performance	PER	Defines the extent or the manner in which, and under what conditions, a function or task must be performed. These are quantitative requirements of system performance and can be verified individually

Integration/ Connectivity	I&C	Definition of how the system is required to interact with external systems (external interface) and specify the requirements relating to the compatibility with other systems both software and hardware
Interoperability	INR	Expresses concerns on compatibility of solution or design with other solutions or compliance to standards
Regulations	REG	Conformance with regulation
Functionality	FUN	Specifies the functionality of the system that will enable it to meet business requirements
Usability	US	Provides the basis for the design and evaluation of systems to meet the user needs. Usability requirements are developed in conjunction with, and form part of, the overall requirements specification of a system

Table 2 List of stakeholders' concerns categories

3.2 System overview

3.2.1 Context

The high level architecture of FEVER solution is presented in Figure 3 below, indicating the major elements of the system, how they interact as well as significant interfaces crossing the system's boundaries.

A short introduction of the architectural elements of the system are elaborated in the following list:

- **Wholesale & Balancing Market Solutions**: Solutions for day-ahead market scheduling and disaggregation (at nodal/area level of the distribution system), intra-day flexibility trading (continuous trading) and real-time balancing and congestion management.
- **DSO Toolbox**: A suite of grid-oriented tools complementing DSO's legacy systems enabling more advanced observability and management of the distribution grid. Composed of:
    - **Business Applications:** Offering advanced grid operations such as critical event prevention, island-mode power management, grid technical loss reduction and self-healing
    - **Advanced Operations:** Enabling novel applications, such as energy forecasting, grid operation planning, prediction of voltage violations and grid congestions, detection of grid faults
    - **Integration Solutions**: Enabling the transparent integration of existing (legacy), external (e.g. weather service) and new applications as well as the communication and management of flexibility signals.
- **Flexibility Management & Trading Solutions:** A suite of solutions enabling the trading and management of flexibility, composed of:
    - **Flexibility Management System:** A system operated by the Flexibility Aggregator to aggregate / disaggregate flexibilities for trading purposes.
    - **Flexibility Trading Platform:** A system responsible for the trading of flexibility among different stakeholders.
    - **Peer to Peer (P2P) Flexibility Trading Toolbox:** System comprising the business and market processes related to p2p business trading and peer management.

The above elements will also leverage flexible assets that will provide the necessary flexibility. Relevant systems are:

- **Energy Management System (EMS) at customer level:** System responsible for monitoring and controlling DER assets. An EMS extracts the potential flexibility from DER assets with regards to their operational status and constraints. Different types of EMS are considered in the project: Factory Energy Management System (FEMS) controls assets present in factories and commercial buildings; Home Energy Management System (HEMS) controls assets in residential buildings; a Charging Energy Management System (CEMS) controls electric vehicle charging stations, etc.

- **Power Electronics Device (PED):** A device used to exchange power with batteries/EVs, as well PV systems, as well as able to provide power quality services. It also offers the ability for direct integration with control centre of the DSO, providing field measurements and direct controllability of flexible assets.

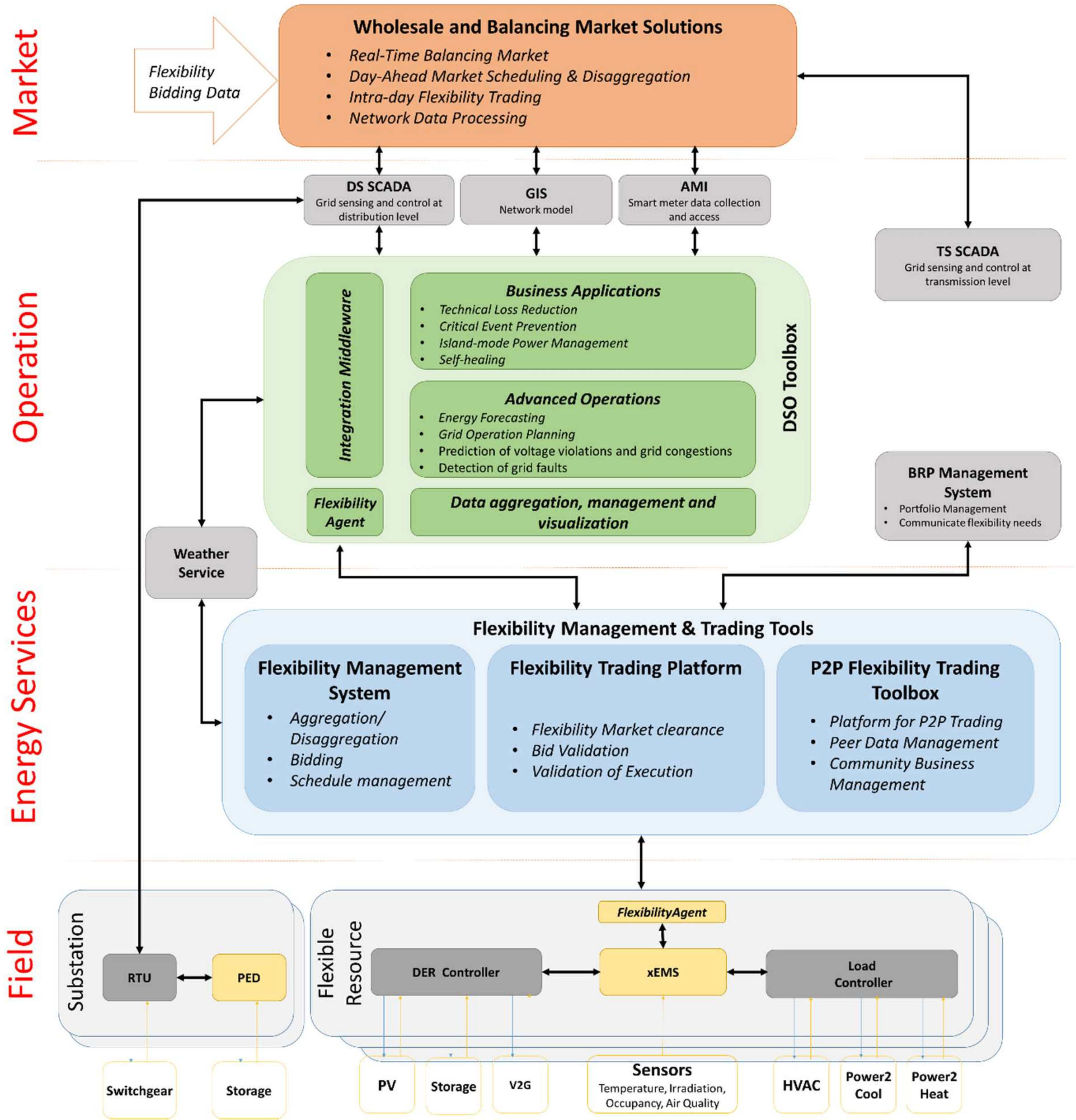


Figure 3 FEVER High Level Architecture (draft)

Finally, the solution will be integrated with existing or acquired solutions, providing the necessary domain information access as well as asset controllability:

- **DS SCADA**: SCADA at the level to distribution system, proving network sensing data, grid operational constraints and controllability of grid assets.
- **TS SCADA**: Transmission system SCADA, providing the grid operational constraints at transmission level
- **AMI**: Advanced Metering Infrastructure providing accessibility to measurement data from smart metering devices.

- **GIS**: Geographical Information System, managing static information related to the grid assets, their location, operational status and parameters.
- **BRPMS**: Management System of a Balancing Responsible Party, enabling portfolio management as well as trading of energy and energy flexibility.

A detailed description of the logical actors, analysing the interactions among the various components of the architecture can be found in deliverable D1.1 [1].

3.2.2 Main functions

The high level functions of FEVER technological offering were thoroughly analysed in D1.1 [1] in the form of Business Use Cases (BUCs) and High Level Use Cases (HLUCs). In this work, we decompose the system in main functions, aiming to facilitate the analysis domain of each subsystem. The main functions, which relate to the key axes of FEVER (presented in Chapter 1), are presented in the following list:

- Market mechanisms: Relate to the market mechanisms supporting and incentivizing flexibility services at the level of wholesale and balancing markets.
- Monitoring and automated control of the distribution grid: Relates to the toolbox offering for DSO for advanced monitoring and controllability of the distribution grid (DSO Toolbox, PED).
- Flexibility management & trading: Relates to the flexibility measures and flexibility-based electricity grid services (Flexibility Management System, Flexibility Trading Platform, P2P Flexibility Trading Toolbox, CEMS, Flexibility Agent)

In Chapter 6, the UCs are presented grouped in the above function blocks.

3.2.3 End users

This section identifies the different type of end users of FEVER solution, towards elaborating the human machine interfaces. The following roles were identified:

- Operator at the control centre of the DSO
- Operator at the control centre of the Microgrid
- Manager of the portfolio of the BRP
- Manager of the portfolio of the Aggregator
- Operator of the market platform
- Operator/manager of an EMS offering flexibility (Prosumer)
- Energy community member (participant in P2P trading solution)

Usability requirements from the viewpoint of the above roles are presented in Chapter 5.

4 Business Requirements

FEVER project aims to implement and demonstrate a wide set of technological solutions ranging from the elicitation of flexibility needs in the distribution grid, to flexibility offering, aggregation, management and trading. This chapter presents the business requirements related to FEVER solution, presenting the characteristics of flexibility measures for building and offering flexibility-based electricity grid services, a summary of the high-level functions of the solution (based on the work of D1.1 [1]) and the non-functional requirements documented, towards establishing the proper qualitative aspects of the design.

4.1 Flexibility characteristics

Flexibility can be described as the capability of modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system [3]. Flexibility can be provided by different sources in the grid (e.g. generation assets, load facilities, storage facilities), whilst it could be used by different business entities e.g. System Operators - for the sake of optimal network management, Balancing Responsible Parties (BRPs) - for portfolio management both in the short and long term (investment) or members of an Energy Community aiming at maximizing self-supply within their community. Different parameters are used to characterize flexibility: the amount of power modulation, the duration, the rate of change, the response time, the location etc. In the following sections, some crucial characteristics of flexibility are analysed: spatial dimension, time dimension and type of provided flexibility.

4.1.1 Spatial dimension of flexibility

System flexibility services at distribution level can facilitate the cost-efficient operation of the network and towards solving local grid constraints. DSOs can procure flexibility to optimally manage the distribution grid as an alternative to traditional (and possibly more costly) grid expansion investments, addressing electricity grid issues related to the local flexibility gap, such as voltage control, congestion management, reverse power flows, and increased technical losses. Flexibility options at the distribution grid level can provide support to DSO grid management and increase DG hosting capacity via active power control and reactive/voltage control. In this context, the value of flexibility is dependent on its physical topology and the constraints of the grid. Flexibility on distribution networks must be located at a lower voltage level than the infrastructure that needs to be alleviated, whilst the lower in voltage the infrastructure is, the less possibilities there are in terms of providers and location of flexibility; thus limiting the pool of available system flexibility service providers and the degree of firmness that they can offer [4].

Within FEVER project, the spatial dimension of flexibility shall be explored in the activation of services (especially from the perspective of the DSO).

4.1.2 Temporal dimension of flexibility

In order to have an efficient matching of the demand and supply side of flexibility services, it is important to apply suitable remuneration schemes via appropriate market tools, taking also into account the planning horizon for these services. Different triggers for flexibility may be more suitable to different flexibility services, which in turn are characterized by different planning horizons and actuation periods, thus requiring different marketplaces. Furthermore, some services are expected to be less suitable for deregulated marketplaces and competition, and could possibly be handled by technical requirements, rather than through markets. The different linkages between the demand for flexibility services, the associated time horizons and potentially applicable market tools are illustrated in Figure 4.

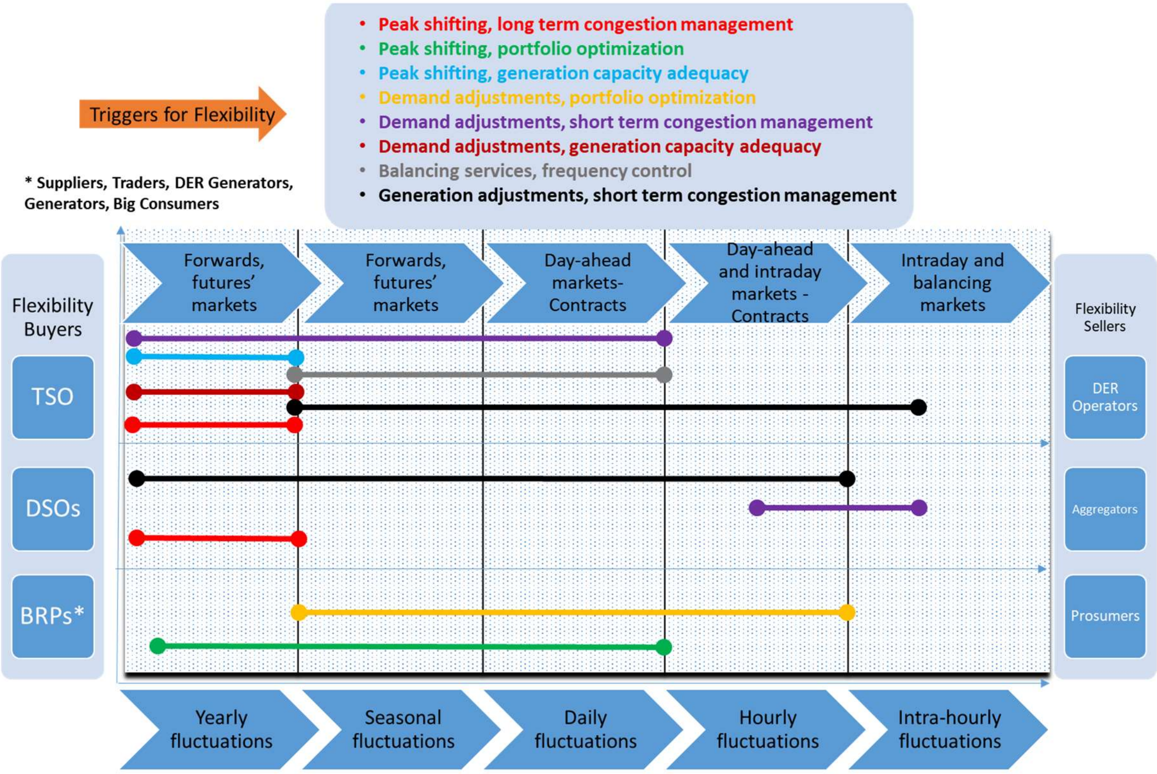


Figure 4 Linkages between the demand for flexibility services, the associated time horizons and potentially applicable market tools (adaptation from [5])

Concerning the temporal aspect of flexibility and the different planning horizons and actuation period, flexibility requirements can also be correlated with the operating mode of system and the relevant business constraints imposed by each situation. The traffic light concept is a method used in the literature for modelling the different operating regimes of the grid, which impost different time constraints on the activation of flexibility (Figure 5).

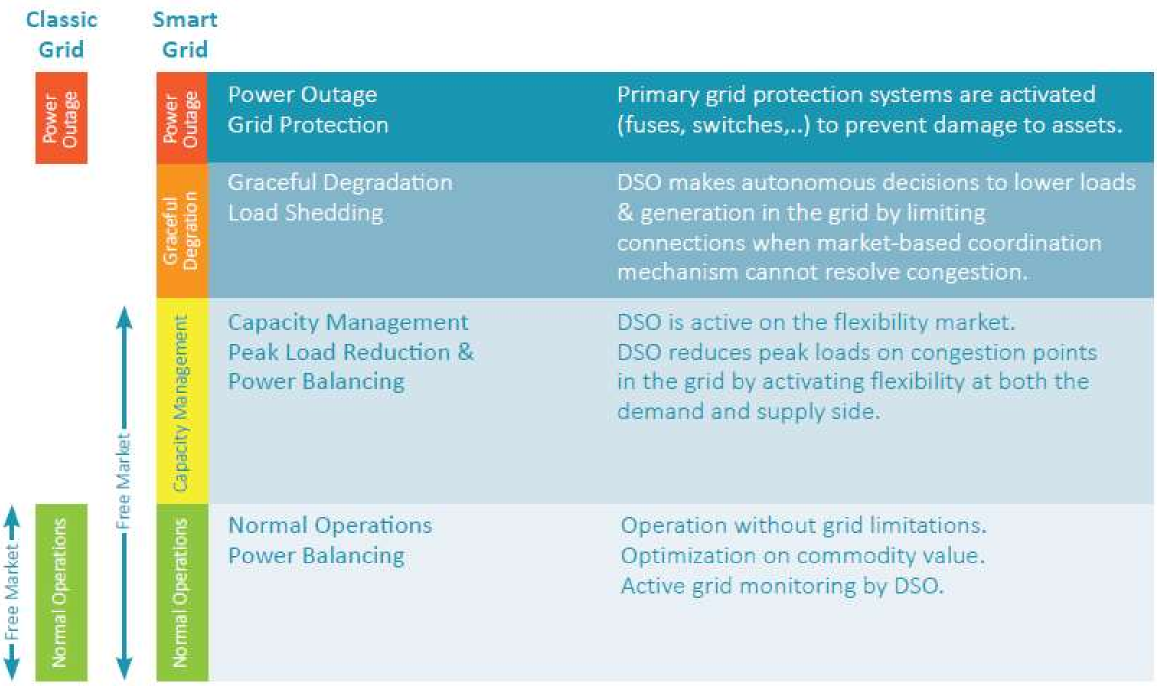


Figure 5 Grid Operating regimes according to USEF [6]

USEF [6] recognizes four different operating regimes: in the green and yellow regimes, the market assures optimal use of the flexibility available for BRPs (green and yellow) and DSOs (yellow); the orange regime is a fall back in case insufficient flexibility is available for the DSO to avoid an outage — the DSO can temporary overrule the market to avoid an outage by limiting connections; in the red regime the grid protection systems are activated to prevent damage to assets. The concept is elaborated in Figure 5.

On the other hand, in a cooperation report [7] by European associations representing the DSOs (CEDEC, E.DSO, EURELECTIC and GEODE), ENTSOE - representing the transmission system operators (TSOs) – and EURELECTRIC, identified the traffic light concept as a method for signalling congestions in the grid. If the traffic light is green, there is no congestion expected. When the traffic light is orange, a congestion is expected. In that case the system operator requires the services from the Flexibility Service Providers to steer the affected area of the grid back to the green state. In this report, this state is called the market phase for procuring flexibility. If the system operator is not successful in bringing the affected area of the grid back to the green state, the system will enter the red state. The red state is the emergency state, requiring immediate corrective actions by DSOs, to bring the grid back to a secure state of operation.

Within FEVER project different flexibility mechanisms i.e. market-based or bilateral contracts shall be investigated for supporting the temporal constraints of the different operational modes of the grid.

4.1.3 Flexibility product type

The creation of flexibility products for different purposes is a prerequisite for the operation of a flexibility market. Different characteristics [7] of flexibility can be identified towards categorizing different products: direction of deviation (up/down), mode of activation (auto/manual), implicit/explicit.

One characteristic that shall be investigated in FEVER project is type of energy – meaning active or reactive energy flexibility. The latter shall enable the realization of use cases such as voltage control and power quality management.

A paradigm of modelling the different characteristics of flexibility in electricity demand and supply is provided by the FlexOffer specification, which was initially proposed by the European project MIRABEL [8]. A so-called FlexOffer can be used to define such a flexibility products and can generally be used in different flexibility services. A FlexOffer explicitly captures flexibility as a pre-defined set of common constraints [9]:

- **Start time constraint**– a range defining the earliest and latest start time of consumption or production of a flexible resource.
- **Energy amount constraint**– a range defining the minimum and maximum energy amounts in a given time slice (typically 15 min). A FlexOffer typically defines a sequence of such constraints.
- **Total energy constraint**– a range defining the minimum and maximum total energy amount within the full active operation of a flexible resource, e.g., the total amount to charge an EV.
- **Dependent energy amount constraint**– for loads with rebound effect (e.g., heat-pump loads), the dependent energy constraint captures the minimum and maximum energy amounts in a given time slice in dependence to the total energy consumed or produced at preceding time slices of the active device operation.
- **Acceptance time constraint**– a parameter that sets the deadline on when a FlexOffer receiving cell should acknowledge successful acceptance or rejection of the FlexOffer. A FlexOffer rejection may occur if, e.g., FlexOffer constraints or other metadata are invalid or in appropriate (e.g., quantities are too small, prices are too high).
- **Assignment time constraint**– a parameter that sets the deadlines on when a FlexOffer schedule update (assignment) is allowed to be sent by the FlexOffer receiving cell to FlexOffer issuing cell. A deadline can be an absolute timestamp or a relative duration with respect to the scheduled operation activation time.

Within FEVER, previous experience of the consortium on this specification will be leveraged, for modelling flexibility and related transactions.

4.2 Functional requirements

This section presents a short summary of the functional requirements of FEVER solution as identified in deliverable D1.1 [1]:

- **BUC 01: Exploit flexibility for preventing network operational issues** aiming to minimize/delay network reinforcement costs. The respective HLUCs realizing this business goal are:
    - **HLUC 01:** Advanced network congestion management considering DER & grid flexibility (seasonal, day-ahead, etc.)
    - **HLUC 02:** Leveraging the batteries' inverters towards reactive power ancillary services
    - **HLUC 08:** Economically optimized flexibility leveraging for a grid-connected microgrid
    - **HLUC12:** Creating dynamic tariffs based on flexibility use in the actual regulatory framework
- **BUC 02: Advanced network management under critical conditions** aiming to increase network security and resilience. The respective HLUCs realizing this business goal are:
    - **HLUC 03:** Leveraging the flexibility of the storage assets for real time detection of uncontrolled islanding
    - **HLUC 04:** Self-healing operation after critical event considering DER & grid flexibility
    - **HLUC 05:** Flexibility exploitation for islanded microgrid operation
- **BUC 03: Reduce technical losses utilizing DER flexibility and power electronics** aiming to enhance network operational efficiency & quality of supply. The respective HLUCs realizing this business goal are:
    - **HLUC 06:** Leveraging DER flexibility towards enhancing network operational efficiency
    - **HLUC 07:** Improving power quality and reducing losses through power electronics
- **BUC 04: Facilitate integration of DER flexibility into wholesale and balancing markets** by introducing new market mechanisms that facilitate DER flexibility exploitation in day-ahead and real-time balancing markets. The respective HLUCs realizing this business goal are:
    - **HLUC 09:** Day-ahead market mechanisms incentivizing energy flexibility trading for mitigating problems of the transmission system & distribution network, integrating wholesale and retail markets
    - **HLUC 11**: Real-time market mechanism incentivizing energy & capacity flexibility trading from BSEs, to address balancing and T&D congestion management, integrating wholesale and retail markets
- **BUC 05: Facilitate integration of DER flexibility into flexibility markets at distribution level** aiming to introduce new market mechanisms facilitating DER flexibility exploitation located at distribution level considering intra-day and close to real-time timeframes. The respective HLUCs realizing this business goal are:
    - **HLUC 10:** Intra-day market mechanisms incentivizing active & reactive energy flexibility trading for mitigating problems of the distribution network
    - **HLUC 13**: Improving the outcome in flexibility by introducing sector coupling
    - **HLUC 14**: Form a first example of a regional flexibility exchange model
- **BUC 06: Facilitate Energy communities through P2P trading,** aiming to introduce novel tools that will facilitate members of Energy Communities to maximize self-supply within their community.
    - **HLUC 15:** P2P flexibility trading.

4.3 Non-functional requirements

This section presents the documentation of the non-functional requirements of the business stakeholders, following the concerns identified in section 3.1.

Requirement ID	Requirement name	Stakeholders	Requirement description

P&S - 01	Privacy of customers' personal data	DSO	Personal data about customers must be protected following GDPR's regulation and all the information associated to individuals must be shared in aggregated form whenever possible or/and anonymized.
P&S - 02	Privacy of sensitive grid data	DSO	Information about the grid and the physical infrastructure should not be shared if not strictly necessary. If it must be shared, it must be considered and treated as sensitive information, possibly removing the geographical reference.
P&S - 03	Secure integration of DSO infrastructure	DSO	There must be a unique point of contact between the DSO's legacy system and the rest of the project system, it must be protected by a firewall and the connection should be private. It is not possible to communicate with any point connected to the electrical grid by any other means than the contact point.
INR - 01	Interoperability of solution	DSO, GMO, FA, FP	The technology provider of the trading platform and of the flexibility extraction systems may be the same entities. Interoperability of solution should be considered towards avoiding the risk of creating a closed environment that does not allow integration of other technologies and the expansion of the flexibility market.
SCA-01	Scalability of flexibility assets	MgR	**(Optional)** Flexible loads managed by BEMS to be simulated with the aid of RTS in order to increase the impact in the emulated grid event.
REG - 01	Regulation compatibility	DSO, GMO, FP, FP	Compatibility of the system with future regulation should be considered.
I&C-01	RTS integration	MgR	**(Optional)** Real Time Simulator (RTS) could communicate with DSO Toolbox applications (i.e. CEPA), since RTS will emulate the artificially imposed grid conditions (e.g. congestion).
I&C-02	EMS-FSPA integration	MgR	Communication between central EMS and flexibility agent needs to be established towards enabling flexibility trading
PER-01	Forecasting performance	MgR	High accuracy spatiotemporal forecasting is required in order the FMS/MgFMS to properly synthesize the flexibility schedule.
PER-02	Microgrid islanding operation	MgR	Microgrid islanding operation requires converters with grid-forming capabilities. Regulation of voltage and frequency by the dedicated converters is dictated in order the

			microgrid to maintain power supply under islanding conditions.
DQ-01	Data granularity	TP	Data of high granularity (1 min. time step) need to be provided via the EMS to the forecasting applications.

Table 3 Non-Functional Requirements

5 User Requirements

This chapter documents requirements related to the interaction between users (or operators) and the solutions developed in the project. Usability of the system is documented on the form of user stories, whilst requirements for the design of the user interfaces are also documented.

5.1 User stories

5.1.1 Operator at the control centre of the DSO

ID	Title	Related Business Requirements	Description
UI_DSO_01	Decide to solve internally	BUC 1-3	I want to have the option to decide whether to solve any issue internally or through the market and I want the system to show me the different options available ordered from the most to the least optimal.
UI_DSO_02	Customize and validate requests	BUC 1-3	I want to be able to validate each request before issuing it to the market, eventually acting on its characteristics.
UI_DSO_03	Have access to the historic of the market	BUC 1-3	I want to have access to the history of market transactions (of flexibility) so as to compare real time needs with similar past transactions. Furthermore this data can be used to feed relevant statistical analyses.
UI_DSO_04	Put a deadline on requests	BUC 1-3	I want to be able to issue flexibility requests with a due time, and eventually to be notified about existing or not existing matches in time to take any necessary alternative action.
UI_DSO_05	Visualize historical costs bore	BUC 1-3	I want to be able to check the cost the DSO had to bear for procuring flexibility on the market so as to compare it with potential grid expansion investments.
UI_DSO_06	Flexibility requests history	BUC 1-3	I want the system to keep a record of the flexibility requests presented to the market in order to identify and indicate recurring events and support decisions in grid planning.
UI_DSO_07	Prosumer reliability	BUC 1-3	I want to see a minimum reliability rating of the prosumer (with regards to flexibility).
UI_DSO_08	Current flexibility requests	BUC 1-3	I want to be able to see the flexibility offers currently on the market, showing information on energy, time, price and location offered.

UI_DSO_09	Automation configuration	BUC 1-3	I want to be able to configure the level of automation depending on the type of solution (e.g. grid configuration is more critical than battery discharging).
UI_DSO_10	Automation notification	BUC 1-3	The system should automatically inform me of the impossibility to receive a service agreed.

5.1.2 Operator at the control centre of the Microgrid

ID	Title	Related Business Requirements	Description
UI_MgMS_01	MgFMS data granularity	BUC 2	Visualise load profiles data with 1 minute time step to be provided by the EMS as these captured by the BEMS.

5.1.3 Operator of the portfolio of the Flexibility Aggregator

ID	Title	Related Business Requirements	Description
UI_AGG_01	Map visualization of assets	BUC 5	I want to have access to a visualization in a digital map and in listed form of the flexibility sources and their most important characteristics, so that I can have the big picture of my portfolio. The main characteristics are: • Type of source (residential demand, industrial demand, V2G, battery, PED, etc.) • Type of Service (active/reactive, downward/upward, power quality, etc.) • Status (active, non-active, available/unavailable), • Manageable flexibility capacity (e.g. 5 kW). • Reliability rating For each flex source I want to see the curve of available flexibility in the next selected period (24 hours, 1 week, etc.)
UI_AGG_02	Visualization of flexibility asset	BUC 5	I want to have access to a visualization of each flexibility asset the curve of available flexibility in the next selected period (24 hours, 1 week, etc.)
UI_AGG_03	Automatic/manual control	BUC 5	I want to be able to control/cancel flexibility sources in an automatic and manual way at any moment.
UI_AGG_04	Configuration	BUC 5	I want to be able to configure:

			- Automatic offers, based on the available energy (total/partial) - Constraints, on the offering/activation of sources, based on the presence of certain conditions
UI_AGG_05	Management of communication from prosumers	BUC 5	**(Optional)** Provide a communication channel to the customer, where it is possible to consult all the historic information regarding a certain flexibility source like a CRM system.
UI_AGG_06	Automatic notification of source unavailability	BUC 5	I want to receive a notification if a flexibility source that should be activated in the future turns “unavailable”, The system should automatically inform me of the impossibility to provide the Service required.
UI_AGG_09	Market results information	BUC 5	I want to be able to visualize the flexibility market results and know if the bids were cleared or not (chart, list, map).
UI_AGG_10	Historic results	BUC 5	I want to be able to see the cashflow of my activity, and the economic income for each source (map, list chart)
UI_AGG_11	Bidding strategy decision support tool	BUC 5	**(Optional)** I need to support my bidding decisions based on flexibility demand information, being able to see if the DSO is requesting flexibility.

5.1.4 Operator of the market platform

ID	Title	Related Business Requirements	Description
UI_GMO_01	Visualization of the timeline of offers and requests	BUC 01-05	I want to have access to a visualization of the timeline of flexibility offers and requests at any moment so that I have the big picture of the market behaviour.
UI_GMO_02	Access the list of actors of the market	BUC 01-05	I want to see the list of all the registered actors and relative flexibility units, with their characteristics.

5.1.5 Operator/Manager of an EMS (Prosumer)

ID	Title	Related Business Requirements	Description

UI_Prosumer_01	Visualize present and future flexibility offers	• HLUC 01 • HLUC 02 • HLUC 03 • HLUC 04 • HLUC 06 • HLUC 07	I want to be able to easily see my present and future flexibility offers, with all their characteristics (price, energy, time), so that I can adapt my plans accordingly.
UI_Prosumer_02	Change/cancel present and future flexibility offers		As a prosumer I want to change/cancel present and future flexibility offers manually, so that I can adapt to ever changing situations of the business.
UI_Prosumer_03	Be informed via periodic report		As a prosumer I want to receive a clear and complete report about incomes associated with flexibility uses of the last period (day/week/month).
UI_Prosumer_04	Check which offers have been accepted		I want to check which of my previous offers have been accepted or not, with their relevant earnings, so that I can fine tune future offers.
UI_Prosumer_05	Flexibility offers constraints configuration		I want to be able to put constraints on the characteristics of my flexibility offers, such as time and power available, so that I do not risk having the need to change my business as usual.
UI_Prosumer_06	Information about flexibility use		I want to be able to know what my flexibility has been used for and by which business actor, so that I can use it for my marketing strategy.
UI_Prosumer_07	Real time notification of usage		I want to be readily notified whenever my flexibility is being used, so that I am aware of real time energy situation of my business.

5.1.5.1 PED Owner

ID	Title	Related Business Requirements	Description
UI_PED_01	Flexibility history of PED and earnings	• HLUC01 • HLUC02 • HLUC07	As a PED owner, I want to see the historical view of flexibility provided by my PED and my earnings, so that I can assess the benefit vs the cost of participation.
UI_PED_02	PED use		As a PED owner, I want to see that the primary use of my PED (e.g. utilisation in EV charging) is not limited by the participation in FEVER.

5.1.5.2 EV Owner

ID	Title	Related Business Requirements	Description
UI_EV_01	Flexibility history and earnings	• HLUC01 • HLUC02 • HLUC07	As an EV owner, I want to see the historical view of flexibility provided by my EV and my earnings, so that I can assess the benefit vs the cost of participation.
UI_EV_02	Charging Preferences	• HLUC06	I would like my EV to be charged to the desired SoC economically.

5.1.6 User of the P2P trading solution

ID	Title	Related Business Requirements	Description
UI_P2P_01	Visualization	HLUC 15	I want to have access to the visualization of the timeline of flexibility offers and requests within my community to learn on how our flexibility affects the behaviour of the whole local energy community (LEC). This way, I can see how all our participation increases self-consumption of my LEC.
UI_P2P_02	Control participation		I want to have the right for opt-in and opt-out of trading so I have full control over my participation as a peer in the P2P trading.
UI_P2P_03	Configuration of business strategy / single assets		I want to be able to choose between business strategies so that I can decide on prioritization of my available assets for either providing flex or its original purpose primarily.
UI_P2P_04	Automatic notification of asset / EMS unavailable		I want to receive an automated notification whenever an asset or my EMS is not available for participation in trading so that I can check on its status.
UI_P2P_05	Trading results information		I want to have access to the visualization of all my trading results so that I know if my bids and requests are traded and how economic it is.
UI_P2P_06	Historic trading results on assets resolution		I want to have access to the visualization of the contribution of each of my assets in terms of (number of flexibility offers/requests, duration, money earned).
UI_P2P_07	Changes in asset structure / composition		I want to be able to change the assets which are available for flexibility provision so that I can add / remove / exchange assets.

5.2 User interface design requirements

This section provides some recommendations in the form of requirements, intended for systems that support flexibility towards offering electricity grid services as part of the FEVER project. These requirements have been generated through analysis and studies of prosumer needs with regards to user-machine interaction and general experiences in using flexible energy solutions, and deduction and description of UI requirements using analysis on user interface design guidelines. The structure and presentation of the following requirements are inspired by the Horizon 2020 Marie Skłodowska-Curie project “Privacy & Us” [10].

Some general principles for interaction design are elaborated in the following list, following the work of Molich and J.Nielsen (i.e. “User Interface Design Guidelines: 10 Rules of Thumb”, “Improving a human-computer dialogue”) [11]:

1. **Visibility of system status:** The system should always keep users informed about what is going on, through appropriate feedback within reasonable time
2. **Match between system and the real world:** The system should speak the users’ language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order
3. **User control and freedom:** Users often choose system functions by mistake and will need a clearly marked “emergency exit” to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
4. **Consistency and standards:** Users should not have to wonder whether different words, situations, or actions mean the same thing.
5. **Error prevention:** Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.
6. **Recognition rather than recall:** Minimize the user’s memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
7. **Flexibility and efficiency of use:** Minimize the user’s memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate
8. **Aesthetic and minimalist design**: Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
9. **Help users recognize, diagnose and recover from errors:** Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
10. **Help and documentation:** Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user’s task, list concrete steps to be carried out, and not be too large.

5.2.1 Visibility of system status

UI-001-SYSTEM-STATUS	
Description	The UI should differentiate among different types of users (and their roles in the system) and display this information clearly and visible in the interface.
Risk	Users might interact with the system without knowing they are not correctly logged in to the system, which could have severe effects.
Rationale	If the system is used by several users, it should be made visible who is currently logged in. The different users have different profiles and also, they might have different degrees of authority in the system.

UI-002-SYSTEM-STATUS	
Description	The UI should show which entities are part of the flexibility market ecosystem. When operating on or switching between e.g. different electricity grids, or energy communities, it is important that the UI clearly displays which part of the application domain (e.g. grid or community) the user is currently working on.
Risk	The user might not notice the context and scope of the work with system, and thus work and operate in the wrong context and environment, e.g. trading for the wrong group of entities.
Rationale	The scope of user interaction and tasks sometimes change within the same interaction or working session. Hence, it becomes pivotal that such changes of system status are visible.

UI-003-SYSTEM-STATUS	
Description	The UI should differentiate between autonomous and manual control in terms of which devices that are directly human-controlled and which are automatic. This could be achieved in different ways, e.g. visual effects or use of specific graphical elements like icons.
Risk	For certain users, it might be difficult, but still important to know what kind of appliances and devices are connected to the system, as this may influence the operation in the UI.
Rationale	Electricity consuming and/or producing devices on the grid exhibit different characteristics on how flexibility can be offered and integrated (e.g. EVs, wet devices, thermostats), and it becomes critical that users clearly have an idea or understanding of how this is potentially affects the system.

5.2.2 Match between system and the real world

UI-001-REAL-WORLD-MATCH	
Description	The UI should display information and data in an understandable way and manner. This is a straightforward classical usability aspect of interactive technologies, where it is important that information and data are represented and visualized in a clear and understandable manner, usually using simple means for communicating this.
Risk	Users often misunderstand and misinterpret information and data in the UI if they are not clearly understandable. This might lead to interaction errors that prevent efficiency and effectiveness of the UI. Also, if information is not easily understandable, it may lead to risky behaviour.
Rationale	Clear and understandable information and data are important for having usable interaction with technologies. Lack of understandability often affects usability (e.g. efficiency and effectiveness) and could potentially also affect users’ experiences (e.g. satisfaction).

UI-002-REAL-WORLD-MATCH

Description	The UI should use and apply common/established vocabulary from the application domain for expert users (e.g., DSO's, grid operators, and aggregators). This is particularly important for expert users, like people trained for certain jobs, or people that frequently use the system.
Risk	Users find it difficult to interact with a system where there is a mismatch between UI's vocabulary and users' understanding of the application domain. These may lead to more mistakes.
Rationale	The application domain contains concepts and vocabulary that often are deeply integrated and embedded into the understanding of tasks and activities. Therefore, for allowing a successful mapping between the UI and the real-world entities and activities, the UI should apply the same vocabulary.

UI-003-REAL-WORLD-MATCH	
Description	The UI could consider using real world metaphors, as this enables recall rather than recognition and thus, users become more efficient and effective and most likely make fewer mistakes. Real world metaphors for flexibility trading could include plug-in devices, or similar.
Risk	Users often find it difficult to interact with a UI and system if they cannot match any of the elements in the UI to real world objects and actions that they know from previous everyday experiences.
Rationale	Real world metaphors increase familiarity, and this affects user recall and recognition. Often it is difficult for users (in particular more casual users) to recall actions and interactions, and metaphors can enable that such interaction is more based on recognition.

UI-004-REAL-WORLD-MATCH	
Description	The UI should translate energy specific information to prosumers in a manner that is understandable and clear. Prosumers are perhaps more novice types of users in terms of frequency of use, but also in terms of energy domain knowledge and expertise. Thus, information should be understandable and perhaps translated or explained.
Risk	Not understanding the energy specific information can potentially lead to errors and users making clear mistakes.
Rationale	While expert users need to be effective and efficient (see UI-002-REAL-WORLD-MATCH), novice users and in particular prosumers, might have less knowledge and understanding about specific details on flexible electricity consumption and production. E.g. if the UI is intended to be used by residential prosumers, it has been found that such a user group often doesn't fully understand even simple concepts such kWh, or time/load flexibility (nor parameters needed to execute flexibility schedules)

UI-005-REAL-WORLD-MATCH	
Description	The UI could utilize energy related information using graphs or other kinds of visual representations instead of numbers. Such visualization techniques could provide simple means for illustrating important aspects

	of energy data, like trends, forecasts, aggregation or correlations between datasets.
Risk	Users might fail noticing and understanding important aspects of datasets and their characteristics. Having large tables or lists with only numbers can be difficult to overview and comprehend.
Rationale	An UI for domains that contains substantial amounts of information and data becomes challenging to overview, and thus making decisions and actions becomes evenly difficult.

5.2.3 User control and freedom

UI-001-CONTROL	
Description	The UI should allow users to abort or cancel actions or selections. During a multi-step process in the interaction, e.g. activating flexibility bids, the UI should provide easy and clear means for aborting or cancelling the entire process and thus returning back in the initial state.
Risk	The risk is that users become inefficient and ineffective if the UI provides no or limited functionality for aborting actions and selections. It furthermore negatively affects user satisfaction which may impact use.
Rationale	Users make mistakes during their interaction with UI – this is a well-known fact within human-computer interaction and it includes both novices and expert users. When completing a task or sub-task that involves multiple steps, the user should be able to abort the process and thereby cancel the steps and actions, without having to do several multiple manual steps.

UI-002-CONTROL	
Description	The UI could support functionality of undo and redo. Most UI integrate a simple means for undoing an action (e.g. ctrl z). This allows users to quickly undo actions, or interactions without much effort.
Risk	The risk is that users make mistake during interaction, and by having functionality for undoing and redoing actions and selections, the UI ensures that such mistakes can easily be fixed. This also reduces risks of further mistakes being made.
Rationale	Users make mistakes during their interaction with UI – this is a well-known fact within human-computer interaction and it includes both novices and expert users. UI with rich means for cancelling, undoing, or redoing actions are much easier and pleasant to use.

UI-003-CONTROL	
Description	The UI could support actions that will occur in the not-near future
Risk	Users might need to specify actions that will happen in the not near-future, e.g. a specific system behaviour during holidays, or changes in seasons. A UI that supports that allows the users to plan ahead and trust that their actions will be carried out.

Rationale	Very often users forget to carry out important for them tasks when these tasks occur in the not-near future. This situation may lead to increased frustration and may have a negative impact on users' experiences.

UI-004-CONTROL	
Description	The UI should save user preferences in a profile. Having profiles in a system ensures that users can be identified, and the preferences enables the individual user to specify various interaction aspects e.g. how data should be visualized, or which functions are most important.
Risk	Without user preferences in an UI, the user risks having to repeat tasks that are trivial, and this might also risk that they have to change how data and information are presented in the UI from session to session.
Rationale	Preferences are a natural part of many UI as they enable control over the UI, and they also provide more efficient and effective use.

5.2.4 Consistency and standards

UI-001-CONSISTENCY	
Description	The UI should maintain a standard and consistency for interaction, which should include both the visual and aesthetic (e.g. colouring of text or use of icons and graphic elements), and also the functional level. Also, the UI elements and objects must be familiar to the user.
Risk	An UI with an inconsistent design may lead to user errors, but also increase the cognitive load of the user. Such overload often results in frustration and dissatisfaction, which clearly affects user experience and overall usability.
Rationale	UI consistency and standards will make it much easier for users to interact and use systems.

UI-002-CONSISTENCY	
Description	The UI should follow external standards from other kinds of systems that are relevant to the domain (energy). This is particularly important to professional users and experts that often use other UI for related or similar work tasks. Therefore, the UI should consider being consistent with such additional systems by utilizing similar visual elements, functions, short-cuts, dialogue windows, etc.
Risk	An UI with an inconsistent design compared to other relevant systems may lead to errors, but may also affect cross-system interaction, e.g. the user may start to make mistakes and errors in other systems. As with (UI-001-CONSISTENCY), overload often results in frustration and dissatisfaction, which clearly affects user experience and overall usability.
Rationale	UI consistency and standards towards other relevant systems makes it much easier for users to interact and use a new system.

UI-003-CONSISTENCY	
Description	The UI could consider balancing the consistency for internal visualization and interaction, external visualization and interaction, and real-world visualization and interaction. Internal consistency reflects within the UI for the same system, whereas external consistency reflects consistency with other UI. Finally, real world consistency reflects consistency towards real world action and objects.
Risk	Users interact with different types of systems and also real-world objects and phenomena, and there might not be consistency between these different kinds of interaction. A risk here is that an inconsistent UI across all three kinds of interaction will lead to more user mistakes.
Rationale	Users interact with various technologies and systems in their everyday lives, and they also use different platforms (e.g. mobile versus desktop, or Windows versus macOS) that use slightly different layouts and conventions. A UI that is completely inconsistent to these external systems will lead to more user mistakes.

UI-004-CONSISTENCY	
Description	The UI should follow international design standards (i.e. ISO9241-11:2018) for achieving a more uniform approach to UI interaction.
Risk	
Rationale	ISO standards – used by many kinds of systems- represent a coherent and validated approach to ensuring consistency in the UI.

5.2.5 Error prevention

UI-001-ERROR	
Description	The UI should disable (grey-out) or hide functions that are either not possible or accessible for the individual user or cannot be performed in a given situation. For example, a flexibility trading functionality should only be active and visible in the UI if actually available.
Risk	Users might activate functions that should not be used or make no sense to activate in a given situation. This may lead to errors, or system failures.
Rationale	The disabling of interaction elements and functionality is a classical solution to avoid certain types of user interaction errors in a UI. As a classical example of this, the Microsoft Office UI enables and disables menu items according to whether they can be used for a particular task.

UI-002-ERROR	
Description	The UI should not allow actions that users are not authorized to carry out. E.g. trading, offering or accepting flexibility should not be permitted outside legal or authorized time horizons or any monetary limits.
Risk	Enforcing restrictions in the UI regarding limits could potentially prevent users from making mistakes and errors. If the UI does not implement such preventions, users might unconsciously perform transactions that clearly exceed limits, e.g. how often (during the day, week, month) or for

	how much (currency, electricity measure, flexibility) a user can specific in the transactions.
Rationale	Users make mistakes during their interaction with UI – this is a well-known fact within human-computer interaction and this applies for both novices and expert users. When completing a task, sometimes users type in wrong numbers or are not aware of limitations, and this could lead to errors, and also potential loss of money, time etc. Therefore, it is important that users trust that the UI will help them prevent that such mistakes arise.

UI-003-ERROR	
Description	The UI should enforce, or ensure that inputs can only be entered in a correct format, e.g. date formats, energy formats or monetary inputs.
Risk	Users might input wrongly formatted values into input fields in the UI and errors resulting from such inputs may lead to system failures, but also decreased efficiency and effectiveness. As a consequence, users become more careful and this demands a higher cognitive load when interacting with the UI.
Rationale	If the UI has an open format for input of values, the user has to remember and recall how this format is, and this often leads to input errors. By enforcing a format to input and entry fields and by clearly informing the users about the format the UI supports recognition and this to a higher degree prevents errors.

UI-004-ERROR	
Description	The UI should require extra confirmation steps when carrying out critical actions or work tasks. The UI should differentiate between more trivial tasks and critical tasks in terms of how the users are becoming aware. Furthermore, such UIs help users acknowledge such critical tasks through additional confirmations.
Risk	Users could potentially carry out tasks of high risk and importance without being explicitly aware of this. This usually involves tasks and interaction of selling and buying something, as opposed to simply browsing information and data.
Rationale	For a user of a UI, errors have different severity levels and consequences. Therefore, it makes sense to enforce extra confirmation and acknowledgement when performing what can be considered critical tasks. A good UI on this matter will decrease cognitive load of the user.

UI-005-ERROR	
Description	The UI should only allow for actions or input values that are system acceptable. The system might operate with dynamic values and actions for entities and characteristics, and the UI should enforce that such system values, actions and limits cannot be violated.
Risk	Here the risk is (as opposed to UI-002-ERROR), that users is going to perform actions, that will not necessarily make the system or UI fail immediately, but it will fail or conduct illegal actions at a later point in

	time. This is critical as the user might not be aware of such violations when using the system.
Rationale	Users make mistakes during their interaction with UI – this is a well-known fact within human-computer interaction and it includes both novices and expert users. When completing a task, sometimes users type in wrong numbers that could be illegal or propose a potential violation.

5.2.6 Recognition rather than recall

UI-001-RECOGNITION	
Description	The UI should carry over data throughout the different interfaces until the action is completed.
Risk	Users might complete tasks wrongly if they have to recall themselves all actions and inputs made to the system. For example sometimes users are interrupted while carrying on a task, and when returning to the system, the UI should clearly display status and earlier inputted data to avoid errors.
Rationale	Users forget their actions and selections, so when carrying out a task, data that has been typed in earlier during the task, should be carried over in the UI so the user does not have to remember them (e.g. value) but rather recognize them.

UI-002-RECOGNITION	
Description	The UI should visualize historical data and actions (e.g. flexibility offers).
Risk	Rather than relying on recall of what happened during the last interaction, the UI should provide functionality and means for visualizing and showing historical actions and data that will enable the user to better recall what happen previously, but also to ensure that repeated tasks can be more easily performed.
Rationale	Users forget their actions and selections, so when carrying out a task, it is important that the UI visualizes historical flexibility data and actions relevant to the task at hand. This minimizes user errors as it supports recognition than recall.

5.2.7 Flexibility and efficiency of use

UI-001-FLEXIBILITY	
Description	The UI should allow user profiles.
Risk	While the system mostly likely needs to log user interaction and actions (which requires user profiles or logins), a user profile also enables flexibility for the individual users.
Rationale	If several users use the system, user profiles are necessary. Integrating user profiles also affects usability (e.g. efficiency and effectiveness) and could potentially also affect user experiences (e.g. satisfaction).

UI-002-FLEXIBILITY	
Description	The UI should enable efficiently and effectively carrying out of tasks that are frequently performed – e.g. if a user trades flexibility every day.
Risk	A lack of carrying our tasks efficiently and effectively becomes very critical if the user carries out similar tasks on a regular basis, and the UI provides no or limited means for automating or making this task faster.
Rationale	Often users conduct the same task (or similar tasks) on a regular basis, where they need to go through the same steps, actions, and inputs. Based on a user profile, the UI should be able to enable ways for efficiently carrying out these tasks.

UI-003-FLEXIBILITY	
Description	The UI could provide shortcuts and macros for carrying out actions for expert users. Such macros could be customizable in order to fit the individual user's needs.
Risk	When users repeat actions and tasks in an UI, they become less efficient if they have to conduct each step of a process every time without being able to automate some of these processes. Such decreased efficiency negatively affects both usability and user experience. A risk is also that users waste valuable time.
Rationale	Expert users often spend considerable amounts of time on UI for supporting their work, and short cuts and macros are used in several commercial IT products for making users more effective, but also to allow personalization.

5.2.8 Aesthetic and minimalist design

UI-001-AESTHETIC	
Description	The UI should only include information that is relevant for the target users and the task at hand. It is important that UI screens are not filled with information that are unnecessary for the user when conducting a task as this will lead to inefficient use.
Risk	Overloaded UI screens with too much information may result in users missing important information and thus having a less successful interaction with the system.
Rationale	Keeping it simple is often a good idea for a UI as it will make users more efficient and prevent them from missing information.

UI-002-AESTHETIC	
Description	The UI should provide dialogue windows that are simple and clear. When prompting the user during interaction, the UI should make these simple, the language should be clear and precise, and possible actions (buttons, etc) should provide well-defined options and selections.
Risk	If dialogue windows are complex, the user might select the wrong action for a particular task. This will result in an error that will lead to inefficiency or even mistakes that are difficult to recover from.

Rationale	Users make mistakes during their interaction with UI – this is a well-known fact within human-computer interaction and it includes both novices and expert users. When interacting with a dialogue window, the UI should ensure that users see important information and instructions, and that actions (e.g. an OK button, or cancel button) are clear, concise and consistent throughout the interface.

UI-003-AESTHETIC	
Description	The UI should follow the same visual design on different platforms
Risk	User will find it difficult to switch from one platform to another if the visual design also changes. This will most likely result in decreased efficiency and potentially less user satisfaction.
Rationale	Many UI today adapt to different platforms to make them more or less independent of the platform being used.

UI-004-AESTHETIC	
Description	The UI could follow simple design guidelines (e.g. the Google material design guidelines[1])
Risk	
Rationale	Following standard material design guidelines ensures that the visual design complies with ideas and approaches that have been widely evaluated and validated in other systems. It also ensures that many users have experienced the visual design layout in other applications.

5.2.9 Help users recognize, diagnose, and recover from errors

UI-001-HELP	
Description	The UI should provide error messages in a simple and understandable language – short and precise, and without blaming the user or using negative wordings. The error messages should further provide instructions to the users on how to solve/avoid the problem.
Risk	If the UI does not help users in understanding when something goes wrong, there is a chance that users will not understand why something went wrong, and this will prevent them from learning from the experience.
Rationale	When users make mistakes, the error messages should be written in a clear and simple language, and they should also be able to understand the problem while reading the message. Also, error messages should not be ambiguous, as the user will fail to understand the nature of the problem. Also, it should be short and not use too much technical jargon. Finally, good error message etiquette promotes that the error message should be humble and should never blame the user.

[1] https://material.io/design

UI-002-HELP	
Description	The UI should provide clear options or exits in case of errors or mistakes
Risk	Often in complex UI that convey a lot of information/functionality users have a difficulty locating the functionality they need, how to terminate a task and how to recover from an error. This may lead to an increase in frustration and may have a negative impact on users' experiences.
Rationale	This is related to (UI-001-HELP) where the UI provides good help in case something goes wrong.

5.2.10 Help and documentation

UI-001-DOCUMENTATION	
Description	The UI should integrate a complete help manual including a search functionality.
Risk	If help (online) is not accessible and available, users might get stuck in the interaction, or may conduct actions wrongly. This will negatively affect their experience with the system, and it will also potentially affect aspects of usability and user experience.
Rationale	Users of expert systems most often do have access help material, and thus they also expect advanced search UI capabilities that enable them to quickly look up information about functions and concepts.

UI-002-DOCUMENTATION	
Description	The UI should provide functionality for help in all (critical) situations. This type of help should – as opposed the more general help – provide tailored and contextual help for the specific situation that the user is in. Thus, the user would not have to search for help, but the help will be specific and concrete.
Risk	Critical situations in the interaction can create uncertainty and frustration for users if they are not fully certain what to do. This can possibly create a bad user experience or decrease efficiency and effectiveness as users spend extra attention and time on completing tasks.
Rationale	Users might more frequently need or request help in critical situations and at the same time, they might also be in a more stressful situation if the task is critical, especially if the task has to be performed under time constraints.

UI-003-DOCUMENTATION	
Description	The UI should provide clear and precise explanations of concepts and terms used in the system.
Risk	In a system trading electricity and flexibility, there is a risk that some users might not understand all key concepts, and this is particularly important if the system has a diverse user group, e.g. experts versus novice residential users.

Rationale	The UI should contain multiple concepts that describe the application domain, and which are vital for the understanding of the task and interaction.

UI-004-DOCUMENTATION	
Description	The UI could provide easily accessible information about external help. The UI should display such information so the user can locate it without any problems.
Risk	If the user is completely stuck in the interaction and cannot complete the task, or if something severe has happened, the user might need to contact support for qualified help. The risk could be that a user is stuck in a critical situation, and tasks are half completed, and without support the system remains in unfavourable states.
Rationale	External help and human support offer extra safety for users when interacting with the system.

6 System Requirements

This chapter documents systemic requirements in the form of use cases, following the standard template of IEC62559 (see D1.1 [1] for more details).

6.1 Monitoring and automated control of the distribution grid (DSO Toolbox)

6.1.1 PUC1 Critical event prevention

6.1.1.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Describes the process of identifying and mitigating potential violations of the network operational constraints (thermal limits of grid infrastructure and voltage excursions from regulated boundaries)
Objective(s)	1) Identify potential violations of the network operational constraints 2) Propose mitigation actions leveraging grid reconfiguration and exploitation of DER flexibility. 3) Evaluate mitigation actions
Related high-level use case(s)	HLUC 01: Advanced network congestion management considering DER & grid flexibility (seasonal, day-ahead, etc.)

6.1.1.2 Narrative of use case

Narrative of use case
Short description
Critical event prevention is the process of identifying and mitigating potential violations of the network operational constraints (thermal limits of grid infrastructure and voltage excursions from regulated boundaries). A power flow analysis is performed based on real monitoring and forecasted data. In case a network operational issue is identified, a mitigation plan is extracted considering grid reconfiguration and exploitation of DER flexibility (as complementary action to grid reconfiguration).
Complete description
The Critical Event Prevention Application (CEPA) is an application of the DSO Toolbox that offers identification of potential violations of the network operational constraints and mitigation actions in different time horizons. In order to identify such issues in the grid, the CEPA leverages information provided by various subsystems: • Grid operational status (see SUC 02: Grid Observability and Monitoring), utilizing data from DS SCADA and AMI. • Forecast of grid profile (see SUC 01: Energy Forecasting) provided by the Energy Forecaster (EF) • Characteristics of the distribution grid assets provided by the GIS • Weather forecast data from Weather Forecaster (WF) The different timeframes identified range from short term to long term, as identified below: • Operational (i.e. Day-ahead) or Long-term (i.e. Seasonal)

- Close-to real time

The different steps of the critical event prevention process are presented in the next paragraphs.

Violation Identification

The identification of potential violations is orchestrated (see SUC 03: Critical Event Forecasting) by the Critical Event Forecaster – CEF (part of the DSO Toolbox). The process may differ, depending the timeframe. Two different scenarios are identified.

Operational / Long-term Scenario

In the seasonal and day-ahead time frame, consumption/generation forecast data are utilized to foresee possible grid issues, leveraging data from AMI and Weather forecaster. The violation of the network constraints –on the basis of the above inputs- is identified by the power flow analysis utilizing a Power Flow Simulator (PFS). CEF compares the results of the power flow analysis (power flows and voltages) with the thermal network limits and the voltage regulated boundaries in order to identify any violation of the network operational constraints.

Close-to real time Scenario

In the close-to real time situation, DS SCADA data are used to monitor in real time the levels of voltage and current in the assets of the grid. Values are continuously assessed in comparison to the network constraints by the CEF. If the measured values exceed a threshold (e.g. 90% of maximum limit) an alarm of critical event is generated in real time.

Propose Mitigation Action

In case a network operational issue is identified, a mitigation plan is extracted by the Grid Operation Planner (GOP) considering grid reconfiguration and exploitation of DER flexibility. The grid reconfiguration entails the proper scheduling of the switchgear operational status. In case that network reconfiguration cannot adequately mitigate the network operational issue, flexibility offered by dispatchable assets located in the problematic area can complementarily be exploited for supporting network operation. Upon calculation of mitigation actions CEP, communicates the Switchgear Dispatch Scheduler (SDS) with the switchgear plan (see PUC 02: Grid reconfiguration Schedule Dispatching) and the Flexibility Service Consuming Agent (FSCA) with the requested flexibility (see PUC 03: Requesting flexibility Services) which will handle the implementation of remedial actions, and returns an update of the flexibility scheduled for activation.

Evaluate Mitigation Action

The effectiveness of the remedial actions is assessed periodically by the Ex-Post Assessment Application (EPAA) based on real data from the DS SCADA (see PUC 06: Ex-post network performance assessment). Based on the above EPAA provides CEF with the outcome of a power flow analysis, hence CEF can compare the network infrastructure loading with the thermal limits and calculate relevant performance metrics.

6.1.1.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC01_1	Responsiveness of close to real-time prevention	Expresses the time required for identifying the potential violation and	1,2

		proposing the mitigation actions in the close-to real time scenario.	
KPI_PUC01_2	Performance of critical event forecasting	True positive, false positive (false alarms), true negative and false negative (missed detections) ratios of forecasted critical events.	1

6.1.1.4 Use case conditions

Use case conditions
Assumption(s)
• GIS information include thermal limits of grid assets
Precondition(s)
• EF is operational and is able to provide consumption and generation forecasts (e.g. forecasting models are trained) • The sensor data provided to EF and CEF are of adequate quality • CEF is operational and parameterized with the characteristics of the distribution grid assets provided by the GIS • Operational/day ahead scenario: smart meter historic data and weather forecaster are available upon demand to CEPA • Near real time scenario: Grid observability data(voltage, current, power) available to (through the DS SCADA)

6.1.1.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
SUC 01: Energy Forecasting **SUC 02: Grid Observability and Monitoring** **SUC 03: Critical Event Forecasting** **SUC 04: Grid Operation Planning** **PUC 02: Grid reconfiguration Schedule Dispatching** **PUC 03: Requesting flexibility Services** **PUC 06: Ex-post network performance assessment**
Level of Depth
Detailed
Prioritization

Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
grid congestion, thermal limit violation, flexibility, grid reconfiguration, grid operational planning

6.1.1.6 Use case diagram

Diagram(s) of use case

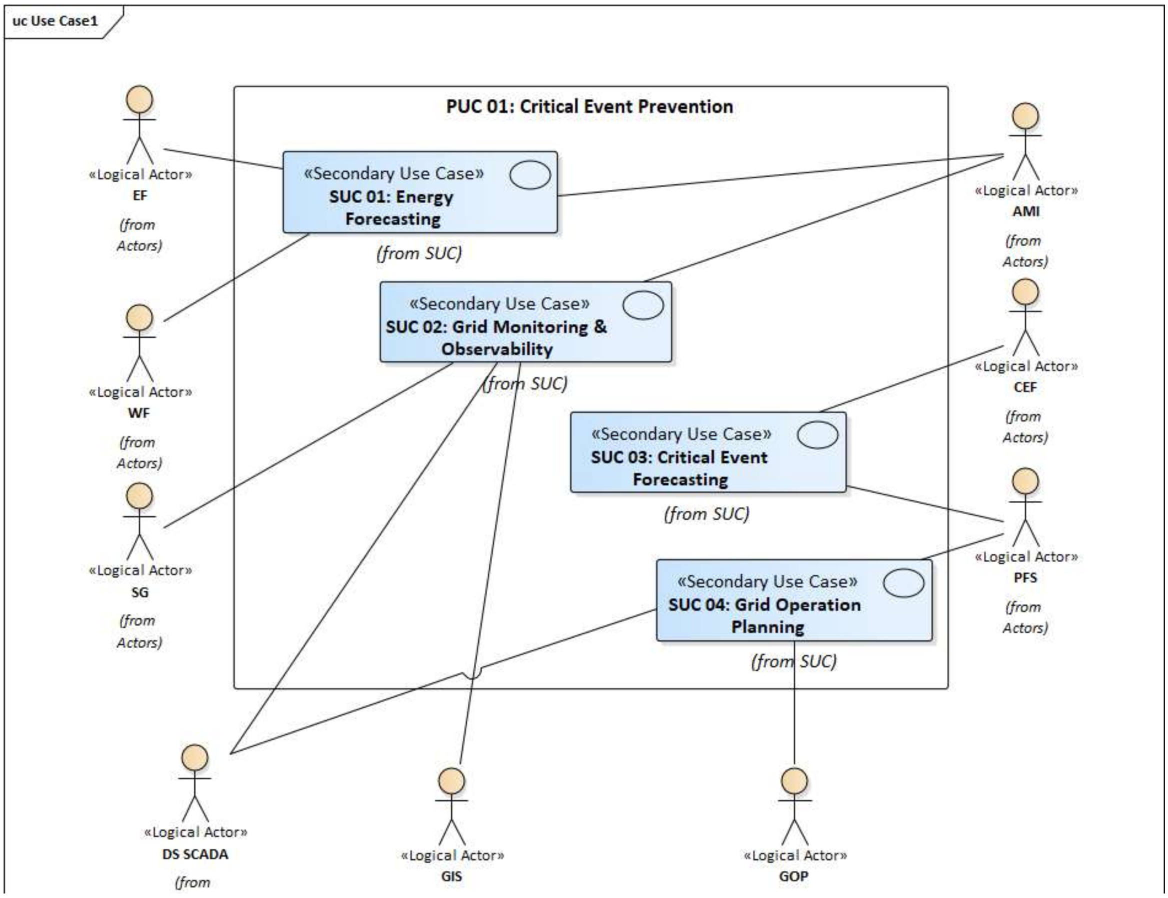


Figure 6 PUC1 UC Diagram

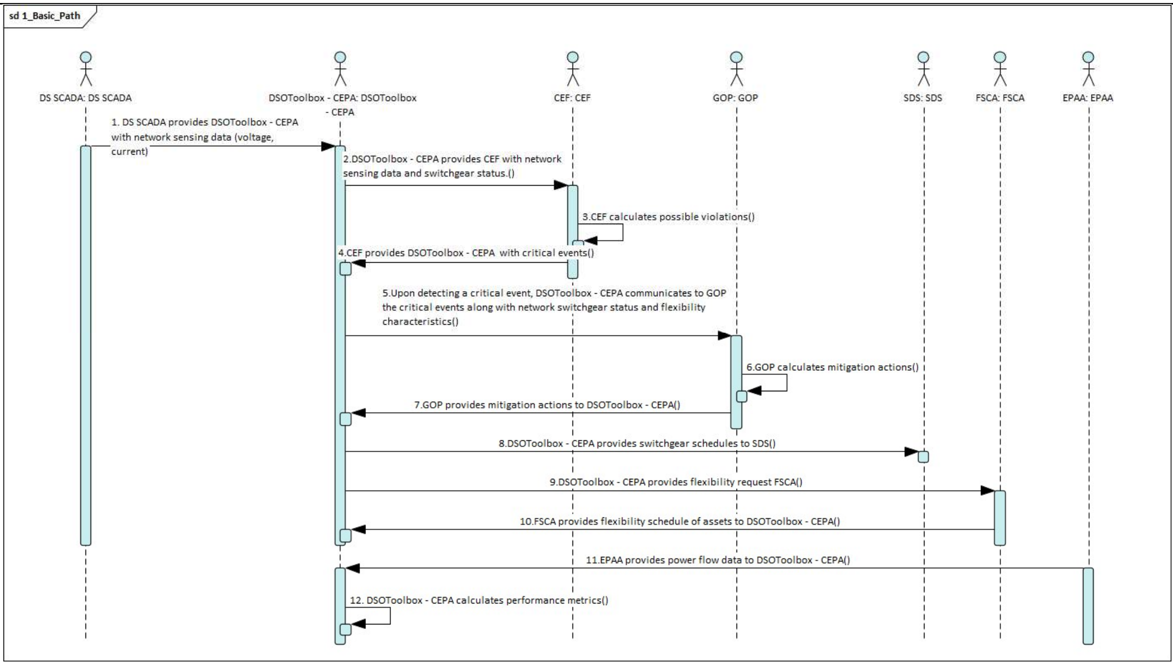


Figure 7 PUC1 Sequence diagram of "Close to real-time Identification" scenario

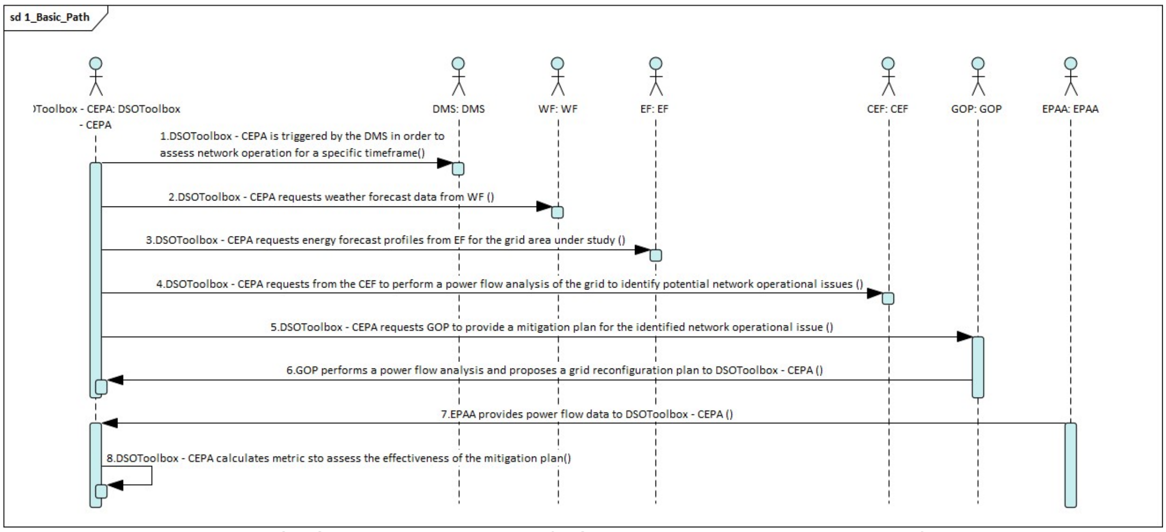


Figure 3 PUC1 Sequence diagram of "Operational / Long-term identification" scenario

6.1.1.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Advanced Metering	System	The system composed of all the devices, applications and data bases that permits to measure, remotely collect and manage data from smart meters.	Provides data for forecasting.

Infrastructure (AMI)			
Critical Event Prevention Application (CEPA)	Application	Application of the DSO Toolbox, in charge of orchestrating the process of predicting possible congestion or over-under voltage events and proposing mitigation actions.	Item under design.
Critical Event Forecaster (CEF)	Application	Application of the DSO Toolbox, in charge of predicting possible congestion or over-under voltage events in the succeeding H-time (forecasting horizon).	Provides predictions of events. Developed in the project.
Energy Forecaster (EF)	Application	A forecasting application, part of the DSO Toolbox, in charge of predicting demand and generation values for specific points of the grid in the succeeding H-time. It facilitates aggregated values of individual consumptions/productions and weather forecast data.	Provides predictions of energy consumption generation. Developed in the project.
Geographic Information System (GIS)	System	System that manages all the static information related to the grid assets, their location, operational status and parameters.	Provides grid asset information, including operational limits.
Grid Operation Planner (GOP)	Application	Service in charge of planning the grid operation satisfying a predefined objective function that depends on the specific scenario. It determines the need of reconfiguration or flexibility. Part of the DSO Toolbox.	Provides mitigation actions. Developed in the project.
Ex-Post Assessment Application (EPAA)	Application	Application for assessing the effectiveness of the remedial actions.	Will provide the ex-post analysis. Developed in the project.
Flexibility Service Consuming Agent (FSCA)	Application	The agent responsible for packing the flexibility needs of an actor into flexibility bid/request in respect to the requirements imposed by the flexibility markets or the bilateral agreements.	Will communicate flexibility request. Developed in the project.
Supervisory Control And Data Acquisition (DS SCADA)	System	A system in charge of overall monitoring and control of the distribution and transmission grid. It integrates communication, remote monitoring and control, signal processing and logic, and data storage functionalities. It includes a user interface called control center room.	Provides sensing data for the distribution grid. Enables switchgear schedule dispatch.

Switchgear Dispatch Scheduler (SDS)	Application	Application responsible for dispatching the grid reconfiguration schedule extracted by other applications of the DSO Toolbox.	
Weather Forecaster (WF)	Application	Application offering weather forecast services.	

6.1.1.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Close to real-time identification	Describes the process for identifying, mitigating and assessing critical events in the close to real-time horizon	CEPA	Periodic Process	Available data for analysis from DS SCADA	Events Identified, Mitigation actions communicated, Performance metrics Calculated
2	Operational / Long-term identification	Describes the process for identifying, mitigating and assessing critical events in the Operational / Long-term horizon	CEPA	Periodic Process	Available data for analysis from AMI, Weather Service	Events Identified, Mitigation actions communicated, Performance metrics Calculated

Scenario							
Scenario name:			Close to real-time Identification				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic Process	Get network sensing data	DS SCADA provides CEPA with network sensing data (voltage, current)	DS SCADA	CEPA	Network Sensing Data	

2	Periodic Process	Request critical event forecast for short-term horizon	CEPA provides CEF with network sensing data and switchgear status.	CEPA	CEF	Network Sensing Data, Switchgear Status	CEPA_REQ_OPE_01
3	Upon request	Calculate critical events	CEF calculates possible violations	CEF	CEF	-	CEPA_REQ_PER_01
4	Upon Calculation	Communicate Critical Events	CEF provides CEPA with critical events	CEF	CEPA	Critical Events	
5	Upon event detection	Request mitigation actions	Upon detecting a critical event, CEPA communicates to GOP the critical events along with network switchgear status and flexibility characteristics	CEPA	GOP	Critical Events, Network Switchgear Status, Flexibility Characteristics	
6	Upon request	Calculate mitigation actions	GOP calculates mitigation actions	GOP	GOP	-	
7	Upon calculation	Communicate mitigation action	GOP provides mitigation actions to CEPA	GOP	CEPA	Switchgear Schedules, Flexibility needs	
8	Upon receiving mitigation action	Send switchgear schedule	CEPA provides switchgear schedules to SDS	CEPA	SDS	Switchgear Schedules	
9	Upon receiving mitigation action	Send flexibility request	CEPA provides flexibility request FSCA	CEPA	FSCA	Flexibility Needs	
10	Upon traded flexibility	Send flexibility schedule	FSCA updates on schedule of flexibility	FSCA	CEPA	Flexibility Schedule	

11	Upon calculation	Send ex-post analysis	EPAA provides power flow data to CEPA	EPAA	CEPA	Power Flow Data	
12	Upon receiving ex-post analysis	Calculates metrics	CEPA calculates performance metrics	CEPA	CEPA	Critical Event Prevention performance metrics	
Scenario name:			Operational / Long-term identification				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1a	Periodic Process	Get network sensing data	CEPA request forecast from EF for a specific time horizon, providing data from the AMI and weather forecast data.	CEPA	EF	Smart Meter Data Weather Forecast	
1b	Periodic Process	Request critical event forecast for short-term horizon	EF provides energy forecast.	EF	CEPA	Energy Forecast	
2a	Periodic Process	Request critical event forecast for short-term horizon	CEPA provides CEF with energy forecast	CEPA	CEF	Energy Forecast, Switchgear Status	
3a	Periodic Process	Request critical event forecast for short-term horizon	CEF calculates possible violations	CEF	CEF	-	CEPA_REQ_OPE_02

6.1.1.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements** **R-ID**
CrEPMetric	Critical event prevention performance metrics	Metrics related to the performance of the operation of the critical event prevention application.	
CrEvent	Critical Events	Information related to possible violation of thermal limits of grid infrastructure and voltage excursions from regulated boundaries.	
EnForecast	Energy Forecast	Consumption and generation forecast for different assets of the grid.	
FlexNeed	Flexibility Needs	Required flexibility with spatial as well as temporal characteristics.	
FlexChar	Flexibility Characteristics	Characteristic of available flexible assets.	
FlexSched	Flexibility Schedule	A concrete planned realization of a flexibility needs.	
NetworkData	Network Sensing Data	Voltage and current, or power, sensing data from the SCADA.	
PfData	Power Flow Data	Voltages and currents in nodes and lines of the grid.	
SmData	Smart Meter Data	Measurement data from smart metering devices.	
SwStatus	Switchgear Status	Status of switchgear equipment.	
SwSchedule	Switchgear schedules	Required Switchgear reconfiguration.	
WetForecast	Weather Forecast	Meteorological forecast.	
GridInfoTplg	Grid Asset Information & Topology	Technical characteristic of grid assets (e.g. nominal power) as well as their connectivity (grid topology).	CEPA_REQ_INR_01

6.1.1.10 Requirements

Requirements ID	Requirement name	Requirement description
CEPA_REQ_INR_01	Grid information modelling standard	The grid asset information shall comply with the CGMES profile of CIM standard series.
CEPA_REQ_PER_01	Max duration of event forecast process	The process of critical event forecast process should not exceed a maximum threshold of 1 minute.
CEPA_REQ_OPE_02	Time Horizon - operational/long term scenario	The time horizon for assessing the grid status for critical events in the operational/long term scenarios is 24h with a granularity of one hour.

6.1.2 PUC2 Grid reconfiguration schedule dispatching

6.1.2.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Describes the process of identifying, validating a dispatching a series of commands for the control of grid switchgear, following a grid reconfiguration plan provided.
Objective(s)	1) Identify series of commands of grid switchgear 2) Validate switchgear commands 3) Dispatch switchgear commands
Related high-level use case(s)	HLUC 01: Advanced network congestion management considering DER & grid flexibility (seasonal, day-ahead, etc.) HLUC 04: Self-healing operation after critical event considering DER & grid flexibility

6.1.2.2 Narrative of use case

Narrative of use case
Short description
A grid reconfiguration plan (e.g. such as the one provided by the Grid Operation Planner –GOP) dictates the proper modification of the operational status of the switchgears. The implementation of the grid reconfiguration plan is scheduled by the Switchgear Dispatch Scheduler (SDS) which executes the reconfiguration plan by requesting the successive modification of the status of the respective switchgears from the DS SCADA.
Complete description
The realization of grid reconfiguration operation dictates the proper safety mechanisms for avoiding

situations where the sequence of control action can create problems in the grid (e.g. isolation of an area). Towards this, each switching action in a grid reconfiguration plan should be validated, whilst its execution must follow validation procedures of each action performed, prior to executing the next action. The Switchgear Dispatch Scheduler (SDS) will be responsible for implementing a grid reconfiguration plan, such as the one provided by the Grid Operation Planner (GOP). Upon receiving a plan with the new status of the switchgear in a grid area, the SDS will devise and provide to the Operator of the control center for validation the sequence of actions (e.g. detailing the switchgear information, previous and new state) to be performed. Upon validation by the Operator the SDS can initiate – at the specified time the process for dispatching the actions, via communicating proper commands to the DS SCADA. For each command dispatched the SDS will query its status from the DS SCADA in order to validate if the switchgear action was performed. Upon validation if we proceed with the next action. In case a switchgear action cannot be validated after a maximum time threshold (e.g. 3 tries), an alert will be provided to the Operator.

6.1.2.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC02_1	Responsiveness of grid reconfiguration planning	Expresses the time required for identifying the series of commands of grid switchgear	1
KPI_PUC02_2	Efficiency of grid reconfiguration planning	Expresses the amount of valid dispatches of the plan, with respect to the total requested.	ALL

6.1.2.4 Use case conditions

Use case conditions
Assumption(s)
• DS SCADA provides an interface for dispatching control commands.
Precondition(s)
• SDS has been preprogrammed with a state machine enabling to identify a valid sequence of actions for the execution of a grid reconfiguration plan

6.1.2.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases

PUC 01: Critical Event Prevention PUC 12: Self-Healing
Level of Depth
Detailed
Prioritization
High
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
grid reconfiguration

6.1.2.6 Use case diagram

Diagram(s) of use case

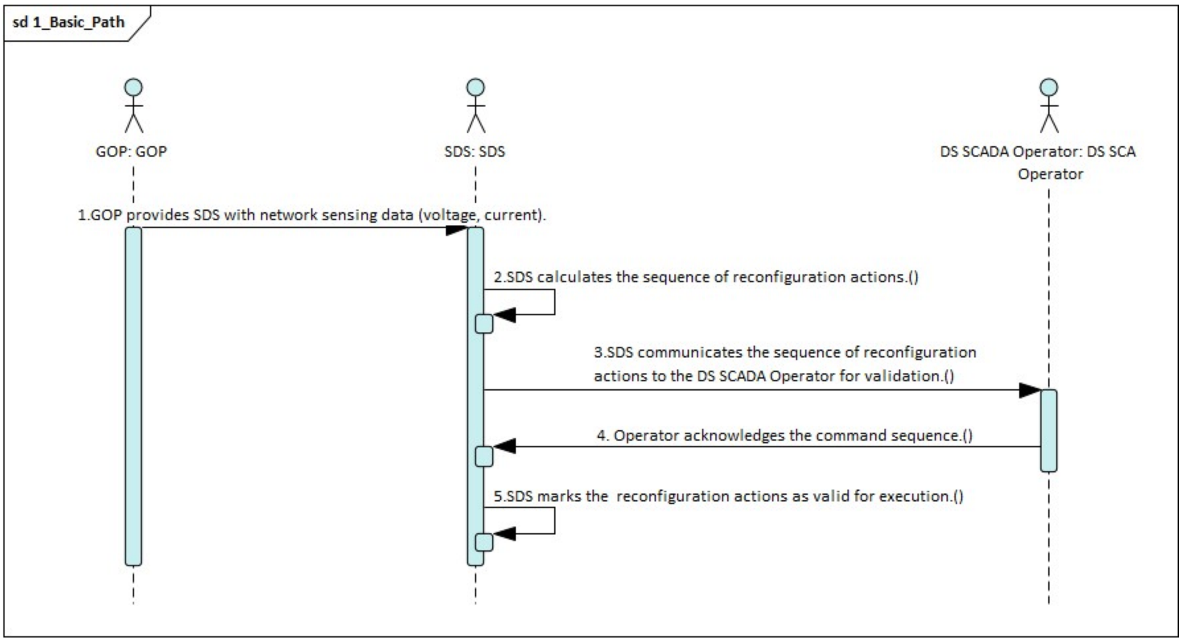



Figure 8 PUC2 Sequence Diagram - Prepare reconfiguration actions scenario

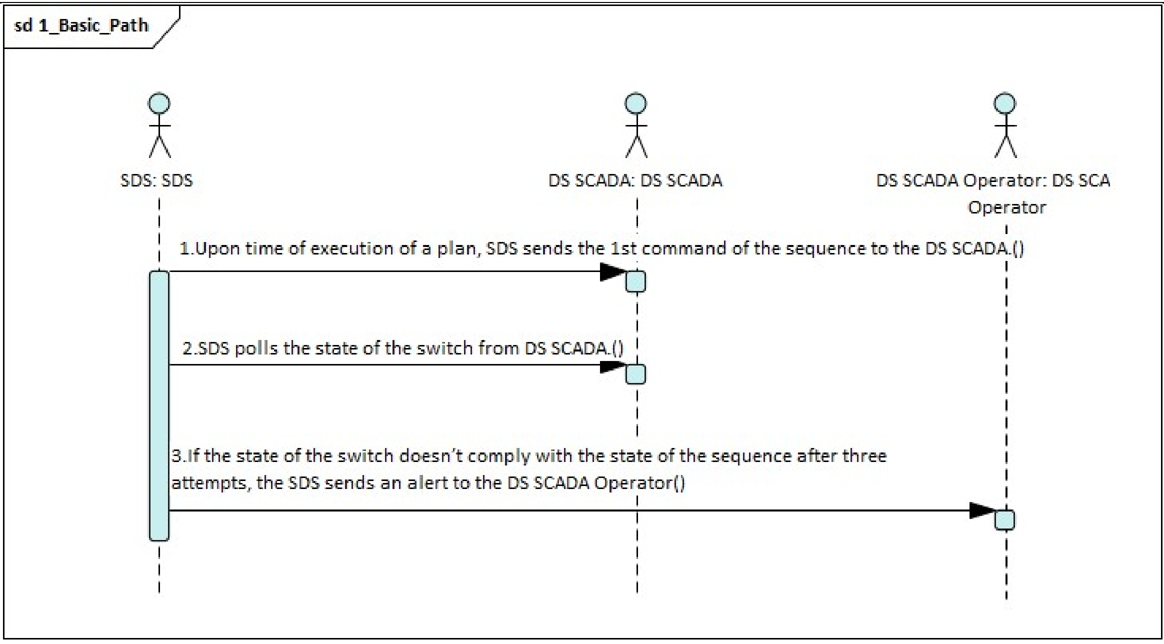


Figure 9 PUC2 Sequence Diagram - Valid execution

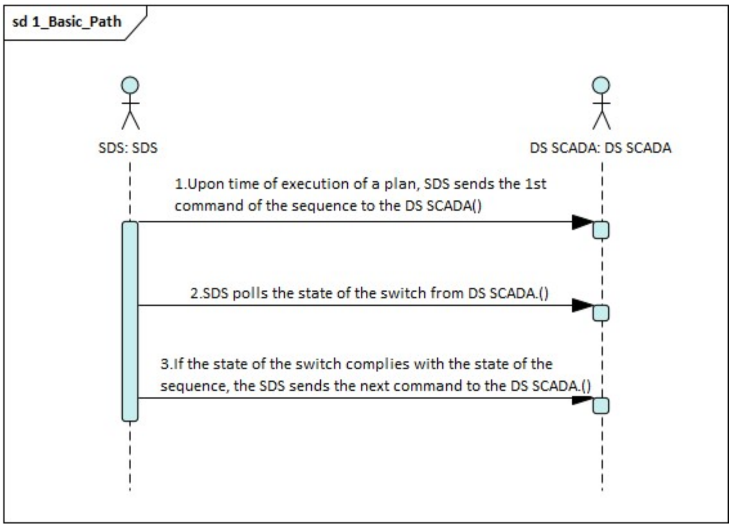


Figure 10 PUC2 Sequence Diagram - Invalid execution

6.1.2.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Grid Operation Planner (GOP)	Application	Service in charge of planning the grid operation satisfying a predefined objective function that depends on the specific scenario. It determines the need of reconfiguration or flexibility. It is included in the DSO Toolbox.	Provides the grid reconfiguration plan

Switchgear Dispatch Scheduler (SDS)	Application	Application responsible for dispatching the grid reconfiguration schedule extracted by other applications of the DSO Toolbox.	The application under design.
Switchgear (SG)	SG	Actuators of the LV grid that permit to switch lines and change grid configuration.	
Supervisory Control And Data Acquisition (DS SCADA)	System	A system in charge of overall monitoring and control of the distribution and transmission grid. It integrates communication, remote monitoring and control, signal processing and logic, and data storage functionalities. It includes a user interface called control center room.	Enables switchgear schedule dispatch.
Operator	Human User	Operator of the distribution system control center.	Validates the switchgear control commands and monitors the dispatch.

6.1.2.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Prepare reconfiguration actions	SDS devises and validates the grid reconfiguration plan.	SDS	Grid reconfiguration request	-	Schedule dispatched
1	Valid execution	Successfully dispatch of the grid reconfiguration plan	SDS	Grid reconfiguration request	Reconfiguration actions available	Schedule dispatched
2	Invalid state during execution	An error occurs during execution of the switch reconfiguration sequence.	SDS	Grid reconfiguration request	Reconfiguration actions available	Alert to Operator

Scenario							
Scenario name:			Prepare reconfiguration actions				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Upon Request	Initiate grid reconfiguration	GOP provides SDS with network sensing data (voltage, current)	GOP	SDS	Grid Reconfiguration Request	
2	Upon Request	Calculate sequence	SDS calculates the sequence of reconfiguration actions.	SDS	SDS	-	

3	Upon calculation	Validate sequence	SDS communicates the sequence of reconfiguration actions to the Operator for validation.	SDS	Operator	Grid Reconfiguration Sequence	
4	Upon request	Switch command	Operator acknowledges the command sequence.	DS SCADA	SDS	Grid Reconfiguration Sequence Acknowledgement	
5	Upon validation	Communicate Critical Events	SDS marks the reconfiguration actions as valid for execution	SDS	SDS	-	
Scenario name:			Valid execution				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Time trigger or next command	Dispatch command	Upon time of execution of a plan, SDS sends the 1st command of the sequence to the DS SCADA	SDS	DS SCADA	Switchgear Command	
2	Upon dispatch	Get state (loop)	SDS polls the state of the switch from DS SCADA.	SDS	DS SCADA	Switchgear Status	
3	Valid state	Next command (loop to step 1)	If the state of the switch complies with the state of the sequence, the SDS sends the next command to the SCADA.	SDS	SDS	-	
Scenario name:			Invalid execution				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**

1	Time trigger or next command	Dispatch command	Upon time of execution of a plan, SDS sends the 1st command of the sequence to the DS SCADA.	SDS	DS SCADA	Switchgear Command	
2	Upon dispatch	Get state (loop)	SDS polls the state of the switch from DS SCADA.	SDS	DS SCADA	Switchgear Status	
3	Invalid state	Alert	If the state of the switch doesn't comply with the state of the sequence after three attempts, the SDS sends an alert to the Operator.	SDS	Operator	-	

6.1.2.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
GridRecReq	Grid Reconfiguration Request	Request containing a plan for control commands on switchgear (initial grid configuration, final grid configuration and time of execution)	
GridRecSeq	Grid Reconfiguration Sequence	A sequence of control actions on switchgear.	
SwCommand	Switchgear Command	The command for a switchgear.	
SwCommandAck	Grid Reconfiguration Sequence Acknowledgement	Acknowledgement of a switchgear command sequence.	
SwStatus	Switchgear Status	Status of switchgear equipment.	

6.1.2.10 Requirements

Requirements ID	Requirement name	Requirement description
SDS_REQ_I&C_01	SCADA Integration	Support for communication protocol of DS-SCADA.

6.1.3 PUC6 Ex-post network performance assessment

6.1.3.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Asset the effectiveness of remedial actions related to grid reconfiguration dispatch and the activation of the requested flexibility
Objective(s)	1) Collect data on operational status and remedial actions 2) Validate effectiveness of remedial actions
Related high-level use case(s)	HLUC 01: Advanced network congestion management considering DER & grid flexibility (seasonal, day-ahead, etc.)

	HLUC 02: Voltage compensation via reactive power procurement HLUC 04: Self-healing operation after critical event considering DER & grid flexibility HLUC 06: Leveraging DER flexibility towards enhancing network operational efficiency

6.1.3.2 Narrative of use case

Narrative of use case
Short description
The Ex-Post Assessment Application (EPAA) is responsible for assessing the effectiveness of remedial actions, related to grid reconfiguration and the activation of the flexibility, based on real data from the DS SCADA.
Complete description
The Ex-Post Assessment Application (EPAA) performs the evaluation of the network operational performance after the implementation of a mitigation plan, dictated by different applications of the DSO Toolbox, towards resolving network operational issues. Upon trigger, the EPAA retrieves real grid monitoring data from the DS SCADA system reflecting the current operational status of the distribution grid for a specific time period. This network operational snapshot is forwarded by the EPAA to power flow simulation application and power flow data are forwards to the relevant DSO Toolbox application in order to validate the proper implementation of the mitigation plan. The EPAA stores the result of the analysis as well as calculates and stores relevant performance metrics, utilizing data from the application that requested the mitigation actions.

6.1.3.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC06_1	Congestion management effectiveness	Average efficiency of congestion management actions.	2
KPI_PUC06_2	Voltage compensation effectiveness	Average efficiency of voltage compensation actions.	2
KPI_PUC06_3	Loss compensation effectiveness	Average efficiency of technical loss reduction actions.	2
KPI_PUC06_4	Self-healing effectiveness	Average efficiency of self-healing reduction actions.	2

6.1.3.4 Use case conditions

Use case conditions
Precondition(s)
Availability of data from DS SCADA

6.1.3.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC 01: Critical Event Prevention **PUC 07: Voltage compensation via reactive power control** **PUC13 Minimizing network technical losses**
Level of Depth
Detailed
Prioritization
High
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
grid reconfiguration

6.1.3.6 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Critical Event Forecaster (CEF)	Application	Application, in charge of predicting possible congestion or over-under voltage events in the succeeding H-time (forecasting horizon).	Will run a power flow and provide information on

			violation of grid constraints.
Ex-Post Assessment Application (EPAA)	Application	Application responsible for assessing the effectiveness of remedial actions, related to grid reconfiguration and the activation of the flexibility	The application under design.
Supervisory Control And Data Acquisition (DS SCADA)	System	A system in charge of overall monitoring and control of the distribution and transmission grid. It integrates communication, remote monitoring and control, signal processing and logic, and data storage functionalities. It includes a user interface called control center room.	Provides data for analysis
DSO Toolbox	System	A suite of gird-oriented tools complementing DSO's legacy systems enabling more advanced observability and management of the distribution grid.	

6.1.3.7 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Normal scenario	Normal scenario for calculating performance metric of a DSO Toolbox application via the use of DS SCADA data	EPAA	Periodic	Data availability	Metric Calculation

Scenario							
Scenario name:							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic	Get data	DS SCADA feeds EPAA with network sensing information	DS SCADA	EPAA	Network Sensing Data	
2	Periodic	Request analysis	EPAA sends data to CEF for executing a power flow analysis.	EPAA	CEF	Network Sensing Data	
3	Upon request	Send Analysis	CEF runs power flow analysis and responds to EPAA	CEF	EPAA	Power Flow Data	
4	Periodic	Send power flow analysis	EPAA provides power flow data to CEPA	EPAA	DSO Toolbox Application	Power Flow Data	
5	Upon receiving data	Calculate & save metrics	CEPA calculates performance metrics	DSO Toolbox Application	EPAA	Performance metrics	

6.1.3.8 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
Network Sensing Data	Network Sensing Data	Voltage and current, or power, sensing data from the SCADA.	
PfData	Power Flow Data	Voltages and currents in nodes and lines of the grid.	
PerMetric	Performance metrics	Metrics related to the performance of a DSO Toolbox operation application.	

6.1.4 PUC7 Voltage compensation via reactive power control

6.1.4.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Describes the process of identifying and mitigating voltage excursions within the distribution grid considering the voltage upper and lower thresholds dictated by Network Codes and international standards
Objective(s)	1) Identify potential violations of the voltage operational constraints using close-to-real time measurements 2) Propose mitigation actions leveraging grid reconfiguration and exploitation of DER flexibility. 3) Evaluate the mitigation actions
Related high-level use case(s)	HLUC 02: Voltage compensation via reactive power procurement

6.1.4.2 Narrative of use case

Narrative of use case
Short description
The Voltage Compensation (VC) is the process of identifying and mitigating voltage excursions within the distribution grid considering the voltage upper and lower thresholds dictated by Network Codes and international standards. A power flow analysis is performed based on close-to-real time voltage measurements provided by the DSO legacy systems, i.e. DS SCADA, as well as local measurement devices – Power Electronics Devices (PEDs) - installed by battery storage owners at DER level. In case a network operational issue is identified, a mitigation plan is extracted exploitation of reactive power control.

Complete description
The Voltage Compensation Application (VCA) offers monitoring of voltage excursions within the distribution grid considering the voltage upper and lower thresholds dictated by Network Codes and international standards, as well as the identification of mitigation actions in the close-to-real time horizon. **Violation Identification** Initially, the VC leverages on close-to-real time voltage measurements provided by the DSO legacy systems, i.e. DS SCADA, as well as from local measurement devices located at battery storage facilities aka the PEDs (see SUC 02: Grid Observability and Monitoring). **Proposal and Implementation of Mitigation Action** These voltage measurements are compared with the predefined voltage constraints by the Critical Event Forecaster (CEF) and in case that voltage excursions are identified, a mitigation plan is devised by the Grid Operation Planner (GOP), which leverages reactive power controllability of flexible assets (see SUC 04: Grid Operation Planning). Upon calculation of mitigation actions CEP, communicates the Flexibility Service Consuming Agent (FSCA) with the requested flexibility (see PUC 03: Requesting flexibility Services) which will handle the implementation of remedial actions. **Evaluate Mitigation Action** The effectiveness of the remedial actions is assessed periodically by the Ex-Post Assessment Application (EPAA) based on real data from the DS SCADA (see PUC 06: Ex-post network performance assessment). Based on the above EPAA provides VC with the outcome of a power flow analysis, hence can compare the network infrastructure loading with the thermal limits and calculate relevant performance metrics.

6.1.4.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC07_1	Responsiveness of close-to real time prevention	Expresses the time required for identifying the potential violation and proposing the mitigation actions.	1,2

6.1.4.4 Use case conditions

Use case conditions
Assumption(s)
• PED provides close to real-time grid measurement data to the DSO
Precondition(s)
• The sensor data provided are of adequate quality • CEF has available information for voltage network limits

• The Grid Asset Information & Topology are available to CEF and GOP

6.1.4.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
SUC 02: Grid Observability and Monitoring **SUC 03: Critical Event Forecasting** **SUC 04: Grid Operation Planning** **PUC 03: Requesting flexibility Services** **PUC 06: Ex-post network performance assessment**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
grid congestion, thermal limit violation, flexibility, grid reconfiguration, grid operational planning

6.1.4.6 Use case diagram

Diagram(s) of use case

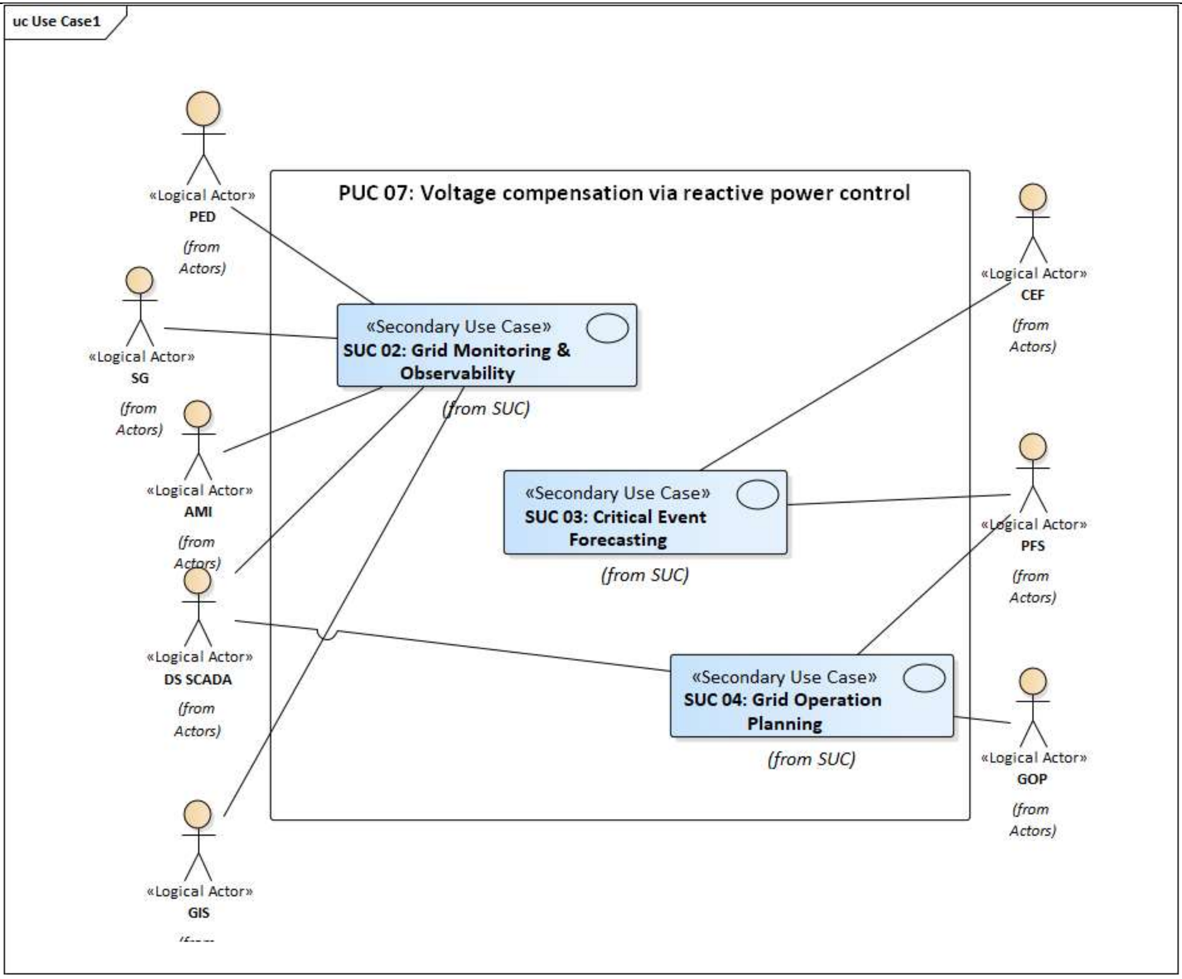


Figure 11 PUC7 UC Diagram

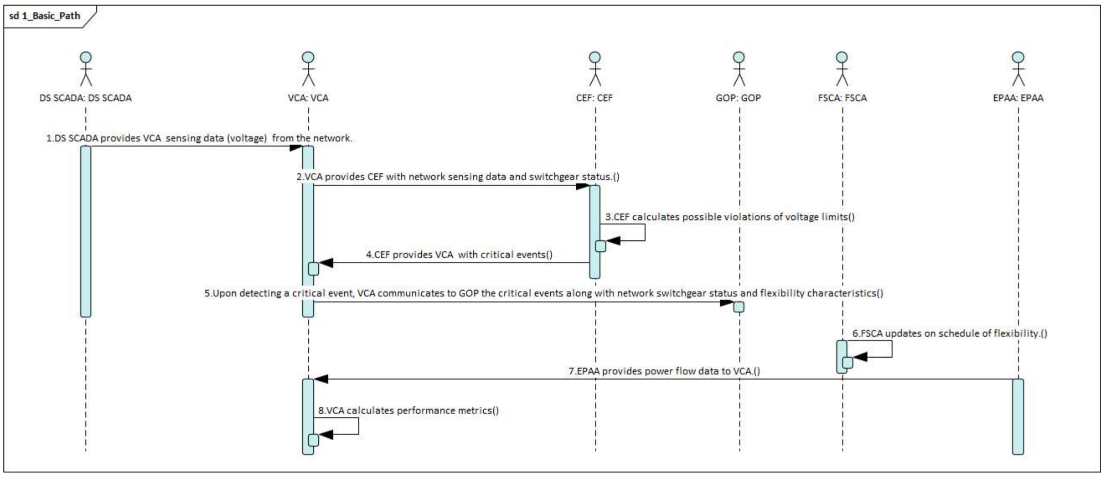


Figure 12 PUC7 Sequence Diagram

6.1.4.7 Actors

Actors

Actor name	Actor type	Actor description	Further information
Critical Event Forecaster (CEF)	Application	Application, in charge of predicting possible congestion or over-under voltage events in the succeeding H-time (forecasting horizon).	Provides predictions of events. Developed in the project.
Geographic Information System (GIS)	System	System that manages all the static information related to the grid assets and location.	Provides grid asset information, including operational limits.
Grid Operation Planner (GOP)	Application	Service in charge of planning the grid operation satisfying a predefined objective function that depends on the specific scenario. It determines the need of reconfiguration or flexibility. It is included in the DSO Toolbox.	Provides mitigation actions. Developed in the project.
Ex-Post Assessment Application (EPAA)	Application	Application for assessing the effectiveness of the remedial actions.	Will provide the ex-post analysis. Developed in the project.
Flexibility Service Consuming Agent (FSCA)	Application	The agent responsible for packing the flexibility needs of an actor into flexibility bid/request in respect to the requirements imposed by the flexibility markets or the bilateral agreements.	Will communicate flexibility request. Developed in the project.
Power Electronics Device (PED)	Device	It is a power electronic device used to exchange power with batteries/EVs, and also PV system, which is also able to communicate with the SCADA/IPMA/PQS, measure grid and islanding status, and also can be commanded by SCADA/IPMA/PQS.	Provides grid measurement data
Supervisory Control And Data Acquisition (DS SCADA)	System	A system in charge of overall monitoring and control of the distribution and transmission grid. It integrates communication, remote monitoring and control, signal processing and logic, and data storage functionalities. It includes a user interface called control center room.	Provides sensing data for the distribution grid. Enables switchgear schedule dispatch.
Voltage Compensation Application (VCA)	Application	Application responsible for monitoring and mitigating voltage excursions via reactive power procurement. It is included in the DSO Toolbox.	Application under design.

6.1.4.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Close to real-time voltage compensation	Describes a valid scenario for identifying, mitigating and assessing voltage problems	VC	Periodic Process	Available data for analysis from DS SCADA, PED	Events Identified, Mitigation actions communicated, Performance metrics calculated

Scenario							
Scenario name:			Close to real-time Identification				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic Process	Get network sensing data	DS SCADA provides VCA sensing data (voltage) from the network.	DS SCADA	VCA	Network Sensing Data, PED Sensing Data	
2	Periodic Process	Request critical event forecast for short-term horizon	VCA provides CEF with network sensing data and switchgear status.	VCA	CEF	Network Sensing Data, Switchgear Status	
3	Upon request	Calculate critical events	CEF calculates possible violations of voltage limits	CEF	CEF	-	VCA_REQ_PER_01
4	Upon Calculation	Communicate Critical Events	CEF provides VCA with critical events	CEF	VCA	Critical Events	

5	Upon event detection	Request mitigation actions	Upon detecting a critical event, VCA communicates to GOP the critical events along with network switchgear status and flexibility characteristics	VCA	GOP	Critical Events, Network Switchgear Status, Flexibility Characteristics	
6	Upon request	Calculate mitigation actions	GOP calculates mitigation actions	GOP	GOP	-	
7	Upon calculation	Communicate mitigation action	GOP provides mitigation actions to VCA	GOP	VCA	Flexibility Needs	
8	Upon receiving mitigation action	Send flexibility request	VCA provides flexibility request FSCA	VCA	FSCA	Flexibility Needs	
9	Upon traded flexibility	Send flexibility schedule	FSCA updates on schedule of flexibility	FSCA	VCA	Flexibility Schedule	
10	Upon calculation	Send ex-post analysis	EPAA provides power flow data to VCA	EPAA	VCA	Power Flow Data	
11	Upon receiving ex-post analysis	Calculates metrics	VCA calculates performance metrics	VCA	VCA	Critical Event Prevention performance metrics	

6.1.4.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
CrEPMetric	Critical event prevention performance metrics	Metrics related to the performance of the operation of the critical event prevention.	
CrEvent	Critical Events	Information related to possible violation of thermal limits of grid infrastructure and voltage excursions from regulated boundaries.	
FlexNeed	Flexibility Needs	Required flexibility with spatial as well as temporal characteristics	
FlexChar	Flexibility Characteristics	Characteristic of available flexible assets.	
FlexSched	Flexibility Schedule	A concrete planned realization of a flexibility needs.	
NetworkData	Network Sensing Data	Sensing data from the SCADA: Voltage and current, or power.	
PedData	PED Sensing Data	Sensing data from the PED: Power, Voltage, and Current.	
DerData	DER sensing data	DER Sensing data: Power, Voltage, and Current.	
PfData	Power Flow Data	Voltages and currents in nodes and lines of the grid.	
SwStatus	Switchgear Status	Status of switchgear equipment.	
GridInfoTplg	Grid Asset Information & Topology	Technical characteristic of grid assets (e.g. nominal power) as well as their connectivity (grid topology).	VCA_REQ_INR_01

6.1.4.10 Requirements

Requirements ID	Requirement name	Requirement description
VCA_REQ_INR_01	Grid information modelling standard	The grid asset information shall comply with the CGMES provide of CIM standard series.
VCA_REQ_PER_01	Max duration of event forecast process	The process of critical event forecast process should not exceed a maximum threshold of 1 minute.

6.1.5 PUC8 Grid monitoring and islanding detection

6.1.5.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Describes the process of detecting an uncontrolled island that has not been detected and de-energized by passive anti-islanding methods due to non-detection zones (NDZ). This is done in LV networks with integrated DER and PED assets.
Objective(s)	1) Detect uncontrolled islands in close to real-time
Related high-level use case(s)	HLUC 03 - Leveraging the flexibility of the storage assets for real time detection of uncontrolled islanding

6.1.5.2 Narrative of use case

Narrative of use case
Short description
When an island is created unintentionally without the possibility to operate it and the passive anti-islanding protections of DER inverters do not detect and de-energize the island due to their non-detection zone (NDZ), an uncontrolled islanding situation occurs. To avoid this risky situation, it is necessary to monitor the grid continuously and detect if there is a mismatch between the supposed grid configuration and the presence of voltage/island and to mitigate the situation rapidly.
Complete description
The Grid Monitoring and Islanding Detection process detects uncontrolled islanding situations. This comprises a situation in which part of the grid is islanded unintentionally without the possibility to operate it and the passive anti-islanding protections of DER inverters do not detect and de-energize the island due to their non-detection zone (NDZ). A NDZ is a zone, where due to a balance between generation and demand, the anti-islanding protection of DERs do not activate and the grid continues to be powered in an uncontrolled and undesired way. The risks associated with uncontrolled islands are:

- Voltage issues that can damage clients' electrical equipment
- Human safety risks, for electrical workers, due to unawareness of voltage presence

The Island Power Management Application (IPMA) is an application that runs in the DSO toolbox and has two principal functionalities of uncontrolled island detection (PUC08) and to de-energize detected islands (PUC09).

The process leverages the data provided by the DS SCADA, the system responsible to collect information about the grid status (see SUC02 Grid observability and monitoring); able to communicate DERs and PEDs, as well as commands the grid assets and the PEDs. The timeframe of the process is close-to real-time.

Finally, the grid monitoring and islanding detection process is executed through the following steps:

1. The DS SCADA is continuously (close to real time) monitoring the grid, DER and PED status. (SUC02)
2. The IPMA gets the monitored information from DS SCADA and detects periodically an uncontrolled and uncontrolled island (due to NDZ) via a set of different algorithms which include graph theory, state estimation, etc.
3. If the IPMA detects an uncontrolled and uncontrolled island, the process "Mitigating uncontrolled islanding" (PUC09) is triggered and the information about the existence of an uncontrolled island is shared with other systems of the DSO (e.g. DS SCADA).

6.1.5.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC08_1	Island´s detected	Expresses the percentage of successful island detections.	1

6.1.5.4 Use case conditions

Use case conditions
Assumption(s)
• DS SCADA has the data related to the grid configuration and status. • DS SCADA can receive/relay close to real-time measurements of DERs and PEDs. • Power electronic devices (PEDs) measures voltage/frequency status. It can communicate this status to DS SCADA. • The DER has a passive anti-islanding protection. It can communicate its status to DS SCADA.
Precondition(s)
• All devices/applications are online and working. • Normal operation of grid. • The Grid Asset Information & Topology are available

6.1.5.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC09 Mitigating uncontrolled islanding **SUC02 Grid observability and monitoring**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Grid monitoring, island, island detection,

6.1.5.6 Use case diagram

Diagram(s) of use case

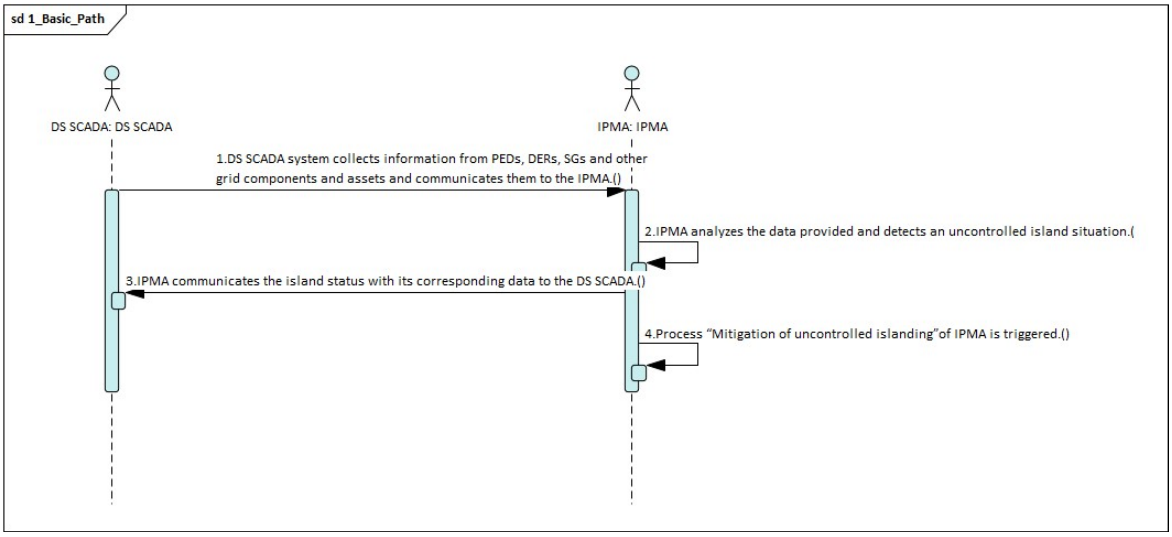


Figure 13 PUC8 Sequence Diagram

6.1.5.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Power Electronic Device (PED)	Device	It is a power electronic device used to exchange power with batteries/EVs, and also PV systems, which is also able to communicate with the DS SCADA, measure grid and islanding status, and also can be command by DS SCADA.	
Island Power Management Application (IPMA)	Application	It is an application located in the DSO toolbox which is responsible of detecting islands and to define a mitigation strategy in case of an uncontrolled island situation. In addition, it is able to communicate with the DS SCADA system.	
Grid Monitoring and Islanding Detection process	Application	It is a process of the IPMA that monitors the grid data and detects uncontrolled island situations.	
Supervisory Control and Data Acquisition system (DS SCADA)	System	It is a supervisory control and data acquisition system which is responsible to manage the distribution grid. In addition, is able to communicate/command with the IPMA and PEDs.	

6.1.5.8 References

References						
No.	**Type**	**Reference**	**Status**	**Impact**	**Originator / Organization**	**URL**
1	Report	D.1.3 Interoperability and integration analysis and requirements	Online	High	RESOLVD	https://resolvd.eu/wp-content/uploads/2019/03/D1.3_FV-rev1.pdf

6.1.5.9 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Close to real-time detection of uncontrolled island	Describes the process for detecting an uncontrolled island in the close to real-time time horizon	IPMA	Periodic process	Available data for analysis from DS SCADA	Island detected/not detected. Process "Mitigating uncontrolled islanding" (PUC09) triggered.

Scenario							
Scenario name:			Close to real-time detection of uncontrolled island				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic Process	Grid status communication	DS SCADA system collects information from PEDs, DERs, SGs and other grid components and assets and communicates them to the IPMA.	DS SCADA	IPMA	Network Sensing Data, Switchgear Status, PED sensing data, DER sensing data	IPMA_REQ_DQ_01
2	Upon Grid status communication	Uncontrolled island detection	IPMA analyzes the data provided by DS SCADA and detects an uncontrolled island situation.	IPMA	IPMA	-	IPMA_REQ_ PER _01

3	Upon uncontrolled island detected	Island status communication	IPMA communicates the island status with its corresponding data to the DS SCADA.	IPMA	DS SCADA	Uncontrolled island data	
4	Upon uncontrolled island detected	Request of island mitigation process	Process “Mitigation of uncontrolled islanding” (PUC09) is triggered.	IPMA	IPMA (Mitigation of uncontrolled islanding)	Network Sensing Data, Switchgear Status, PED sensing data, DER sensing data, Uncontrolled island data	

6.1.5.10 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
NetworkData	Network Sensing Data	Sensing data from the SCADA • Transformer: Power, Voltage, Current, Frequency • Grid monitoring devices: Power, Voltage, Current, Frequency	IPMA_REQ_DQ_01
SwStatus	Switchgear Status	Switchgear status of equipment in the affected area	IPMA_REQ_DQ_01
PedData	PED sensing data	Sensing data from the PED: Power, Voltage, Current, Frequency, Status of island detection from PED in the affected area	IPMA_REQ_DQ_01
DerData	DER sensing data	DER Sensing data: Power, Voltage, Current, Frequency, Status of island detection from DERs in the affected area	IPMA_REQ_DQ_01
UnIslandData	Uncontrolled island data	Island detected: Grid zone, Available grid assets in grid zone	IPMA_REQ_ PER _01
GridInfoTplg	Grid Asset Information & Topology	Technical characteristic of grid assets (e.g. nominal power) as well as their connectivity (grid topology).	IPMA_REQ_INR_01

6.1.5.11 Requirements

Requirements ID	Requirement name	Requirement description
IPMA_REQ_PER_01	Island detection performance	The island detection process is carried out in close-to real time.
IPMA_REQ_INR_01	Grid information modelling standard	The grid asset information shall comply with the CGMES provide of CIM standard series.
IPMA _REQ_DQ_01	Data quality, resolution and granularity	Power quality improvement relies on the analysis of accurate data and status of different assets.

6.1.6 PUC9 Mitigating uncontrolled islanding

6.1.6.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Describes the process of mitigating and de-energizing an uncontrolled island that has not been detected and de-energized by passive anti-islanding methods due to their non-detection zone (NDZ). This is done in LV networks with integrated DER and PED assets.
Objective(s)	1) De-energize uncontrolled islands in close to real-time
Related high-level use case(s)	HLUC 03 - Leveraging the flexibility of the storage assets for real time detection of uncontrolled islanding

6.1.6.2 Narrative of use case

Narrative of use case
Short description
The Mitigating Uncontrolled Islanding process de-energizes uncontrolled islands that have been detected by the Island Power Management Application (see PUC08). A mitigation strategy is devised considering grid reconfiguration and the exploitation of PED flexibility (active and reactive power) in the problematic area.
Complete description
The Island Power Management Application (IPMA) incorporates the Mitigating Uncontrolled Islanding process, which aims to de-energize the uncontrolled island with a close-to real-time timeframe. The IPMA, upon detection of an uncontrolled island (PUC08), devised a mitigation strategy and communicates appropriate control commands or flexibility dispatch signals to manage the distribution grid assets (switchgear, PEDs). The process is executed through the following steps: 1. Upon detection of uncontrolled island event, by the Grid Monitoring and Island Detection process (PUC08), the IPMA defines a mitigation strategy using decision tree algorithms. The mitigation strategy considers grid reconfiguration and the exploitation of PED flexibility (active and reactive power) in the problematic area. The grid reconfiguration entails scheduling of the switchgear operational status. 2. The IPMA communicates the mitigation strategy of grid reconfiguration (see PUC02) to Switchgear Dispatch Scheduler (SDS) and the flexibility to be activated to the Flexibility Service Consuming Agent (FSCA) or DS SCADA. 3. The FSCA communicates the flexibility signal to the Flexibility Service Providing Agent (FSPA) for activation of the PED flexibility if FSCA and FSPA participate. 4. IPMA is notified on the scheduled flexibility via FSCA (opt. DS SCADA). 5. Upon time, SDS performs the necessary actions for dispatching the new grid configuration. 6. Set points of PEDs are communicated as part of the mitigation strategy to PEDs via DS SCADA or FSPA.

6.1.6.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC09_01	Responsiveness of close-to real time mitigation	Expresses the time required for de-energizing the uncontrolled island after the mitigation request.	1
KPI_PUC09_02	Islands mitigated	Expresses the percentage of successfully mitigated uncontrolled islanding situation problems.	1

6.1.6.4 Use case conditions

Use case conditions
Assumption(s)

• DS SCADA has the data related to the grid configuration and status.
• Power electronic devices (PEDs) are able to:
    ○ measure voltage/frequency status
    ○ communicate with the SCADA or with FSCA/FSPA.
    ○ receive commands to adapt their exchanged power to a specific schedule
• Bilateral contracts between the DSO and the PED/DER owners
• IPMA is aware of all relevant information on availability of assets

Precondition(s)
• All devices/applications are online and working. • Islanding situation detected from IPMA process (PUC08).

6.1.6.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC02 Grid Reconfiguration Schedule Dispatching **PUC08 Grid Monitoring and Islanding Detection** **SUC02 Grid observability and monitoring**
Level of Depth
Detailed

Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Grid monitoring, uncontrolled island, island detection,

6.1.6.6 General Remarks

General Remarks
Bilateral contracts between the DSO and the PED/DER owners are considered mandatory for the realization of this use case. Such bilateral agreements concern the provision of monitoring and control capabilities from the PED/DER directly to the DSO for the time frame required to response in such emergency situations.

6.1.6.7 Use case diagram

Diagram(s) of use case

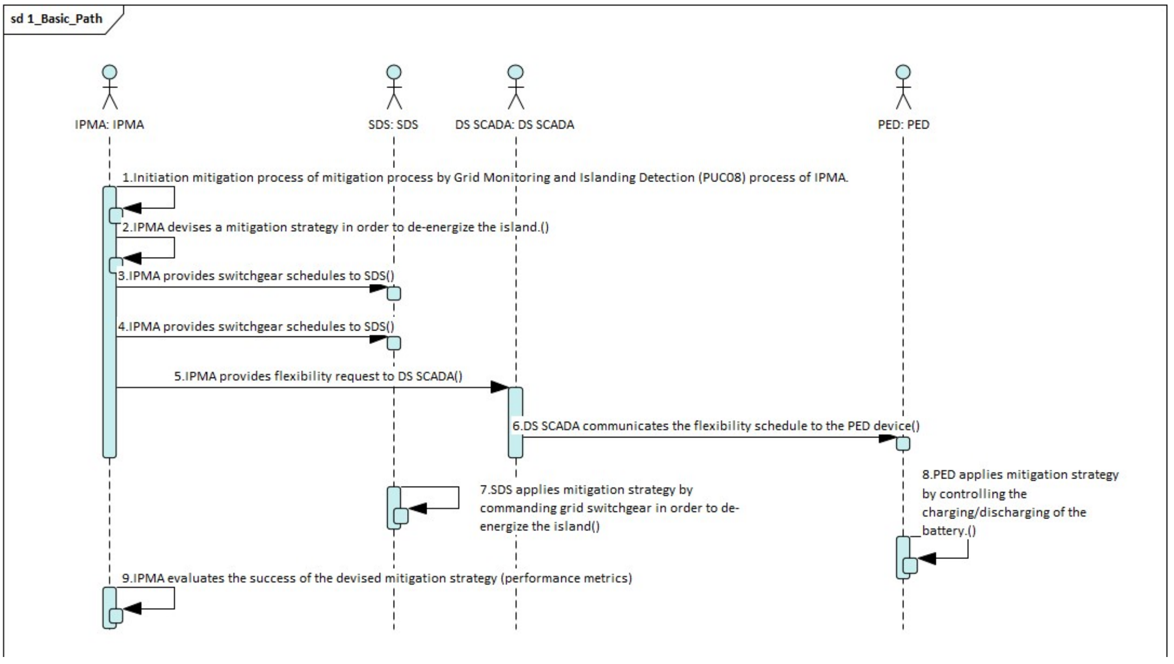


Figure 14 PUC9 Sequence Diagram – Scenario 1

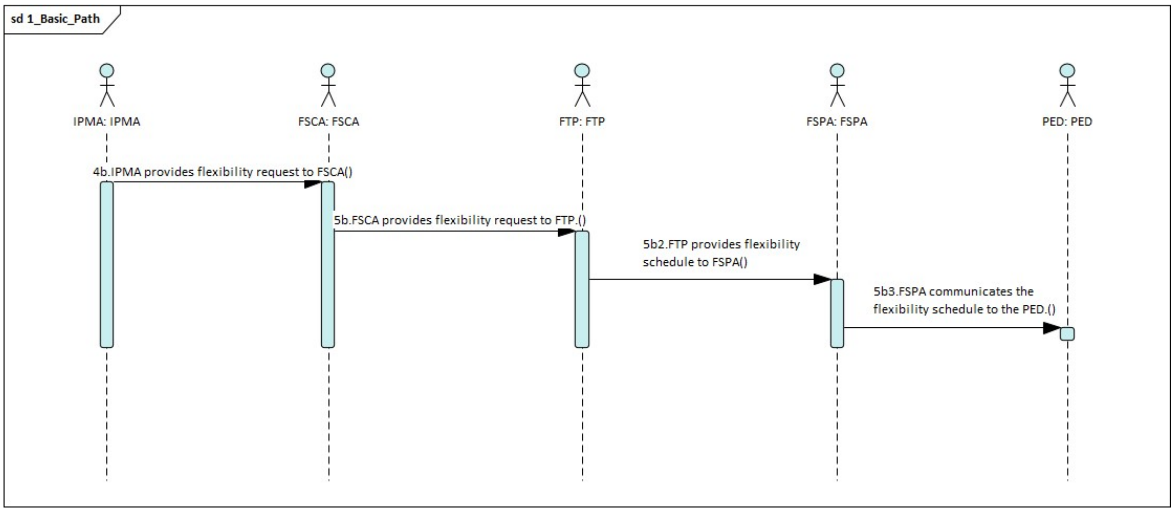


Figure 15 PUC9 Sequence Diagram – Scenario 2

6.1.6.8 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Power Electronic Device (PED)	Device	It is a power electronic device used to exchange power with batteries/EVs, and also PV systems, which is also able to communicate with the DS SCADA, measure grid and islanding status, and also can be command by DS SCADA.	Offers controllability of battery as a flexible asset.
Island Power Management Application (IPMA)	Application	It is an application located in the DSO toolbox which is responsible of detecting islands and to define a mitigation strategy in case of an uncontrolled island situation. In addition, it is able to communicate with the DS SCADA system. Is composed by • Grid Monitoring and Islanding Detection process: monitors the grid data and detects uncontrolled island situations. Is composed by • Mitigating Uncontrolled Islanding process: calculates and dispatches actions for de-energising uncontrolled island situations.	Creates and orchestrates a mitigation strategy for an uncontrolled islanding situation

Supervisory Control and Data Acquisition system (SCADA)	System	It is a supervisory control and data acquisition system which is responsible to manage the distribution grid. In addition, is able to communicate/command with the IPMA and PEDs.	Offer monitoring and controllability of grid assets
Flexibility Service Consuming Agent (FSCA)	Application	The agent responsible for packing the flexibility needs of an actor into flexibility bid/request in respect to the requirements imposed by the flexibility markets or the bilateral agreements.	Will communicate flexibility request.
Flexibility Service Providing Agent (FSPA)	Application	The agent responsible for transforming the available flexibility of an actor to a bidding strategy in respect to the requirements imposed by the flexibility markets or the bilateral agreements	Will receive flexibility request and translate it to a schedule for the PED.
Switchgear Dispatch Scheduler (SDS)	Application	Application responsible for dispatching the grid reconfiguration schedule extracted by other applications of the DSO Toolbox.	Will receive and execute a grid reconfiguration request
Switchgear (SG)	SG	Actuators of the LV grid that permit to switch lines and change grid configuration.	

6.1.6.9 References

References						
No.	**Type**	**Reference**	**Status**	**Impact**	**Originator / Organization**	**URL**
1	Deliverable	D.1.3 Interoperability and integration analysis and requirements.	Online	High	RESOLVD	https://resolvd.eu/wp-content/uploads/2019/03/D1.3_FV-rev1.pdf

6.1.6.10 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	De-energizing of uncontrolled island (direct controllability of assets)	Describes the process for de-energizing an uncontrolled island via a mitigation strategy utilizing direct controllable of assets.	IPMA	Detection of an uncontrolled island by the IPMA.	Available data for analysis from DS SCADA	• Mitigation actions communicated, • Performance metrics calculated (Island de-energized), • Emergency and alert situations mitigated.
2	De-energizing of uncontrolled island (indirect controllability of assets)	Describes the process for de-energizing an uncontrolled island via a mitigation strategy utilizing indirect controllable of assets.	IPMA	Detection of an uncontrolled island by the IPMA.	Available data for analysis from DS SCADA	• Mitigation actions communicated, • Performance metrics calculated (Island de-energized), • Emergency and alert situations mitigated.

Scenario							
Scenario name:			**De-energizing of uncontrolled island (direct controllability of assets**				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements , R-ID**
1	Upon Request	Initiate mitigation process	Initiation mitigation process of mitigation process by Grid Monitoring and	IPMA (Grid Monitoring and Islanding Detection)	IPMA (Mitigating Uncontrolled Islanding)	• Network Sensing Data	IPMA_REQ_DQ_01

			Islanding Detection (PUC08) process of IPMA.			• Switchgear Status • PED sensing data • DER sensing data • Uncontrolled island data	
2	Upon Request	Mitigation strategy formulatio n	IPMA devises a mitigation strategy in order to de-energize the island.	IPMA	IPMA	-	
3	Upon mitigation strategy formulation	Send switchgear schedule	IPMA provides switchgear schedules to SDS	IPMA	SDS	Switchgear Schedules	
4	Upon mitigation strategy formulation	Communic ate asset schedule	IPMA provides flexibility request to DS SCADA	IPMA	DS SCADA	Flexibility Needs	
5	After step 4 – If FSCA and FSPA present	Communic ate asset schedule	DS SCADA communicates the flexibility schedule to the PED device	DS SCADA	PED	PED Schedule	
6	Upon time of activation	Switchgea r activation	SDS applies mitigation strategy by commanding grid switchgear in order to de-energize the island.	SDS	DS SCADA	Switchgear Schedules	
7	Upon time of activation	PED activation	PED applies mitigation strategy by controlling the	PED	PED	-	

			charging/discharging of the battery.				
8	Upon Request	Evaluation of mitigation strategy	IPMA evaluates the success of the devised mitigation strategy (performance metrics)	IPMA (Mitigating Uncontrolled Islanding process)	IPMA (Mitigating Uncontrolled Islanding process)	Uncontrolled island data, Islanding Mngmt Performance metrics	

Scenario							
Scenario name:			**De-energizing of uncontrolled island (Indirect controllability of assets**				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
4b	Upon mitigation strategy formulation	Send flexibility request	IPMA provides flexibility request to FSCA	IPMA	FSCA	Flexibility Needs	
5b	After step 4b – If FSCA and FSPA present	Communicate flexibility request	FSCA provides flexibility request to FTP for controlling the PED.	FSCA	FTP	Flexibility Needs	
5b2	After step 5b	Communicate flexibility offer	FTP provides flexibility schedule for controlling the PED to FSPA.	FTP	FSPA	Flexibility Schedule	
5b2	After step 5b3	Communicate schedule	FSPA communicates the flexibility schedule to the PED.	FSPA	PED	Charging/Discharging Schedule	

6.1.6.11 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
NetworkData	Network Sensing Data	Sensing data from the SCADA • Transformer: Power, Voltage, Current, Frequency • Grid monitoring devices: Power, Voltage, Current, Frequency	IPMA_REQ_DQ_01
SwStatus	Switchgear Status	Switchgear status of equipment in the affected area	IPMA_REQ_DQ_01
PedData	PED sensing data	Sensing data from the PED: Power, Voltage, Current, Frequency, Status of island detection from PED in the affected area	IPMA_REQ_DQ_01
DerData	DER sensing data	DER Sensing data: Power, Voltage, Current, Frequency, Status of island detection from DERs in the affected area	IPMA_REQ_DQ_01
UnIslandData	Uncontrolled island data	Island detected: Grid zone, Available grid assets in grid zone	
SwSchedule	Switchgear schedules	Required Switchgear reconfiguration	
FlexNeed	Flexibility Needs	Required flexibility with spatial as well as temporal characteristics	
FlexSchedule	Flexibility Schedule	A concrete planned realization of a FlexOffer/flexibility offer	
IpmaMetrics	Islanding Mngmt Performance metrics	Performance metrics about the island mitigation process	
PedSchedule	PED Schedule	Schedule with operational setpoints (e.g. charging/discharging the battery) of the PED.	

6.1.7 PUC10 Grid monitoring and power quality assessment

6.1.7.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	The scope of this use case is to describe the operation of detecting power quality issues in the distribution network, in respect to the network quality standards dictated by the Network Code and trigger a mitigation action for exploiting distributed PED/DER assets to resolve them.
Objective(s)	1) Monitor distribution grid field and group the power quality data 2) Determine the power quality status 3) Request the optimal scheduling for power quality operation
Related high-level use case(s)	HLUC 07: Improving power quality and reducing losses through power electronics

6.1.7.2 Narrative of use case

Narrative of use case
Short description
The Power Quality Service (PQS) analyses the network power quality issues and extends the monitoring capabilities of the DSO's conventional DS SCADA. Monitoring data from the DERs and PEDs are processed in close to real-time by the PQS. The PQS compares the monitored values with the power quality standards dictated by the Network Codes and international standards in order to identify potential power quality issues. Upon detecting a problem, mitigation plan leveraging power quality operation of the PEDs is requested.
Complete description
The grid monitoring and power quality assessment process of the Power Quality Service (PQS) offers an analysis of the network power quality issues, acting as an extension of the monitoring capabilities offered by DSO's conventional DS SCADA and enabling the close to real-time monitoring of grid status at prosumer or grid zonal level. Leveraging the monitoring data of the grid assets and real time power quality monitoring data of controllable DER assets -provided by the PEDs - the PQS assesses the compliance of the status of the network in relation to the power quality standards dictated by the Network Codes and international standards in order to identify potential power quality issues. This process is executed via a continuous operation (near to real time) and the steps are the following: 1) DS SCADA is continuously (near real time) monitoring the grid, DER and PED status (see the SUC 02: Grid Observability and Monitoring). 2) The PQS analyses the measurements data collected by the DS SCADA and combines with the topological configuration of the grid and provides a feedback about the grid status. 3) If the parameters of the grid status violate defined thresholds, an optimal scheduling for power quality operation of the PEDs is requested (see. PUC 11: Mitigating network power quality issues is triggered) The PQS is based on a three-phase power flow and harmonic analysis of the grid and a deterministic optimization algorithm for finding the set points of PEDs.

6.1.7.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC10_1	Power Quality Indicator	Expresses the percentage of successful detection of power quality requirement violations.	1,2,3

6.1.7.4 Use case conditions

Use case conditions
Assumption(s)
• DS SCADA has the data related to the grid configuration and status. • DS SCADA has close to real-time measurements of DERs and PEDs. • PQS can get the data related to the grid configuration and close to real-time measurement of DERs and PEDs from the DS SCADA • PQS has access to the technical characteristics of the grid assets • PQS can be parameterized with the operational limits – thresholds • Some contractual agreement among the DSO and the PED owners exist, enabling leveraging the assets for monitoring and power quality control purposes.
Precondition(s)
• DS SCADA and PQS are online and working properly. • Normal operation of grid • Power Quality Requirements (thresholds) have been defined by DSO • Grid Asset Information & Topology is available from the GIS

6.1.7.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
SUC 02: Grid Observability and Monitoring PUC 11: Mitigating network power quality issues
Level of Depth
Detailed
Prioritization

Optional
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Grid monitoring, Power quality assessment, Power quality issues

6.1.7.6 Use case diagram

Diagram(s) of use case

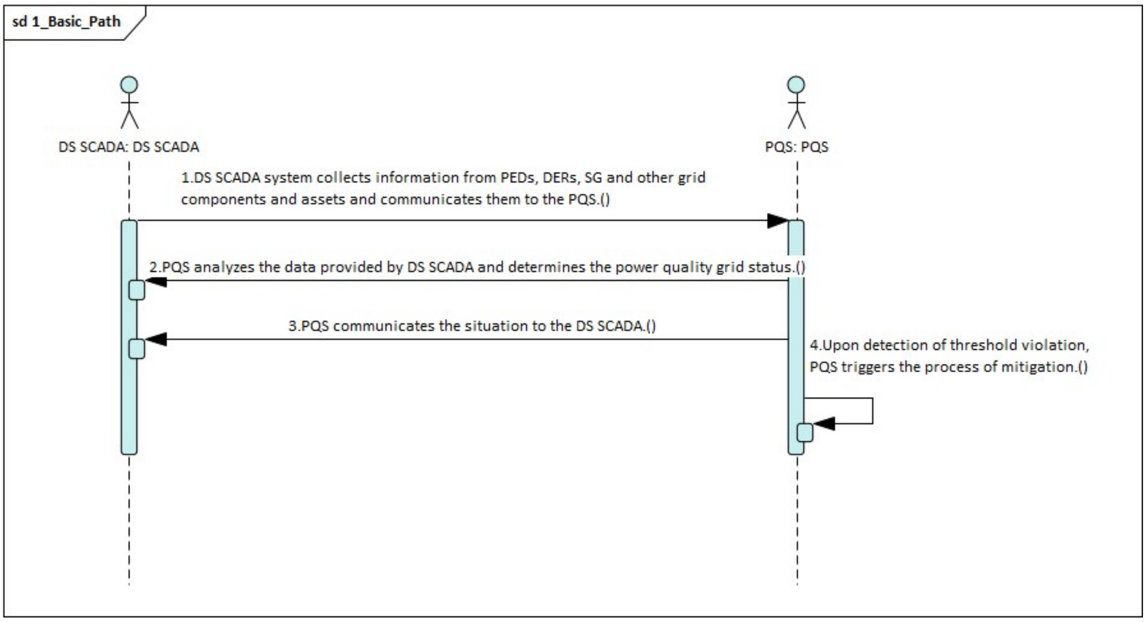


Figure 16 PUC10 Sequence Diagram

6.1.7.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Supervisory Control And Data	System	A system in charge of overall monitoring and control of the distribution and transmission grid. It integrates communication, remote	Provides Network Sensing Data, Switchgear

Acquisition (DS SCADA)		monitoring and control, signal processing and logic, and data storage functionalities. It includes a user interface called control center room.	Status, PED sensing data, DER sensing data.
Power Quality Service (PQS)	Application	Application that determine the power quality status and calculates setpoints for devices to mitigate power quality issues. It is included in the DSO Toolbox	Provides the power quality status of the grid and triggers the optimal scheduling for power quality operation request

6.1.7.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Close to real-time power quality assessment	Describes the process for determining the power quality status in the close to real-time horizon	PQS	Periodic Process	Available data for analysis from DS SCADA	Power quality status and the optimal scheduling for power quality operation request

Scenario							
Scenario name:							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic Process	Grid status communication	DS SCADA system collects information from PEDs, DERs, SG and other grid components and assets and communicates them to the PQS.	DS SCADA	PQS	Network Sensing Data, Switchgear Status, PED sensing data, DER sensing data	PQS_REQ_DQ_01 PQS_REQ_INR_01
2	Upon grid status communication	Power quality assessment	PQS analyzes the data provided by DS SCADA and determines the power quality grid status.	PQS	PQS	-	
3	Upon power quality assessment	Power quality status communication	PQS communicates the situation to the DS SCADA.	PQS	DS SCADA	Power quality status	

4	Upon a negative power quality assessment (violation of thresholds of power quality)	Optimal scheduling for power quality operation request	Upon detection of threshold violation, PQS triggers the process of mitigation.	PQS	PQS	Optimal scheduling for power quality operation request	

6.1.7.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
NetworkData	Network Sensing Data	Sensing data from the SCADA • Transformer: Power, Voltage, Current, Frequency • Grid monitoring devices: Power, Voltage, Current, Frequency • Power quality analyzer: THDs, Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30	PQS_REQ_DQ_01
SwStatus	Switchgear Status	Switchgear status of equipment in the area	PQS_REQ_DQ_01
PedData	PED sensing data	Sensing data from the PED: Power, Voltage, Current, Frequency	PQS_REQ_DQ_01
DerData	DER sensing data	DER Sensing data: Power, Voltage, Current, Frequency	PQS_REQ_DQ_01
GridInfoTplg	Grid Asset Information & Topology	Technical characteristic of grid assets (e.g. nominal power) as well as their connectivity (grid topology).	PQS_REQ_DQ_01
PwQlStatus	Power quality status	Monitoring Power Quality data with regards to standards (e.g. EN 50160, IEC 61000-4-30).	
PwQlMonitReq	Optimal scheduling for power quality operation request	Request for activation of power quality mitigation action, including, collected information during analysis and the area/zone.	

6.1.7.10 Requirements

Requirements ID	Requirement name	Requirement description
PQS_REQ_DQ_01	Data quality, resolution and granularity	Power quality improvement relies on the analysis of accurate data and status of different assets.
PQS_REQ_INR _01	Grid information modelling standard	The grid asset information shall comply with the CGMES provide of CIM standard series.

6.1.8 PUC11 Mitigating network power quality issues

6.1.8.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	The scope of this use case is to improve the power quality and, consequently, to reduce the technical losses of the distribution network in respect to the network quality standards dictated by the Network Codes. This will be achieved by exploiting distributed PED/DER assets for monitoring and compensating harmonics and phase asymmetries.
Objective(s)	1) Propose the optimal scheduling for power quality operation 2) Improve power quality leading to reduced losses
Related high-level use case(s)	HLUC 07: Improving power quality and reducing losses through power electronics

6.1.8.2 Narrative of use case

Narrative of use case
Short description
The Mitigating network power quality process proposes a power quality strategy using the PEDs of the area/zone for a general objective (e.g. reducing losses, reducing congestions, etc.) defined by the DSO. The PQS is based on a three-phase power flow and harmonic analysis of the grid and a deterministic optimization algorithm for finding the set-points of PEDs in order to improve power quality. The PQS is based on power quality standards dictated by the Network Codes and international standards in order to propose a power quality strategy.
Complete description
This UC permits the mitigation the power quality issues and it is an extension of the control capabilities offered by DSO’s conventional DS SCADA enabling the close real-time controlling of grid assets at prosumer or grid zonal level. The process for mitigating network quality issues is triggered by the PQS (PUC 10: Grid Monitoring and Power Quality Assessment) in order to ensure the power quality of the network operation after the power quality assessment phase. Upon being triggered, the PQS calculates the operational set-points of the PEDs based on a three-phase power flow (exploiting PFS) and harmonic analysis of the grid and a deterministic optimization algorithm taking into account the technical specifications/restrictions of the PED/DER assets. Operational power quality set-points defined by the PQS are communicated via the DS SCADA to the PEDs which are responsible of executing the ordered operational set-points. This UC is executed via a triggered operation and the steps are the following: 1) PUC10 requests the power quality operation of the PEDs. PQS calculates the setpoints based on a three-phase power flow and harmonic analysis of the grid and a deterministic optimization algorithm taking into account the PED restrictions. 2) DS SCADA receives the power quality setpoints from the PQS. Finally, the DS SCADA communicates the power quality setpoints to PEDs (SUC 04: Grid Operation Planning).

The actors and their responsibilities are:

- The PQS is the main actor of this UC. It is an application of the DSO Toolbox. It has two principal functionalities to determine the power quality status (PUC 10) and proposes a power quality strategy using the PEDs of the area/zone for a general objective (e.g. reducing losses, reducing congestions, etc.) defined by the DSO (PUC 11).
- The DS SCADA is the responsible to manage the distribution grid assets, and it can be able to communicate with PQS, DERs and PEDs (SUC 04).

6.1.8.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC11_01	Improvement of power quality	Expresses the reduction of losses due to reduction of harmonics and reduction of imbalances in presence of lack of power quality.	1,2

6.1.8.4 Use case conditions

Use case conditions
Assumption(s)
• DS SCADA has the data related to the grid configuration and status. • DS SCADA can manage in close real-time the DERs and PEDs. • PQS can get the information related to the power quality status, grid configuration and close to real-time measurements of DERs and PEDs from PUC 10. • PED provides direct controllability to the DS SCADA
Precondition(s)
• DS SCADA and PQS are online and working properly. • Normal operation of grid

6.1.8.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
SUC 04: Grid Operation Planning PUC 10: Grid Monitoring and Power Quality Assessment
Level of Depth

Detailed
Prioritization
Optional
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Optimal scheduling for Power Quality operation, Power quality strategy,

6.1.8.6 Use case diagram

Diagram(s) of use case

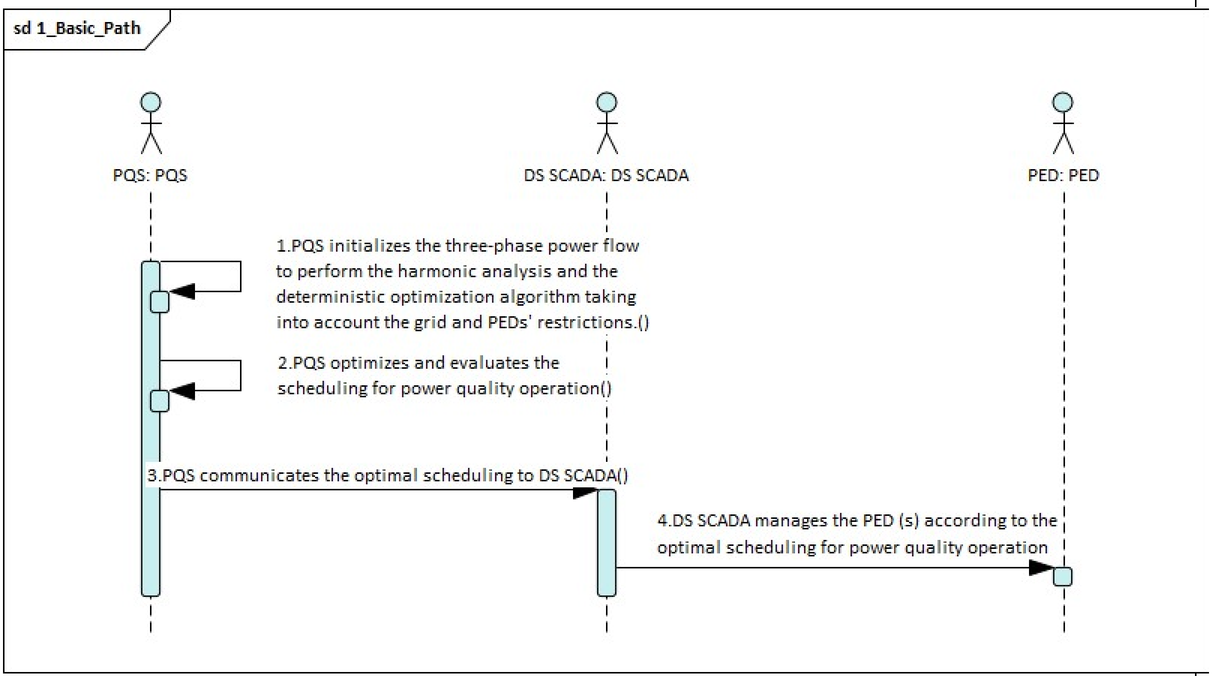


Figure 17 PUC11 Sequence Diagram

6.1.8.7 Actors

Actors

Actor name	Actor type	Actor description	Further information
Supervisory Control And Data Acquisition (DS SCADA)	System	A system in charge of overall monitoring and control of the distribution and transmission grid. It integrates communication, remote monitoring and control, signal processing and logic, and data storage functionalities. It includes a user interface called control center room.	Controls the PEDs according to the optimal scheduling of for power quality operation
Power Quality Service (PQS)	Application	Application that determine the power quality status and calculates set-points for devices to mitigate power quality issues. It is included in the DSO Toolbox	In this PUC provides the optimal scheduling of PEDs for power quality operation
Power Electronic Device (PED)	Device	It is a power electronic device used to exchange power with batteries/EVs, and also PV systems, which is also able to communicate with the SCADA, measure grid and islanding status, and also can be command by SCADA.	
Grid Operation Planner (GOP)	Application	Service in charge of planning the grid operation satisfying a predefined objective function that depends on the specific scenario. It determines the need of reconfiguration or flexibility. It is included in the DSO Toolbox.	Provides mitigation actions. Developed in the project.

6.1.8.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Close to real-time optimal scheduling for power quality operation	Describes the process for determining the optimal scheduling for power quality operation in the close to real-time horizon	PQS	Upon request	Available data from PUC 10	The optimal scheduling for power quality operation. Power quality requirements fulfilled.

Scenario							
Scenario name:							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Power quality mitigation request	Initializing the optimal scheduling for power quality operation	PQS initializes the three-phase power flow to perform the harmonic analysis and the deterministic optimization algorithm taking into account the grid and PED restrictions.	PQS	PQS	-	
2	Upon optimal scheduling for power quality request	Optimizing the scheduling for power quality operation	PQS optimizes and evaluates the scheduling for power quality operation	PQS	PQS	-	
3	Upon Optimizing the scheduling for power quality operation	Communicating the optimal scheduling	PQS communicates the optimal scheduling to DS SCADA to manage the PEDs.	PQS	DS SCADA	The optimal scheduling for	

		for power quality operation				power quality operation	
4	Upon the communicating the optimal scheduling for power quality operation	Managing the PEDs	DS SCADA manages the PEDs according to the optimal scheduling for power quality operation	DS SCADA	PED	PED Schedule	

6.1.8.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
PwQISchReq	Power quality operation request schedule	The activation request for the mitigation action enclosing all the relevant information of the area/zone.	PQS_REQ_DQ_01
NetworkData	Network Sensing Data	Sensing data from the SCADA • Transformer: Power, Voltage, Current, Frequency • Grid monitoring devices: Power, Voltage, Current, Frequency Power quality analyzer: THDs, Monitoring Power Quality Beyond EN 50160 and IEC 61000-4-30	PQS_REQ_DQ_01
SwStatus	Switchgear Status	Switchgear status of equipment in the area	PQS_REQ_DQ_01
PedData	PED sensing data	Sensing data from the PED: Power, Voltage, Current, Frequency	PQS_REQ_DQ_01
DerData	DER sensing data	DER Sensing data: Power, Voltage, Current, Frequency	PQS_REQ_DQ_01
PwQISchedule	Power quality operation schedule	The optimal scheduling for power quality operation of PEDs of the area/zone.	
GridInfoTplg	Grid Asset Information & Topology	Technical characteristic of grid assets (e.g. nominal power) as well as their connectivity (grid topology).	PQS_REQ_DQ_01
PedSchedule	PED Schedule	Schedule with operational setpoints (e.g. charging/discharging the battery) of the PED.	

6.1.9 PUC12 Self-healing

6.1.9.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Describes the process of identifying network faults and defining a mitigation plan for limiting the boundaries of the faulted grid area
Objective(s)	1) Identify network faults 2) Propose mitigation actions leveraging grid reconfiguration and exploitation of DER flexibility. 3) Evaluate mitigation actions
Related high-level use case(s)	HLUC 04: Self-healing operation after critical event considering DER & grid flexibility

6.1.9.2 Narrative of use case

Narrative of use case
Short description
Self-healing is the process for identifying network faults and defining a mitigation plan for limiting the boundaries of the faulted grid area and maximizing the number of electrified network users. Two remedial mechanisms are considered, grid reconfiguration by modifying properly the network switchgears and procurement of DER active energy flexibility.
Complete description
The Self-Healing Application (SHA) is responsible for the self-healing process. In order to resolve grid issues, the SHA leverages operations provided by various subsystems: • Fault analysis (see SUC10: Fault Detection and Localization) • Forecast of grid loads/generations' profile (see SUC 01: Energy Forecasting) • Forecast of potential violations of the network operational constraints (critical events – see SUC03: Critical Event Forecasting) • Calculation of a mitigation plan (SUC04: Grid Operation Planning) The steps of the process are described below. **Fault Detection** After a fault occurs, it entails the detection of the fault followed by its location. This is performed by the Fault Detection Application (FDA), utilizing grid operational status data from DS SCADA (see SUC 02: Grid Observability and Monitoring), as well as topological characteristics of the distribution grid provided by the GIS. The outcome of this analysis comprises the fault type, and the identification of affected components (in terms of lines, buses, switchgears, etc.). **Propose Mitigation Action** The outcome of fault analysis is communicated to the Grid Operation Planner (GOP) in order to define a grid reconfiguration plan aiming to minimize the faulted grid area and maximizing the number of electrified network users. Since the network topology is modified, the power flows in that area are affected consequently. In light of this, an analysis is performed by the Critical Event Forecaster (CEF)

in order to identify potential grid operational constraint violations (i.e. network congestion, voltage excursions). The analysis requires forecasted production/consumption profiles for - generated by the Energy Forecaster (EF) - in respect to the weather forecast provided by the weather forecast agency. The timeframe of the analysis is defined by the estimated duration of the fault. In case that critical network events are forecasted, GOP analyses the potential exploitation of available DER flexibility. The flexibility needs identified by this analysis comprise the requested amount and type of power, the spatial and temporal requirements. Upon calculation of mitigation actions, SHA, communicates to (Switchgear Dispatch Scheduler) SDS the switchgear plan (see PUC 02: Grid reconfiguration Schedule Dispatching) and the Flexibility Service Consuming Agent (FSCA) with the requested flexibility (see PUC 03: Requesting flexibility Services) which will handle the implementation of remedial actions, and returns an update of the flexibility scheduled for activation. **Evaluate Mitigation Action** The effectiveness of the remedial actions is assessed periodically via the use of data from field devices (e.g. from the AMI or DS SCADA). It is facilitated by the Ex-Post Assessment Application (EPAA).

6.1.9.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC10_1	Responsiveness of self-healing	Expresses the time required for identifying the fault and proposing the mitigation actions.	1,2

6.1.9.4 Use case conditions

Use case conditions
Assumption(s)
• Bilateral contracts or market procured flexibility are utilized for resolving the critical grid situation. In the former case contracts contain all the details (i.e. flexibility capacity, spatial indication of DERs relevant to electricity grid, etc.) for activating flexibility.
Precondition(s)
• All required data are available (e.g weather data, grid operational status, characteristics of grid assets) • All subsystems (e.g. FDA, GOP, EF, CEF) are operational and able to provide required operation • Data from sensor devices (i.e. SCADA, AMI) are of adequate quality

6.1.9.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
SUC 01: Energy Forecasting **SUC 02: Grid Observability and Monitoring** **SUC 03: Critical Event Forecasting** **SUC 04: Grid Operation Planning** **PUC 02: Grid reconfiguration Schedule Dispatching** **PUC 03: Requesting flexibility Services** **PUC 06: Ex-post network performance assessment**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Self-healing, flexibility, grid reconfiguration, grid operational planning

6.1.9.6 Use case diagram

Diagram(s) of use case

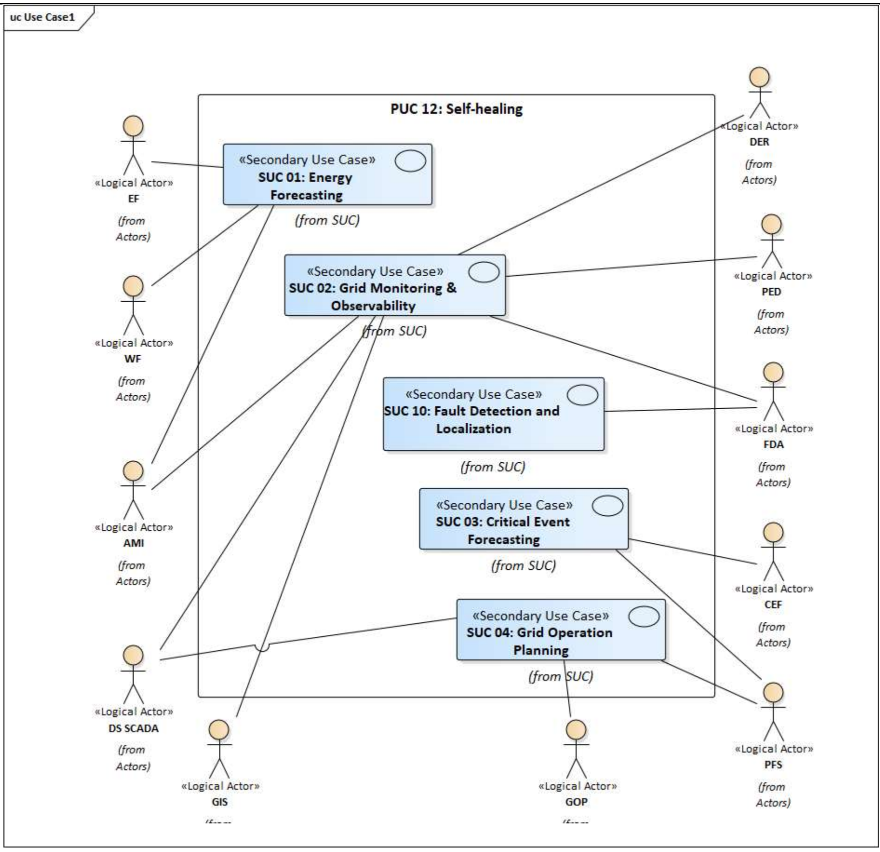


Figure 18 PUC12 UC Diagram

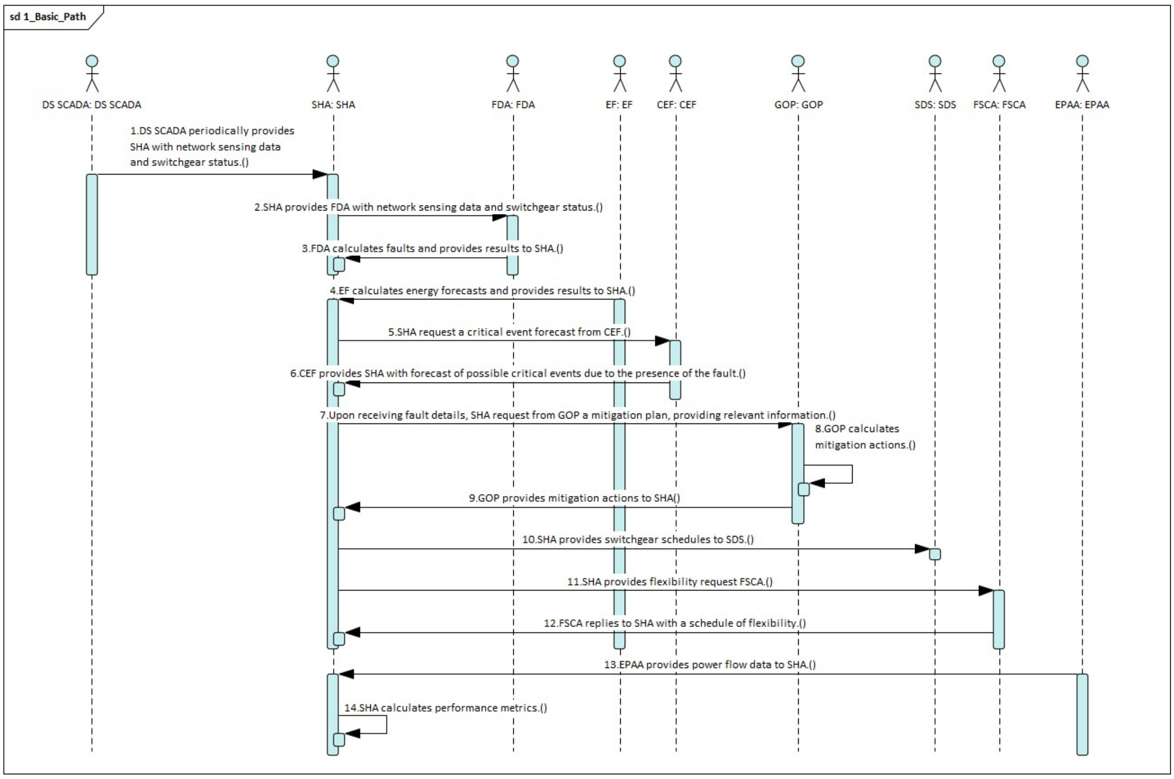


Figure 19 PUC 12 Sequence Diagram

6.1.9.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Advanced Metering Infrastructure (AMI)	System	The system composed of all the devices, applications and data bases that permits to measure, remotely collect and manage data from smart meters.	Provides data for forecasting.
Critical Event Forecaster (CEF)	Application	Application, in charge of predicting possible congestion or over-under voltage events in the succeeding H-time (forecasting horizon).	Provides predictions of events. Developed in the project.
Energy Forecaster (EF)	Application	A forecasting application in charge of predicting demand and generation values for specific points of the grid in the succeeding H-time. It facilitates aggregated values of individual consumptions/productions and weather forecast data.	Provides predictions of energy consumption generation. Developed in the project.
Fault Detection Application (FDA)	Application	Application, in charge of orchestrating the process of fault detection and isolation	
Geographic Information System (GIS)	System	System that manages all the static information related to the grid assets, their location, operational status and parameters.	Provides grid asset information, including operational limits.
Grid Operation Planner (GOP)	Application	Service in charge of planning the grid operation satisfying a predefined objective function that depends on the specific scenario. It determines the need of reconfiguration or flexibility. It is included in the DSO Toolbox.	Provides mitigation actions. Developed in the project.
Ex-Post Assessment Application (EPAA)	Application	Application for assessing the effectiveness of the remedial actions.	Will provide the ex-post analysis. Developed in the project.
Flexibility Service Consuming Agent (FSCA)	Application	The agent responsible for packing the flexibility needs of an actor into flexibility bid/request in respect to the requirements imposed by the flexibility markets or the bilateral agreements.	Will communicate flexibility request. Developed in the project.

Self-Healing Application (SHA)	Application	Application responsible for mitigating faults in distribution grid considering grid and DER flexibilities.	Item under design.
Supervisory Control And Data Acquisition (DS SCADA)	System	A system in charge of overall monitoring and control of the distribution and transmission grid. It integrates communication, remote monitoring and control, signal processing and logic, and data storage functionalities. It includes a user interface called control center room.	Provides sensing data for the distribution grid. Enables switchgear schedule dispatch.
Weather Forecaster (WF)	Application	Application offering weather forecast services.	

6.1.9.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Fault detection and mitigation plan dispatch	Describes the process of identifying, mitigating and assessing faults in the grid	SHA	Periodic Process	Available data for analysis from DS SCADA	Faults Identified, Mitigation actions communicated, Performance metrics Calculated

Scenario							
Scenario name:			Close to real-time Identification				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic Process or upon detecting a fault	Get network status	DS SCADA periodically provides SHA with network sensing data and switchgear status.	DS SCADA	SHA	Network Sensing Data, Switchgear Status	
2	Periodic Process	Request fault analysis	SHA provides FDA with network sensing data and switchgear status.	SHA	FDA	Network Sensing Data, Switchgear Status	
3	Upon request	Calculate fault information	FDA calculates faults and provides results to SHA.	FDA	SHA	Fault information: fault detection and isolation	

4	Upon request	Calculate energy forecasting	EF calculates energy forecasts and provides results to SHA.	EF	SHA	Energy forecasting	
5	Upon Calculation	Request CEF	SHA request a critical event forecast from CEF.	SHA	CEF	Network Sensing Data, Energy Forecast, Switchgear Status (updated with fault information)	
6	Upon Calculation	Communicate fault information	CEF provides SHA with forecast of possible critical events due to the presence of the fault.	CEF	SHA	Fault Prognosis	
7	Upon fault detection	Request mitigation actions	Upon receiving fault details, SHA request from GOP a mitigation plan, providing relevant information.	SHA	GOP	Fault Diagnosis, Network Switchgear Status, (updated with faulty situation) Flexibility Characteristics	
8	Upon request	Calculate mitigation actions	GOP calculates mitigation actions.	GOP	GOP	-	
9	Upon calculation	Communicate mitigation action	GOP provides mitigation actions to SHA.	GOP	SHA	Switchgear Schedules, Flexibility needs	
10	Upon receiving mitigation action	Send switchgear schedule	SHA provides switchgear schedules to SDS.	SHA	SDS	Switchgear Schedules	
11	Upon receiving mitigation action	Send flexibility request	SHA provides flexibility request FSCA.	SHA	FSCA	Flexibility Needs	

12	Upon traded flexibility	Send flexibility schedule	FSCA replies to SHA with a schedule of flexibility.	FSCA	SHA	Flexibility schedule	
13	Upon calculation	Send ex-post analysis	EPAA provides power flow data to SHA.	EPAA	SHA	Power Flow Data	
14	Upon receiving ex-post analysis	Calculates metrics	SHA calculates performance metrics.	SHA	SHA	Self-healing performance metrics	

6.1.9.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
EnForecast	Energy Forecast	Consumption and generation forecast for different assets of the grid.	
FltDiagnos	Fault Diagnosis	Existence or not of a fault, type and list of involved variables.	
FlexNeed	Flexibility Needs	Required flexibility with spatial as well as temporal characteristics	
FlexChar	Flexibility Characteristics	Characteristic of available flexible assets.	
NetworkData	Network Sensing Data	Voltage and current, or power, sensing data from the SCADA	
PfData	Power Flow Data	Voltages and currents in nodes and lines of the grid.	
SmData	Smart Meter Data	Measurement data from smart meter devices.	
SwStatus	Switchgear Status	Status of switchgear equipment	
WetForecast	Weather Forecast	Meteorological forecast data	
GridInfoTplg	Grid Asset Information & Topology	Technical characteristic of grid assets (e.g. nominal power) as well as their connectivity (grid topology).	
FltProgn	Fault prognosis	Fault Diagnosis + forecasted Critical event information	

6.1.9.10 Requirements

Requirements ID	Requirement name	Requirement description
SHA_REQ_INR_01	Grid information modelling standard	The grid asset information shall comply with the CGMES provide of CIM standard series.

6.1.10 PUC13 Minimizing network technical losses

6.1.10.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	The scope of this use case is the exploitation of the flexibility offered by distributed energy resources towards increasing network efficiency by reducing technical losses. The procurement of DER flexibility offered by Flexibility Service Providers will be realized via either bilateral contacts or flexibility markets.
Objective(s)	1) To minimize the network technical losses and increasing network operational efficiency in presence of DRES by reducing energy exchange with the main grid at substation level.
Related high-level use case(s)	HLUC 06: Leveraging DER flexibility towards enhancing network operational efficiency

6.1.10.2 Narrative of use case

Narrative of use case
Short description
Under a high RES penetration scenario in distribution network, there is a need for increasing the local consumption of RES production at primary or secondary substation level. The exploitation of dispatchable distributed production/consumption/storage assets for better matching the consumption and generation profiles locally as well as for shedding network peak demands will enable better exploitation of the existing grid capacity.
Complete description
The Loss Reduction Application (LRA), which is a component of the DSO Toolbox to be developed within the framework of the project, is responsible for extracting the flexibility needs which will enable the flattening of the network demand curve measured at substation level and will result in the minimization of the network technical losses. The LRA acts as orchestrator for the execution of the task by invoking other services and managing the data flow. The different steps of the loss reduction process are presented in the next paragraphs. The timeframe for this application is a day-ahead scheduling.

Flexibility planning Under some triggering action - on demand (e.g. by DS SCADA), or periodically - the LRA initiates the process for reducing the grid losses. Initially LRA requests the forecast of the energy production and consumption profiles by the Energy Forecaster (EF) (see SUC 01: Energy Forecasting). It then relays the forecast data and relays them to the Grid Operation Planner (GOP), together with the grid configuration acquired by the SCADA. The GOP identifies the expected generation-consumption unbalances in terms of time, amount of energy and related grid area and extracts the flexibility needs (energy production and consumption) for specific time instances and for specific grid areas. The flexibility needs generated by the GOP are communicated to the Flexibility Service Consuming Agent of the DSO (FSCA), who is responsible for realizing such interactions adhering to the communication principles and specifications imposed by the flexibility markets or bilateral agreements flexibility (see PUC 03: Requesting flexibility Services). **Evaluate Action** The effectiveness of LRA is assessed by the Ex-Post Assessment Application (EPAA) based on real data from the DS SCADA (see PUC 06: Ex-post network performance assessment) measuring exchanged energy at substations once the plan has been executed and comparing with expected values without the plan execution.

6.1.10.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC13_1	Loss reduction	Percentage of loss reduction w.r.t BAU.	1

6.1.10.4 Use case conditions

Use case conditions
Assumption(s)
• SCADA information include current grid configuration • LRA has access to grid asset information from GIS • Energy and weather forecaster are available upon demand to LRA (through EF). • Flexibility Characteristics are available via the flexibility service provider
Precondition(s)
• The Energy Forecaster is operational and is able to provide consumption and generation forecasts (e.g. forecasting models are trained) • The sensor data provided to EF are of adequate quality • The GOP has access to an updated grid model and configuration for the purposes of power flow simulation.

6.1.10.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
SUC 01: Energy Forecasting **SUC 02: Grid Observability and Monitoring** **SUC 04: Grid Operation Planning** **PUC 02: Grid reconfiguration Schedule Dispatching** **PUC 03: Requesting flexibility Services** **PUC 06: Ex-post network performance assessment**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
grid operational planning, technical loss minimisation

6.1.10.6 Use case diagram

Diagram(s) of use case

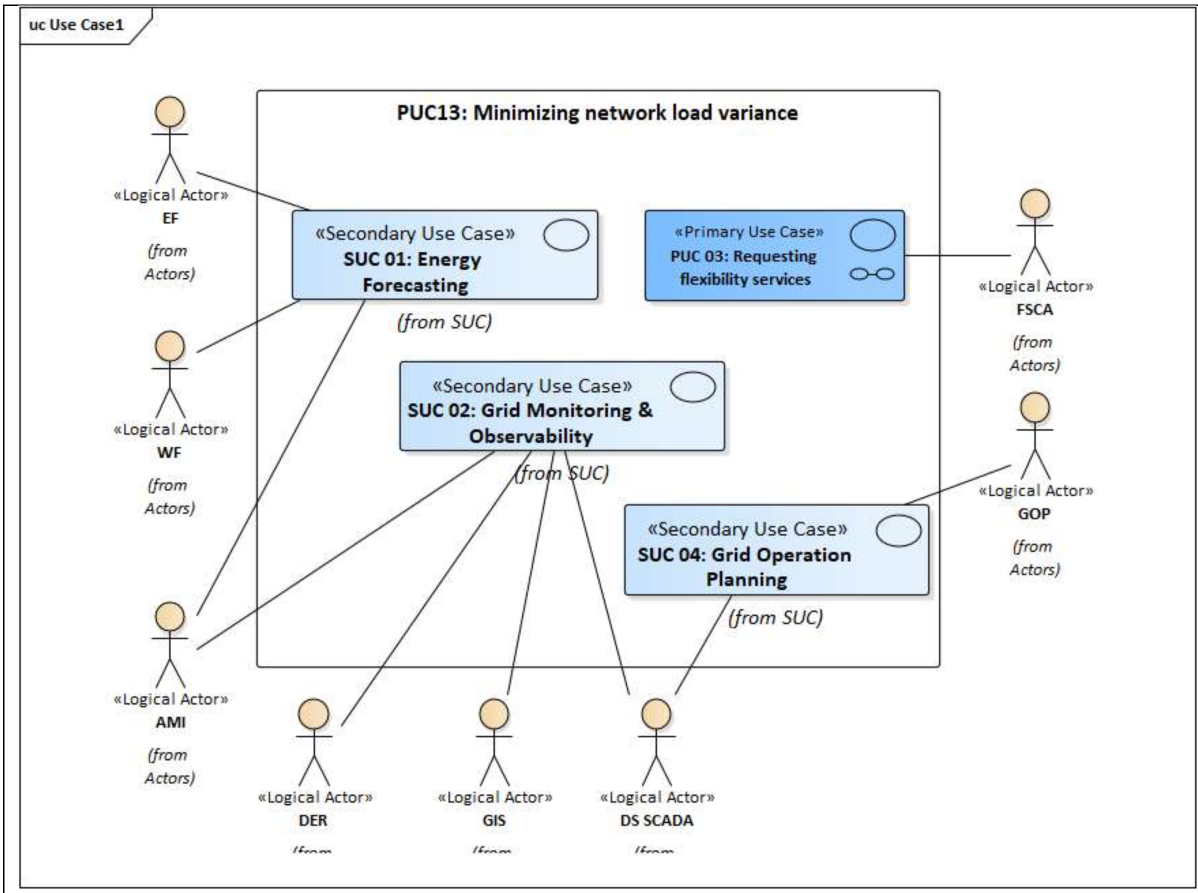


Figure 20 PUC13 UC Diagram

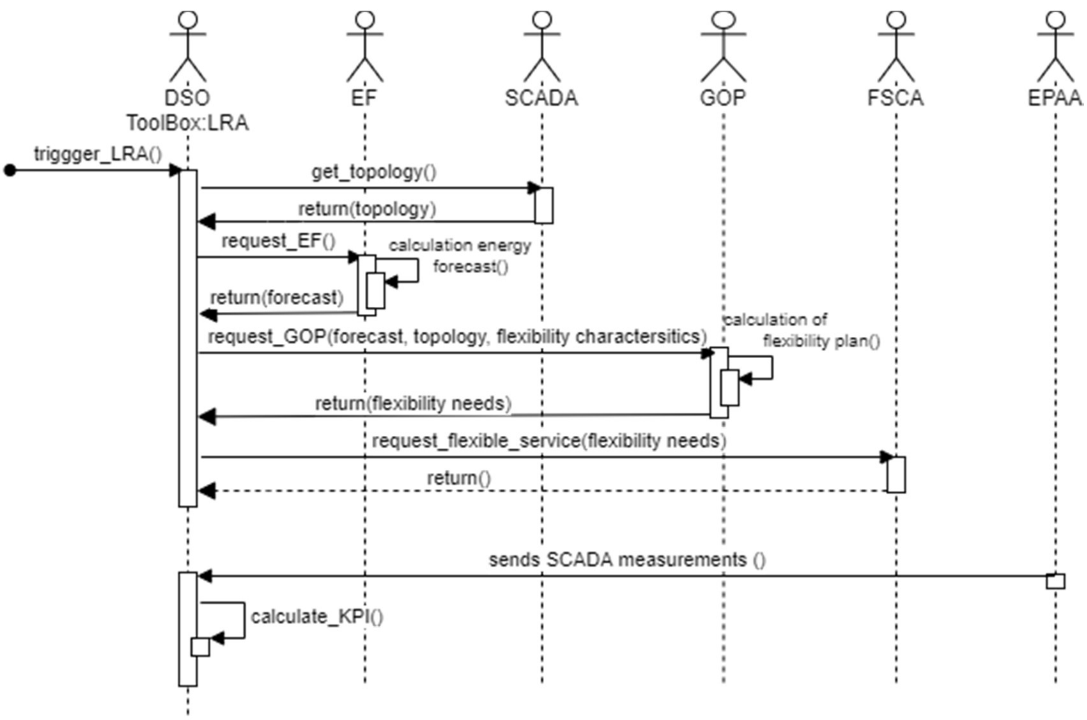


Figure 21 PUC13 Sequence diagram

6.1.10.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Energy Forecaster (EF)	Application	A forecasting application in charge of predicting demand and generation values for specific points of the grid in the succeeding H-time. It facilitates aggregated values of individual consumptions/productions and weather forecast data.	Provides predictions of energy consumption generation.
Geographic Information System (GIS)	System	System that manages all the static information related to the grid assets, their location, operational status and parameters.	Provides grid asset information, including operational limits.
Grid Operation Planner (GOP)	Application	Service in charge of planning the grid operation satisfying a predefined objective function that depends on the specific scenario. It determines the need of reconfiguration or flexibility. It is included in the DSO Toolbox.	Provides mitigation actions.
Ex-Post Assessment Application (EPAA)	Application	Application for assessing the effectiveness of the remedial actions.	Will provide the ex-post analysis.
Loss Reduction Application (LRA)	Application	Application responsible for extracting the flexibility needs which will enable the flattening of the network demand curve measured at substation level and will result in the minimization of the network technical losses. It is included in the DSO Toolbox.	Application under design.
Flexibility Service Consuming Agent (FSCA)	Application	The agent responsible for packing the flexibility needs of an actor into flexibility bid/request in respect to the requirements imposed by the flexibility markets or the bilateral agreements.	Will communicate flexibility request and activation schedule.
Supervisory Control And Data Acquisition (DS SCADA)	System	A system in charge of overall monitoring and control of the distribution and transmission grid. It integrates communication, remote monitoring and control, signal processing and logic, and data storage functionalities. It includes a user interface called control center room.	Provides sensing data for the distribution grid including grid configuration data.

6.1.10.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Day ahead flexibility demand planning for an efficient operation of the grid	Describes the process for calculating optimal demand of flexibility to operate the grid efficiently by minimizing losses.	LRA	On demand	EF capable to provide day ahead forecast GOP able to provide plan	Flexibility schedules for activation Performance metrics Calculated

Scenario							
Scenario name:			Day ahead flexibility demand planning for an efficient operation of the grid				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Upon request	Request grid configuration	LRA requests to DS SCADA the grid info	LRA	DS SCADA	-	
2	Upon request	Get grid configuration and connection points of SM	SCADA provides LRA with grid configuration data.	DS SCADA	LRA	Switchgear Status	
3	After 2	Request energy forecast	LRA requests generation and demand forecast for nodes in the grid	LRA	EF	-	

4	Upon request	Calculation of generation and demand forecast	EF computes energy forecast.	EF	EF	-	
5	After calculation	Send forecast	EF sends result of generation and demand forecast calculations to LRA	EF	LRA	Energy forecast	
6	Upon receiving forecast	Request flexibility needs schedule	LRA requests GOP a schedule of flexibility minimize losses and communicates characteristic of available flexible assets in the grid.	LRA	GOP	Energy Forecast Grid Configuration	
7	Upon request	Calculation of flexibility needs	GOP computes the needs for flexibility to minimize the grid losses.	GOP	GOP	-	
8	After calculation	Sends flexibility needs	GOP sends result of flexibility needs	GOP	LRA	Flexibility Needs	
9	Upon receiving flexibility schedule	Send flexibility request	LRA provides flexibility request FSCA	LRA	FSCA	Flexibility Needs	
10	Upon traded flexibility	Send flexibility schedule	FSCA updates on schedule of flexibility	FSCA	LRA	Flexibility Schedule	
11	Upon calculation	Send ex-post analysis	EPAA provides SCADA data to LRA	EPAA	LRA	Network Sensing Data	
12	Upon receiving ex-post analysis	Calculates metrics	LRA calculates performance metrics	LRA	LRA	Loss Reduction performance metrics	

6.1.10.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
LossMetric	Loss reduction performance metrics	Metrics related to the performance of the operation of the loss reduction application.	
EnForecast	Energy Forecast	Consumption and generation forecast for different assets of the grid.	
FlexNeed	Flexibility Needs	Required flexibility with spatial as well as temporal characteristics	
FlexChar	Flexibility Characteristics	Characteristic of available flexible assets.	
FlexSchedule	Flexibility Schedule	A concrete planned realization of a flexibility need/request	
NetworkData	Network Sensing Data	Voltage and current, or power, sensing data from the SCADA	
SwStatus	Switchgear Status	Status of switchgear equipment in the area of interest.	
GridInfoTplg	Grid Asset Information & Topology	Technical characteristic of grid assets: in particular generation and consumption points and associated meters (location and connection nodes), basic characteristics (e.g. type, nominal power) as well as their connectivity (grid topology).	LRA_REQ_INR_01

6.1.10.10 Requirements

Requirements ID	Requirement name	Requirement description
LRA_REQ_INR_01	Grid information modelling standard	The grid asset information shall comply with the CGMES provide of CIM standard series.

6.1.11 SUC1 Energy forecasting

6.1.11.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Calculates generation and demand forecasting for specific time horizon and at the specific grid points, leveraging data from metering instruments (e.g. smart meters).
Objective(s)	1) Forecast energy demand at specific points of the grid 2) Forecast generation at specific points of the grid where energy production plants are installed.
Related high-level use case(s)	HLUC 01: Advanced network congestion management considering DER & grid flexibility (seasonal, day-ahead, etc.) HLUC 06: Leveraging DER flexibility towards enhancing network operational efficiency

6.1.11.2 Narrative of use case

Narrative of use case
Short description
Calculates generation and demand forecasting for specific time horizon and at the specific points where metering instruments (e.g. smart meters) are available based on either data driven or physical models.
Complete description
The energy forecaster (EF) is an application that provides both generation and demand forecasting at specific nodes of the grid where meters are placed or aggregation of them at specific points of the grid, based on either machine learning or mathematical models, and information from metering infrastructure and weather forecasting (numerical weather prediction). The application leverages information provided by: • Grid operational status (see SUC 02: Grid Observability and Monitoring), utilizing smart meter data from AMI. • Topological characteristics of the distribution grid provided by the GIS • Weather forecast data from Weather Forecaster (WF) The application provides forecasting, for given time-horizon (e.g. day-ahead), with the same time-granularity as the input data. It has two operation modes (scenarios): training and forecasting. The different steps of those modes, or scenarios, are described below: **Training mode:** This requires historic data of both demand/generation data and exogenous variables (weather, calendar) included in the model, to be used either for training a machine learning model or adjust parameters. Numerical Weather Predictions (NWP) forecasts (global horizontal irradiance and ambient temperature) are used in the generation models together with energy data from the generators. This task is performed under demand, periodically or triggered by some condition. The EF is invoked by passing the historic energy and weather data and trains a specific model for every generation and consumption point. When required it can perform aggregated forecasting at specific nodes of the grid

based on the topology. The EF manages the models internally. **Forecasting mode:** This mode requires the existence of the energy models previously created and trained. Forecasting is performed periodically (optionally it can be executed under demand) and it provides generation and demand forecasting with the granularity and horizon used for training, e.g.: once a day It computes hourly forecasting for the day ahead. When invoked, the EF receives an energy vector of recent values and a vector of forecasted weather for during the horizon. EF provides generation and demand forecasting based on these inputs and the models previously trained, and a quality index of the forecasting.

6.1.11.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_SUC01_1	Performance of forecasting	Accuracy of the forecasting: Mean absolute percentage error (MAPE)	1,2

6.1.11.4 Use case conditions

Use case conditions
Assumption(s)
• GIS information include node connection of metering instruments and topology (required only for aggregated forecasting) • AMI and Weather Forecaster are available upon demand to EF • Data provided are of high quality data in terms of accuracy, significance and completeness.
Precondition(s)
• During forecasting, the existence of a model previously trained is required.

6.1.11.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC 01: Critical Event Prevention **PUC 07: Voltage compensation via reactive power control** **PUC 12: Self-Healing** **PUC 13: Minimizing network technical losses**

Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Generation and demand energy forecasting

6.1.11.6 Use case diagram

Diagram(s) of use case

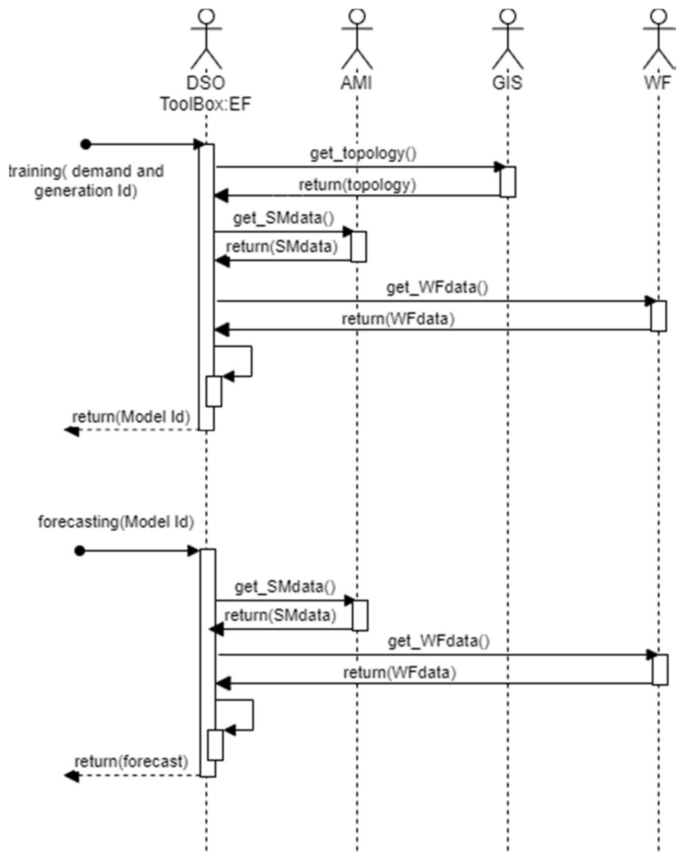



Figure 22 SUC1 Sequence diagram (training and forecasting modes)

6.1.11.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Advanced Metering Infrastructure (AMI)	System	The system composed of all the devices, applications and data bases that permits to measure, remotely collect and manage data from smart meters.	Provides data for forecasting.
Energy Forecaster (EF)	Application	A forecasting application in charge of predicting demand and generation values for specific points of the grid in the succeeding H-time. It facilitates aggregated values of individual consumptions/productions and weather forecast data.	Provides predictions of energy consumption generation. Developed in the project.
Geographic Information System (GIS)	System	System that manages all the static information related to the grid assets, their location, operational status and parameters.	Provides grid asset information, including operational limits.
Weather Forecaster (WF)	Application	Application offering weather forecast services.	Provides weather forecasting data.

6.1.11.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Training	Describes the process for training data driven models	EF	On demand or Periodic Process	Data available	Forecasting models trained.
2	Forecasting	Describes the process for forecasting energy generation and demand	EF	On demand	Existence of model Data available	Demand and/or generation forecasts

Scenario							
Scenario name:			Training				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic or upon request	Start training	Launches energy forecaster training.	External (other application, service or user)	EF	Demand and Generation Id	
2	After 1	Grid asset and topology information request	Request information on generation and consumption points (nominal power, type of generation) and associated meters. Grid status (switchgears) and topology.	EF	GIS	Grid Asset Information & Topology Request	

3	Upon request	Get grid configuration and connection points of SM	GIS provides EF with grid configuration data.	GIS	EF	Grid Asset Information & Topology	EF_REQ_INR_01
4	After 3	Smart meter data request	Request energy (generation and demand) historic data from all the meters that want to be trained a model.	EF	AMI		
5	Upon request	Get SM energy data	AMI provides EF with historic smart metering data from generation and consumption points.	AMI	EF	Smart Meter data	EF_REQ_OPE_01 EF_REQ_OPE02
6	After 5	Weather data request	Request weather forecast historic data for the area and same period as energy data.	EF	WF	Geographic location	
7	Upon request	Get weather forecasting data	WF provides EF with weather forecasting historic data.	WF	EF	Weather forecasting data	EF_REQ_OPE_01 EF_REQ_OPE02
8	Once 3,5 and are completed	Training forecasting models	Invokes training procedures for both generation and demand.	EF	EF	-	
9	After 9	End training	Inform that training has finished and returns a model id.	Demand and Generation Id	External App who started the request	Model Id	
Scenario name:			Forecasting				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**

1	Forecasting triggering	Start forecasting	Launches energy forecasting.	External (other application, service or user)	EF	Model Id	EF_REQ_OPE03
2	Upon initiation	Smart meter data request	Request energy (generation and demand) data from all the meters that want to be trained a model.	EF	AMI		
3	Upon request	Get SM energy data	AMI provides EF with smart metering data from generation and consumption points.	AMI	EF	Smart Meter Data	
4	Upon receiving SM data	Weather data request	Request energy (weather forecast data for the area and time horizon.	EF	WF	Geographic location	
5	Upon request	Get weather forecasting data	WF provides EF with weather forecasting data.	WF	EF	Weather forecasting data	
6	After completing 3 and 5	Forecasting energy and demand	Invokes forecasting procedure both generation and demand.	EF	EF	Energy Forecast	

6.1.11.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
FcstPointId	Demand and Generation Id	Identifiers of generation and demand points where forecasting has to be performed	
SmData	Smart Meter Data	Energy measurement data from smart metering devices.	
WetForecast	Weather forecasting data	Meteorological forecasting data.	
GridInfoTplg	Grid Asset Information & Topology	Technical characteristic of grid assets (e.g. nominal power) as well as their connectivity (grid topology).	
GridInfoTplgReq	Grid Asset Information & Topology Request	Request information on generation and consumption points, associated meters and topology.	
EnForecast	Energy Forecast	Consumption and generation forecast for different location of the grid.	
FcstModeld	Model Id	Identifier of the set of generation and demand assets that constitutes the grid. To be used when requested forecasting	

6.1.11.10 Requirements

Requirements ID	Requirement name	Requirement description
EF_REQ_INR_01	Grid information modelling standard	The grid asset information shall comply with the CGMES provide of CIM standard series.
EF_REQ_OPE_01	Training data	At least 3 months of complete historic data is required for training (energy and weather data within the same training period and resolution)
EF_REQ_OPE02	Synchronized and located data	All historical data (energy generation and demand) required as input for training has to be time aligned (same time stamp) and geographically associated to the point of interest (where forecasting is assigned): This includes energy

		generation and demand, and weather forecasts (Numerical Weather Prediction (NWP) as well for the whole training period.
EF_REQ_OPE03	Consistent Model Id	The model ID used to request a forecasting has to be consistent with the current topology (same topology for forecasting and training)

6.1.12 SUC2 Grid observability and monitoring

6.1.12.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Collect grid monitoring data for the use in energy services.
Objective(s)	1) Collect grid monitoring data 2) Check consistency of grid monitoring data 3) Provide grid performance metrics
Related high-level use case(s)	HLUC 01: Advanced network congestion management considering DER & grid flexibility (seasonal, day-ahead, etc.) HLUC 02: Leveraging the batteries' inverters towards reactive power ancillary services HLUC 03 - Leveraging the flexibility of the storage assets for real time detection of uncontrolled islanding HLUC 04: Self-healing operation after critical event considering DER & grid flexibility HLUC 06: Leveraging DER flexibility towards enhancing network operational efficiency HLUC 07: Improving power quality and reducing losses through power electronics

6.1.12.2 Narrative of use case

Narrative of use case
Short description
This UC aims to complement and pre-process the collection of grid monitoring data provided by the DMS. The "Grid Monitoring and Observability" process provides grid monitoring and observability data, collected by monitoring systems, such as DS SCADA, from grid assets. Data unification, consistency check and accessibility to the energy services of FEVER for grid monitoring data are provided: measurement of data relevant to the operation of the PED, DERs and other grid assets (V, I, P, Q, SoC, etc.), local analysis by dedicated monitoring application, grid performance metrics.
Complete description

From the DMS it is always possible to monitor the state of the grid by means of data collection from systems such as DS SCADA, PQM and AMI. Complementary to the conventional DSO's legacy systems, the grid monitoring can be enhanced by the acquisition of field measurement data at prosumer level for grid operation purposes, i.e. power quality measurements, voltages, etc. The sampling and the transmission frequency is case dependent (i.e. fault detection, grid power quality monitoring etc.).

The grid observability infrastructure is composed of a set of instruments and applications aimed to monitor and gather information about the grid. This infrastructure can be sub-divided into the following segments:

- The AMI (Advanced Metering Infrastructure), which is composed by various systems Meter Data Management System (MDMS), data concentrators (e.g. MDC, DCU) and metering device at customer level (Smart Meter – SM) or grid level (Grid Meter – GM). This segment is responsible for measuring consumption and generation profile of customer or different points of the grid, whilst power quality measurement (e.g. voltage) are also available. The sampling period of the instruments of this segment varies from a few minutes to an hour. The information gathered in this segment, is stored in the MDMS, will be further used to forecast energy supply and demand and critical events.
- The SCADA, which integrates sensing and control equipment (i.e. switchgear) at substation level through communication devices (RTU), as well as Power Electronic Devices (PEDs). SCADA receives the status of the PEDs and the switchgear as collected and communicated by the RTU, in frequent time intervals. This segment is dedicated to report the grid configuration and status, i.e. the state of the PEDs' batteries and the state of switchgears. The SCADA is responsible of storing the information.

In summary, the "Grid Monitoring and Observability" process provides grid monitoring and observability data, collected by monitoring systems, such as DS SCADA, from grid assets. Data is unified, consistency checked and provided to the energy services of FEVER which rely on grid monitoring data. Measurement of data relevant to the operation of the PED, DERs and other grid assets (V, I, P, Q, SoC, etc.) and local analysis by a dedicated monitoring application, whilst enabling the provision of grid performance metrics.

6.1.12.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_SUC02_1	Data received	Percentage of data received vs expected per time period.	1
KPI_SUC02_2	Frequency of data received	Percentage of data received in expected refreshing period.	1
KPI_SUC02_3	Consistency of data received	Percentage of consistent data.	2

6.1.12.4 Use case conditions

Use case conditions
Assumption(s)
- Grid assets (PEDs, DERs, SGs, etc.) are able to communicate with the DS SCADA. - Grid assets (PEDs, DERs, SGs, etc.) have monitoring capabilities. - Grid assets (PEDs, DERs, SGs, etc.) provide a monitoring data collection interface in the required data format. - Grid Asset Information & Topology is available via the GIS
Precondition(s)
- All devices/applications are online and working.

6.1.12.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC01 Critical Event Prevention **PUC07 Voltage compensation via reactive power control** **PUC12 Self-Healing** **PUC13 Minimizing network technical losses**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Grid monitoring, observability

6.1.12.6 Use case diagram

Diagram(s) of use case

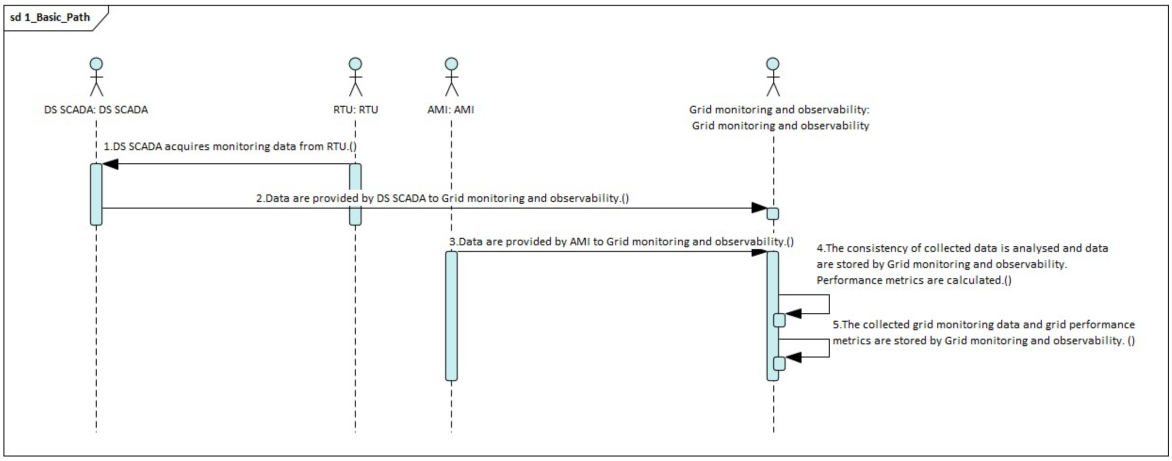


Figure 23 SUC2 Sequence Diagram

6.1.12.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Grid monitoring and observability	Application	Application to collect, analyse and provide access to grid monitoring data. It is included in the DSO Toolbox	Item under design
Advanced Metering Infrastructure (AMI)	System	The system composed of all the devices, applications and data bases that permits to measure, remotely collect and manage data from smart meters.	Provides data from SMs.
Supervisory Control and Data Acquisition system (DS SCADA)	System	It is a supervisory control and data acquisition system which is responsible to manage the distribution grid. In addition, is able to communicate/command with the IPMA and PEDs.	Provides grid sensing data.
PED	Device	It is a power electronic device used to exchange power with batteries/EVs, and also PV system, which is also able to communicate with the SCADA/IPMA/PQS, measure grid and islanding status, and also can be commanded by SCADA/IPMA/PQS.	Provides field measurement data.
RTU	Device	A communications enabled Intelligent Electric Device (IED) that interfaces the Supervisory Control and Data Acquisition (SCADA) system and field devices for	

		exchanging telemetry data and control messages.	
DSO Toolbox	System	A suite of gird-oriented tools complementing DSO's legacy systems enabling more advanced observability and management of the distribution grid.	
Switchgear	Device	Actuators of the LV grid that permit to switch lines and change grid configuration.	

6.1.12.8 References

References						
No.	**Type**	**Reference**	**Status**	**Impact**	**Originator / Organization**	**URL**
	Deliverable	D.1.3 Interoperability and integration analysis and requirements.	Online	High	RESOLVD	https://resolvd.eu/wp-content/uploads/2019/03/D1.3_FV-rev1.pdf

6.1.12.9 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Grid monitoring and observability in close to real-time	Describes the process of monitoring through DS SCADA.	Grid monitoring and observability	Periodic process	Grid assets provide monitoring data for collection by DS SCADA.	Monitoring data collected.

Scenario							
Scenario name:			**Undetected island**				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic Process	Grid status communication	DS SCADA acquires monitoring data from RTUs.	DS SCADA	RTU	Network Sensing Data, Switchgear Status, PED sensing data	
2	Upon monitoring data collection	Grid monitoring data provision	Data are provided by DS SCADA to Grid monitoring and observability.	DS SCADA	Grid monitoring and observability	Network Sensing Data, Switchgear Status, PED sensing data	REQ_DQ_01 REQ_INR_01
3	Periodic Process	Smart Meter Data	Data are provided by AMI to Grid monitoring and observability.	AMI	Grid monitoring and observability	DER sensing data	REQ_DQ_01 REQ_INR_01

4	Upon request or periodic process	Grid monitoring data consistency check	The consistency of collected data is analysed and data are stored by Grid monitoring and observability. Performance metrics are calculated.	Grid monitoring and observability	Grid monitoring and observability		
5	Upon consistency check or Upon Demand	Grid monitoring data storage	The collected grid monitoring data and grid performance metrics are stored.	Grid monitoring and observability	DSO Toolbox Application (CEPA, IPMA etc.)	Network Sensing Data, Switchgear Status, PED sensing data, DER sensing data, Grid performance metrics, Performance metrics	

6.1.12.10 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
NetworkData	Network Sensing Data	Sensing data from the SCADA • Transformer: Power, Voltage, Current, Frequency • Grid monitoring devices: Power, Voltage, Current, Frequency	IPMA_REQ_DQ_01
SwStatus	Switchgear Status	Switchgear status of equipment in an area	IPMA_REQ_DQ_01
PedData	PED sensing data	Sensing data from the PED: Power, Voltage, Current, Frequency, Status of island detection from PED in the affected area	IPMA_REQ_DQ_01
DerData	DER sensing data	DER Sensing data: Power, Voltage, Current, Frequency, Status of island detection	IPMA_REQ_DQ_01
MonPfMetric	Performance metrics	Performance metrics about the grid monitoring process	
GridPmMetric	Grid performance metrics	Performance metrics about the grid status.	
GridInfoTplg	Grid Asset Information & Topology	Technical characteristic of grid assets (e.g. nominal power) as well as their connectivity (grid topology).	IPMA_REQ_INR_01

6.1.12.11 Requirements

Requirements ID	Requirement name	Requirement description
IPMA_REQ_DQ_01	Data quality, resolution and granularity	Grid monitoring relies on accurate data and status of different assets.
IPMA_REQ_INR_01	Grid information modelling standard	The grid asset information shall comply with the CGME provide of CIM standard series.

6.1.13 SUC3 Critical event forecasting

6.1.13.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Calculates the existence of critical events (congestions and sub/over voltages) in the grid during specific forecasting time horizon for which generation and demand forecasting is available.
Objective(s)	1) Forecast Critical Events (congestions and voltage variations) in the grid
Related high-level use case(s)	HLUC 01: Advanced network congestion management considering DER & grid flexibility (seasonal, day-ahead, etc.)

6.1.13.2 Narrative of use case

Narrative of use case
Short description
The Critical Event Forecaster is responsible for evaluating network operation and identifying critical event conditions (congestions and voltage variation) in the distribution grid.
Complete description
The Critical Event Forecaster (CEF) is an application that provides an estimation of possible congestions (current over thermal limits or equivalent operating threshold) or variations of the voltage out of limits (sub/over voltages) permitted by the regulation or equivalent grid codes used by the DSO. The application leverages information provided by the energy forecaster (EF) and leverages topological characteristics and parameters (i.e. lines, cables, transformers, etc.) of the distribution grid provided by the GIS. The application provides critical event forecasting, for given time-horizon (e.g. day-ahead), with the same time-granularity as the input generation and demand data; and estimates the occurrence of critical events in the forecasted period with the same granularity. Critical event forecasting is performed under upon demand and requires as input energy generation and demand for the forecasting period. It performs a power flow simulation and compares simulated currents at the grid lines and voltages at the nodes with their operation limits (e.g. thermal limits for currents and quality limits for voltage) and returns a list of possible critical events.

6.1.13.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**

KPI_SUC03_1	Performance of critical event forecasting	Ratio of false alarms and missed detection of events	1

6.1.13.4 Use case conditions

Use case conditions
Assumption(s)
• GIS information includes detailed information of grid assets to perform power flow simulation and also operational limits of grid assets.
Precondition(s)
• A power flow simulator is available with up to date grid information.

6.1.13.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC 01: Critical Event Prevention **PUC 07: Voltage compensation via reactive power control** **PUC 12: Self-Healing**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Critical event forecasting, congestions, over/subvoltages

6.1.13.6 General Remarks

General Remarks
In case of single phase loads and generators, an accurate 3-phase PFS is highly recommended.

6.1.13.7 Use case diagram

Diagram(s) of use case

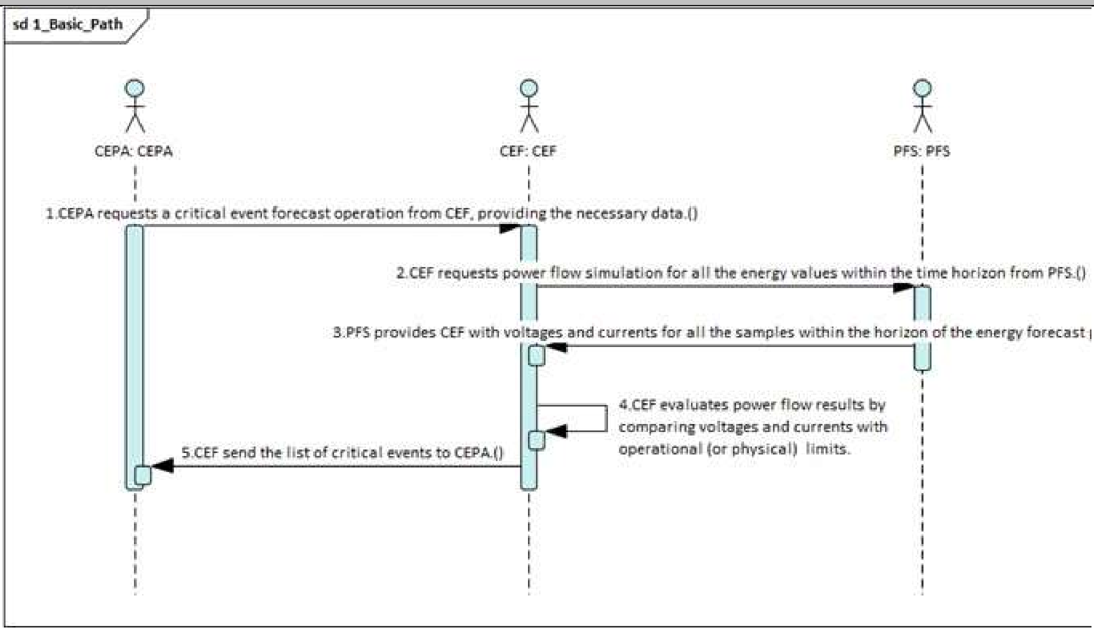


Figure 24 SUC3 Sequence diagram

6.1.13.8 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Critical Event Forecaster (CEF)	Application / service	Provides estimation of possible critical events in the grid for a given vector of energy generation and demand.	Provides information of congestions and/or voltage variations of out limits
Energy Forecaster (EF)	Application	A forecasting application in charge of predicting demand and generation values for specific points of the grid in the succeeding H-time. It facilitates aggregated values of individual consumptions/productions and weather forecast data.	Provides predictions of energy consumption generation.

			Developed in the project.
Geographic Information System (GIS)	System	System that manages all the static information related to the grid assets, their location, operational status and parameters.	Provides grid asset information, including operational limits.
Power Flow Simulator (PFS)	Application	Application offering power flow simulation	Provides voltages and currents on the grid for a given generation and demand profile

6.1.13.9 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Close to real-time Identification	Close to real-time identification of grid events for critical event prevention application.	CEF	Upon request	Data availability (networks sending data)	Critical events
2	Operational / Long-term identification	Long-term forecast of grid events for critical event prevention application.	CEF	Upon request	Data availability (energy forecast)	Critical events

Scenario							
Scenario name:			Close to real-time Identification				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Upon request	Requests critical event forecasting	CEPA requests a critical event forecast operation from CEF, providing the necessary data.	DSO Toolbox Application (e.g. CEPA)	CEF	Network Sensing Data, Switchgear Status	
2	After 2	Power flow simulation request	CEF requests power flow simulation for all the energy values within the time horizon from PFS.	CEF	PFS	Power flow simulation request	
3	Upon request	Get PFS	PFS provides CEF with voltages and currents for all the	PFS	CEF	Power flow data	CEF_REQ_OPE_01

			samples within the horizon of the energy forecast provided.				
4	Once 3 is completed	Estimation of Critical events	CEF evaluates power flow results by comparing voltages and currents with operational (or physical) limits.	CEF	CEF	-	
5	Once 4 is completed	Estimation of Critical events	CEF send the list of critical events to CEPA.	CEF	DSO Toolbox Application (e.g. CEPA)	Critical events	
Scenario							
Scenario name:			Operational / Long-term identification				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1b	Upon request	Requests critical event forecasting	CEPA request a critical event forecast operation from CEF, providing the necessary data.	DSO Toolbox Application (e.g. CEPA)	CEF	Energy Forecast, Switchgear Status	

6.1.13.10 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
EnForecast	Energy Forecasting	Consumption and generation forecast for different assets of the grid.	
GridInfoTplg	Grid Asset Information & Topology	Technical characteristic of grid assets (e.g. nominal power) as well as their connectivity (grid topology).	CEF_REQ_INR_01
PfSimRe	Power flow simulation request	Request for power flow simulation, providing the necessary data for analysis.	
PfData	Power flow data	Voltages and currents in all the nodes and lines of the grid	
CrEvents	Critical Events	List of possible congestions and voltage variations out of limits with information on the occurrence and location	
NetworkData	Network Sensing Data	Voltage and current, or power, sensing data from the SCADA	
SwStatus	Switchgear Status	Status of switchgear equipment.	

6.1.13.11 Requirements

Requirements ID	Requirement name	Requirement description
CEF_REQ_INR_01	Grid information modelling standard	The grid asset information shall comply with the CGMES provide of CIM standard series.

6.1.14 SUC4 Grid operation planning

6.1.14.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Calculates an optimal dispatch schedule of both, the grid configuration and flexibility demand at specific points of the grid, to accomplish some pre-defined optimisation criteria during a specific time horizon.
Objective(s)	1) To optimally plan the operation of the distribution grid to avoid congestions (HLUC1) 2) To optimally plan the operation of the distribution grid to avoid voltage variations out of operational limits (HLUC2) 3) To optimally reconfigure the distribution grid once a fault has been detected (HLUC4) 4) To optimally plan the operation of the distribution grid for minimizing the network technical losses and increasing network operational efficiency (HLUC6)
Related high-level use case(s)	HLUC 01: Advanced network congestion management considering DER & grid flexibility (seasonal, day-ahead, etc) HLUC 02: Voltage compensation via reactive power procurement HLUC 04: Self-healing operation after critical event considering DER & grid flexibility HLUC 06: Leveraging DER flexibility towards enhancing network operational efficiency

6.1.14.2 Narrative of use case

Narrative of use case
Short description
Calculates a schedule for the distribution network operation leveraging both network reconfiguration and the energy flexibility which can be potentially provided by the DERs associated with the grid area of interest. Different pre-defined optimisation criteria (e.g. congestion avoidance) can be supported as well as different time horizons (near real-time, day-ahead).
Complete description
The grid operation planning (GOP) is an application that provides the schedule of the switching elements in the grid that allow grid reconfiguration and also a schedule of flexibility demand at specific points of the grid to optimally accomplish certain operational objectives. The application leverages the following information: • Grid operational status (see SUC 02: Grid Observability and Monitoring), utilizing smart meter data from AMI, or filed data from SCADA. • Topological characteristics of the distribution grid provided by the GIS • Generation and demand forecasting provided by EF.

The service gives response to two time-frame scheduling problems:

- *Day-ahead*: it provides the hourly schedule of switchgears and flexibility demand for a 24 hour time-horizon (e.g. starting at 01h the next day), when invoked.
- *Close to real time*: it provides a rescheduling of the grid and a demand of flexibility to be applied immediately in order to avoid a critical situation; i.e. congestions, unpermitted voltage excursion or a fault.

Depending on the optimization criteria and time frame different, GOP has to cope with different goals, according to the next table. Scenarios1.x deal with the near real time scheduling whereas scenarios 2.x are devoted to solve day-ahead planning problems. Differences among scenarios are given by both the origin and typology of input data and the fitness function used as optimisation objective.

<table>
<tr><th rowspan="2">Optimisation goal</th><th colspan="2">Time frame</th></tr>
<tr><th>Near real time</th><th>Day-ahead</th></tr>
<tr><td>Minimising the impact of critical events:
- Congestions
- Voltage variation</td><td>Scenario 1.1: Congestion avoidance (HLUC1)
Scenario 1.2: Voltage compensation (HLUC2)</td><td>Scenario 2.1: Prevention of critical events (HLUC1)</td></tr>
<tr><td>Maximal supply in presence of a fault</td><td>Scenario 1.3: Self-healing in presence of a fault (HLUC4)</td><td>-</td></tr>
<tr><td>Minimise energy exchange at substation level and peak shaving to increase grid efficiency and loss reduction</td><td>-</td><td>Scenario 2.2: Day ahead planning for efficient operation (HLUC6)</td></tr>
</table>

Thus, two main scenarios have been defined within the use case, for which different fitness function should be selected as parameter.

Scenario 1: Near real time scheduling

In this scenario the GOP gets data from monitoring infrastructure (i.e. SCADA) and provides a schedule for grid planning that maximises a specific fitness function.
The following particularities apply:

Scenario 1.1: Congestion avoidance (HLUC1).

Scenario 1.2: Voltage compensation (HLUC2): schedules demand of reactive power at specific points of the grid

Scenario 1.3: Self-healing in presence of a fault (HLUC4): This scenario aims to maximize the number of customers or power supplied during a fault. It follows fault detection.

It has some particularities that have to be addressed before the GOP:

- estimation of duration of the reconfiguration (from reconfiguration until end of repair), grid boundaries (lines, switching elements, sources and prosumers to be considered in the reconfiguration).

• For the proposed configuration, an estimation of demand and generation (EF) at critical points of the grid affected by the reconfiguration has to be forecasted. • The GOP will propose an schedule in which possible critical events will be evaluated **Scenario 2: Day-ahead grid scheduling** In this scenario the GOP gets as input the forecasts of energy forecast (generation and demand) at specific buses of the grid and information on the fitness function to be maximised. As a response, the GOP executes an optimisation algorithm and provides a schedule for the grid configuration and/or flexibility demand that maximises a specific fitness function. The following particularities apply: Scenario 2.1: Prevention of congestions: GOP is invoked by PUC01 Critical Event prevention and schedule of both grid configuration and flexibility demand is expected to avoid congestions. Scenario 2.2: Day ahead planning for efficient operation (HLUC6): GOP is invoked by PUC13 Minimizing network technical losses and it provides schedule of both Switchgears and flexibility needs for an optimal operation of the grid according to a pre-defined fitness function.

6.1.14.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_SUC04_1	Performance of planning	Measured in terms of improvement of the optimisation criteria.	all

6.1.14.4 Use case conditions

Use case conditions
Assumption(s)
• GIS provides grid asset information (including node connection of metering instruments and topology) • Energy forecasts, for day ahead planning, are supplied when invoking and the data provided is of enough quality in terms of accuracy, significance and completeness. • Grid asset information are utilized for the parameterization of the power flow simulation
Precondition(s)
• A fitness function (of a specific optimization scenario) is parameterised.

6.1.14.5 Further information to the use case for classification/mapping

Classification information

Relation to other use cases
PUC 01: Critical Event Prevention (invokes GOP) PUC 02: Grid Reconfiguration Schedule Dispatch (executes GOP output: switchgear activation) PUC 03: Requesting flexibility Services (manages GOP output: flexibility demand) PUC 07: Voltage compensation via reactive power control (invokes GOP) PUC 12: Self-Healing (invokes GOP) PUC 13: Minimizing network technical losses (invokes GOP)
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Optimisation, scheduling

6.1.14.6 Use case diagram

Diagram(s) of use case

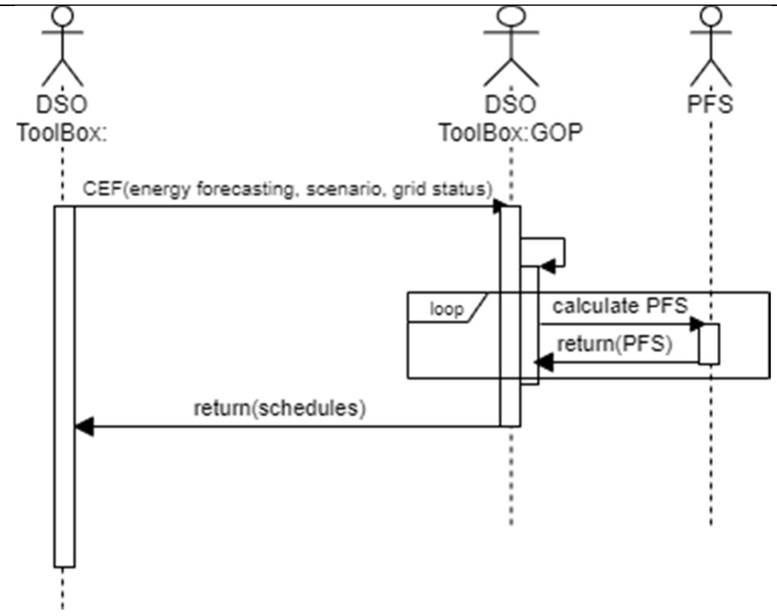


Figure 25 SUC4 Sequence diagram

6.1.14.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
DSO Toolbox	System	A suite of gird-oriented tools complementing DSO's legacy systems enabling more advanced observability and management of the distribution grid.	**DSO Toolbox**
Grid Operation Planner (GOP)	Application	Service in charge of planning the grid operation satisfying a predefined objective function that depends on the specific scenario. It determines the need of reconfiguration or flexibility. It is included in the DSO Toolbox.	Provides mitigation actions. Developed in the project.
Power Flow Simulator (PFS)	Application	An application that simulates power flows in the grid, predicting the voltage and current values of each bus for the following H-time. The calculation is based on the existence of a vector of measurements or predictions, related to demand and generation, for the same H-time.	Provides power flow simulation.

6.1.14.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	**Day-ahead grid scheduling**	Scheduling of grid configuration and flexibility demand for a day—ahead with a granularity of one hour.	GOP	Service requested by a DSO toolbox application	Available energy forecast data at different generation and demand points of the grid and the current grid configuration	Grid operation and flexibility demand planning for the next day with a granularity of 24h
2	**Near real time scheduling**	Scheduling of the grid configuration to avoid specific situation detected in real time.	GOP	Service requested by a DSO toolbox application	Available data from the monitoring system and current grid configuration	Grid operation and flexibility demand to be applied asap.

Scenario							
Scenario name:			Day-ahead grid scheduling				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Request service	Invoke GOP	Some application from the DSO ToolBox invokes GOP and sends the required inputs	DSO ToolBox Application	GOP	Energy forecasting Grid Asset Information & Topology Fitness function	CEF_REQ_INR_01
2	Upon request	Optimisation	Invokes optimisation algorithm	GOP	GOP		

3	During 2, periodically	Request Simulation	Power flow simulation	GOP	PFS	-	
4	During 2, periodically	Return Simulation	Power flow simulation	PFS	GOP	Power flow data	GOP_REQ_OPE_03
5	During 2, periodically	Evaluation	Evaluates results	GOP	GOP	-	
6	After 5	Return result	Sends schedule	GOP	DSO ToolBox Application	Switchgear Schedules, Flexibility needs	CEF_REQ_OPE_02
Scenario name:			Near real time scheduling				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1b	Request service	Invoke GOP	Some application from the DSO ToolBox invokes GOP and sends the required inputs	DSO ToolBox Application	GOP	Power at monitored points of the grid Grid Asset Information & Topology Fitness function	CEF_REQ_INR_01 CEF_REQ_OPE_04

6.1.14.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
GridInfoTplg	Grid Asset Information & Topology	Grid assets connectivity (grid topology).	REQ_INR_01
EnForecast	Energy Forecasting	Consumption and generation forecast for different assets of the grid.	
SwSchedule	Switchgear schedules	Required Switchgear reconfiguration	
FlexNeed	Flexibility Needs	Required flexibility with spatial as well as temporal characteristics	
PfData	Power flow Data	Voltages and currents in nodes and lines of the grid.	
FitFunction	Fitness function	Identifier of the specific scenario to be optimized according to time horizon and optimization goal.	

6.1.14.10 Requirements

Requirements ID	Requirement name	Requirement description
GOP_REQ_INR_01	Grid information modelling standard	The grid asset information shall comply with the CGMES provide of CIM standard series.
GOP_REQ_OPE_01	Time Horizon	The time horizon for assessing the grid status for critical events in the close to real time scenario is the last current instant represented by the last measurements of the grid.
GOP_REQ_OPE_02	Time Horizon	The time horizon for assessing the grid status for critical events in the operational/long term scenarios 24h with a granularity of one hour
GOP_REQ_OPE_03	Grid model	Grid model has to be implemented and ready for execution in the power flow simulator.
GOP_REQ_OPE_04	Monitoring data	Data provided from monitoring system in the near-to real time scenario is enough to observe possible critical

		events; i.e. congestions, voltage excursions or faults when performing the power flow simulation

6.1.15 SUC5 Asset monitoring and control

6.1.15.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Provides monitoring and control capabilities.
Objective(s)	1) Provide interfaces to assets 2) Provide state information of assets 3) Provide state control of assets
Related high-level use case(s)	HLUC 04: Leveraging the flexibility of the storage assets for real time detection of uncontrolled islanding HLUC 05: Flexibility exploitation for islanded microgrid operation HLUC 06: Reducing technical losses through local storage utilization

6.1.15.2 Narrative of use case

Narrative of use case
Short description
Asset monitoring and control provides the possibility for relevant actors to obtain information about the asset state, asset consumption and demand, as well as the possibility to control the asset state including its consumption.
Complete description
The provision of flexibility from a DER asset requires monitoring and control capabilities. Such capabilities can be partially or completely offered by the power electronic interfaces of the DERs. Access to that capabilities can realized either directly (ex. Modbus communication) or via web interfaces. In case that additional monitoring or control capabilities are needed for project purposes, these will be realized by the implementation of additional hardware and software i.e. DER Flexibility Service Provider Agents (FSPA) and Energy Management Systems (EMS). See further description in SUC 02: Grid Monitoring & Observability.

6.1.15.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**

KPI_SUC05_1	Asset state response time	Asset monitoring response time is defined and respected (within agreed limits).	2
KPI_SUC05_2	Asset control reaction time	Asset control reaction time is defined and kept (within agreed limits).	3

6.1.15.4 Use case conditions

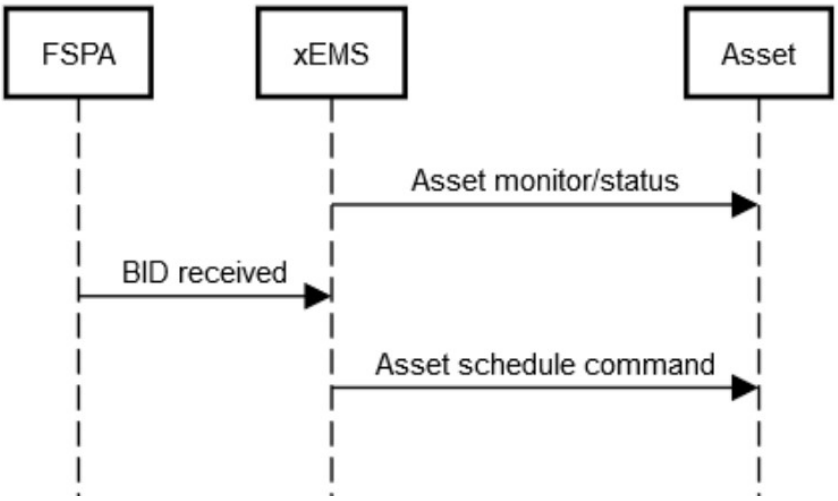
Use case conditions
Assumption(s)
• Assets are able to communicate with the relevant actors
Precondition(s)
• Assets have monitoring and control capabilities

6.1.15.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC 03: **Requesting flexibility Services** **PUC 04: Offering Flexibility Services** **PUC 08: Grid Monitoring and Islanding Detection** **PUC 29: Managing optimally microgrid's flexibility**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical

Further keywords for classification
Generation and demand energy forecasting

6.1.15.6 Use case diagram

Diagram(s) of use case
 Figure 26 SUC5 Sequence Diagram

6.1.15.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
DER	Device	Any device, load, battery, or generation asset that can change its consumption / injection of electricity upon request of the aggregator/prosumer, providing flexibility to the system	The actual asset to be monitored or controlled
Energy Management System (xEMS)	System	The system responsible for monitoring and controlling DER assets. EMS extracts the potential flexibility from DER assets with regards to their operational status and constraints. Different types of EMS are considered in the project: Factory Energy Management System (FEMS) controls factories and commercial buildings; Home Energy Management System (HEMS) controls residential locations; a Charging Energy Management System (CEMS)	Commercial and custom made by INEA / FLEX – with input from AAU

		controls electric vehicle charging stations, etc.	
Flexibility Service Providing Agent (FSPA)	Application	The agent responsible for transforming the available flexibility of an actor to a bidding strategy in respect to the requirements imposed by the flexibility markets or the bilateral agreements	Will communicate flexibility offer to the market. Developed in the project.

6.1.15.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Asset monitoring in close to real-time	Describes the collecting of asset prosumption and status information	xEMS	Periodic	Assets provide monitoring data for collection by xEMS.	Monitoring data collected.
2	Asset control of presumption	Describes the control of asset	xEMS	On demand	Flexibility Schedule received	Flexibility schedule executed

Scenario							
Scenario name:			Asset Monitoring				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Upon request	Collect asset information	xEMS requests asset prosumption and status information	Asset	xEMS	Power, Voltage, Current, Frequency, Asset status	Asset_REQ_DQ_01
2	Periodic/ Upon request	Send asset information	xEMS send asset prosumption and status information to FSPA	xEMS	FSPA	Asset monitor data	Asset_REQ_DQ_01
Scenario name:			Asset control				

Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements , R-ID**
1	Upon request	Receive flexibility siganl	xEMS receives flexibility schedule by FSPA	FSPA	xEMS	Flexibility Schedule	xEMS_REQ_INR_01
2	Upon request	Control asset presumption	xEMS commands asset to follow a prosumption profile xEMS receives flexibility schedule by FSPA	xEMS	Asset	Asset control command	xEMS_REQ_INR_01

6.1.15.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
AssetData	Asset monitor data	Power, Voltage, Current, Frequency, Asset status	xEMS_REQ_DQ_01
AssetCmd	Asset control command	Asset prosumption profile (TBD)	xEMS_REQ_INR_01
FlexSchedule	Flexibility Schedule	A concrete planned realization of a FlexOffer/flexibility offer	xEMS_REQ_INR_01

6.1.15.10 Requirements

Requirements ID	Requirement name	Requirement description
xEMS_REQ_DQ_01	Data quality, resolution and granularity	Asset monitoring relies on accurate data and status of different assets.
xEMS_REQ_INR_01	Asset presumption profile standard (TBD)	The asset control information shall comply with the FlexOffer standard.

6.1.16 SUC10 Fault detection and localization

6.1.16.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Leverages data grid monitoring data (e.g. from DS SCADA) to detect possible faults and isolate variables involved in the situation.
Objective(s)	1) Detect faults and misbehaviors in the grid 2) Isolate variables that better describe the faulty situation.
Related high-level use case(s)	HLUC 04: Self-healing operation after critical event considering DER & grid flexibility

6.1.16.2 Narrative of use case

Narrative of use case
Short description

Fault Detection consists in detecting faults by checking the consistency of monitoring data provided by the DS-SCADA, or equivalent instrumentation infrastructures (e.g. smart meters providing near real time data or synchrophasor networks). Once an inconsistency is detected it follows fault location.
Complete description
Fault Detection Application (FDA) provides fault detection and isolation (FDI) in order to enhance monitoring systems through automated fault detection. The application leverages monitoring data provided by the DS-SCADA or other instrumentation infrastructures (e.g. smart meters providing near real time data or synchrophasor networks) to identify the fault and its location. The procedure consists on checking consistency of monitoring data with respect to a model of the grid describing normal operation conditions. Once a fault is detected, the diagnosis procedure follows towards identifying fault location. This implies two stages: • Fault isolation: isolating the variables that cause the inconsistency in the monitoring system • Pinpoint location: properly identifying the faulty element, or alternatively, providing an estimation of the distance from the measuring point to the fault. In the context of FEVER, FDA leverages the following data : • Grid operational status (see SUC 02: Grid Observability and Monitoring), utilizing DS-SCADA or alternative monitoring infrastructure (i.e. PED and smart metering data) • Topological characteristics of the distribution grid provided by the GIS. The FDA will evaluate with the frequency and granularity of the input data. Different operation modes (scenarios) apply for the FDA. The training operation, for creating the fault detection models based on grid data and the monitoring operation, where the application monitors the data and detect the inconsistencies and possible fault locations. The different steps of scenarios, are described below: **Modelling (training) mode:** During the training phase, historic data representing normal operation conditions - gathered by the DS-SCADA- are utilized. This task is performed upon demand, periodically or triggered by some condition. The FDA is invoked by passing the historic grid sensor data and status of switchgears and trains one or several models, depending on the grid configuration. A different model will be required for every different combination of switchgears. **Monitoring (FDI) mode:** The FDI operation is performed periodically (optionally it can be executed upon demand) by sending the current vector of DS-SCADA data. The service evaluates the consistency of the data and in case of detecting a fault automatically performs the fault isolation, and returns the result. This mode requires the existence of the reference models previously created and trained.

6.1.16.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_SUC10_1	Performance of fault detection	Ratio of false alarms and missed detections	1,2

6.1.16.4 Use case conditions

Use case conditions
Assumption(s)
• DS-SCADA is available provides high quality grid monitoring data in terms of accuracy, significance and completeness. • DS-SCADA provides status of switchgears
Precondition(s)
• During monitoring operation, the existence of a previously trained model is required. • Historical monitoring data from the DS-SCADA are available

6.1.16.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
SUC 02: Grid Observability and Monitoring (provides input to FDA) **PUC 12: Self-Healing (receives FDA results)**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Fault detection

6.1.16.6 General Remarks

General Remarks
In FEVER the method proposed for fault detection and location is a data-driven method based on

multivariate statistics and projection methods. It means that the reference model built using the Principal Component Analysis (PCA) with datasets gathered during normal operation conditions (and periodically updated), and fault detection consist in analyzing the consistency of new data with this model. Two statistics, the Hotteling T^2 and the Square Prediction Eror (SPE) are used for this purpose. Once an observation is detected as faulty, the contribution analysis is used to isolated the variables responsible for the situation. Pinpoint location cannot be performed using only statistic models. It implies developing additional methods that use precise models of the grid and it is out of scope of this project.

6.1.16.7 Use case diagram

Diagram(s) of use case

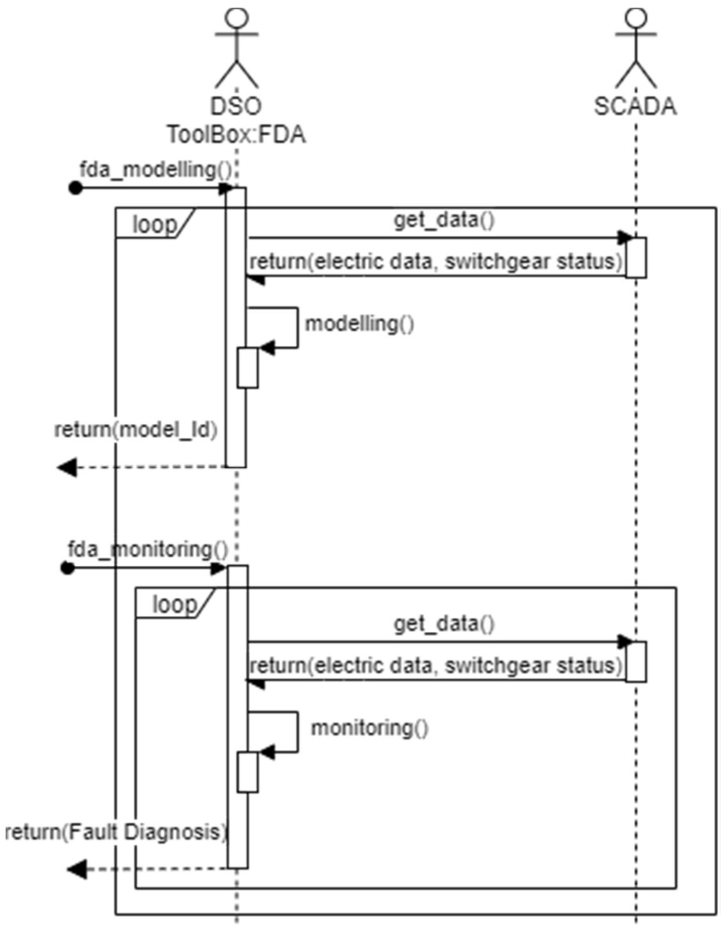


Figure 27 SUC10 - Sequence diagram (modelling and monitoring modes)

6.1.16.8 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**

Fault Detection Application (FDA)	Application	Application, in charge of orchestrating the process of fault detection and isolation	System under design.
Supervisory Control And Data Acquisition (DS SCADA)	System	A system in charge of overall monitoring and control of the distribution and transmission grid. It integrates communication, remote monitoring and control, signal processing and logic, and data storage functionalities. It includes a user interface called control center room.	Provides sensing data for the distribution grid. Enables switchgear schedule dispatch.
DSO Toolbox	System	A suite of gird-oriented tools complementing DSO's legacy systems enabling more advanced observability and management of the distribution grid.	

6.1.16.9 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Modelling	Describes the process for modelling normal operation conditions of the grid using statistical methods	FDA	Periodic Process	Available data from SCADA	Statistical model created
2	Monitoring	Describes the process for enhancing monitoring by providing fault detection and isolation capabilities.	FDA	Periodic Process	Existence of model Available data from SCADA	Fault diagnosis evaluation

Scenario							
Scenario name:			Modelling				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	modelling triggering	Start modelling	A DSO Toolbox Application launches statistical modelling process	DSO Toolbox Application	FDA	Identifier of variables	
2	Periodically or on demand	Request data to SCADA	Request historic data representative of recent normal operating conditions and the corresponding status of switchgear	FDA	DS SCADA		

3	Upon request	Get historic data and switchgear status	SCADA provides FDA with electric data at substations and switchgear status.	DS SCADA	FDA	Network Sensing Data Switchgear Status	
4	Once 3 is completed	Train statistical model	Invokes modelling procedures and calculates the fault detection statistical model	FDA	FDA		
5	Once 4 is completed	End of modelling	Returns a message and identifier informing that the modelling process has end	FDA	DSO Toolbox Application	Model Identifier	
Scenario name:			Monitoring				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Monitoring triggering	Start monitoring	A DSO Toolbox Application launches statistical monitoring process	DSO Toolbox Application	FDA	Model Identifier	
2	Periodically or on demand	Request data to SCADA	Request historic data representative of recent normal operating conditions and the corresponding status of switchgear	FDA	DS SCADA		
3	Upon request	Get real time data and current switchgear status	SCADA provides FDA with electric data at substations and switchgear status.	DS SCADA	FDA	Network Sensing Data, Switchgear Status	

4	Once 3 is completed	Perform fault detection and isolation	Invokes fault detection and isolation process	FDA	FDA	Fault Diagnosis	
5	Once 4 is completed	Fault Diagnosis Status	Returns the result of evaluating monitored data and informs of possible faults and identification of affected variables	FDA	DSO Toolbox Application	Fault Diagnosis	

6.1.16.10 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements** **R-ID**
FltVariable	Identifier of variables	Identifier of variables (or sources) from the SCADA that should be included in the model for fault detection	
FltModelId	Model Identifier	Identifier of the trained model for fault detection	
NetworkData	Network Sensing Data	Voltage and current, or power, sensing data from the SCADA	
SwStatus	Switchgear Status	Status of switchgear equipment	
FltDiagnos	Fault Diagnosis	Existence or not of a fault, type and list of involved variables.	

6.2 Flexibility management & trading

6.2.1 PUC3 Requesting flexibility services

6.2.1.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Define the process of requesting flexibility services, to be employed by a flexibility service consumer (e.g. DSO, BRP).
Objective(s)	1) Define a common unified way for accessing flexibility services. 2) Specify two ways for accessing flexibility services: a) through direct bilateral contracts with flexibility service providers and b) via a market 3) Specify the process of evaluating the amounts of delivered flexibility 4) Specify the process of settling requested flexibility
Related high-level use case(s)	HLUC 01: Advanced network congestion management considering DER & grid flexibility (seasonal, day-ahead, etc.) HLUC 05: Flexibility exploitation for islanded microgrid operation HLUC 08: Managing optimally microgrid’s flexibility

6.2.1.2 Narrative of use case

Narrative of use case
Short description
Flexibility service consumers (e.g., DSOs, BRPs) need to have access to flexibility services (e.g., for portfolio optimization, cost reduction, critical event mitigation). This requires (1) calculating the need for flexibility to request, (2) issuing a bid to a market or an explicit flexibility service request directly to a flexibility service provider; (3) validating the delivery of the flexibility service, (4) settling the delivered flexibility service based on either the bilateral contract or with respect to the market rules.
Complete description

When the need for flexibility (services) emerge (e.g., critical events occur or are expected), flexibility service consumers (e.g., DSOs, BRPs) can request flexibility services from flexibility service providers. Two different ways for accessing flexibility services need to be provided:

- **Direct** when services are requested directly from specific flexibility service providers (e.g., aggregators)
- **Indirect** when services are requested via a market.

In both cases, a unified way of accessing these services is desired so the same ICT stack can be (re-)used when new flexibility providers and/or markets need to be accessed.

To be able to define and exchange requests for flexibility in a unified way, the *FlexOffer concept* will be used. A visual representation of a FlexOffer (used for expressing flexibility needs) is shown in the figure below.

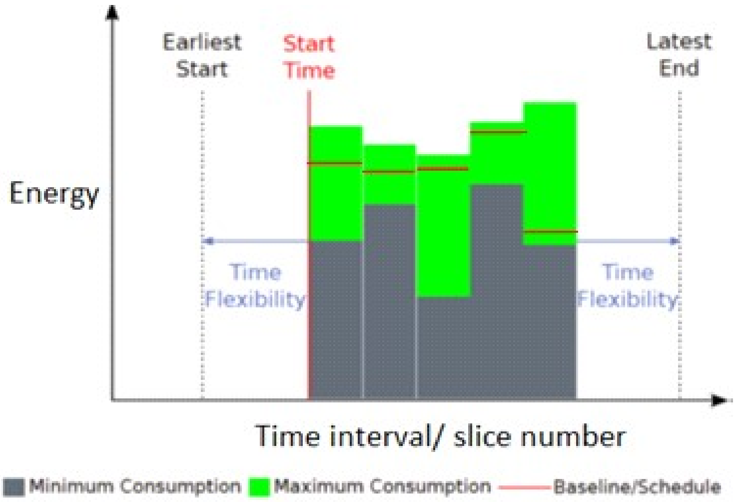


Figure 28 FlexOffer concept visual representation example

Each bar in the graph corresponds to a time slice (e.g., of 15 min duration). Each time slice is assigned a *baseline amount (shown in red),* which indicates the preferred energy amount requested at a particular time interval. If a flexibility service consumer tolerates some (marginal) deviations from this baseline, a FlexOffer allows defining *energy amount* and *time flexibility* bounds which allow restricting these deviations. Here, the lower part of the energy flexibility bounds (shown in green) defines the acceptable minimum amount of energy and the upper part represents the acceptable maximum amount of energy for each slice. Likewise, *time flexibility* indicates a time interval, from *earliest start time* to *latest end time,* in which the requested block of energy is allowed to be moved in time. Only specific time shifts and energy amounts that satisfy all energy amount and time flexibility constraints are considered *valid* fulfilments (schedules) of the FlexOffer. When needed, additional constraints (attributes) can be included into a FlexOffer, e.g. constraints on the location, the time

when the FlexOffer has to be accepted, assigned a schedule, etc. Thus, a flexibility service consumer (e.g., DSOs, BRPs) can express its needs to modify consumption/production patterns in a particular geographical area, irrespective of the concrete flexibility service providers. Requesting flexibility using FlexOffers involves a number of steps: (1) **Calculating flexibility needs** requires information from various operation planning and/or event detection systems (see SUC 02: Grid Observability and Monitoring, PUC01 Critical event Prevention) to forecasts flexibility needs on a daily basis. The forecasting timeframes range from short term to long term. (2) **Issuing a bid or explicit request, t**his task requires translating flexibility needs into the FlexOffer form and issuing it to the desired recipient, which can either be a dedicated FlexOffer-compliant flexibility market, or a specific flexibility service provider. In both cases, it is a Flexibility Agent (e.g., DSO-FSCA) which is responsible for realizing such FlexOffer exchange transactions and following the designated FlexOffer exchange protocol. (3) **Validating** the delivery of the flexibility service requires analyzing the actual consumption (production) profile (e.g., from DS SCADA and AMI) and then validating each flexibility request (FlexOffer) with respect to the conditions of the bilateral contract or market rules. (4) **Settling** involves paying the involved flexibility service providers their remunerations according to the conditions of the bilateral contract or market rules, while taking into account correctly (valid) and incorrectly executed requests.

6.2.1.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC03_1	Amount of requested energy flexibility	Expresses the total amount of energy deviation (ΔkWh) **requested** by a flexibility service consumer (e.g., DSO, BRP).	3-4
KPI_PUC03_2	Amount of delivered energy flexibility	Expresses the total amount of energy deviation (ΔkWh) **delivered** in a response to a flexibility request.	3-4
KPI_PUC03_3	Total flexibility request cost	Expresses the total flexibility service consumer (e.g., DSO, BRP) cost incurred for requesting flexibility services.	3-4

6.2.1.4 Use case conditions

Use case conditions
Assumption(s)
• Infrastructure and/or data for validating the fulfilment of flexibility service(-s) are in place.

• Connectivity between a Flexibility Agent (e.g., DSO-FSCA) and a Flexibility Providing Agent and/or a Flexibility Market is established.
Precondition(s)
• All information required for calculating flexibility needs is available • Contracts between a flexibility service consumer and a flexibility service provider (-s) and/or (a) market (-s) are in place and legally effective.

6.2.1.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
SUC 02: Grid Observability and Monitoring **SUC 03: Critical Event Forecasting** **PUC 01: Critical Event Prevention** **SUC 04: Grid Operation Planning** **PUC 04: Offering Flexibility Services** **PUC 06: Ex-post network performance assessment**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
flexibility, flexibility requesting, grid congestion, grid operational planning

6.2.1.6 Use case diagram

Diagram(s) of use case

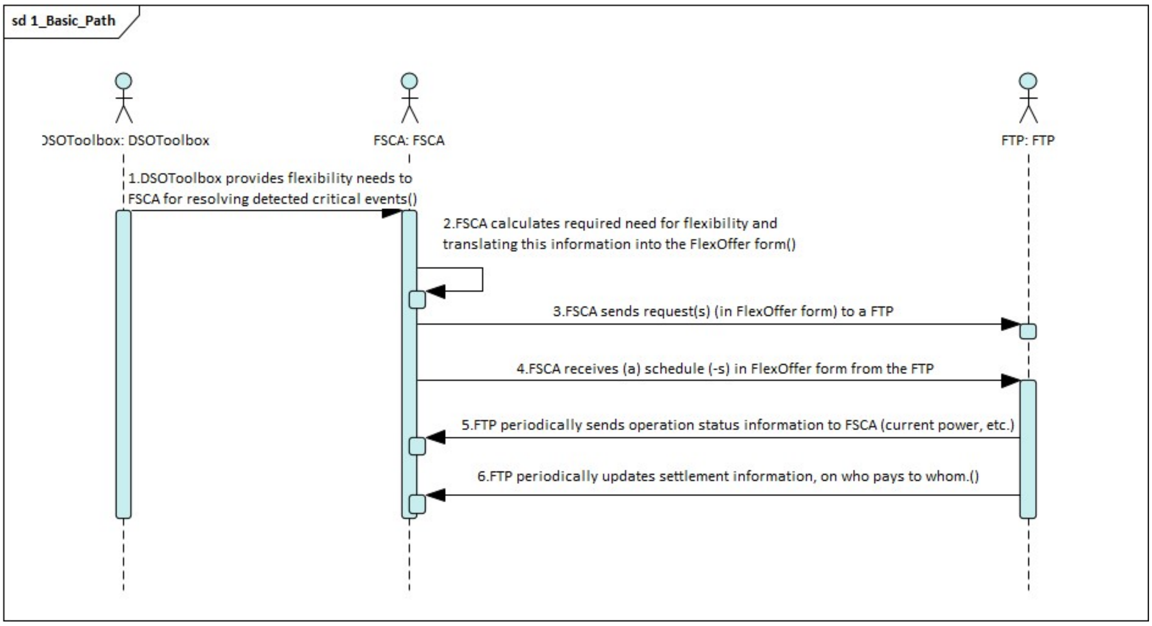


Figure 29 PUC3 Sequence Diagram

6.2.1.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Flexibility Service Consuming Agent (FSCA)	Application	The agent responsible for packing the flexibility needs of an actor into a standard FlexOffer form, and offering the FlexOffer with respect to the requirements imposed by the flexibility markets or the bilateral agreements	Will communicate flexibility request in FlexOffer form. Developed in the project.
Flexibility Service Providing Agent (FSPA)	Application	The agent responsible for transforming the available flexibility of an actor to a bidding strategy in respect to the requirements imposed by the flexibility markets or the bilateral agreements	Will communicate flexibility offer to the market. Developed in the project.
Flexibility Trading Platform (FTP)	Application	The system responsible for the trading of flexibility among different stakeholders	Developed in the project.

Balancing Responsible Party	Business actor	From the FEVER role model	Will use FSCA
System Operator	Business actor	From the FEVER role model	Will use FSCA
Flexibility Service Provider	Business actor	From the FEVER role model	Will provide flexibility assets
Generic Market Operator	Business actor	From the FEVER role model	
DSO Toolbox	System	A suite of gird-oriented tools complementing DSO's legacy systems enabling more advanced observability and management of the distribution grid.	Communicates flexibility needs to FSCA (trigger event)
Balancing Responsible Party Management System (BRP-MS)	System	The system managing BRP's portfolio including trading of energy and energy flexibility.	Communicates flexibility needs to FSCA (trigger event)

6.2.1.8 References

References						
No.	**Type**	**Reference**	**Status**	**Impact**	**Originator / Organization**	**URL**
1		Generation and evaluation of flex-offers from flexible electrical devices. In e-Energy 2017 - Proceedings of the 8th International Conference on Future Energy Systems (pp. 143-156). Association for Computing Machinery.		**FlexOffer concept**	Neupane, B., Siksnys, L., Pedersen, T. B.	https://doi.org/10.1145/3077839.3077850

6.2.1.9 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	DSO requesting flexibility via a market	DSO requests flexibility upon occurrence or detection of critical events	DSO Toolbox	Upon event detection	Event detected by a Critical Event Prevention Application (PUC01)	FlexOffers sent, FlexOffer schedules received, FlexOffer validated, flexibility services settled
2	BRP requesting flexibility via a market	BRP requests flexibility in order to optimize its portfolio, to minimize imbalances	BRPMS	Periodic Process	BRP is in a process of executing operational intra-day schedule	FlexOffers sent, FlexOffer schedules received, FlexOffer validated, flexibility services settled

Scenario							
Scenario name:			DSO requesting flexibility via the market				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1a	Periodic Process	Detect critical events	DSOToolbox provides flexibility needs to FSCA for resolving detected critical events	DSOToolbox (Critical Event Prevention Application)	Flexibility Service Consuming Agent (FSCA)	Flexibility Needs	
2	Upon event detection	Flexibility amount calculation	FSCA calculates required need for flexibility and translating this information into the FlexOffer form	FSCA	FSCA	-	

3	Upon completion of Nr 2	Flexibility exchange	FSCA sends request(s) (in FlexOffer form) to a Flexibility Trading Platform	FSCA	FTP	Flexibility Request	FSCA_REQ_INR_01
4	Upon completion of Nr 3-4	FlexOffer Schedule receive	FSCA receive (a) schedule (-s) in FlexOffer form from the	FTP	FSCA	Flexibility schedule (schedule to be executed by the highest bidder)	FSCA_REQ_INR_01
5	Periodic process during flexibility activation	Receive operation status	FTP periodically sends operation status information to FSCA (current power, etc.)	FTP	FSCA	Operation status (current power, status of flexibility request being executed, etc.)	
6	Periodic Process (e.g., every 1 hour)	Receive settlement information	FTP periodically updates settlement information, on who pays to whom.	FTP	FSCA	Settlement information (electronic invoice per participant)	
Scenario name:			BRP requesting flexibility via the market				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1b	Periodic Process	Ask for available flex sources for specific time	BRPMS provides a request for flexibility to the FSCA.	BRPMS	FSCA	Flexibility Need	

6.2.1.10 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
FlexOffer	Flexibility Offer	A FlexOffer which combines flexibility request requirements/ constraints with spatial and temporal characteristics	
FlexSchedule	Flexibility Schedule	A concrete planned realization of a FlexOffer/flexibility requirement	
OperStatus	Operation status	Operation status, including current and expected power; FlexOffer execution status, etc.	
FlexNeed	Flexibility Needs	Required flexibility with spatial as well as temporal characteristics	
FlexSettleInfo	Billing/settlement information	Settlement information (e.g. electronic invoice per participant)	

6.2.1.11 Requirements

Requirement Categories		
Categories ID	**Category name**	**Category description**
FSCA_REQ_INR_01	Compliant to the FlexOffer protocol	Flexibility information exchanged between parties should comply to the FlexOffer protocol specification [8]

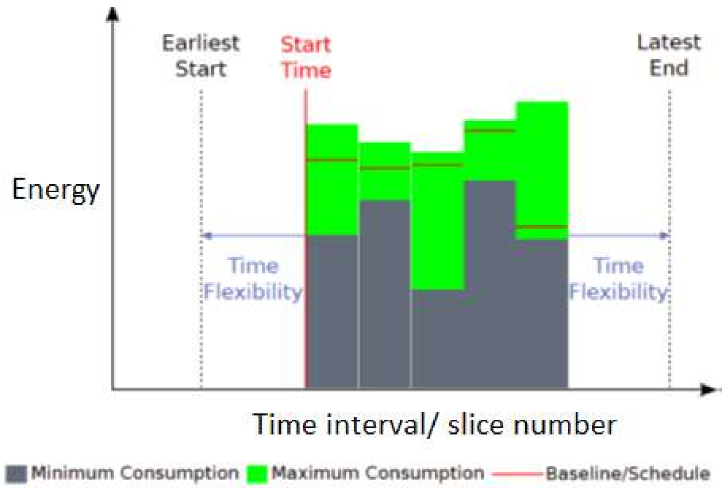
6.2.2 PUC4 Offering flexibility services

6.2.2.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Defines the process of offering flexibility for trading from one or more distributed energy resources (DERs). DER flexibilities can be offered either individually or in an aggregated way, e.g., when the trading risk of distributed resources is high enough due to their dynamic behavior or market participation of DER units individually is prohibited by the market rules.
Objective(s)	1) Define a common unified way for offering flexibility services. 2) Specify two ways for offering DER flexibility: directly or via an aggregator

	3) Define ways to evaluate amounts of offered and delivered flexibility 4) Define ways to remunerate flexibility
Related high-level use case(s)	HLUC 04: Leveraging the flexibility of the storage assets for real time detection of uncontrolled islanding HLUC 05: Flexibility exploitation for islanded microgrid operation HLUC 06: Reducing technical losses through local storage utilization HLUC 08: Economically optimised flexibility leveraging for a connected microgrid HLUC 09: Market mechanisms incentivising flexibility or other market tools for mitigating problems of the network HLUC 12: Creating dynamic tariffs based on flexibility use in the actual regulatory framework HLUC 13: Improving the outcome in flexibility by introducing sector coupling HLUC 14: Form a first example of a regional flexibility exchange model

6.2.2.2 Narrative of use case

Narrative of use case
Short description
This use case describes the process of how a party connected to the grid (i.e., a prosumer) can offer flexibility services to various stakeholders (e.g., DSOs, BRPs). This process involves a number of steps such as asset monitoring and control (SUC 05), flexibility extraction (SUC 06), aggregation of flexibility (optional, SUC 07), flexibility trading, schedule execution, and settlement. Different software systems are involved to carry out these steps.
Complete description
Parties connected to the grid (i.e., prosumers) can play the role of a Flexible Prosumer (see the FEVER role model) and offer their flexibility assets/DERs to various stakeholders (e.g., DSOs, BRPs). To be able to exchange information about energy flexibility in a common unified way, a FlexOffer will be used to represent flexibility of various flexibility assets/DERs. 

Each bar in the graph corresponds to a time slice of energy consumption (production), with the lower part representing the minimum amount of energy that a flexible resource needs to provide its service, and the upper part an interval within which it can adjust its consumption, while still satisfying functional constraints (e.g., comfort temperature). This is called (energy) *amount flexibility*. Another type of flexibility is *time flexibility*, also shown in the figure. Time flexibility is provided when an energy load can be shifted within a time interval, defined by an earliest start time at which the flexible resource can start its consumption, and a latest end time by which it should be done. When created, a FlexOffer is assigned a *baseline schedule* that corresponds to the consumption pattern that the associated flexible resource prefers to follow. Updated schedules can be assigned to the FlexOffers to modify the consumption behaviour of the flexible resource, utilizing its provided flexibility. More advanced forms of FlexOffers exist, which include additional types of flexibility/constraints.

Offering flexibility in the FlexOffer form involves a number of actors/software systems that carries out certain functions:

- Energy Management System (xEMS) monitors and manages the flexibility assets and extracts the potential flexibility that can be offered by the DERs considering their operational status and constraints. It also executes operation schedules that define desired energy amounts to be fulfilled by DERs / Prosumer, originating from the market orders.
- Flexibility Service Providing Agent (FSPA) manages the potential flexibilities identified by the xEMS and defines the bidding strategy in terms of complete or partial selection of potential flexibility to be traded, the temporal and spatial characteristics of the flexibility, and the respective activation cost. It translates the selected portion of flexibility into the FlexOffer form and sends the respective message to the flexibility trading platform (FTP). When a market order is received, FSPA generates the respective operation schedule and passes it to xEMS for execution. It also collects operational data from xEMS, validates execution of each FlexOffer, and visualizes rewards obtained for offering flexibility on the market.
- Flexibility Management System (FMS) is involved, e.g., when DER/flexible loads are relatively small, or when the risk of trading the DER's flexibility is high due to their dynamic behavior, or when the participation of individual DER units in the market is prohibited (typically because each individual one is too small). It manages collections of flexible loads and aggregates them towards a specific flexibility market. Different remuneration mechanisms are offered to end-Prosumers.
- Flexibility Trading Platform (FTP) receives flexibility offers in the FlexOffer form and processes them based on various market mechanisms.

6.2.2.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC04_1	Amount of offered energy flexibility	Expresses the total amount of energy flexibility (ΔkWh) **offered** by the flexibility service provider.	3
KPI_PUC04_2	Amount of delivered energy flexibility	Expresses the total amount of energy flexibility (ΔkWh) **delivered** in response to a market order	3

KPI_PUC04_3	Total reward	Expresses total reward obtained for issuing flexibility services.	4

6.2.2.4 Use case conditions

Use case conditions
Assumption(s)
• One or more systems can act as xEMS, FSPA, and FMS.
Precondition(s)
• xEMS is operational and is able to generate load/flexibility predictions and program the load to follow user-defined schedules; • FTP (Flexibility Trading Platform) is in place and ready to receive offers • A (legal) contract between a flexibility service provider and/or market operator and/or aggregator is established.

6.2.2.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC 04: Requesting flexibility services **SUC 05: Asset monitoring and control** **SUC 06: Extracting DER flexibility**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification

flexibility, flexibility offering, aggregation

6.2.2.6 Use case diagram

Diagram(s) of use case

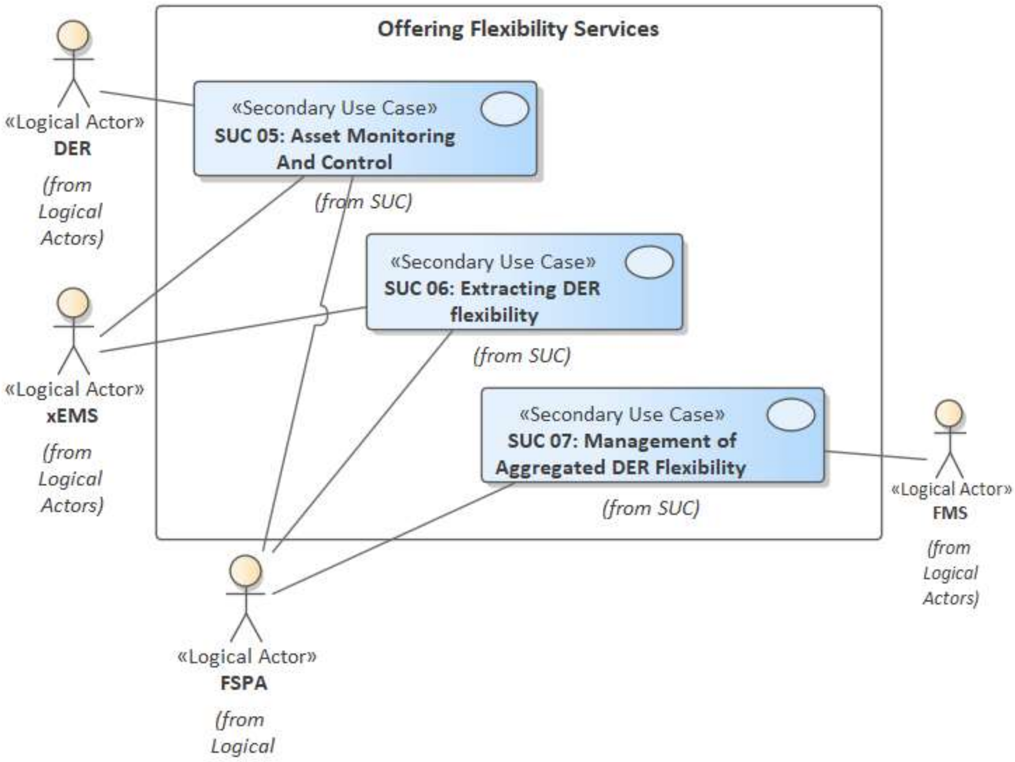


Figure 30 PUC04 UC Diagram

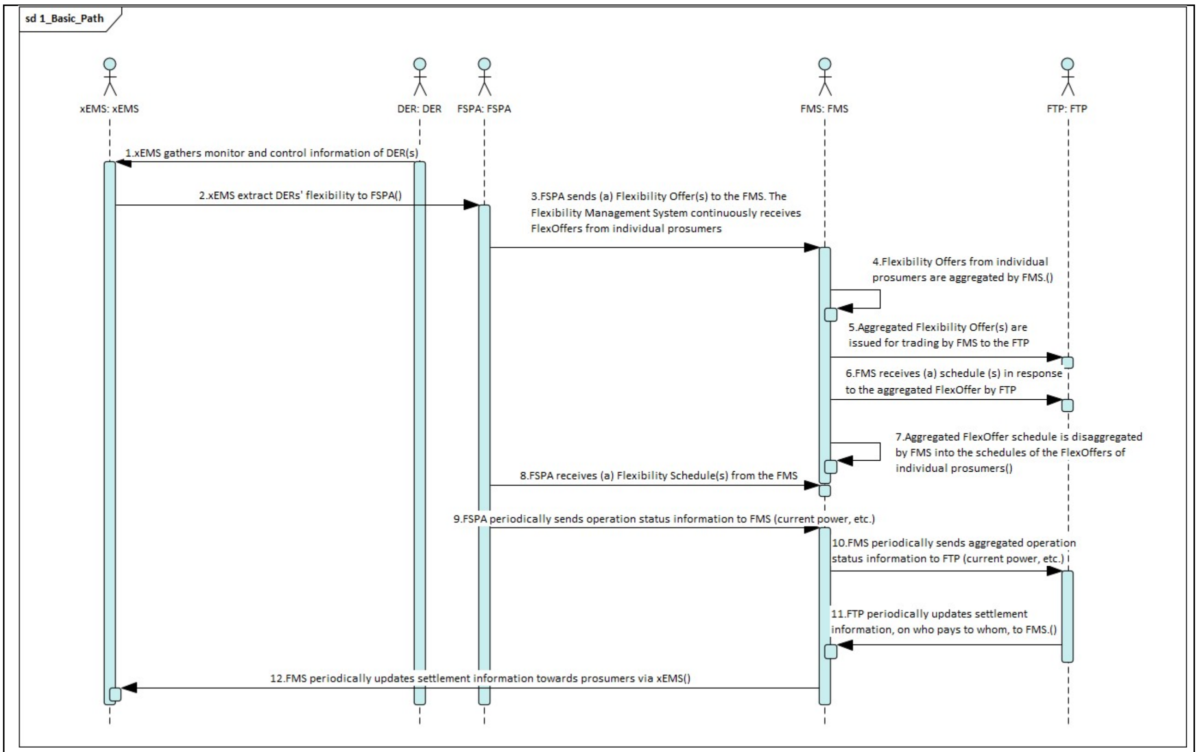


Figure 31 PUC4 Sequence Diagram

6.2.2.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
DER	Device	Any device, load, storage, or generation asset that can change its consumption / injection of electricity upon request of the aggregator/prosumer, providing flexibility to the system	Will be monitored and controlled
Energy Management System (xEMS)	System	The system responsible for monitoring and controlling DER assets. xEMS extracts the potential flexibility from DER assets with regards to their operational status and constraints. Different types of xEMS are considered in the project: Factory Energy Management System (FEMS) controls factories and commercial buildings; Home Energy Management System (HEMS) controls residential locations; a Charging Energy Management System (CEMS)	Commercial and custom made by INEA, AUU, FLEX

		controls electric vehicle charging stations, etc.	
Flexibility Service Providing Agent (FSPA)	Application	The agent responsible for transforming the available flexibility of an actor to a bidding strategy with respect to the requirements imposed by the flexibility markets or the bilateral agreements	Will communicate flexibility offer to the market. Developed in the project.
Flexibility Trading Platform (FTP)	Application	The system responsible for the trading of flexibility among different stakeholders	Developed in the project.
Flexibility Management System (FMS)	System	The system operated by the flexibility aggregator to aggregate / disaggregate flexibilities for trading purposes	Will be developed in the project by FLEX/ INEA/ AAU
Flexible Prosumer	Actor	A prosumer that owns and manages dispatchable DER generation/ consumption/ storage asset(s)	
Party Connected to the Grid	Actor	A party that contracts for the right to consume or produce electricity at an Accounting Point.	
Flexibility Aggregator	Role	A party that aggregates flexibility for usage by a service provider for flexibility services.	

6.2.2.8 References

References						
No.	**Type**	**Reference**	**Status**	**Impact**	**Originator / Organization**	**URL**
1		Generation and evaluation of flex-offers from flexible electrical devices. In e-Energy 2017 - Proceedings of the 8th International Conference on Future Energy Systems (pp. 143-156). Association for Computing Machinery.		**FlexOffer concept**	Neupane, B., Siksnys, L., Pedersen, T. B.	https://doi.org/10.1145/3077839.3077850

6.2.2.9 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Prosumer providing flexibility directly to a market	Prosumer offers flexibility directly to a market on periodic basis	Flexible Prosumer	Periodic Process	Contract with Market Operator	Flexibility Offers sent, Flexibility schedules received, Flexibility executed, Settlment
2	Prosumer providing flexibility (as FlexOffers) to the market via the aggregator	Prosumer offers flexibility to the market via the aggregator on a periodic basis	Flexible Prosumer	Periodic Process	Contract with Aggregator	Flexibility Offers sent, Flexibility schedules received, Flexibility executed, Settlment

Scenario							
Scenario name:			Prosumer providing flexibility directly to the market				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic Process	Asset Monitoring and Control	Monitor and control DER(-s)	DER	xEMS	Operation status, control signals, etc.	
2	Periodic Process	Extracting DER Flexibility	Extract DER flexibility	xEMS	FSPA	Load models, Flexibility constraints	

3	Upon completion of Nr 2	Flexibility exchange	Send (a) FlexOffer(s) to the Flexibility Trading Platform	FSPA	FTP	Flexibility Offer	FSPA_REQ_ INR _01
4	Upon completion of Nr 4	FlexOffer Schedule receive	Receive (a) FlexOffer schedule(s) from the Flexibility Trading Platform	FTP	FSPA	Flexibility schedule (schedule to be executed by the highest bidder)	FSPA_REQ_ INR _01
5	Periodic Process	Send operation status	FSCA periodically sends operation status information to FTP (current power, etc.)	FSPA	FTP	Operation status (current power)	
6	Periodic Process (e.g., every 1 hour)	Receive settlement information	Flexibility Trading Platform periodically updates settlement information, on who pays to whom.	FTP	FSPA	Settlement information (electronic invoice per participant)	
Scenario name:			Prosumer providing flexibility (as FlexOffers) to the market via the aggregator				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic Process	Asset Monitoring and Control	xEMS gathers monitor and control information of DER(-s).	DER	xEMS	Operation status, control signals, etc.	
2	Periodic Process	Extracting DER Flexibility	xEMS extracts DER flexibility to FSPA.	xEMS	FSPA	Load models, flexibility parameters and constraints	

3	Upon completion of Nr 2	Flexibility exchange	FSPA sends (a) Flexibility Offer(s) to the FMS. The Flexibility Management System continuously receives FlexOffers from individual prosumers.	FSPA	FMS	Flexibility Offer	
4	Periodic	Aggregate flexibility	Flexibility Offers from individual prosumers are aggregated by FMS.	FMS	FMS	Flexibility Offer	
5	Periodic	Trade aggregated flexibility	Aggregated Flexibility Offer(s) are issued for trading by FMS to the FTP.	FMS	FTP	Flexibility Offer (aggregates)	
6	Upon completion of Nr 6	FlexOffer Schedule receive	FMS receives (a) schedule (s) in response to the aggregated FlexOffer by FTP.	FTP	FMS	Flexibility Offer schedule (aggregated)	
7	Periodic Process	FlexOffer Schedule Disaggregation	Aggregated FlexOffer schedule is disaggregated by FMS into the schedules of the FlexOffers of individual prosumers.	FMS	FMS		
8	Upon completion of Nr 8	FlexOffer Schedule receive	FSPA receives (a) Flexibility Schedule(s) from the FMS.	FMS	FSPA	Flexibility Schedule (non-aggregated)	
9	Periodic Process	Send operation status	FSPA periodically sends operation status information to FMS (current power, etc.)	FSPA	FMS	Operation status (current power)	
10	Periodic Process	Send aggregated	FMS periodically sends aggregated operation status information to	FMS	FTP	Aggregated operation status (current power)	

		operation status	FTP (current power, etc.).				
11	Periodic Process (e.g., every 1 hour)	Receive settlement information	FTP periodically updates settlement information, on who pays to whom, to FMS.	FTP	FMS	Settlement information (electronic invoice per participant)	
12	Periodic Process (e.g., every 1 hour)	Receive settlement information	FMS periodically updates settlement information towards prosumers via xEMS	FMS	Prosumer (xEMS)	Settlement information (electronic invoice per participant)	

6.2.2.10 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
FlexOffer	Flexibility Offer	A FlexOffer which combines flexibility offer requirements/ constraints with spatial and temporal characteristics	
FlexSchedule	Flexibility Schedule	A concrete planned realization of a FlexOffer/flexibility offer	
OperStatus	Operation status	Operation status, including current and expected power; FlexOffer execution status, etc.	
FlexConstraints	Flexibility constraints	Time, energy, and total energy constraints, flexibility prices (e.g., EUR/ ΔkWh) and other parameters	
FlexAggSettleInfo	FMS billing/settlement information	KPIs and amount of rewards earned by prosumers for offering (and executing) flexibility.	
FlexSettleInfo	FTP billing/settlement information	Settlement information (e.g. electronic invoice per participant)	

6.2.2.11 Requirements

Requirements ID	Requirement name	Requirement description
FSPA_REQ_ INR _01	Compliant to the FlexOffer protocol	Flexibility information exchanged between parties should comply to the FlexOffer protocol specification [8].

6.2.3 PUC5 Flexibility Trading

6.2.3.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Defines the process of trading flexibility between prosumers and end-users (e.g. DSOs). The process is implemented using automatic trading algorithms; the exchange protocol is FlexOffer.
Objective(s)	1) Define rules of the local flexibility market operation 2) Define exchange protocol
Related high-level use case(s)	HLUC 01: Advanced network congestion management considering DER & grid flexibility (seasonal, day-ahead, etc) HLUC 04: Leveraging the flexibility of the storage assets for real time detection of uncontrolled islanding HLUC 05: Flexibility exploitation for islanded microgrid operation HLUC 06: Reducing technical losses through local storage utilization HLUC 08: Economically optimised flexibility leveraging for a connected microgrid HLUC 09: Market mechanisms incentivising flexibility or other market tools for mitigating problems of the network HLUC 12: Creating dynamic tariffs based on flexibility use in the actual regulatory framework HLUC 13: Improving the outcome in flexibility by introducing sector coupling HLUC 14: Form a first example of a regional flexibility exchange model HLUC 15: P2P flexibility trading (in Energy Communities)

6.2.3.2 Narrative of use case

Narrative of use case
Short description
Flexibility Trading Platform (FTP) provides a process for automatic flexibility trading between parties connected to the grid (prosumers) and various end-users, stakeholders (e.g. DSOs, BRPs). It is tightly coupled with the process for requesting flexibility services (PUC03) and offering flexibility services (PUC04). FTP supports provision of flexibility by different entities: Prosumer providing flexibility directly to the market or via an aggregator, whilst it can handle offers in both directions – increase or decrease of absorption/injection of energy from/to the grid.
Complete description
Flexibility Trading Platform (FTP) provides a process for automatic flexibility trading between parties connected to the grid (prosumers) and various end-users, stakeholders (e.g. DSOs, BRPs). It can handle offers in both directions – increase or decrease for absorption/injection of energy from/to the grid and supports multiple layers of flexibility offering; flexibility directly to the market by prosumers or via an aggregator (Flexibility Aggregator). FTP can perform many trades simultaneously and can, if the location information is part of the flexibility offer, differentiate between different locations on the grid. Market participants offer or request flexibility (PUC03 and PUC04 respectively) to the Flexibility Trading Platform (FTP) using FlexOffer protocol. Flexibility is described in time, energy, location, price and several time constraints. Participants offering flexibility services (e.g. prosumer) can issue any number of offers to the FTP, whilst offers are exchanged using Flexibility Service Provider Agent (FSPA). On the other hand, participants requesting flexibility provide their needs to FTP via Flexibility Service Consuming Agent (FSCA). Upon receiving, FTP validates the sent offer/request and rejects it, if any of the parameters is incorrect. If the offer is valid, FTP places it into the pool of flexibility. The offer will exist in the pool until the time, allowed by the time constraints. Afterwards, FTP will remove it automatically. Once the requesting offer is received from the end-user via FSCA component, the FTP will run the optimization algorithm, which will produce the most optimal configuration of all FlexOffers in all dimensions. The output from this algorithm is a schedule set for all activated FlexOffers. All prosumers and end-users are informed about the schedules using FSPA and FSCA components. FSPA components are also responsible for transcribing schedules to control signals and forwarding those signals to responsible systems (xEMS) for execution. After the execution is completed, FTP will gather metering information from FSPA components and validate the execution. This is done using characteristic energy profile, which is automatically constructed for each prosumer. The executed flexibility is the deviation from standard profile. FTP calculates these KPIs for each prosumer.

6.2.3.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC05_1	Prosumer reliability	Describes how well certain flexibility providers deliver the traded flexibility.	

6.2.3.4 Use case conditions

Use case conditions
Assumption(s)
• Market operation is enabled with some form of contracting among the different stakeholders • Controllability of flexible assets at prosumer level is enabled by xEMS • Energy metering information can be provided by FSCA components
Precondition(s)
• FSPA and FSCA systems in place and able to communicate with FTP • FTP (Flexibility Trading Platform) is in place and ready to receive offers • xEMS is operational and is able to generate load/flexibility predictions and program the load to follow user-defined schedules; • Contracts between a flexibility service consumer and a flexibility service provider (-s) and/or (a) market (-s) are in place

6.2.3.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC 03: Requesting flexibility services **PUC 04: Offering flexibility services** **SUC 06: Extracting DER flexibility**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
flexibility, flexibility offering, flexibility trading

6.2.3.6 Use case diagram

Diagram(s) of use case

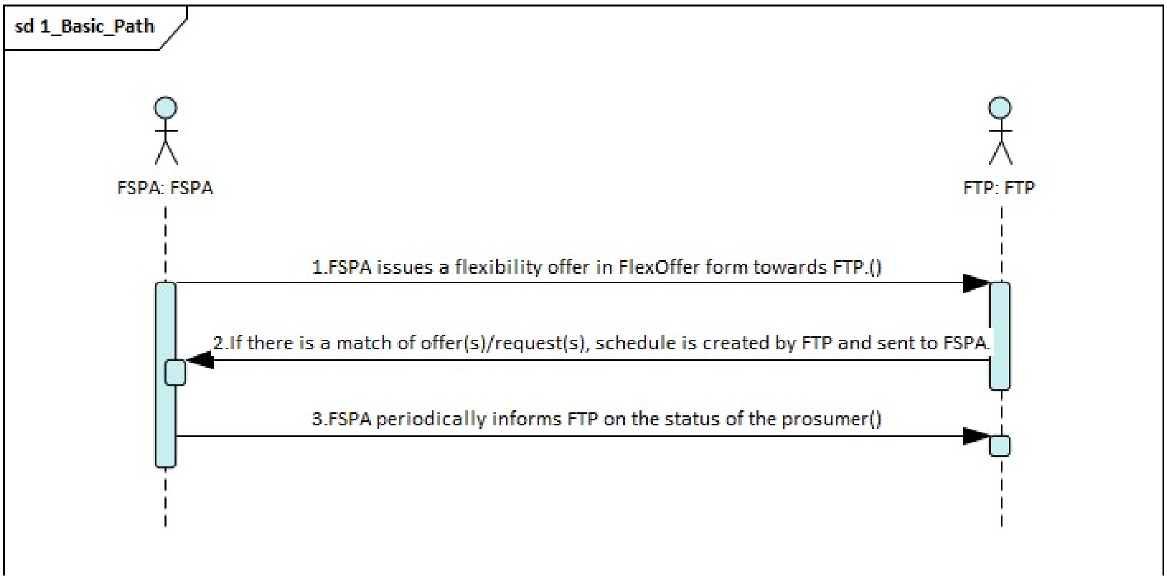


Figure 32 PUC5 Sequence diagram - Scenario 1

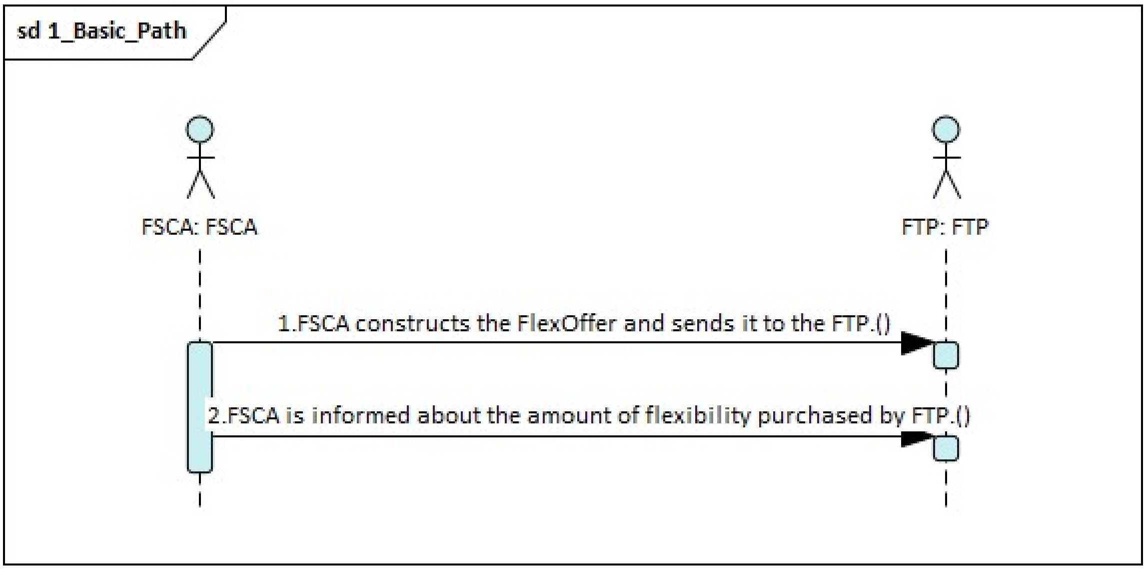


Figure 33 PUC5 Sequence Diagram - Scenario 2

6.2.3.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Flexibility Service	Application	Agent, responsible for issuing automatic bids on the FTP, based on the transients, predicted by the DSO Toolbox.	

Consuming Agent (FSCA)			
Flexibility Service Providing Agent (FSPA)	Application	The agent responsible for transforming the available flexibility of an actor to a bidding strategy with respect to the requirements imposed by the flexibility markets.	
Flexibility Trading Platform (FTP)	Application	The system responsible for the trading of flexibility among different stakeholders	
Flexible Prosumer	Actor	A prosumer that owns and manages dispatchable DER generation/ consumption/ storage asset(s)	
Party Connected to the Grid	Actor	A party that contracts for the right to consume or produce electricity at an Accounting Point.	
Flexibility Aggregator	Role	A party that aggregates flexibility for usage by a service provider for flexibility services.	

6.2.3.8 References

References						
No.	**Type**	**Reference**	**Status**	**Impact**	**Originator / Organization**	**URL**
1		Generation and evaluation of flex-offers from flexible electrical devices. In e-Energy 2017 - Proceedings of the 8th International Conference on Future Energy Systems (pp. 143-156). Association for Computing Machinery.		**FlexOffer concept**	Neupane, B., Siksnys, L., Pedersen, T. B.	https://doi.org/10.1145/3077839.3077850

6.2.3.9 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Offering flexibility	Prosumer offers flexibility directly to a market on periodic basis	FSPA	Periodic Process	Contract with Market Operator	FlexOffers sent, FlexOffer schedules received, FlexOffer executed, flexibility services settled
2	Buying flexibility	Flexibility procurer (e.g. DSO, BRP) puts the buying request to the FTP	FSCA	Need for flexibility (e.g. predicted transient in the grid for DSO, balancing need for BRP)	Contract with Market Operator	Flexibility delivered and validated

Scenario							
Scenario name:			Prosumer providing flexibility directly to the market				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements , R-ID**
1	On change	Status change	When consumption/production amount changes,	FSPA	FTP	Flexibility Offer	FTP_REQ_ INR _01

			prosumer (FSPA) issues a flexibility offer in FlexOffer form towards FTP.				
2	On change	Flex bought	If the offer from DSO matches the offer from step 1, schedule is created by FTP and sent to FSPA.	FTP	FSPA	Flexibility schedule	FTP_REQ_ INR _01
3	Periodic	Operation Info	FSPA periodically informs FTP on the status of the prosumer	FSPA	FTP	Operation status	
Scenario name:			Prosumer providing flexibility (as FlexOffers) to the market via the aggregator				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements , R-ID**
1	On change	Predicted grid transient	DSO toolbox predicts the transient and informs FSCA with details (amount, location, ...). FSCA constructs the FlexOffer and sends it to the FTP.	FSCA	FTP	Flexibility Offer	FTP_REQ_ INR _01
2	On change	Flex bought	FSCA is informed about the amount of flexibility purchased by FTP.	FTP	FSCA	Flexibility Schedule	FTP_REQ_ INR _01

6.2.3.10 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
FlexOffer	Flexibility Offer	A FlexOffer which combines flexibility offer requirements/ constraints with spatial and temporal characteristics	FTP_REQ_ INR _01
FlexSchedule	Flexibility Schedule	A concrete planned realization of a FlexOffer/flexibility offer	FTP_REQ_ INR _01
OperStatus	Operation status	Operation status, including current and expected power; FlexOffer execution status, etc.	FTP_REQ_ INR _01

6.2.3.11 Requirements

Requirements ID	Requirement name	Requirement description
FTP_REQ_ INR _01	Compliant to the FlexOffer protocol	Flexibility information exchanged between parties should comply to the FlexOffer protocol specification.

6.2.4 PUC22 Control EVs

6.2.4.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Describes the process from managing EV charging, in order to leverage flexibility.
Objective(s)	1) Charge an EV to the desired SoC 2) Provide flexibility
Related high-level use case(s)	HLUC 06 - Leveraging DER flexibility towards enhancing network operational efficiency HLUC 13 - Improving the outcome in flexibility by introducing sector coupling

6.2.4.2 Narrative of use case

Narrative of use case
Short description
EV pose a promising asset of flexibility. The described EV charging process charges EVs to their desired SoC and provides flexibility using EV chargers (EVSE) and the traction battery of EVs.
Complete description
The EV charger (EVSE) is a system controlling the charging of EV. EVSE contains an EV Energy Management System (EV EMS). A novel EV charging strategy will be implemented to provide flexibility using the traction battery of EVs (eg. V2G), while respecting the charging preferences (e.g. desired SoC, departure time) of the EV user. The EVSE shall communicate with external stakeholders for providing flexibility through the Flexibility Service Providing Agent (FSPA). This agent enables the EV charger to communicate with flexibility markets (FTP) or Flexibility Management Systems (FMS) of aggregators or even to the DSO control centre (in critical circumstances), enabling the leveraging of EV flexibility. Process is executed through the following steps: • Upon plug-in of the EV at the EVSE the relevant charging process information is communicated to the EVSE (for instance SoC). Additional information like target SoC, desired departure time, vehicle id (type) might be also be made available to the EVSE. • EVSE starts charging the EV according to a defined baseline charging strategy. • EVSE communicates the charging process information to FSPA and FSPA calculates the available flexibility. • FSPA provides a flexibility bid to the FTP or FMS, which upon clearance communicates back the flexibility schedule • FSCA provide the schedule to EVSE which applies the proper control actions to the charging process.

6.2.4.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC22_01	Target SoC reached	Expresses the percentage of target SoCs reached.	1
KPI_PUC22_02	Economic benefit of using FEVER EV charging	Expresses the economic benefit of using FEVER EV charging.	1,2

6.2.4.4 Use case conditions

Use case conditions

Assumption(s)
- Bilateral contracts between the DSO and the EVSE owners for the provision of monitoring and control capabilities from the EVSE directly to the DSO are important for the realization of this use case - EVs are able to communicate with EVSE. - EVSE are able to set charging power of EV - SoC (or equivalent attribute) of EV is communicated to EVSE - Charging preferences (e.g. SoC, Target SoC, desired departure time) are communicated to the EVSE - EVSEs can be commanded to reduce or increase their exchanged power
Precondition(s)
- All devices/applications are online and working. - FSPA is running.

6.2.4.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
SUC06 Extracting DER Flexibility **PUC03 Requesting flexibility services**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
EV charging, V2G

6.2.4.6 Use case diagram

Diagram(s) of use case

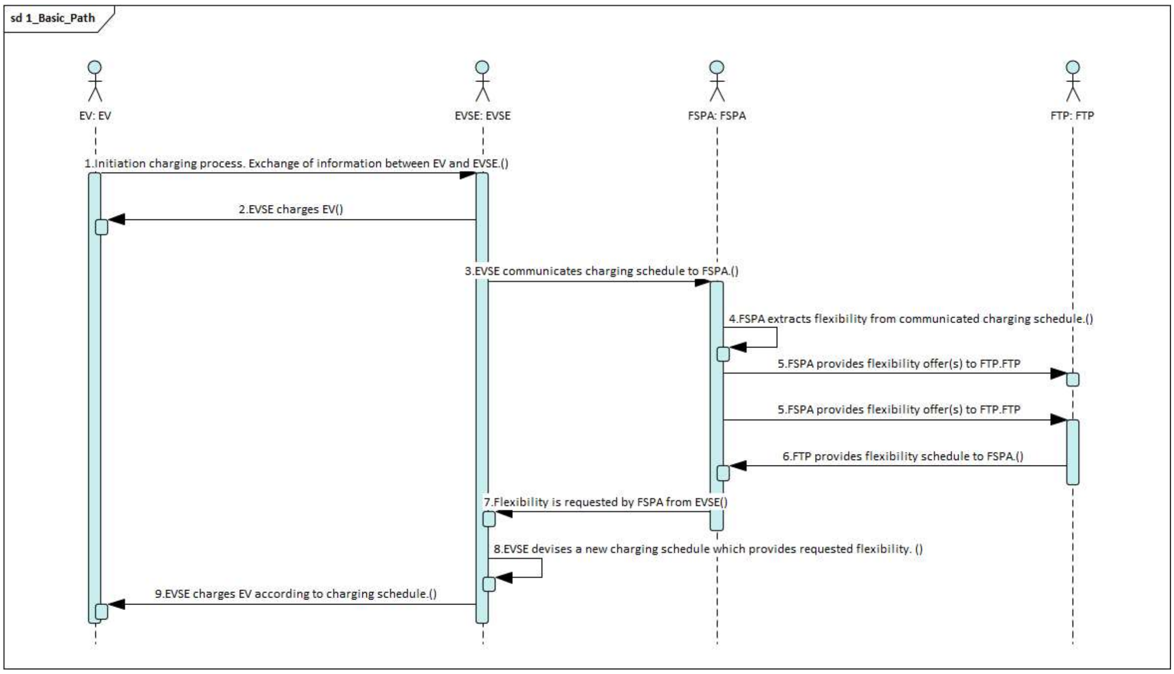


Figure 34 PUC22 Sequence Diagram

6.2.4.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Electric Vehicle (EV)	Device	Electric vehicle.	Will act as the controllable asset
Electric Vehicle Supply Equipment (EVSE)	Device	Electric vehicle supply equipment.	Implements the novel EV charging strategy will be implemented
Flexibility Service Providing Agent (FSPA)	Application	The agent responsible for transforming the available flexibility of an actor to a bidding strategy in respect to the requirements imposed by the flexibility markets or the bilateral agreements	Handles flexibility relate communications.
Flexibility Trading Platform (FTP)	Application	The system responsible for the trading of flexibility among different stakeholders	

Flexibility Management System (FMS)	Application	The system operated by the flexibility aggregator to aggregate / disaggregate flexibilities for trading purposes.	

6.2.4.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	EV charging	Describes the process of charging an EV and providing flexibility.	EVSE	Plug-in of electric vehicle	Available data for analysis from EV. Information about EV (capacity, charging behavior, target SoC)	EV charged to target SoC.

Scenario							
Scenario name:			EV charging				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Upon Plug-in of EV	Initiate charging process	Initiation charging process. Exchange of information between EV and EVSE.	EV	EVSE	EV data	REQ_DQ_01
2	Upon Plug-in of EV	Start charging process	EVSE charges EV	EVSE	EV	EVSE charging data	REQ_DQ_01

3	Upon Plug-in of EV	Communicate charging schedule	EV EMS communicates charging schedule to FSPA.	EVSE	FSPA	EV charging schedule	REQ_DQ_01
4	Upon charging schedule communi cation	Flexibility extraction	FSPA extracts flexibility from communicated charging schedule.	FSPA	FSPA	-	
5	Upon flexibility extraction	Flexibility biding	FSPA provides flexibility offer(s) to FTP.	FSPA	FTP	Flexibility Offer	
6	Upon activation	Flexibility scheduling	FTP provides flexibility schedule to FSPA.	FTP	FSPA	Flexibility Schedule	
7	Upon Flex offer request	Charging schedule calculation with flexibility execution	Flexibility is requested by FSPA from EVSE	FSPA	EVSE	Flexibility Request	
8	Upon charging schedule calculatio n	Charging schedule communicatio n	EVSE devises a new charging schedule which provides requested flexibility.	EVSE	EVSE	EV charging schedule	REQ_DQ_01
9	Upon charging schedule communi cation	Charging schedule is executed. EV is charged.	EVSE charges EV according to charging schedule.	EVSE	EV	EVSE charging data	REQ_DQ_01

6.2.4.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
EvData	EV data	SoC, Target SoC, EV type	EV_REQ_DQ_01
EvChargingData	EVSE charging data	Power set point, maximum charging current	EV_REQ_DQ_01
EvSchedule	EV charging schedule	Power set-points with time information	EV_REQ_DQ_01
FlexRequest	Flexibility request	A concrete planned realization of a flexibility offer	
FlexOffer	Flexibility Offer	A FlexOffer which combines flexibility offer requirements/ constraints with spatial and temporal characteristics	FTP_REQ_ INR _01
FlexSchedule	Flexibility Schedule	A concrete planned realization of a FlexOffer/flexibility offer	FTP_REQ_ INR _01

6.2.4.10 Requirements

Requirements		
Requirements ID	**Requirement name**	**Requirement description**
EV_REQ_DQ_01	Data quality, resolution and granularity	EV charging and scheduling relies on accurate data.
EV_REQ_ INR _01	Compliant to the FlexOffer protocol	Flexibility information exchanged between parties should comply to the FlexOffer specification.

6.2.5 PUC27 Managing BRP's portfolio

6.2.5.1 Scope and objectives of use case

Scope and objectives of the use case

Scope	The scope of this use case is the development of BRP's management system as an automated flexibility trading system. The BRP's management system should be enhanced with a trading mechanism which matches the flexibility needs of the BRP with the flexibility bids offered by the dispatchable consumption/production assets owned by the members of its balancing group.
Objective(s)	1) Automate flexibility trading for BRP 2) Make balancing of balance group more efficient
Related high-level use case(s)	HLUC 13: Improving the outcome in flexibility by introducing sector coupling

6.2.5.2 Narrative of use case

Narrative of use case
Short description
In FEVER project, the potentials from the exploitation of the flexibility offered by the balancing group is the main scope. Given that the exploitation of the balancing group's flexibility is more cost-efficient solution than the other market alternatives, the development of the respective flexibility market mechanisms enabling the flexibility trading within the balancing area is necessary. The Balance Responsible Party Management System (BRP-MS) shall leverage automatic flexibility trading provided by the Flexibility Trading Platform (FTP) to balance balance its group more efficiently.
Complete description
According to the Harmonized Electricity Market Role Model, the Balance Responsible Party (BRP) is the party that has a contract proving financial security and identifying balance responsibility with the Imbalance Settlement Responsible of the Scheduling Area entitling the party to operate in the market. The meaning of the word "balance" in this context signifies that the quantity contracted to provide or to consume must be equal to the quantity really provided by or consumed within its balancing group. In case of imbalances, the energy gap between the market-agreed energy profile and the real can be adjusted by the BRP either via intra-day or balancing markets. In FEVER project, the potentials from the exploitation of the flexibility offered by the balancing group is the main scope. Given that the exploitation of the balancing group's flexibility is more cost-efficient solution than the other market alternatives, the development of the respective flexibility market mechanisms enabling the flexibility trading within the balancing area is necessary. The BRP's Management System (BRP-MS) should be enhanced with a trading mechanism which matches the flexibility needs of the BRP with the flexibility bids offered by the dispatchable consumption/production assets owned by the members of its balancing group. A trading mechanism provided by the Flexibility Trading Platform (FTP), shall enable the BRP to leverage the flexibility of assets part of its balancing group, provided by flexible prosumers or aggregators in the market.

6.2.5.3 Key performance indicators

Key performance indicators

ID	Name	Description	Reference to mentioned use case objectives
KPI_PUC27_1	Daily Number of interventions	The number of interventions within 24 h to compensate for deviations from planning.	1,2
KPI_PUC27_2	Amount of needed energy flexibility	The amount of energy flexibility needed by the BRP management system over a given period of time e.g. day or month (tbd).	1,2
KPI_PUC27_3	External procurement	Internal prioritization of own generation, storage and flexibility depending on price signals; External procurement below the specified value.	2

6.2.5.4 Use case conditions

Use case conditions
Assumption(s)
• BRP has automated balancing group management implemented (BRPMS) • BRP's energy schedule is already defined • BRP's unbalances have been identified • An automated flexibility trading system is implemented (FTP) • DSO needs to provide information on the share of energy within the distribution area (physical) that is not consumed from the balancing group of the BRP • FTP is able to receive flexibility offers from assets of different energy sectors, i.e. electricity, gas, transportation etc.
Precondition(s)
• Data on daily procurement are available (day-ahead planning) • FTP is operational and able to receive requests for flexibility from BRPMS

6.2.5.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
Includes PUC05: Flexibility Trading **Invokes PUC03: Requesting Flexibility Services**
Level of Depth

Detailed
Prioritization
Mandatory, high
Generic, regional or national relation
National, regional
Nature of the use case
Business/market
Further keywords for classification
Flexibility trading, Balancing

6.2.5.6 Use case diagram

Diagram(s) of use case

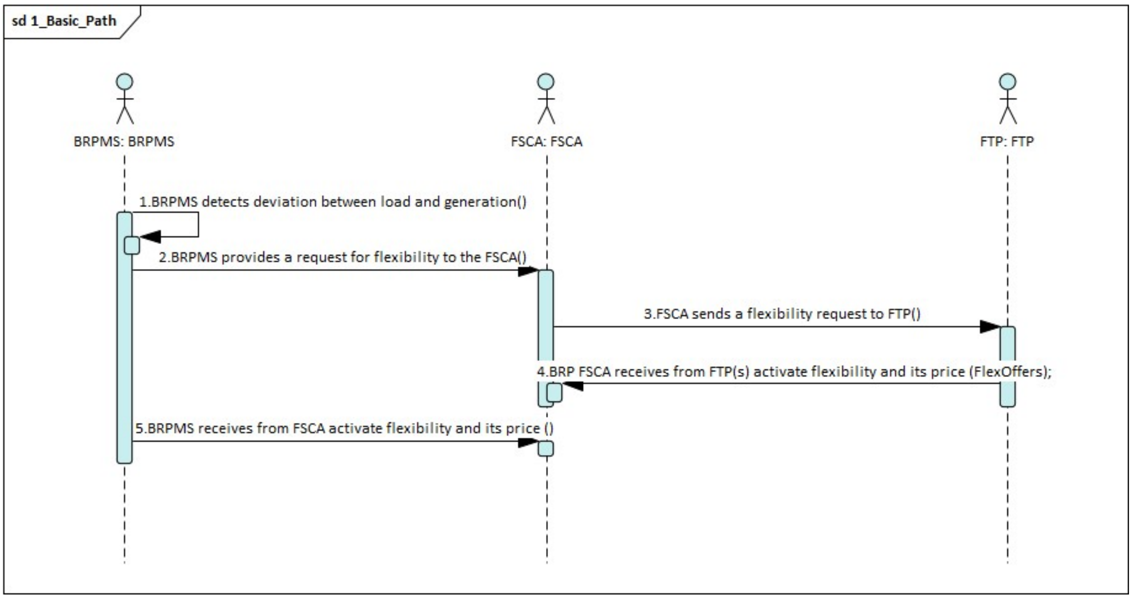


Figure 35 PUC27 Sequence Diagram – Scenario 1

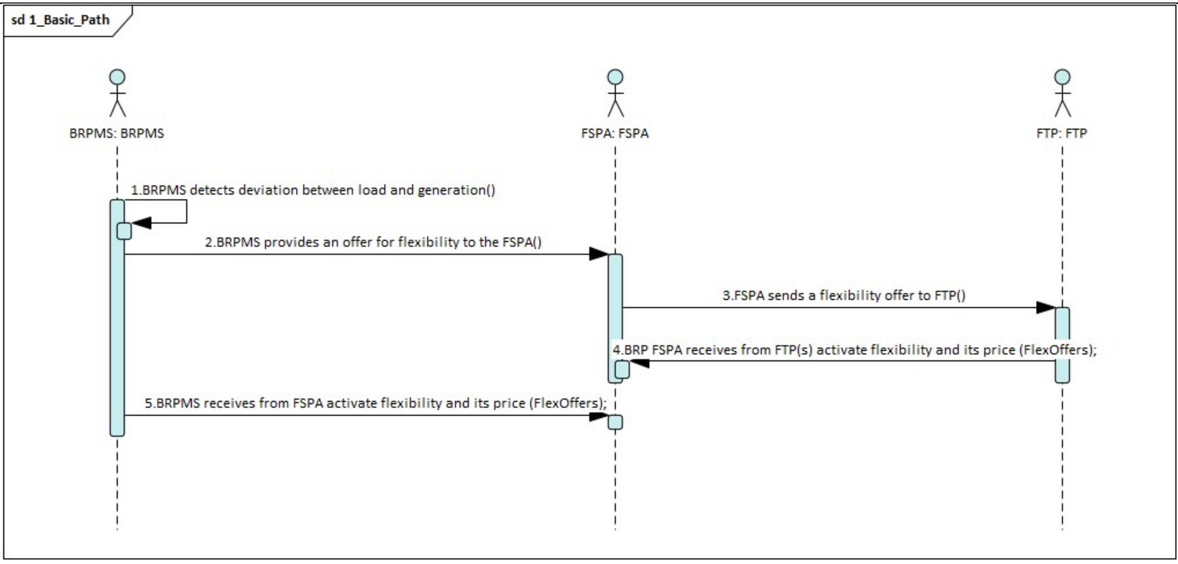


Figure 36 PUC27 Sequence Diagram – Scenario 2

6.2.5.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Balancing Responsible Party Management System (BRP-MS)	System	The system managing BRP's portfolio including trading of energy and energy flexibility.	Communicates flexibility needs
Flexibility Trading Platform (FTP)	Application	The system responsible for the trading of flexibility among different stakeholders	Provides a process for automatic flexibility trading between parties
Flexibility Service Consuming Agent (FSCA)	Application	Agent, responsible for issuing automatic bids on the FTP, based on requests of BRPMS.	Enables communication of BRP-MS and FTP
Flexibility Service Providing Agent (FSPA)	Application	Agent, responsible for issuing automatic bids on the FTP, based on offers of BRPMS.	Enables communication of BRP-MS and FTP

Balancing Responsible Party (BRP)	Business Entity	A party with reserve-providing units or reserve-providing groups able to provide balancing services to one or more Load-Frequency Control (LFC) Operators	Requests flexibility via the FTP
Flexibility Aggregator	Business Entity	A party that aggregates flexibility for usage by a service provider for flexibility services.	Provides flexibility via the FTP
Flexible Prosumer	Business Entity	A prosumer that owns and manages dispatchable DER generation/ consumption/ storage asset(s)	Provides flexibility via the FTP

6.2.5.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Balancing BRP group by buying flexibility from market.	BRP needs flexibility	BRP-MS	Deviation from plan	• Contract with market operator • FTP has an adequate flexibility pool	• Flexibility received • Balancing group balanced
2	Balancing BRP group by selling flexibility at market.	BRP offers flexibility	BRP-MS	Deviation from plan	• Contract with market operator • BRP has an adequate flexibility pool or excess flexibility • Flexibility bought which is then not needed	• Flexibility sold • Balancing group balanced

Scenario							
Scenario name:			**Balancing BRP group by buying flexibility from market.**				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**

1	Triggered by event (periodic check)	Flexibility needed for BRP	BRPMS detects deviation between load and generation.	BRPMS	BRPMS	-	
2	Upon completio n of 1	Ask for available flex sources for specific time	BRPMS provides a request for flexibility to the FSCA.	BRPMS	FSCA	Flexibility Need	
3	Upon completio n of 2	Request flexibility form the market	FSCA sends a flexibility request to FTP.	FSCA	FTP	Flexibility Need	BRPMS_REQ_ INR_1
4	Upon completio n of 3	Receive activated flexibility	BRP FSCA receives from FTP(s) activate flexibility and its price (FlexOffers);	FTP	FSCA	Flexibility Schedule	BRPMS_REQ_ INR_1
5	Upon completio n of 3	Receive activated flexibility	BRPMS receives from FSCA activate flexibility and its price (FlexOffers);	FSCA	BRPMS	Flexibility Schedule	
Scenario name:			**Balancing BRP group by selling flexibility at market.**				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Triggered by event (periodic check)	Excess Flexibility bought by BRP	BRPMS detects deviation between load and generation	BRPMS	BRPMS	-	

2	Upon completion of 1	Offer available flex sources for specific time	BRPMS provides an offer for flexibility to the FSPA	BRPMS	FSPA	Flexibility Offer	
3	Upon completion of 2	Offer flexibility to the market	FSPA sends a flexibility offer to FTP	FSPA	FTP	Flexibility Request	BRPMS_REQ_INR_1
4	Upon completion of 3	Offer activated flexibility	BRP FSPA receives from FTP(s) activate flexibility and its price (FlexOffers);	FTP	FSPA	Flexibility Schedule	BRPMS_REQ_INR_1
5	Upon completion of 3	Receive activated flexibility	BRPMS receives from FSPA activate flexibility and its price (FlexOffers);	FSPA	BRPMS	Flexibility Schedule	

6.2.5.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
FlexNeed	Flexibility Need	Requirements on flexibility with spatial and temporal characteristics	
FlexRequest	Flexibility Request	A concrete planned realization of a flexibility offer	
FlexSchedule	Flexibility Schedule	A concrete planned realization of a flexibility request	

6.2.5.10 Requirements

Requirements ID	Requirement name	Requirement description
BRPMS_REQ_ INR_1	Compliant to the FlexOffer protocol	Information on and description of flexibility should be made according to FlexOffer specifications
BRPMS_REQ_ INR_2	Interfacing with FSCA	The FSCA should provide an interface for communicating the flexibility needs of the BRP

6.2.6 PUC29 Managing optimally microgrid's flexibility

6.2.6.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Describes the process of managing and scheduling the operation of the microgrid either in interconnected or islanded operation mode.
Objective(s)	1) <u>In case of interconnected microgrid operation</u>: the MgFMS synthesizes the flexibility schedule aiming to minimizing the overall operational cost of the microgrid and maximizing revenues from the provision of flexibilities services to DSOs. 2) <u>In case of islanded microgrid operation</u>, the MgFMS aims to support the critical loads and maintain optimal operation within the microgrid.
Related high-level use case(s)	HLUC 05: Flexibility exploitation for islanded microgrid operation HLUC 08: Managing optimally microgrid's flexibility

6.2.6.2 Narrative of use case

Narrative of use case
Short description
Microgrid can operate either in interconnected or in islanded mode. In interconnected mode the Microgrid Operator (MgO) undertakes the role of the Flexibility Service Provider (FSP) offering flexibility services to support network operation. The primary consideration of the Microgrid Flexibility Management System (MgFMS) when scheduling microgrid's flexibility capacities is to minimize expenditure and maximize flexibility trading associated revenue, while ensuring that all systems are functional and there are no noticeable inconveniences. At the same time, prosumers within the microgrid context trade their flexibility having in mind to minimize their energy bills and/or maximize their profits from trading. On the other hand, DSO can benefit from microgrid islanding operation, as critical loads will remain connected, aiming to the maximum possible power supply reliability. In islanding operation, the Microgrid Operator (MgO) can leverage the flexibility capabilities within microgrid context to ensure security of supply within microgrid and ensure the reliability of the distribution grid. The storage converters support the islanding operation by providing voltage and frequency references as well as serve the critical loads by offering flexibility when possible. The MgFMS schedules the available DER flexibility so as to keep the energy cost as low as possible.
Complete description
<u>Grid interconnection operation:</u> The MgO undertakes the role of the flexibility service provider via the implementation of the Microgrid Flexibility Management System (MgFMS) which synthesizes the flexibility schedules. The MgFMS comprises of the microgrid EMS which manages the flexibility resources and the Flexibility Service Providing Agent (FSPA) responsible for the flexibility trading. It is responsible for developing a local optimization strategy based on the DSO flexibility request communicated through the Flexibility Trading Platform (FTP) and the spatial short-term load and generation forecasts. Subsequently, it informs the prosumers within the microgrid context concerning the operational status modification of the DERs in order to serve the grid flexibility needs. The flexibility needs of the DSO are matched with the flexibility bids offered by the MgO via the trading mechanism FTP. The bid(s) of the MgO matching partially or completely the energy flexibility needs of the DSO are concluded. <u>Islanding operation:</u> Islanding operation of the microgrid can be achieved via a bilateral agreement of the Microgrid Operator (MgO) and the DSO. The former extracts flexibility from prosumers, via also bilateral contracts, in order to manage a number of converter-based assets. By this way, the DSO will be able to ensure power supply continuity of critical loads (and thus avoid associated penalties) as well as retain the voltage and frequency of the islanded microgrid within the limits dictated by the Grid Code. The islanded operation of the microgrid is initiated upon the disconnection of the microgrid from the electricity grid at the Point of Common Coupling (PCC). This islanded detection can be identified by the MgO based on real measurements acquired from the PCC or by the DSO via the DS SCADA, DMS and DSOToolbox applications. In the latter case, an islanding notification should be forwarded to the MgO. When islanding operation initiates, the MgO leverages local flexibility to serve the most critical loads. Initially, the MgFMS collects actual and forecasting generation and consumption data in order to schedule the required flexibility measures required for the islanding operation. The first priority is to

maintain voltage and frequency within acceptable limits and then apply the appropriate management in order to ensure the connection stability of the critical loads. The extraction and trading of the flexibility capacities from distributed, dispatchable energy resources (DER), during both grid-connected and islanding mode, are managed by the Microgrid Energy Management System (Microgrid EMS) and the local Flexibility Service Provider Agent (FSPA) which as mentioned constitute the principal components of MgFMS.

6.2.6.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
	Critical loads connectivity	Critical loads to remain connected.	HLUC05 objective: Ensure power supply continuity to critical loads.
	Frequency regulation	Retain frequency within limits: • Δf → ε • RoCoF<1.7Hz/s sustained in less than 600ms	HLUC05 objective: Regulate voltage/frequency within limits imposed by the grid code.
	Voltage regulation	Retain voltage within limits: • ΔV → ε and • 95% of the 10-minute mean r.m.s values for 1 week (±10% of nominal voltage). • 100% of the 10-minute mean r.m.s values for 1 week (+10% / -15% of nominal voltage) According to the defined EN 50160 Standards (this refers to non-islanding circumstances however there is no standard referring to islanding operation), bus bar voltage magnitudes must comply with the aforementioned allowed range of variation.	HLUC05 objective: Regulate voltage/frequency within limits imposed by the grid code.
	Power supply continuity	SAIFI and SAIDI indices will be measured under the prism of a Major Event Day (MED): $SAIFI = \sum \frac{Total\ Number\ of\ Customers\ Interrupted}{Total\ number\ of\ Customers\ Served}$ $SAIDI = \sum \frac{Total\ Minutes\ of\ Interruption}{Total\ Number\ of\ Customers\ Served}$ In addition, the MED threshold (T_{MED}) will have to be calculated using the following equation: $T_{MED} = e^{(\alpha+2.5\beta)}$ where	HLUC05 objective: Ensure power supply continuity to critical loads.

		α is the log-average of all daily SAIDI values β is the log-standard deviation of all daily SAIDI values.	
	Flexible loads	Number of flexible loads implemented for trading flexibility.	HLUC05, HLUC08 objective: Maximize trading revenues
	Trading flexibility	Evaluation of the DER utilization for ancillary services (UAS). This KPI is expressed by the ratio between the energy used for ancillary services (EASE) and the total energy produced (TEP). $UAS\% = \frac{EASE}{TEP} \times 100$	HLUC05, HLUC08 objective: Maximize trading revenues.
	Operation cost	Operation Cost with flexibility – Operation Cost without flexibility > 0	HLUC08 objective: Minimize cost of energy

6.2.6.4 Use case conditions

Use case conditions
Assumption(s)
• **The grid flexibility needs are predefined when the microgrid is interconnected:** This use case focuses on the microgrid processes and tools required for scheduling flexibility and supporting network operation when the microgrid is interconnected. In light of this, **i**t is assumed that DSO has already defined its flexibility needs exploiting its legacy systems (DS SCADA, DMS, etc.) as well as the advanced monitoring and management applications of the DSOToolbox developed within this project. The DSO's aspects are considered in HLUCs 01 and 02 • **Uncontrolled islanding has been detected and the microgrid transferred to the islanded operation:** The mechanisms for detecting the uncontrolled islanding are not within the scope of this use case. It is considered that the microgrid is already disconnected from the distribution grid. The FEVER solution for detecting islanding conditions is described in HLUC 03:"*Leveraging the flexibility of the storage assets for real time detection of uncontrolled islanding*". An external triggering event will be considered to initiate the use case. • **The priority order of the microgrid loads is predefined:** Under islanded conditions, the MgO exploits the production units and storages within the context of microgrid to serve local energy needs. In case that local production can partially serve the consumption, the loads will be electrified in priority order ensuring that the most critical loads are primarily served.
Precondition(s)
<u>Microgrid interconnection mode:</u> • Grid technical constraints such as congestion, unbalance. • Flexibility request (FlexOffer) is available via FTP.

Microgrid islanding mode: • The uncontrolled islanding has already occurred and been detected. • The microgrid operates under islanding condition Generic • Flexibility agents are integrated and operational

6.2.6.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
SUC 01: Energy Forecasting **SUC 05: Asset Monitoring and Control** **SUC 06: Extracting DER flexibility** **SUC 11: Optimal management of microgrid's flexibility**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Microgrid optimal operation, flexibility extraction, islanding management

6.2.6.6 Use case diagram

Diagram(s) of use case

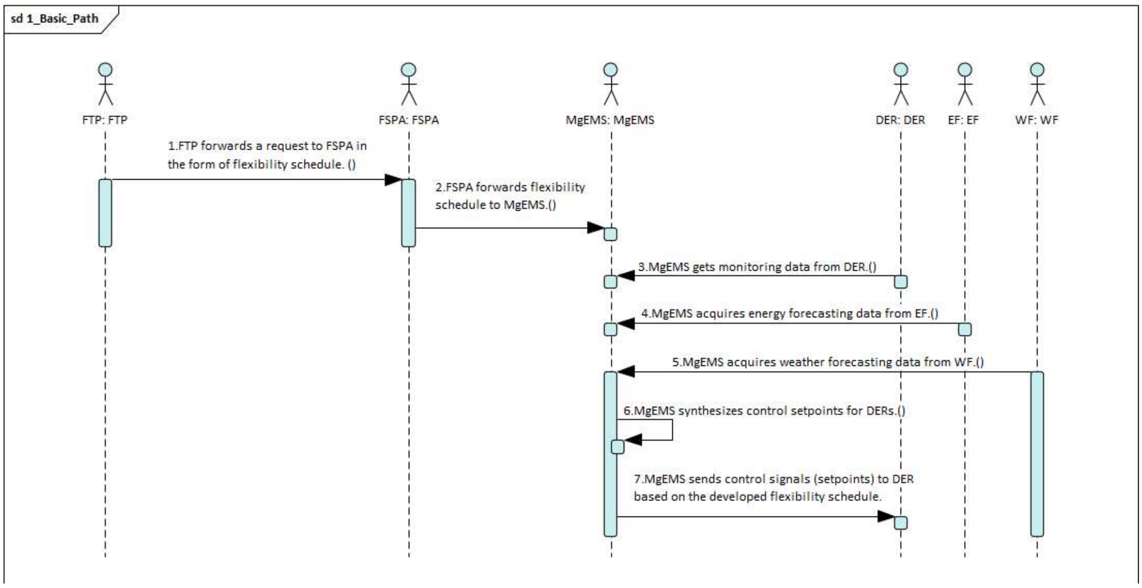


Figure 37 PUC29 Sequence Diagram – Scenario 1

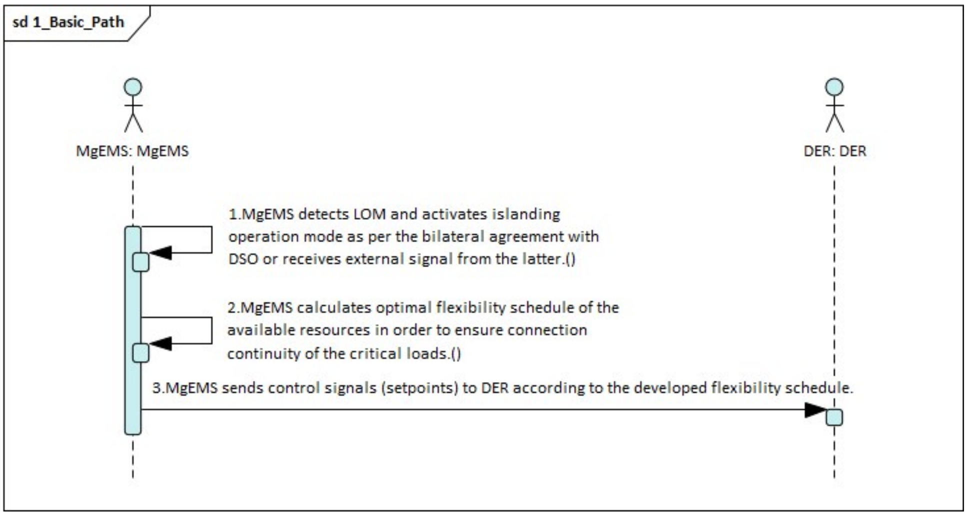


Figure 38 PUC29 Sequence Diagram - Scenario 2

6.2.6.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Microgrid Flexibility Management System (MgFMS)	Flexibility actor	System responsible for managing the microgrid operation and offering flexibility services to energy stakeholders via bilateral contracts or flexibility markets.	Provides optimal flexibility schedule within a microgrid. It combines the operations of a

			microgrid EMS and FSPA. The former will define the optimal strategy of the grid while the FSPA will communicate the flexibility offers to the flexibility market.
Flexibility Service Provider Application (FSPA)	Application	The agent responsible for constructing and communicating the flexibility offers to the market operator, in respect to the flexibility availability of the FSPs.	Will communicate flexibility request.
Microgrid EMS (MgEMS)	System	Monitoring, control and optimization of microgrid's operation	Optimal management of microgrid assets
Weather Forecaster (WF)	Application	Application offering weather forecast services.	Provides predictions of weather conditions
Energy Forecaster (EF)	Application	A forecasting application in charge of predicting demand and generation values for specific points of the grid in the succeeding time horizon. It facilitates aggregated values of individual consumptions/productions forecast data.	Provides predictions of energy consumption and generation. To be developed in the project.
Real Time Simulator (RTS)	System	RTS is able to simulate a grid event artificially.	The real time simulator is able to emulate grid events i.e. congestion. It will be considered during piloting as a solution for simulating the conditions for flexibility needs.
Power Electronic Device (PED)	Device	Storage converter providing flexibility depending on the flexibility request.	Power converter deployed by the prosumer as a flexibility asset.

6.2.6.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Economical operation under flexibility trading due to grid constraint foreseen by the DSO.	A congestion event is foreseen by the DSO which is emulated by the Real Time Simulator (RTS). To resolve the issue, the latter requests flexibility from the flexibility trading platform (FTP) whereas the MgO (flexibility provider) can trade of the flexibilities provided by the prosumers' assets, which are available internally in the microgrid while it first ensured its economical optimal operation	MgFMS (EMS+ FSPA)	A flexibility request from DSO communicated via the FTP after a ramp-up load increase.	Economically optimized and balanced operation of both parties. MgFMS is available to provide flexibility.	The two systems operate in an optimal economical manner
2	Islanding during over or under frequency conditions	Islanding operation is activated via detection or external signal for the DSO during a time where local production and consumption are not in balance. The MgEMS leverages flexibility to optimally operate the Microgrid.	MgEMS	Islanding signal is sent to microgrid MgEMS	1. Bilateral contract between MgO and Prosumer foreseeing such a service. 2. Availability of grid-forming storage power converter. 3. Availability of MgEMS islanding operation mode.	Voltage/frequency are regulated within acceptable boundaries and power supply is provided to critical loads. Optimization of islanded operation to serve maximum number of customers (in addition to critical loads)

Scenario

Scenario name:			Microgrid interconnection mode				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Upon request	Flexibility request	FTP forwards a request to FSPA in the form of flexibility schedule.	FTP	FSPA	Flexibility Schedule	
2	Upon request	Flexibility request	FSPA forwards flexibility schedule to Microgrid EMS	FSPA	MgEMS	Flexibility Schedule	
3	After step 4	Monitoring	MgEMS gets monitoring data from DERs.	MgEMS	DERs	AssetData	
4	After step 4	Retrieve energy forecast	MgEMS acquires energy forecasting data from EF.	MgEMS	EF	Energy Forecast	
5	After step 4	Retrieve weather forecast	MgEMS acquires weather forecasting data from WF.	MgEMS	WF	Weather forecasting data	
6	After completion of steps 5-7	Internal optimization process	MgEMS synthesizes control setpoints for DERs.	MgEMS	MgEMS	-	
7	After step 8	DERs control	MgEMS sends control signals (setpoints) to DERs based on the developed flexibility schedule.	MgEMS	DERs	Asset control commands	
Scenario name:			**Microgrid islanding mode – over-frequency conditions**				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**

1	Local imbalance detection or external signal	Islanding operation mode activation	MgEMS detects LOM and activates islanding operation mode as per the bilateral agreement with DSO or receives external signal from the latter.	MgEMS (Sensor or External Signal)	MgEMS	Islanding operation activation	
2	DERs optimal management	Optimal flexibility schedule creation	MgEMS calculates optimal flexibility schedule of the available resources in order to ensure connection continuity of the critical loads.	MgEMS	MgEMS	-	
3	Upon request	Dispatch Schedule	MgEMS sends control signals (setpoints) to DERs according to the developed flexibility schedule.	MgEMS	DER	Asset control commands	

6.2.6.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
EnForecast	Energy Forecast	Consumption and generation forecast for different assets of the grid.	
WetForecast	Weather forecasting data	Meteorological forecasting data.	
FlexNeed	Flexibility Needs	Required flexibility with spatial as well as temporal characteristics	
FlexSchedule	Flexibility Schedule	A concrete planned realization of a FlexOffer/flexibility requirement	
AssetData	Asset monitor data	Power, Voltage, Current, Frequency, Asset status	
AssetCmd	Asset control command	Asset prosumption profile (TBD)	

6.2.6.10 Requirements

Requirements ID	Requirement name	Requirement description
MgFMS_REQ_DQ	Data granularity	Data of high granularity (1 min. time step) to be provided via the microgrid EMS to the forecasting applications.
MgFMS_REQ_PER	Forecasting performance	High accuracy spatiotemporal forecasting is required in order the MgFMS to properly synthesize the flexibility schedule of corresponding assets placed within the microgrid.
MgFMS_REQ_INR	EMS-FSPA interoperability	Communication between central EMS and flexibility agent needs to be established in order the latter have access to the data provided by the former and perform the flexibility trading.
MgFMS_REQ_OPE	Microgrid islanding operation	Microgrid islanding operation requires converters with grid-forming capabilities. Regulation of voltage and frequency by the dedicated converters is dictated in order the microgrid to maintain power supply under islanding conditions.

6.2.7 PUC31 Participating in regional flexibility markets

6.2.7.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	The scope of this use case is the development of BRP's management system as an automated flexibility trading system. The BRP's management system should be enhanced with a trading mechanism which matches the flexibility needs of the BRP with the flexibility bids offered by a regional flexibility market.
Objective(s)	1) Manage balance group more effectively via flexibility trading on regional flexibility market(s).
Related high-level use case(s)	HLUC14: Form a first example of a regional flexibility exchange model

6.2.7.2 Narrative of use case

Narrative of use case
Short description
The participation of the BRPs in the regional flexibility market requires the extraction of their flexibility needs or surplus in respect to the available DER flexibilities within their balancing group. This process receives as input the outcomes of the BRP's portfolio management and communicates the balancing needs or the flexibility surplus to the regional flexibility trading platform. This interaction adheres to the rules and restriction that the regional flexibility market imposes.
Complete description
According to the Harmonized Electricity Market Role Model4, the BRP is the party that has a contract proving financial security and identifying balance responsibility with the Imbalance Settlement Responsible of the Scheduling Area entitling the party to operate in the market. The meaning of the word "balance" in this context signifies that the quantity contracted to provide or to consume must be equal to the quantity really provided by or consumed within its balancing group. In case of imbalances, the energy gap between the market-agreed energy profile and the real can be adjusted by the BRP either via intra-day or balancing markets. The initial step for BRP's participation in the regional flexibility market is the internal flexibility management within its balancing group by the BRP Management System (BRP-MS). In case that the available flexibility pool within the balancing group is not adequate to meet the flexibility needs of the responsible BRP, a second level of flexibility trading among BRPs at regional level is realized. This regional flexibility market (FTP) facilitates the trading among BRPs with energy flexibility needs which are not fulfilled internally and the BRPs with excess of energy flexibility. The former BRP acts as a flexibility service consumer represented by a Flexibility Service Consuming Agent (FSCA) while the latter acts as Flexibility Service Provider represented by a Flexibility Service Providing Agent (FSPA). The BRP's management system should be enhanced with a trading mechanism which matches the flexibility needs of the BRP with the flexibility bids offered by another BRP on a regional flexibility trading platform.

6.2.7.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC31_1	External procurement	Internal prioritization of own generation, storage and flexibility depending on price signals; External procurement below the specified value	1

6.2.7.4 Use case conditions

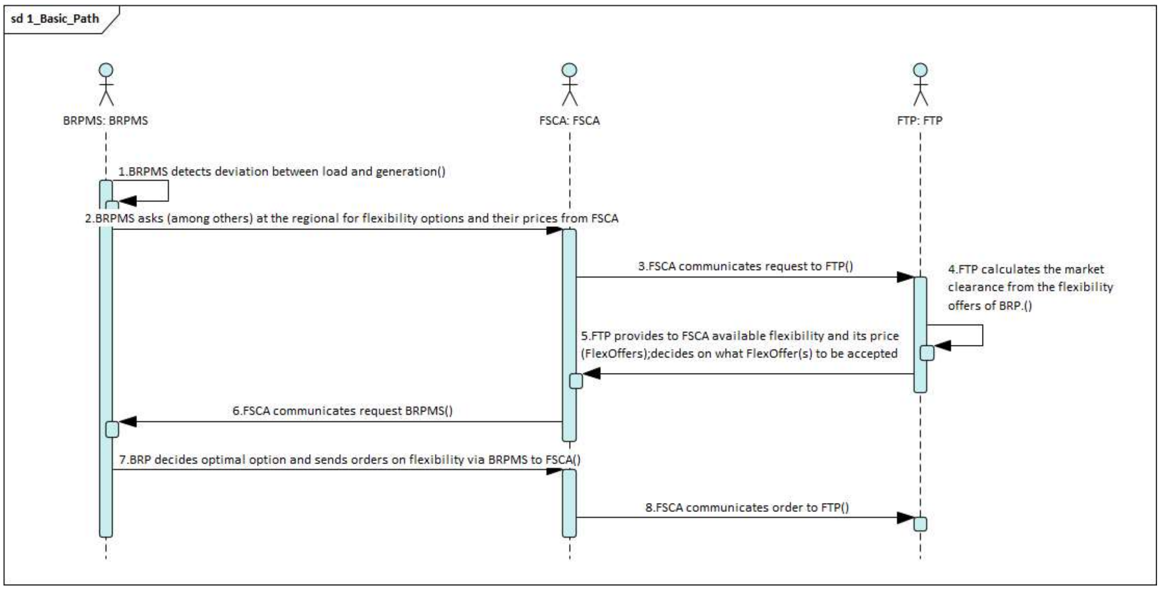
Use case conditions
Assumption(s)
• BRP has automated balancing group management implemented (BRPMS) • An automated flexibility management is implemented (FTP) • Regional flexibility market for BRPs implemented (FTP) • Energy Communities integrated as flexibility service providers within a balancing group • BRP's energy schedule is already defined
Precondition(s)
• Data on daily procurement is available (day-ahead planning) • BRP provide flexibility needs to FTP

6.2.7.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
Includes PUC04: Offering Flexibility Services **Includes PUC03: Requesting Flexibility Services**
Level of Depth
detailed
Prioritization
medium
Generic, regional or national relation

National, regional
Nature of the use case
Technical
Further keywords for classification
Flexibility trading, Regional balancing

6.2.7.6 Use case diagram

Diagram(s) of use case
 **Figure 39 PUC31 Sequence Diagram - Scenario 1**

6.2.7.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Balancing Responsible Party Management System (BRP-MS)	System	The system managing BRP's portfolio including trading of energy and energy flexibility.	Communicates flexibility needs

Flexibility Service Consuming Agent (FSCA)	Application	Agent, responsible for issuing automatic bids on the FTP, based on requests of BRPMS.	Enables communication of BRP-MS and FTP
Flexibility Service Providing Agent (FSPA)	Application	Agent, responsible for issuing automatic bids on the FTP, based on offers of BRPMS.	Enables communication of BRP-MS and FTP
Flexibility Trading Platform (FTP)	Application	The system responsible for the trading of flexibility among different stakeholders	Will be developed in the project by INEA
Balancing Responsible Party (BRP)	Business Entity	A party with reserve-providing units or reserve-providing groups able to provide balancing services to one or more Load-Frequency Control (LFC) Operators	Requests/Provides flexibility via the FTP

6.2.7.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Regional trading when flexibility is needed	BRP needs flexibility and buys at regional level	BRP-MS	Deviation from plan	• Contract with market operator • FTP has an adequate flexibility pool	• Flexibility received; • Balancing group balanced
2	Regional trading when flexibility can be offered	BRP has excess flexibility and sells at regional level	BRP-MS	Deviation from plan	• Contract with market operator • FTP has an adequate flexibility pool • Flexibility bought which is then not needed	• Flexibility sold; • Balancing group balanced

Scenario							
Scenario name:			Regional trading when flexibility is needed				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Triggered by event (periodic check)	Flexibility needed for BRP	BRPMS detects deviation between load and generation	BRPMS	BRPMS		

2	Upon completion of 1	Ask for available flex sources for specific time and their prices	BRPMS asks (among others) at the regional for flexibility options and their prices from FSCA	BRPMS	FSCA	Flexibility Need	
3	Upon completion of 2	Receive flex offer	FSCA communicates request to FTP	FSCA	FTP	Flexibility Need	BRPMS_REQ_INR_1
4	Periodically	Market clearance	FTP calculates the market clearance from the flexibility offers of BRP.	FTP	FTP	-	
5	Upon completion of 4	Receive FlexOffers from regional FTP	FTP provide available flexibility and its price (FlexOffers); decides on what FlexOffer(s) to be accepted	FTP	FSCA	Available flexibility	BRPMS_REQ_INR_1
6	Upon completion of 5	Communicate offer to BRPMS	FSCA communicates request BRPMS	FSCA	BRPMS	Available flexibility	
7	Upon completion of 6	Send out orders to regional market	BRP decides optimal option and sends orders on flexibility via BRPMS to FSCA	BRPMS	FSCA	Flexibility Measures	
8	Upon completion of 7	Send out orders to FTP	FSCA communicates order to FTP	FSCA	FTP	Flexibility Measures	BRPMS_REQ_INR_1
Scenario name:			Regional trading when flexibility can be offered				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Triggered by event (periodic check)	Excess Flexibility bought BRP	BRP MS detects deviation between load and generation	BRPMS	BRPMS		
2	Upon completion of 1	Offer available flex sources for specific time and their prices	BRPMS provides (among others) at the regional market an offer for flexibility options and their prices from FSPA	BRPMS	FSPA	Flexibility Offer	

3	Upon completion of 2	Send flex offer	FSPA communicates offer to FTP	FSPA	FTP	Flexibility Offer	BRPMS_REQ_INR_1
4	Periodically	Market clearance	FTP calculates the market clearance from the flexibility offers of BRP.	FTP	FTP	-	
5	Upon completion of 4	Receive FlexOffers from regional FTP	FTP provides requested flexibility and its price (FlexOffers); decides on what FlexOffer(s) to be accepted	FTP	FSPA	Requested flexibility	BRPMS_REQ_INR_1
6	Upon completion of 5	Communicate requests to BRPMS	FSPA communicates request to BRPMS	FSPA	BRPMS	Requested flexibility	
7	Upon completion of 6	Send out (offering) orders to regional market	BRP decide optimal option and sends orders on flexibility	BRPMS	FSPA	Flexibility Measures	
8	Upon completion of 7	Send out orders to FTP	FSPA communicates order to FTP	FSPA	FTP	Flexibility Measures	BRPMS_REQ_INR_1

6.2.7.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
FlexNeed	Flexibility Need	Requirements on flexibility with spatial and temporal characteristics	BRPMS_REQ_ INR_1
FlexOffer	Flexibility Offer	Flexibility offer with constraints with spatial and temporal characteristics	BRPMS_REQ_ INR_1
FlexAvailable	Available flexibility	Price of flexibility requested	BRPMS_REQ_ INR_1
FlexMeasures	Flexibility Measures	Order of flexibility	BRPMS_REQ_ INR_1

6.2.7.10 Requirements

Requirements ID	Requirement name	Requirement description
BRPMS_REQ_ INR_1	Compliant to the FlexOffer protocol	Information on and description of flexibility should be made according to FlexOffer specifications

6.2.8 PUC32 Peer-to-peer flexibility trading

6.2.8.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	The use case describes the distributed ledger technologies (DLT) based Peer-to-Peer Flexibility Trading Platform (P2P-FTP) that provides P2P market toolbox.
Objective(s)	1) The main objective of the use case is the implementation of the P2P-FTP that is a toolbox capable to support P2P flexibility trading on the basis of distributed ledger technologies.
Related high-level use case(s)	HLUC 15: P2P flexibility trading (in Energy Communities)

6.2.8.2 Narrative of use case

Narrative of use case

Short description
The P2P-FTP is a distributed ledger technologies (DLT) based platform for providing the environment to directly trade flexibility requests provided by the Flexibility Service Consumers with the flexibility bids offered by the Flexibility Service Providers. Depending on their current needs, in P2P trading peers can take on the role of Flexibility Service Consumer or Flexibility Service Provider. This can vary with each trading process.
Complete description
In order to facilitate P2P flexibility trading and extract & trade flexibilities close to real time, the P2P-FTP platform will be coupled with the Automated Flexibility Trading Platform (AFTP), where flexibilities are described in time, energy, location, price and several time constraints. P2P-FTP provides the toolbox for the market operations that will be used to trade flexibility offers and flexibility requests submitted through AFTP by the peers. The coupling between flexibility request and flexibility offer should be realised in all the dimensions of the flexibility vector: energy, spatial, temporal and price. The contracting and billing will be realized by Distributed Ledger Technologies. The P2P-FTP platform coupled with AFTP can be utilised at different levels of the electricity grid. The P2P-FTP can be utilised at prosumer's level for optimal flexibility management and balancing of the local resources, in particular when they form a socio-economic system with its set of values and objectives, ex. within a microgrid, an energy community, etc. Furthermore, the P2P-FTP enables Flexibility Service Providers to optimize their flexibility portfolio for providing flexibility to various energy stakeholders. Moreover, P2P-FTP can be utilized by BRPs when operating in the local and regional market for managing optimally the flexibility lying either inside or outside their area of responsibility for balancing purposes. Finally, the P2P-FTP facilitates independent Market Operators to develop local markets for flexibility trading within the distribution domain. P2P-FTP platform implements governance policies and incentive mechanisms like special-tariffs or pseudo-currencies that allow the realization of that feedback via mathematical algorithms that can be parameterized by the different sub-communities with their dynamic business logics via set of libraries and modules, including open, closed and smart contracts. Peers are required to be registered to the P2P-FTP platform in order to perform flexibility trades. Peer registration might involve various practices to satisfy regulation compliance, such as Know Your Customer (KYC) practices. Peers identity will be managed by the P2P-FTP platform through suitable identity management protocols, such as: centralized, federated, decentralized identity protocols. P2P-FTP protocol will implement necessary technologies like Membership Service Providers with Certificate Authority and Chain of Trusts will be implemented and deployed as modules on the DLT. By utilizing the identity management service provided by the P2P-FTP platform, peers will be able to identify, communicate and perform trades with other peers on the network. Peer's privacy that participate in the P2P-FTP platform is protected through APIs that allow the application of the privacy and anonymization software, and set of data privacy protection libraries, modules.

6.2.8.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI _PUC32_1	Transaction processing throughput	Expresses the throughput of transaction processed by the platform should be scalable and able to process high throughput	1

		of number of flexibilities traded between peers.	
KPI _PUC32_2	Number of peers	Number of peers that are actively participating in the peer to peer trading platform by requesting and offering flexibilities.	1

6.2.8.4 Use case conditions

Use case conditions
Assumption(s)
The main assumptions are the assumptions concerning the type of and position of the local energy community of the use case. It is assumed that i) system infrastructure for automatic flexibility trading to field-test and demonstrate the Use case solution will be available and that ii) the framework community business model will be provided and the prosumers engagement will be secured by the partner that will provide the trial site and demonstrate the solution. It is assumed that necessary regulatory compliance requirements will be identified, such as: • the users' identification as peers, • peer's registration to the network (e.g. KYC practices), • trading and multi-category business model settlement will be identified P2P-FTP platform either will implement and/or integrate such necessary regulatory compliance practices as systems modules.
Precondition(s)

• The basic precondition is that the complementary part of the combined two-level flexibility trading solution in WP2 will be developed, adapted and coupled with P2P toolbox as planned.
• Additionally,that interdependent WPs and task will develop and make available for testing & demonstration as planned in particular
  ○ WP3 (DSO Toolbox)
  ○ WP6 (Integration deployment and field testing)
  ○ WP7 (Demonstration and validation)
• All preconditions from PUC03 PUC04 PUC05.

6.2.8.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC 03: Requesting flexibility services **PUC 04: Offering flexibility services** **PUC 05: Flexibility Trading**

Level of Depth
High-level
Prioritization
Mandatory
Generic, regional or national relation
Generic use case applicable to local energy communities that will represent a distributed business system based on any number of constitutional laws. Two cases may be relevant: • commune: virtual business system consisting of members (peers) • distributed (virtual) business system composed of »responsible party« and members (peers) In both cases, the peer-to peer business system is open to trade the surplus or the lack or flexibility externally on the accessible local or regional market. Depending on the type of the community, the role can be played out either by a business actor or an emulated technical role of the system.
Nature of the use case
Technical and business, a new concept bringing technical automated and business trading processes together.
Further keywords for classification
p2p trading, flexibility trading, distributed ledger technology, pseudocurrency

6.2.8.6 General Remarks

General Remarks
There are open questions that need to be discussed through the development phase (i.e. of WP2-WP5) that will affect the scenarios of the PUC32: • How peers will provide information on the flexibility options • How new additional assets will be added to the peers' asset portfolio • How peers will choose/modify their business strategy on trading • How peers will decide on the prioritization of their available assets

6.2.8.7 Use case diagram

Diagram(s) of use case

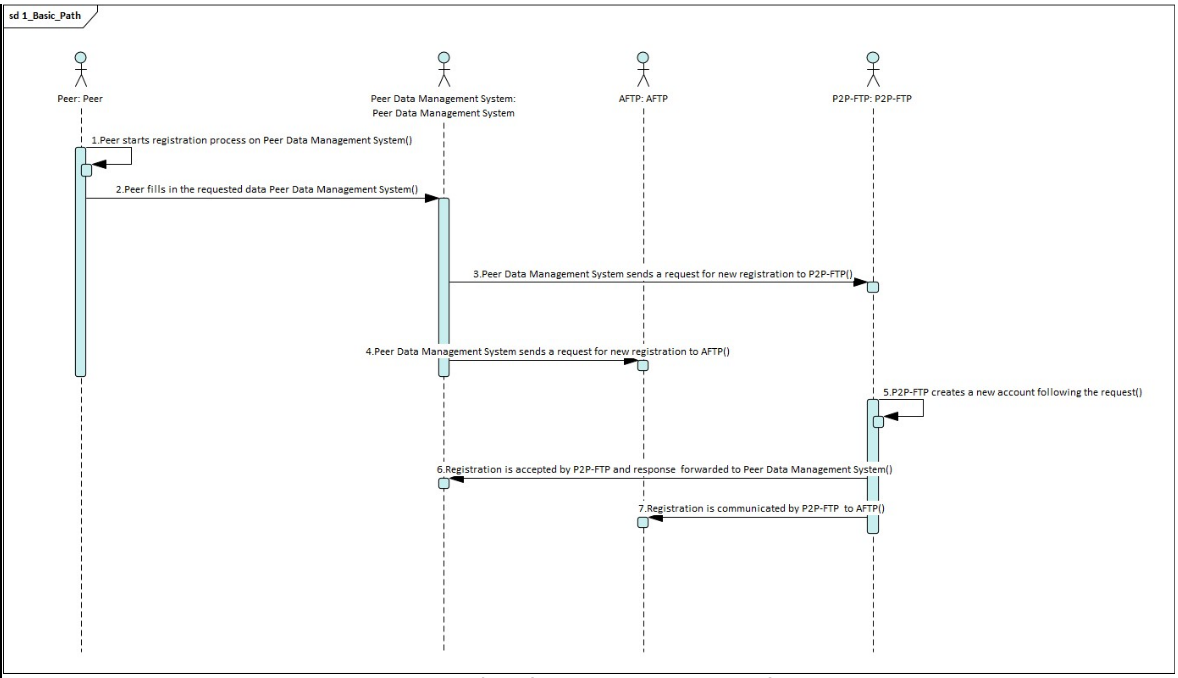


Figure 40 PUC32 Sequence Diagram - Scenario 1

6.2.8.8 Actors

Roles defined are those participating in the trading process in the energy community and the adjacent local and regional markets when and where the energy community trades flexibility also externally. Both selling and buying roles are included. For practical purposes, markets that are not directly accessible are not included.

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Flexibility Service Consuming Agent (FSCA)	Application	The agent responsible for transforming the needed flexibility of an actor to a bidding strategy in respect to the requirements imposed by the flexibility markets or the bilateral agreements	Will communicate flexibility offer to the market. Developed in the project.
Flexibility Service Providing Agent (FSPA)	Application	The agent responsible for transforming the available flexibility of an actor to a bidding strategy in respect to the requirements imposed by the flexibility markets or the bilateral agreements	Will communicate flexibility offer to the market. Developed in the project.

Peer-to- Peer Flexibility Trading Platform (P2P-FTP)	Application	The system responsible for the peer-to-peer trading of flexibility between different stakeholders in communal business model categories, based on Automated flexibility trading in pseudocurrency	Developed in the project.
Peer Data Management Module	Application	The module of peer's energy management system responsible for peer data management and communication to P2P FTP.	
Automated flexibility trading platform	Application	The system responsible for automated peer-to-peer trading of flexibilities between different stakeholder systems in pseudocurrency	
Community Business Management System	Application	The system responsible for managing peers in the communities, such as; management of business processes, accounting etc.	

6.2.8.9 References

References						
No.	**Type**	**Reference**	**Status**	**Impact**	**Originator / Organization**	**URL**
1	Journal Paper	A Novel Peer-to-Peer Local Electricity Market for Joint Trading of Energy and Uncertainty	published	Step-by-step description of P2P-trading (1.4.2) after flowchart (Fig. 3 in paper)	Zhong Zhang, Ran Li, and Furong Li; in: IEEE TRANSACTIONS ON SMART GRID, VOL. 11, NO. 2, MARCH 2020	link

6.2.8.10 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Registration of peer for participating in trading	Peer registers at FTP by providing login credentials	Peer	Peer starting registration process	• Peer not registered • Trading website / app for peer available on PC / Smartphone	• Peer registered • Credentials given to FTP peer management system
2	P2P trading between two peers (in energy community)	Prosumers offer flexibility to p2p trading market on periodic basis	Periodic process; FSPA and FSCA	Periodic Process	Contract on participation in p2p trading via market platform (with Market Operator)	FlexOffers traded directly between offering parties

Scenario							
Scenario name:			Registration of peer for participating in trading				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Action by (new) Peer	Peer starts Registration process	Peer starts registration process by choosing / clicking link on website / in app	Peer (Role)	Peer Management System	"Peer wants to register"	
2	Upon completion of 1	Loading registration form / page	New page on website or in app loads where Peer needs to fill in his/her personal data	Peer Management System	Peer Management System	Loading of new page	

3	Upon completion of 2	Giving registration data	Peer types in her/his data requested from system and presses "continue"	Peer (Role)	Peer Management System	Registration Data from peer	
4	Upon completion of 3	Sending request to FTP-P2P platform	Request for new registration is sent to FTP-P2P trading platform	Peer Management System	FTP-P2P	Registration Data from peer	
4a	Upon completion of 3	Sending request to AFTP platform	Request for new registration is sent to AFTP trading platform	Peer Management System	AFTP	Registration Data from peer	
5	Upon completion of 4	Checking request on criteria and creating Peer's account	Creating a new account for the registering Peer	FTP-P2P	FTP-P2P	Registration data ok; Account created	
6	Upon completion of 5	Accepting registration	Registration is accepted and Peer forwarded to some kind of welcome page or his/her profile	FTP-P2P	Peer Management System	Acceptance of registration	
6a	Upon completion of 5	communicating registration	Registration is communicated and Peer forwarded to AFTP peer base	FTP-P2P	AFTP	Acceptance of registration	
Scenario name:			P2P trading between two peers (in energy community)				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic Process	Collection of FlexOffers traded on AFTP	All p2p FlexOffers of the registered peers are collected and traded in pseudocurrency on through the AFTP coupled to P2P-FTP	FSPA, FSCA, AFTP	P2P-FTP	Flexibility Offer	

2	Periodic process	Sort FlexOffers of community business model	Sorting of all FlexOffers from FSPA and FSCA traded in pseudocurrency on P2P-FTP, by necessary dimensions (such as energy, spatial, temporal, price) using transformational matrix of community business model.	P2P-FTP	P2P-FTP		
3	Upon completion of #2	Match FlexOffers	P2P-FTP matching of providing and receiving FlexOffers according to the application logic encoded into DLT smart contracts; save results	P2P-FTP	P2P-FTP		
4	Upon completion of #3	Broadcast matching results	Broadcast information on matching (and not matching) results to Community virtual business system ("ERP")	P2P-FTP	Community virtual business system ("ERP")	Settlement information	
5	Upon completion of #4	settlement	Community virtual business system ("ERP") performs necessary accounting actions for peers.	Community virtual business system (ERP)	Peers	Updated information on the peers' business processes, accounts etc.	

6.2.8.11 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
FlexOffer	Flexibility Offer	A FlexOffer which packs flexibility offer requirements/ constraints with spatial and temporal characteristics	
ComBisModel	Community business model	Transformational matrix establishing relationship between pseudocurrency trading, attributers of FSPA and FSCA, and categories of community business model	
PeerSettlInfo	Settlement information	FlexOffer trade execution proof on the settlement upon completion of the consensus process of the DLT platform.	

6.2.8.12 Requirements

Requirement Categories		
Requirements ID	**Requirement name**	**Requirement description**
P2P_REQ_ INR _01	Compliance with FlexOffer definition	Flexibility information exchanged specified according to the FlexOffer specification and protocol.
P2P_REQ_PER_02	Compliance with community business model	Match of weights of flexibility exchanged in different categories of community business model
P2P_REQ_PER_01	Transaction processing throughput and number of peers	P2P-FTP platform has to be met pre-defined metrics on the number of processed FlexOffer trade transactions per time intervals, and number of total external and internal peers participating in the network.

6.2.9 SUC06 Extracting DER flexibility

6.2.9.1 Scope and objectives of use case

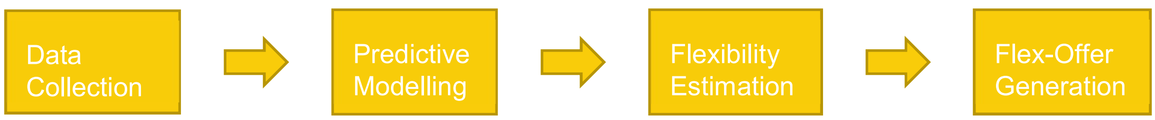
Scope and objectives of the use case

Scope	Calculates flexibility potential of a specific DER and encodes it as a Flex-Offer, leveraging collected DER data, predictive models, business and user constraints.
Objective(s)	1) Calculate flexibility potential for a given DER. 2) Encode flexibility data as a Flex-Offer for exchange with other actors.
Related high-level use case(s)	HLUC 04: Leveraging the flexibility of the storage assets for real time detection of uncontrolled islanding HLUC 05: Flexibility exploitation for islanded microgrid operation HLUC 06: Reducing technical losses through local storage utilization HLUC 08: Economically optimized flexibility leveraging for a connected microgrid HLUC 09: Market mechanisms incentivizing flexibility or other market tools for mitigating problems of the network HLUC 12: Creating dynamic tariffs based on flexibility use in the actual regulatory framework HLUC 13: Improving the outcome in flexibility by introducing sector coupling HLUC 14: Form a first example of a regional flexibility exchange model

6.2.9.2 Narrative of use case

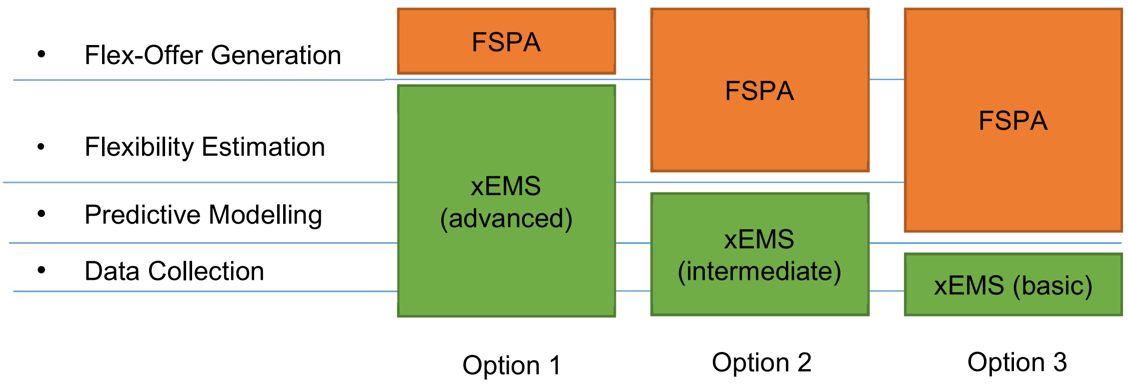
Narrative of use case
Short description
This UC uses real-time data, available context information, user and business constraints and leverages this information to generate meaningful flexibility offers (Flex-Offers) for exchange between different actors (e.g. FMS, FTP).
Complete description

Flexibility extraction for a concrete DER involves several steps depicted in the following figure:



- **Data collection** – necessary data are collected. This includes DER state measurements (e.g., power consumption, temperature, humidity, etc.), user and business constraints, external data (e.g. meteorological data).
- **Predictive modelling** – detailed predictive models of a DER loads are selected, trained, and validated in terms of performance. Outdated models are maintained by training them (periodically or on-demand) using latest collected data.
- **Flexibility Estimation** – DER flexibility constraints are estimated using up-to-date predictive models and collected data.
- **Flex-Offer Generation** – Flex-Offers are generated based on the estimated device flexibility constraints.

Depending on the existing capabilities of xEMS and FSPA, the aforementioned flexibility extraction steps can, potentially, be realized by different actors involved in this use-case, as depicted in the figure below:



- **Option 1** – FSPA is a lightweight component handling mostly data (Flex-Offer) exchange; while xEMS has advanced functionalities integrated: advanced predictive models, state estimation capabilities, and flexibility extraction techniques.
- **Option 2** – FSPA is responsible for Flex-Offer exchange and flexibility estimation; while xEMS integrates accurate predictive models and model maintenance capabilities.
- **Option 3** – FSPA integrate advance predictive modelling and flexibility estimation capabilities; while xEMS is a lightweight component, mostly handling data collection and DER control.

Option 1 is considered the default deployment scenario in the project and is used throughout higher-level use cases and other documentation. However, option 2 and option 3 deployment scenarios are also feasible and the final design will be decided in the next phases of the project.

6.2.9.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_SUC06_1	Number of Flex-Offers per time unit	Expresses a total number of Flex-Offers generated within a time unit	2
KPI_SUC06_2	Flex-Offer accuracy	Accuracy of Flex-Offers: MSE between predicted baseline energy and actual consumed energy	1,2

6.2.9.4 Use case conditions

Use case conditions
Assumption(s)

• DER/loads are observable, predictable, and controllable. Their predictive (flexibility) models can be defined. • FSPA and xEMS have sufficient capabilities to perform the flexibility extraction steps, e.g., in one of the deployment options (Option 1-3).
Precondition(s)
• Real-time communication, data exchange, and control of DER are established. • All user and business constraints are known;

6.2.9.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
SUC 05: Asset Monitoring and Control **SUC 07: Management of Aggregated DER Flexibility**
Level of Depth
Detailed
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Critical event forecasting, congestions, over/subvoltages

6.2.9.6 Use case diagram

Diagram(s) of use case

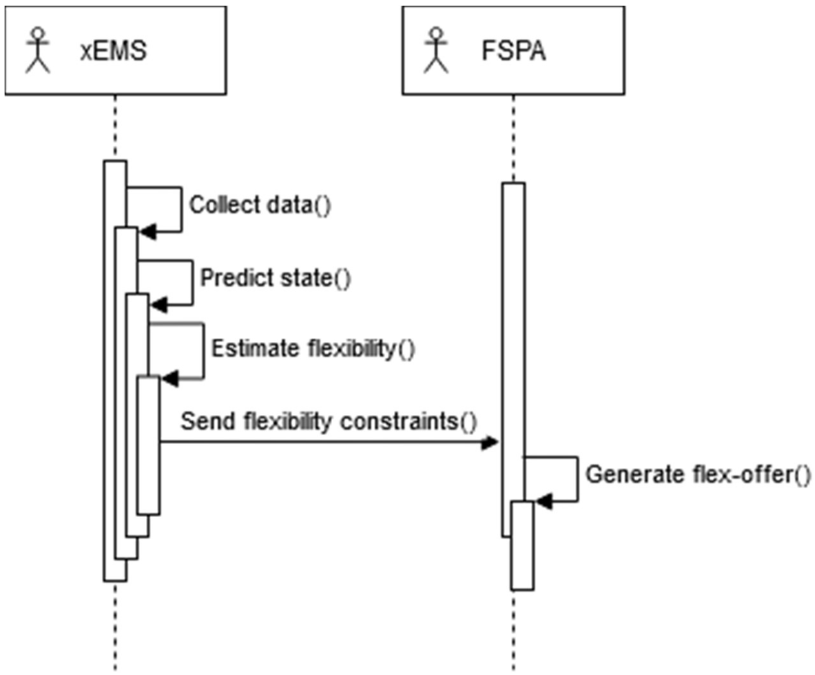


Figure 41 SUC6 Sequence diagram

6.2.9.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Energy Management System (xEMS)	system	The system responsible for monitoring and controlling DER assets. xEMS may integrate advanced predictive functionality, and thus it may extract the potential flexibility directly from DER assets with regards to their operational status and constraints (deployment option 1). Different types of xEMS are considered in the project: Factory Energy Management System (FEMS) controls factories and commercial buildings; Home Energy Management System (HEMS) controls residential locations; a Charging Energy Management System (CEMS) controls electric vehicle charging stations, etc.	Commercial and custom made by INEA, AUU, FLEX
Flexibility Service Providing Agent (FSPA)	Application	The agent responsible for transforming the available flexibility of an actor to a Flex-Offer expressing a bidding strategy with respect to the requirements imposed by the flexibility markets or the bilateral agreements	Will communicate flexibility offer to the market. Developed in the project.

6.2.9.8 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Load Model Maintenance	Describes the process of training load modes used in flexibility estimation	xEMS (Option 1,2) FSPA (Option 3)	New data available, settings/constraint changes	New data available	Up-to-date model instance available
2	Flexibility Estimation and Flex-Offer Generation	Described the process how load model instances are transformed into Flex-Offers	FSPA	On demand or periodic process	Existence of up-to-date model instance	Flex-Offer(-s) available

Scenario							
Scenario name:			Prosumer providing flexibility to the market via the aggregator(FSPA)				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	New data available, settings/constraints change	Start model maintenance	Launches load model maintenance	xEMS	Primary actor	New data and settings (see below)	
2	After 1	Model validation	Validates the model with respect to new data/settings	Primary actor	Primary actor	-	EDF_REQ_OPE_01, EDF_REQ_OPE_02

3	If model maintenance is required	Model maintenance	Updated model instance trained based on new data/settings	Primary actor	Primary actor	-	EDF_REQ_OPE_01, EDF_REQ_OPE_02

Scenario							
Scenario name:			Flexibility Estimation and Flex-Offer Generation (as of Option 1)				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	On demand or periodically	Start flexibility estimation	Launches flexibility estimation	xEMS	xEMS	-	
2	After 1	Fetch up-to-date load model instance	Fetches up-to-date load model instance	xEMS	xEMS	-	
3	After 2	Flexibility estimation	Calculates flexibility constraints and parameters using up-to-date model	xEMS	xEMS	-	
4	After 3	Exchange of flexibility constraints	Send the computed flexibility constraints to FSPA	xEMS	FSPA	Flexibility constraints (see below)	
5	After 4	Flex-Offer generation	Pack the compute flexibility constraints into the Flex-Offer representation	FSPA	FSPA	-	EDF_REQ_INR_01

6.2.9.9 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
FlexData	Data and settings	Measurement (e.g. power consumption, temperature, humidity, etc.) data from smart metering devices, user and business constraints (e.g., from xEMS GUI), external data (e.g., meteorological data)	
FlexConstraints	Flexibility constraints	Time, energy, and total energy constraints, flexibility prices (e.g., EUR/ ΔkWh) and other parameters	

6.2.9.10 Requirements

Requirements ID	Requirement name	Requirement description
EDF_REQ_INR_01	Flex-Offer specification compliance	The generated Flex-Offer should be compliant to the standard Flex-Offer specification.
EDF_REQ_OPE_01	Training data	At least 3 months of complete historic data is required for training
EDF_REQ_OPE_02	Up-to-date information	User/business constraints and data need to be at least 15 min old.

6.3 Market mechanisms

6.3.1 PUC14 Processing network data

6.3.1.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Process network technical specifications provided by the Geographical Information System (GIS), the TS SCADA and DS SCADA applications and convert these network data in a form that can be used by the Day-ahead Market Scheduler application (DAMSc) and the Power Flow Simulator (PFS).
Objective(s)	1) Process network data and convert to a predefined format applicable to the DAMSc and PFS

Related high-level use case(s)	HLUC 09: Day-ahead market mechanisms incentivizing energy flexibility trading for mitigating problems of the transmission system & distribution network, integrating wholesale and retail markets

6.3.1.2 Narrative of use case

Narrative of use case
Short description
The Network Data Processing Application (NDPA) processes heterogeneous network technical data and converts them in a predefined format applicable to the DAMSc and PFS. Network data are provided by the GIS, the systems of TSO and DSO either in a standard or in different formats. NDPA's goal is to convert the heterogeneous network data files in a predefined format that can be used by the Day-ahead Market Scheduler and the Power Flow Simulator.
Complete description
The Network Data Processing Application receives network data (e.g. topologies, thermal limits, switch status) from different sources and in different formats. In particular network data are transferred by the: • GIS • SCADA of the TSO (TS SCADA) • SCADA of the DSO (DS SCADA) Data and can be in a standardized format (e.g. Common Information Model – CIM) or in heterogeneous data formats. The exploitation of heterogeneous network data files by a specific process entails the pre-processing of these data and its conversion to a predefined data format. The NDPA is responsible for converting the GIS, TSO and DSO network data in a predefined form that can be used by the Day-ahead Market Scheduler application and the Power Flow Simulator.

6.3.1.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC14_1	Conversion time/number of nodes	Expresses the time required to convert the data to the predefined format, in reference with the number of nodes of the system/network	1

6.3.1.4 Use case conditions

Use case conditions

Assumption(s)
• Network data are provided by GIS, TS & DS SCADA applications (in heterogeneous formats)
Precondition(s)
• GIS, TS & DS SCADA are operational and able to provide network information • Data provided for processing are valid

6.3.1.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC 18: Day-ahead market scheduling **PUC 17: Market schedule prequalification**
Level of Depth
Detailed
Prioritization
High
Generic, regional or national relation
Regional
Nature of the use case
Business/Market
Further keywords for classification
TS & DS SCADA, unified network data format

6.3.1.6 Use case diagram

Diagram(s) of use case

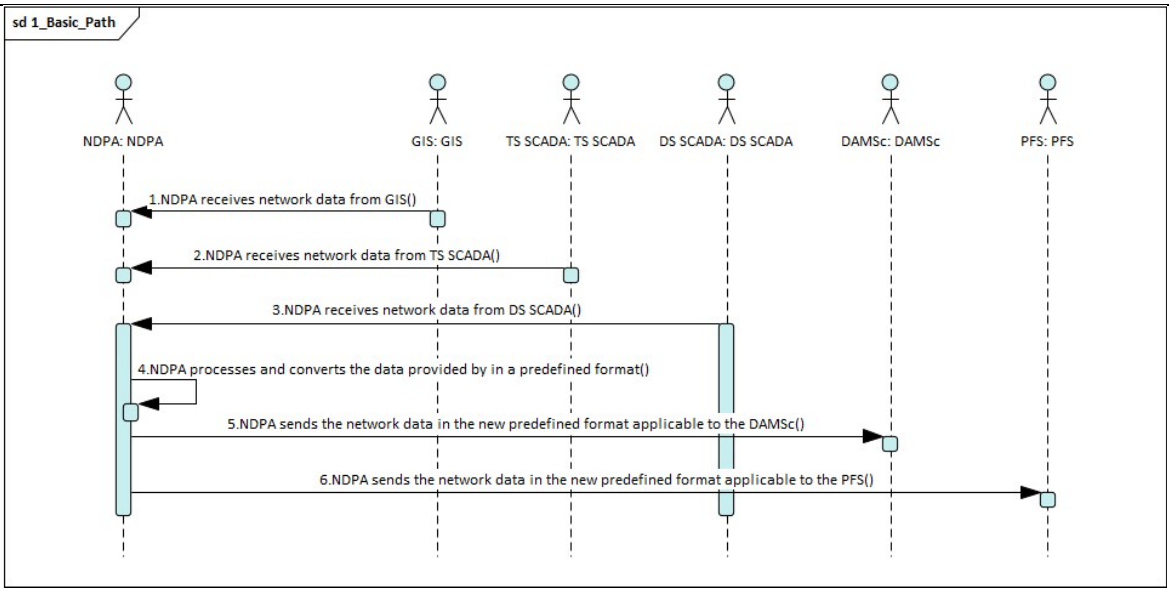


Figure 42 PUC14 Sequence Diagram

6.3.1.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Network Data processing Application (NDPA)	Application	Application that processes the received network data and converts them in a format that can be inserted to the Day-ahead market scheduler and the Power Flow Simulator.	Application under design.
TS SCADA	Application	A system in charge of overall monitoring and control of the transmission grid.	Provides grid operation information
Geographic Information System (GIS)	System	System that manages all the static information related to the grid assets and location.	Provides grid asset information, including operational limits.
DS SCADA	System	A system in charge of overall monitoring and control of the distribution grid.	Provides grid operation information
Day-ahead Market Scheduler	Application/Logical Actor	Application that implements a day-ahead market which is a mandatory pool or power exchange where the	

(DAMSc)		market model clears buy and sell orders using marginal pricing	
Power Flow Simulator (PFS)	Application	Application that performs the optimal power flow of the Distribution System	Provides power flow simulation.

6.3.1.8 References

References						
No.	**Type**	**Reference**	**Status**	**Impact**	**Originator / Organization**	**URL**
1	Report	TSO – DSO REPORT: AN INTEGRATED APPROACH TO ACTIVE SYSTEM MANAGEMENT	Published			
2	Publication	M. Caramanis, E. Ntakou, W. W. Hogan, A. Chakrabortty and J. Schoene, "Co-Optimization of Power and Reserves in Dynamic T&D Power Markets With Nondispatchable Renewable Generation and Distributed Energy Resources," in Proceedings of the IEEE, vol. 104, no. 4, pp. 807-836, April 2016.	Published			
3	Publication	Samson Yemane Hadush, Leonardo Meeus, DSO-TSO cooperation issues and solutions for distribution grid congestion management, Energy Policy, Volume 120, 2018, Pages 610-621	Published			

6.3.1.9 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Processing Network Data	Describes the process of converting heterogeneous network technical data in a predefined format that can be used by the Day-ahead Market Scheduler application and the Power Flow Simulator	Network Data processing Application (NDPA)	Periodic process	The GIS, TS & DS SCADA applications are operational and able to provide Network Data information Network Data provided by GIS, TS & DS SCADA applications are within a group of predefined possible format options. Data provided are valid	Data transformed and provided to DAMSc and PFS

Scenario							
Scenario name:			Processing Network Data				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Upon request	Get network data from GIS	NDPA receives network data from GIS	GIS	NDPA	Grid Information & Topology	
2	After step 1	Get network data from TS SCADA	NDPA receives network data from TS SCADA	TS SCADA	NDPA	Grid Information & Topology	

3	After step 2	Get network data from DS SCADA	NDPA receives network data from DS SCADA	DS SCADA	NDPA	Grid Information & Topology	
4	Upon request	Process network data from all sources (GIS, TS SCADA, DS SCADA	NDPA processes and converts the data provided by in a predefined format	NDPA	NDPA		NDPA_REQ_SCA_01
5	After step 4	Send processed network data from all sources (GIS, TS SCADA, DS SCADA) to DAMSc	NDPA sends the network data in the new predefined format applicable to the DAMSc	NDPA	DAMSc	Processed Grid Information & Topology	
6	After step 5	Send processed network data from all sources (GIS, TS SCADA, DS SCADA) to PFS	NDPA sends the network data in the new predefined format applicable to the PFS	NDPA	PFS	Processed Grid Information & Topology	

6.3.1.10 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
GridInfoTplg	Grid Information & Topology	Information related to topologies, thermal limits, switch status etc. Information is provided by the GIS, TS SCADA and DS SCADA in various formats.	
PrcsGridInfoTplg	Processed Grid Information & Topology	Network data retrieved from various system sources (GIS, TS SCADA, DS SCADA) converted in a predefined format that can be used by DAMSc and the PFS.	

6.3.1.11 Requirements

Requirements ID	Requirement name	Requirement description
NDPA_REQ_SCA_01	NDPA Scalability	NDPA should be able to convert data from small to medium scale network topologies

6.3.2 PUC16 Disaggregating day-ahead market schedule

6.3.2.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Describes the process of disaggregating the day ahead market schedule to consumption/production profiles at nodal/area level of distribution grid.
Objective(s)	1) Decompose the market schedules at nodal/area level of distribution grid.
Related high-level use case(s)	HLUC 09: Day-ahead market mechanisms incentivizing energy flexibility trading for mitigating problems of the transmission system & distribution network, integrating wholesale and retail markets

6.3.2.2 Narrative of use case

Narrative of use case
Short description

The day-ahead market (DAM) schedule communicates the market schedules for the market participants. These schedules reflect the aggregated consumption/production profiles of the DERs of market stakeholder (BRP or FSP). The disaggregation process aims to decompose the energy market schedule to several profiles reflecting the consumption/production profiles at nodal/area level of distribution system (DS).
Complete description
The Day-ahead Market Schedule Disaggregation Application (DAMSDA) receives the market schedules of BRPs or FSPs. The market schedules reflect the aggregated consumption/production profiles of the DERs of each BRP or FSP and are produced by the Day-ahead Market Scheduler (DAMSc) considering constraints of the transmission system. The Day-ahead Market Schedule Disaggregation Application (DAMSDA) disaggregates the market schedules to consumption/production profiles on a Distribution System (DS) nodal level. BRPs or FSPs send to the DAMSc disaggregation coefficients, which reflect estimates on the proportion of each FSP's/BRP's aggregated consumption / production that corresponds to each node of the DS. The DAMSDA uses the disaggregation coefficients provided by the BRPs or FSPs to produce the disaggregated profiles per DS node and per BRP or FSP. Then the disaggregated profiles per DS node for all BRPs and FSPs are easily calculated. The disaggregated profiles produced by the DAMSDA are introduced to the Power Flow Simulator (PFS) which performs an optimal power flow at the distribution system in order to ensure that network operational constraints are not violated.

6.3.2.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
1	Responsiveness of the Day-ahead Market Schedule Disaggregation Application	Expresses the time required to decompose the initial market schedules after receipt of the disaggregation coefficients	1

6.3.2.4 Use case conditions

Use case conditions
Assumption(s)
• DAM model is solved by applying a two iterative solution mechanism
Precondition(s)
• The DAMSc is operational and is able to provide accurate market schedules

• The BRPs or FSPs are able to provide information relevant to disaggregation (disaggregation coefficients)

6.3.2.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC 18: Day-ahead market scheduling **PUC 17: Market schedule prequalification**
Level of Depth
Detailed
Prioritization
High
Generic, regional or national relation
Regional
Nature of the use case
Business/Market
Further keywords for classification
day-ahead market schedule disaggregation, nodal level disaggregated consumption, nodal level disaggregated production

6.3.2.6 Use case diagram

Diagram(s) of use case

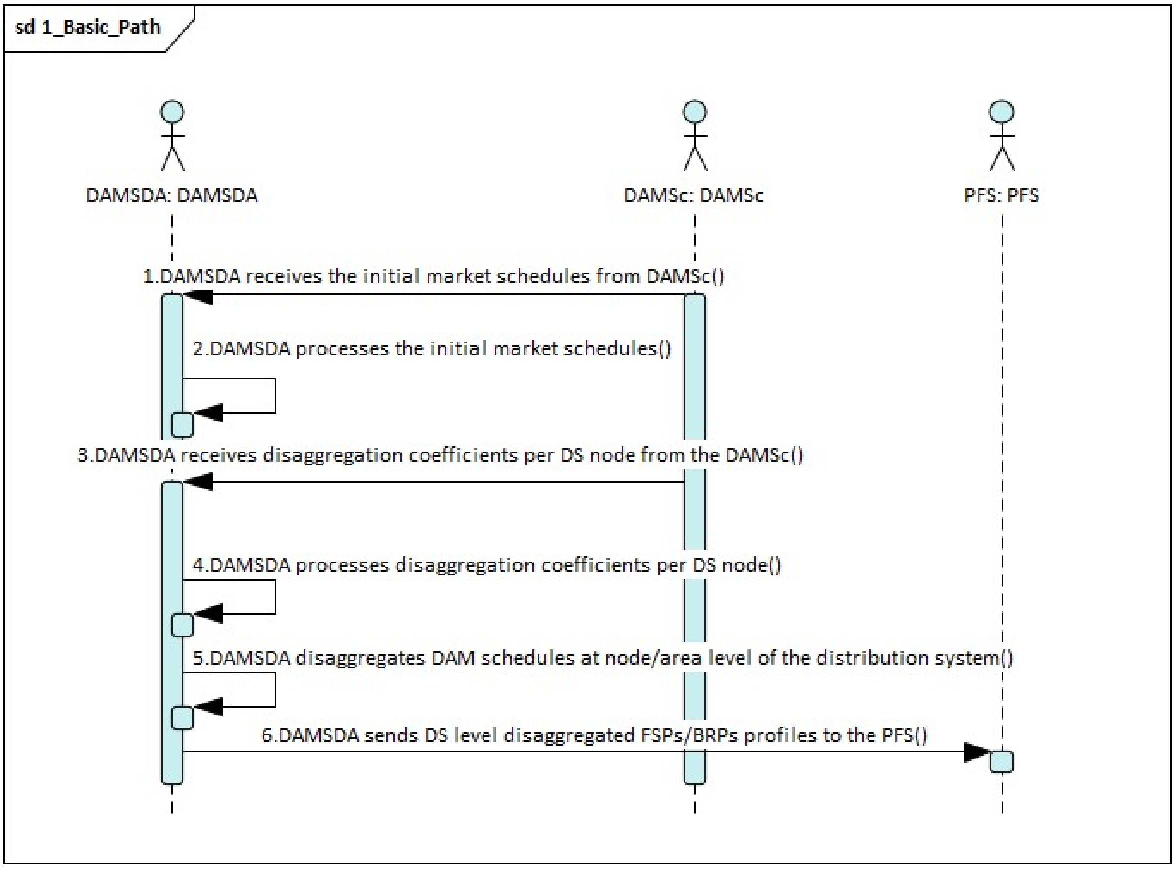


Figure 43 PUC16 Sequence Diagram

6.3.2.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
DAM schedule disaggregation application (DAMSDA)	Application	Application that performs the initial market schedule disaggregation at node/area level of the distribution system	
Day-ahead Market Scheduler (DAMSc)	Application	Application that solved the day-ahead market	
Power Flow Simulator (PFS)	Application	Application that performs the optimal power flow of the Distribution System	Provides power flow simulation.

6.3.2.8 References

References						
No.	**Type**	**Reference**	**Status**	**Impact**	**Originator / Organization**	**URL**
1	Publication	. Loukarakis, J. W. Bialek and C. J. Dent, "Investigation of Maximum Possible OPF Problem Decomposition Degree for Decentralized Energy Markets," in IEEE Transactions on Power Systems, vol. 30, no. 5, pp. 2566-2578, Sept. 2015. doi: 10.1109/TPWRS.2014.2365959	Published			

6.3.2.9 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Disaggregating day-ahead market schedule	Disaggregation of the DAM schedules at node/area level of the distribution system	DAM Schedule Disaggregation Application (DAMSDA)	Periodic process	The DAMSc is solved and can provide accurate market schedules	DS level disaggregated FSPs/BRPs profiles are created

Scenario							
Scenario name:			Disaggregating day-ahead market schedule				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	After solution of the initial DAM	Receive initial DAM schedules	DAMSDA receives the initial market schedules from DAMSc	DAMSc	DAMSDA	Initial DAM schedules	
2	Upon receiving data	Process the initial market schedules	DAMSDA processes the initial market schedules send by the DAMSc	DAMSDA	DAMSDA		
3	Upon request	Receive disaggregation coefficients	DAMSDA receives disaggregation coefficients per DS node from the DAMSc	DAMSc	DAMSDA	Disaggregation coefficients	DAMSDA_REQ_DQ_01

4	Upon receiving data	Process disaggregation coefficients	DAMSDA processes disaggregation coefficients per DS node from the DAMSc	DAMSDA	DAMSDA		
5	Periodic Process	Disaggregate DAM schedules	DAMSDA disaggregates DAM schedules at node/area level of the distribution system	DAMSDA	DAMSDA		DAMSDA_REQ_SCA_01
6	Upon disaggregation	Forward disaggregated results	DAMSDA sends DS level disaggregated FSPs/BRPs profiles to the Power Flow Simulator	DAMSDA	PFS	DS level disaggregated FSPs/BRPs profiles	

6.3.2.10 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
DamSchedule	Initial DAM Schedules	Initial DAM schedules produced by the DAMSc considering constraints of the transmission system	
DissCoef	Disaggregation coefficients	Estimates on the proportion of each FSP's/BRP's aggregated consumption / production that corresponds to each node of the DS	DAMSDA_REQ_DQ_01
NodeProfile	DS level disaggregated FSPs/BRPs profiles	Consumption/production profiles on a Distribution System (DS) nodal level	

6.3.2.11 Requirements

Requirements ID	Requirement name	Requirement description
DAMSDA_REQ_DQ_01	Disaggregation coefficients quality	The BRPs or FSPs are able to provide accurate information relevant to disaggregation (disaggregation coefficients)
DAMSDA_REQ_SCA_01	DAMSDA Scalability	DAMSDA needs to be functional for medium scale distribution networks (i.e. networks with approx. 500 lines, 130 nodes)

6.3.3 PUC17 Market schedule prequalification

6.3.3.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	Describes the process of performing an optimal power flow at the distribution system, to ensure that the market schedule is not violating the voltage and line flow constraints of the distribution grid.
Objective(s)	1) Use the disaggregated day-ahead market schedule to perform an optimal power flow at the distribution system 2) Modify the initial disaggregated day-ahead market schedule to ensure secure and reliable operation of the distribution grid

Related high-level use case(s)	HLUC 09: Day-ahead market mechanisms incentivizing energy flexibility trading for mitigating problems of the transmission system & distribution network, integrating wholesale and retail markets

6.3.3.2 Narrative of use case

Narrative of use case
Short description
The disaggregated day-ahead market schedule produced by the Day-ahead Market Schedule Disaggregation Application (DAMSDA) are introduced to the Power Flow Simulator (PFS). The PFS performs an optimal power flow at the distribution level. This way new disaggregated market schedules are produced, considering the distribution grid topology and operational constraints. The disaggregated profiles are send to the Day-ahead Market Scheduler (DAMSc) in order to re-solve the day-ahead market.
Complete description
The market schedule prequalification process aims to assess the impact of the market scheduling of DER assets located at distribution level on the operation of the distribution grid. The prequalification is realized through an optimal power flow of the distribution grid considering its topology and its operational constraints. The optimal power flow is performed by the PFS and it requires the outcome of the disaggregated day-ahead market schedule process as well as the technical specifications of the distribution network provided by the NDPA. In addition the DAMSc provides to the PFS operation and techno economic data of the FSPs and the BRPs. The optimal power flow can result in a modification of the initial disaggregated market schedule so that the voltage and line flow constraints are not violated. Possible requested modification of the market schedule ensuring the secure and reliable operation of the distribution grid are forwarded to the DAMSc in order to re-solve the day-ahead market and output the final day-ahead market schedules. In this way, the stable and secure network operation is considered by the day-ahead market scheduler.

6.3.3.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC17_1	% change of the initial disaggregated market schedules	Expresses the percentage change between the initial disaggregated DAM schedules and the modified disaggregated DAM schedules, as resulting from the PFS	2
KPI_PUC17_2	Number of power lines on which thermal limits are reached	Expresses the number of power lines where the thermal limits are reached as a binding constraint of the optimization	1

KPI_PUC17_3	Number of nodes on which voltage limits are reached	Expresses the number of nodes where the voltage limits are reached as a binding constraint of the optimization	1
KPI_PUC17_4	Optimization execution time	Expresses the time needed by the PFS to solve the optimization problem	1

6.3.3.4 Use case conditions

Use case conditions
Assumption(s)
• DAM model is solved by applying a two iterative solution mechanism
Precondition(s)
• The DAMSc is operational and is able to provide accurate market schedules • The DAMSDA is operational and is able to provide disaggregated market schedules and techno-economic data of the FSPs/BRPs. • The NDPA is operational and able to provide applicable network data

6.3.3.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC 18: Day-ahead market scheduling **PUC 14: Processing network data** **PUC 16: Disaggregating day-ahead market schedule**
Level of Depth
Detailed
Prioritization
High
Generic, regional or national relation
Regional
Nature of the use case

Business/Market
Further keywords for classification
power flow simulation, distribution grid topology, distribution grid operational constraints, market schedule validation

6.3.3.6 Use case diagram

Diagram(s) of use case

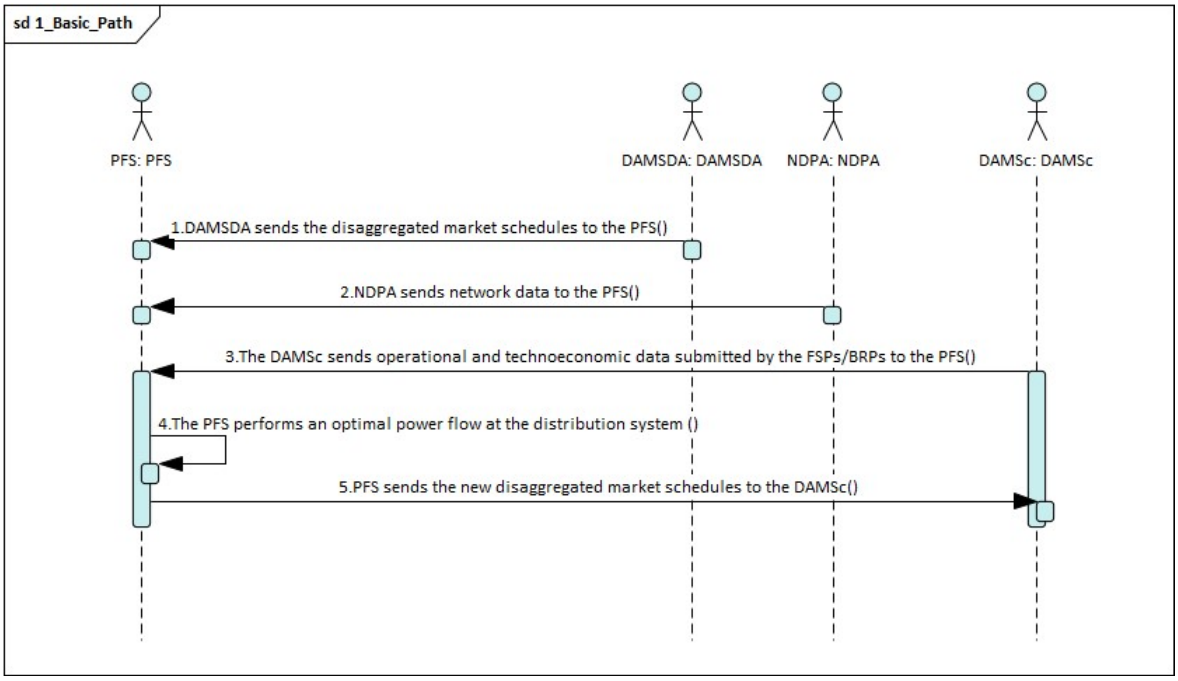


Figure 44 PUC17 Sequence Diagram

6.3.3.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Power Flow Simulator (PFS)	Application	Application that performs the optimal power flow of the Distribution System.	Provides power flow simulation.
DAM schedule disaggregation application (DAMSDA)	Application	Application that performs the initial market schedule disaggregation at node/area level of the distribution system.	

Network Data processing Application (NDPA)	Application	Application that processes the received network data and converts them in a form that can be inserted to the Day-ahead market scheduler.	
Day-ahead Market Scheduler **(DAMSc)**	Application	Application that solves the day-ahead market.	

6.3.3.8 References

References						
No.	**Type**	**Reference**	**Status**	**Impact**	**Originator / Organization**	**URL**
1	Publication	M. Caramanis, E. Ntakou, W. W. Hogan, A. Chakrabortty and J. Schoene, "Co-Optimization of Power and Reserves in Dynamic T&D Power Markets With Nondispatchable Renewable Generation and Distributed Energy Resources," in Proceedings of the IEEE, vol. 104, no. 4, pp. 807-836, April 2016.	Published			
2	Publication	P. Andrianesis and M. Caramanis, "Distribution Network Marginal Costs: Enhanced AC OPF Including Transformer Degradation," in IEEE Transactions on Smart Grid.	Published			
3	Publication	Helena Gerard, Enrique Israel Rivero Puente, Daan Six, Coordination between transmission and distribution system operators in the electricity sector: A conceptual framework, Utilities Policy, Volume 50, 2018, Pages 40-48	Published			
4	Publication	Samson Yemane Hadush, Leonardo Meeus, DSO-TSO cooperation issues and solutions for distribution grid congestion management, Energy Policy, Volume 120, 2018, Pages 610-621	Published			

5	Publication	. Loukarakis, J. W. Bialek and C. J. Dent, "Investigation of Maximum Possible OPF Problem Decomposition Degree for Decentralized Energy Markets," in IEEE Transactions on Power Systems, vol. 30, no. 5, pp. 2566-2578, Sept. 2015. doi: 10.1109/TPWRS.2014.2365959	Published			

6.3.3.9 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Market schedule prequalification	Describes the process for validating DAM results on a distribution system level, via performing a DS optimal power flow	PFS	Periodic Process	Availability of data	New disaggregated market schedules validated on the distribution level

Scenario							
Scenario name:			Market schedule prequalification				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic Process	Get disaggregated market schedules	DAMSDA sends the disaggregated market schedules to the PFS	DAMSDA	PFS	Disaggregated market schedules	
2	Periodic Process	Get Network data	NDPA sends network data to the PFS	NDPA	PFS	Grid Topology	PFS_REQ_INT_01
3	Periodic Process	Get operational/technoeconomic data	The DAMSc sends operational and technoeconomic data submitted by the FSPs/BRPs to the PFS	DAMSc	PFS	Operational / techno-economical data	
4	Periodic Process	Perform DS Optimal Power Flow	The Power Flow Simulator (PFS) performs	PFS	PFS		PFS_REQ_SCA_01,

			an optimal power flow at the distribution system				PFS_REQ_PER_01
5	Periodic Process	Communicate new disaggregated market schedules	PFS sends the new disaggregated market schedules to the DAMSc	PFS	DAMSc	New disaggregated market schedules validated on the distribution level	

6.3.3.10 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
DisaggrSchedule	Disaggregated market schedules	The initial market schedules as produced by the first run of the DAMSc and disaggregated by the DAMSDA	
GridTopology	Grid Topology	Information related to the grid topology and operational constraints	PFS_REQ_INT_01
TechEconData	Operational / techno-economic data	Operational / techno economic data submitted by the FSPs/ BRPs to the DAMSc	
UpdDisaggrSchedule	New disaggregated market schedules validated on the distribution level	The disaggregated market schedules as modified by the PFS	

6.3.3.11 Requirements

Requirements ID	Requirement name	Requirement description
PFS_REQ_SCA_01	PFS Scalability	PFS needs to be functional for medium sized distribution networks (i.e. networks with approx. 500 lines and 130 nodes)
PFS_REQ_PER_01	Max duration of PFS execution	The process of performing the optimal power flow of the Distribution System should not violate the operating timeline
PFS_REQ_INR_01	NDPA data interoperability	NDPA converts information from the network to a form applicable to the PFS

6.3.4 PUC18 Day-ahead market scheduling

6.3.4.1 Scope and objectives of use case

Scope and objectives of the use case

Scope	The scope of the day ahead market scheduling is to simulate a centralized wholesale market mechanism enabling the exploitation of the flexibility available both in the transmission system & in the distribution grid.
Objective(s)	1) Produce optimal market schedules which optimize market welfare 2) Consider the impact of grid constraints provided by the TSO & DSO to ensure market schedule feasibility 3) Offer innovative energy products for flexibility resources
Related high-level use case(s)	HLUC 09: Day-ahead market mechanisms incentivizing energy flexibility trading for mitigating problems of the transmission system & distribution network, integrating wholesale and retail markets

6.3.4.2 Narrative of use case

Narrative of use case
Short description
Day ahead market scheduling is a process of considering network operational constraints (both transmission and distribution), FSP offers (bidding strategy) and BRP forecasts to produce optimal market schedules. Optimization is considered in maximizing market welfare.
Complete description
The day ahead market scheduling is a centralized wholesale market mechanism enabling the exploitation of the flexibility sitting in both the transmission system & distribution grid. The day-ahead market can be a mandatory pool or power exchange where the market model clears buy and sell orders using marginal pricing. It is an iterative market clearing solution which facilitates the trading of energy, in order to match supply with demand at day-ahead level and incorporates grid constraints provided by the TSO & DSO to ensure market schedule feasibility and to improve congestion management. This market model produces also Locational Marginal Prices at T&D nodes/areas. The Retailers are able to exploit the locational variability of the prices to impose flexible pricing schemes to their customers. The Day-ahead Market Scheduler (DAMSc) is solved iteratively to achieve optimal market schedules that consider both T&D constrains. The execution steps of the main scenario (DAM two iterative solution mechanism) are as follows: • The Network Data processing application (NDPA) sends the transmission system data and GIS system data to the DAMSc • The BRP forecasts the injection/offtake of non-dispatchable resources and submits the forecast to the DAMSc. • FSP submit orders (bidding strategy) to the DAMSc through a Bidding Application • FSPs and BRPs submit operational / techno economic data to the DAMSc • An initial run of the DAMSc is executed and produces the initial aggregated market schedules. • The initial aggregated market schedules are sent as input to the DAM schedule Disaggregation Application (DAMSDA) where they are disaggregated at nodal/area level of the distribution system. • The disaggregated results are then fed to the Power Flow Simulator (PFS) where a DS

optimal power flow is executed in order to prequalify the initial market schedule. • The optimal power flow results are then sent back the DAMSc which is re-executed and produces the final market schedules. A second scenario (DAM multi-iterative solution mechanism) in solving the DAMSc will also be investigated, through which the T&D constraints will be integrated in a single model. The second scenario results in market solutions with optimal welfare but requires higher model complexity.

6.3.4.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC18_1	Absolute/relative optimality gap tolerance	Expresses the absolute/relative gap tolerance between the theoretical optimum feasible solution and the solution achieved within a predefined time limit.	1
KPI_PUC18_2	Optimization execution time	Expresses the time needed by the DAMSc to reach a predefined optimality gap, namely to reach a solution with a predefined distance from the theoretical optimum feasible solution	1
KPI_PUC18_3	Reduction of welfare due to market schedule prequalification	Expresses the difference between the welfare of the initial DAMSc execution and the welfare of the second DAMSc execution, which reflects the constraints imposed by the market schedule prequalification. The KPI is applicable only in the "DAM two iterative solution mechanism" scenario.	1, 2

6.3.4.4 Use case conditions

Use case conditions
Assumption(s)
• Day-ahead market model is designed as a mandatory power pool or a power exchange with marginal pricing • Asset based participation in the wholesale market
Precondition(s)
• The Network Data Processing Application (NDPA) is operational and able to provide Network Data information in a predefined form • The FSPs/BRPs are able to submit their bidding strategies to the DAMSc • The FSPs/BRPs are able to submit operational and techno economic data to the DAMSc

• The DAM Schedule Disaggregation Application (DAMSDA) is operational and able to provide disaggregated profiles • The Power Flow Simulator (PFS) is operational and able to evaluate the initial market schedules considering DS constraints.

6.3.4.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC 14: Processing network data **PUC 16: Disaggregating day-ahead market schedule** **PUC 17: Market schedule prequalification**
Level of Depth
Detailed
Prioritization
High
Generic, regional or national relation
Regional
Nature of the use case
Business/Market
Further keywords for classification
Market Welfare Optimization, Market schedule, Bidding offers clearing

6.3.4.6 Use case diagram

Diagram(s) of use case

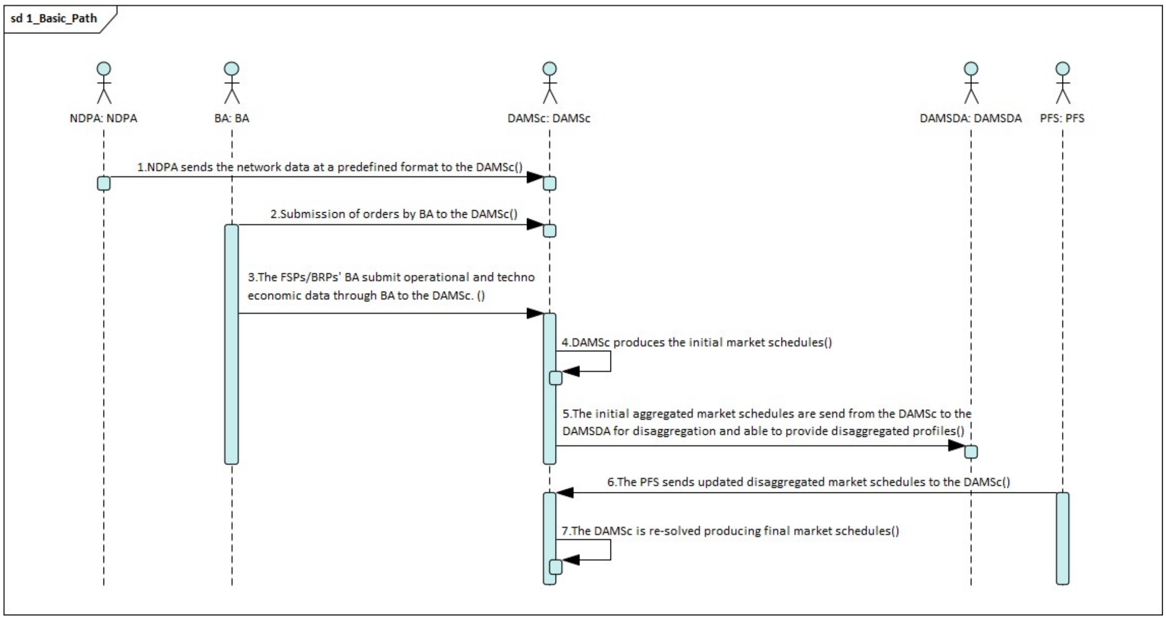


Figure 45 PUC18 Sequence Diagram - Scenario 1

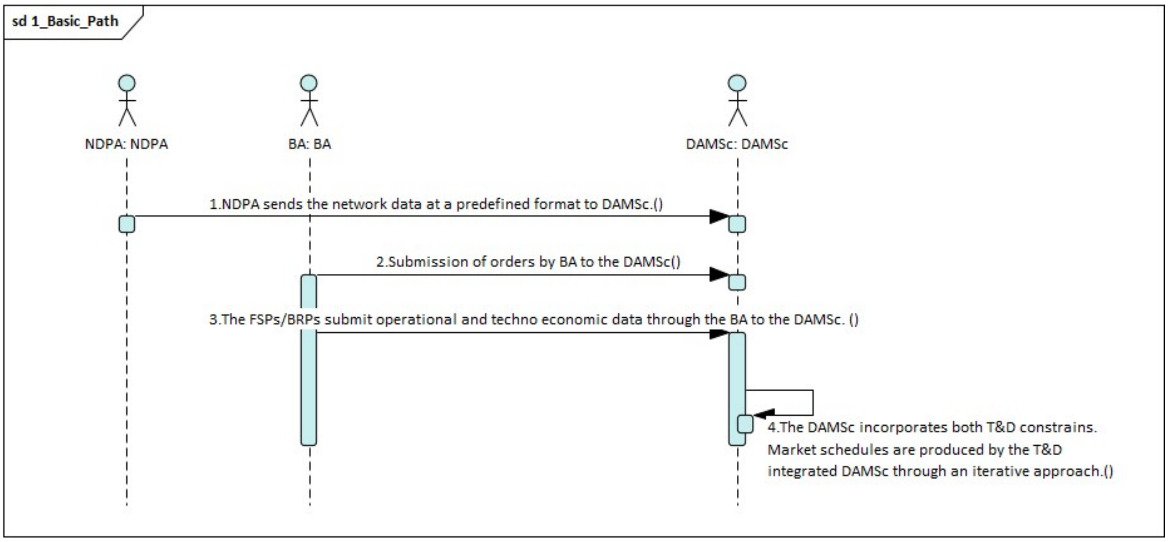


Figure 46 PUC18 Sequence Diagram - Scenario 2

6.3.4.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Power Flow Simulator (PFS)	Application	Application that performs the optimal power flow of the Distribution System.	Provides power flow simulation.

DAM schedule disaggregation application **(DAMSDA)**	Application	Application that performs the initial market schedule disaggregation at node/area level of the distribution system.	
Day-ahead Market Scheduler **(DAMSc)**	Application	Application that solved the day-ahead market.	
Network Data processing Application (NDPA)	Application	Application that processes the received network data and converts them in a form that can be inserted to the Day-ahead market scheduler.	
Bidding application (BA)	Application	Application that performs the bidding strategy of a DAM participant.	Will not be developed in the project. Indicative bidding strategies will be simulated and send to the DAMSc.

6.3.4.8 References

References						
No.	**Type**	**Reference**	**Status**	**Impact**	**Originator / Organization**	**URL**
1	Regulation	Clean Energy Package https://www.eurelectric.org/policy-areas/clean-energy-package/	Published			
2	Publication	M. Caramanis, E. Ntakou, W. W. Hogan, A. Chakrabortty and J. Schoene, "Co-Optimization of Power and Reserves in Dynamic T&D Power Markets With Nondispatchable Renewable Generation and Distributed Energy Resources," in Proceedings of the IEEE, vol. 104, no. 4, pp. 807-836, April 2016.	Published			
3	Publication	P. Andrianesis and M. Caramanis, "Distribution Network Marginal Costs: Enhanced AC OPF Including Transformer	Published			

		Degradation," in IEEE Transactions on Smart Grid.				
4	Publication	Helena Gerard, Enrique Israel Rivero Puente, Daan Six, Coordination between transmission and distribution system operators in the electricity sector: A conceptual framework, Utilities Policy, Volume 50, 2018, Pages 40-48	Published			
5	Publication	Samson Yemane Hadush, Leonardo Meeus, DSO-TSO cooperation issues and solutions for distribution grid congestion management, Energy Policy, Volume 120, 2018, Pages 610-621	Published			
6	Publication	. Machamint, K. Oureilidis, V. Efthymiou and G. E. Georghiou, "Investigation of the Role of an Aggregator Operating in the European Spot and Balancing Markets; the Case of an Island," 2018 15th International Conference on the European Energy Market (EEM), Lodz, 2018, pp. 1-5. doi: 10.1109/EEM.2018.8469913	Published			
7	Publication	K. Zhang, Y. Song, Z. Yan and Y. Yu, "Research on bidirectional decision-making for load aggregators participating in market transactions and load dispatching," in CIRED - Open Access Proceedings Journal, vol. 2017, no. 1, pp. 2874-2878, 10 2017. doi: 10.1049/oap-cired.2017.0164	Published			
8	Publication	. Loukarakis, J. W. Bialek and C. J. Dent, "Investigation of Maximum Possible OPF Problem Decomposition Degree for Decentralized Energy Markets," in IEEE Transactions on Power Systems, vol. 30, no. 5, pp. 2566-2578, Sept. 2015. doi: 10.1109/TPWRS.2014.2365959	Published			
9	Publication	D. Papadaskalopoulos and G. Strbac, "Decentralized Participation of Flexible Demand	Published			

		in Electricity Markets—Part I: Market Mechanism," in IEEE Transactions on Power Systems, vol. 28, no. 4, pp. 3658-3666, Nov. 2013. doi: 10.1109/TPWRS.2013.2245686				
10	Publication	M. C. Caramanis and J. M. Foster, "Coupling of day ahead and real-time power markets for energy and reserves incorporating local distribution network costs and congestion," 2010 48th Annual Allerton Conference on Communication, Control, and Computing (Allerton), Allerton, IL, 2010, pp. 42-49. doi: 10.1109/ALLERTON.2010.5706886	Published			

6.3.4.9 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	DAM two iterative solution mechanism	Describes the process for solving the DAMSc in two steps. The first iteration produces the DAM schedules considering the transmission constraints. Then the DAM results are validated on a DS level through the DS PFS and the respective results are subsequently fed to the DAM model which is rerun and produces the final market schedules. The DAM reaches a sub-optimal market welfare.	DAMSc	Periodic Process	Data Availability DAMSDA is operational and able to provide disaggregated profiles PFS is operational and able to evaluate the initial market schedules considering DS constraints.	Market schedules produced
2	DAM multi-iterative solution mechanism	In this scenario the DAM is an integrated model, where a multi-iterative procedure is adopted to incorporate both T&D constrains The benefit of this approach is that the market solution will reach the optimal welfare. This comes at the expense of higher model complexity that has to be dealt with incorporating complex mathematical programming techniques.	DAMSc	Periodic Process	Data Availability	Market schedules produced

Scenario	
Scenario name:	DAM two iterative solution mechanism

Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Inf. Producer (Actor)	Inf. Receiver (Actor)	Inf. Exchanged	Requirements, R-ID
1	Periodic Process	Data reception from NDPA	NDPA sends the network data at a predefined format to DAMSc.	NDPA	DAMSc	Grid Topology	DAMSc_REQ_DQ_02 DAMSc_REQ_INT_01
2	Upon request	Data reception from the Bidding Application	Submission of orders by BA to the DAMSc.	BA	DAMSc	FSP orders	DAMSc_REQ_DQ_01
3	Upon request	Data reception from the FSPs/BRPs	The FSPs/BRPs submit operational and techno economic data through the BA to the DAMSc.	BA	DAMSc	Operational and techno economic data	
4	Periodic Process	Produce initial market schedules	DAMSc produces the initial market schedules.	DAMSc	DAMSc	-	DAMSc_REQ_SCA_01, DAMSc_REQ_PER_01
5	Upon calculation	Send initial market schedules to the DAMSDA	The initial aggregated market schedules are send from the DAMSc to the DAMSDA for disaggregation and able to provide disaggregated profiles.	DAMSc	DAMSDA	Initial aggregated market schedules	
6	Upon request	Receive disaggregated market schedules as modified by the PFS	The PFS sends updated disaggregated market schedules to the DAMSc.	PFS	DAMSc	Updated disaggregated market schedules	
7	Upon receiving power flow data	DAMSc final solution	The DAMSc is re-solved producing final market schedules.	DAMSc	DAMSc		DAMSc_REQ_SCA_01, DAMSc_REQ_PER_01

Scenario							
Scenario name:			DAM multi-iterative solution mechanism				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
4b	Periodic Process	Produce optimal market schedules	The DAMSc incorporates both T&D constrains. Market schedules are produced by the T&D integrated DAMSc through an iterative approach.	DAMSc	DAMSc		DAMSc_REQ_SCA_01, DAMSc_REQ_PER_01

6.3.4.10 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
GridTopology	Grid Topology	Data produced by the NDPA delivering network information	DAMSc_REQ_DQ_02 DAMSc_REQ_INT_01
FspOrder	FSP orders	The orders (bidding strategy) submitted by the FSPs	DAMSc_REQ_DQ_01
TechEconData	Operational and techno economic data	The operational and techno economic data submitted by the FSPs/BRPs to the DAMSc.	
AggrSchedule	Initial aggregated market schedules	The initial aggregated market schedules send from the DAMSc to the DAMSDA	
DisaggrSchedule	Updated disaggregated market schedules	The updated disaggregated market schedules send from the PFS to the DAMSc	

6.3.4.11 Requirements

Requirements ID	Requirement name	Requirement description
DAMSc_REQ_DQ_01	Bidding information quality	The Bidding Application is able to provide information on the bidding strategies.
DAMSc_REQ_DQ_02	Network Data quality	The NDPA is able to provide applicable Network Data information
DAMSc_REQ_SCA_01	DAMSc scalability	DAMSc supports simulation of market mechanisms in medium sized power systems
DAMSc_REQ_PER_01	Max duration of DAMSc Solution	The process of producing the DAM schedules should not violate the operating timeline
DAMSc_REQ_INR_01	NDPA data interoperability	NDPA converts information from the network to a form applicable to the DAMSc

6.3.5 PUC20 Intra-day active/reactive energy flexibility trading

6.3.5.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	The scope of the PUC is to incentivize intra-day active/ reactive energy flexibility trading at the distribution grid, in order to address distribution network issues on a continuous level.
Objective(s)	1) Trade active and reactive energy at specific location and time.
Related high-level use case(s)	HLUC 10: Intra-day market mechanisms incentivizing active & reactive energy flexibility trading for mitigating problems of the distribution network

6.3.5.2 Narrative of use case

Narrative of use case
Short description
The Intra-day Flexibility Trading Mechanism (IDFTM) enables the trading of DER energy flexibility after the solution of the Day-Ahead Market and before the real-time market mechanisms. The market products will be the active and reactive energy at specific location and time. Two options will be investigated: a generator producing random disturbances of the distribution grid, which will be addressed by the intraday flexibility mechanism; flexibility trading data from FEVER pilots (in a second stage). The full set of product requirements will be specified along the development of the relevant market tool.
Complete description
The Intra-day Flexibility Trading Mechanism (IDFTM) enables the trading of active and reactive energy (flexibility) products. Two different data sets are considered for testing the application: one created by a generator and one utilizing flexibility trading data from FEVER pilots. The generator produces random grid issues and identifies and communicates the corresponding flexibility need to the intra-day active/reactive flexibility trading application, in the form of an offer requesting flexibility. It is assumed that offers providing flexibility are submitted in the intra-day active/reactive flexibility trading application on a constant basis. So, we simulate a pool of different offers by the Flexibility Service Providers that are continuously active in the intra-day active/reactive flexibility trading application, until their match with the corresponding requested need. When two offers are matched, then a trade is concluded and the offers are withdrawn from the platform. A second implementation that tests the compatibility of the intra-day active/reactive flexibility trading application with FEVER tools may be examined in a second stage, as described in the followings. By exploiting the FEVER DSO toolbox, the DSO identifies potential grid issues and requests the necessary flexibility by constructing an active/reactive flexibility request. The request is communicated via the Flexibility Service Consumer Agent (FSCA) to the IDFTM. IDFTM also receives flexibility offers from Flexibility Service Providers with assets sitting within the location where flexibility is needed. The offers of the Flexibility Service Providers are constructed and communicated by the Flexibility Service Provider Agent (FSPA). The active/reactive flexibility requests/offers are constructed by defining the flexibility type (active/reactive power), the direction ("buy/sell"), the location in DS grid (on a node/area level), the starting time for activating the flexibility and the duration for activating the flexibility. The intra-day active/reactive flexibility trading application on a continuous basis matches requests/offers. When a set is matched, then a trade is concluded and the corresponding requests/offers are withdrawn from the platform. The relative DSO and the FSP are notified for the trade.

6.3.5.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC20_1	Percentage of critical events addressed through the intraday market mechanism	Describes the percentage of critical events that are successfully addressed by the intraday market mechanism compared to the total number of critical events produced by the generator/ or by the DSO toolbox in case of the second implementation option	1

6.3.5.4 Use case conditions

Use case conditions
Assumption(s)
Precondition(s)
• Distribution grid issues are produced by a random system disturbances generator (only valid in the first implementation option) • The DSO can utilize the FEVER tools and identify distribution grid issues (only valid in the second implementation option) • Flexibility Service Consumer Agent (FSCA) and Flexibility Service Provider Agent (FSPA) can provide trading information

6.3.5.5 Further information to the use case for classification/mapping

Classification information
Relation to other use cases
PUC 03: Requesting flexibility services **PUC 04: Offering Flexibility Services**
Level of Depth
Detailed
Prioritization

High
Generic, regional or national relation
Regional
Nature of the use case
Business/Market
Further keywords for classification
Flexibility Trading, Distribution Grid Flexibility, FlexOffer, Intraday continuous trading

6.3.5.6 Use case diagram

Diagram(s) of use case

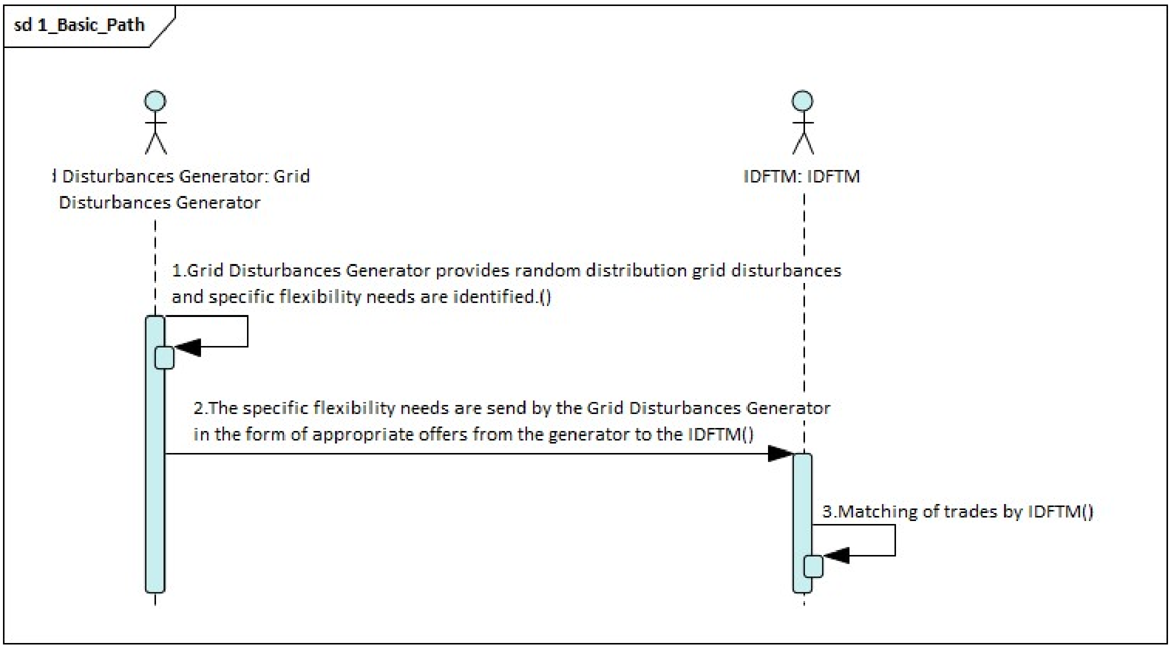


Figure 47 PUC20 Sequence diagram - Scenario 1

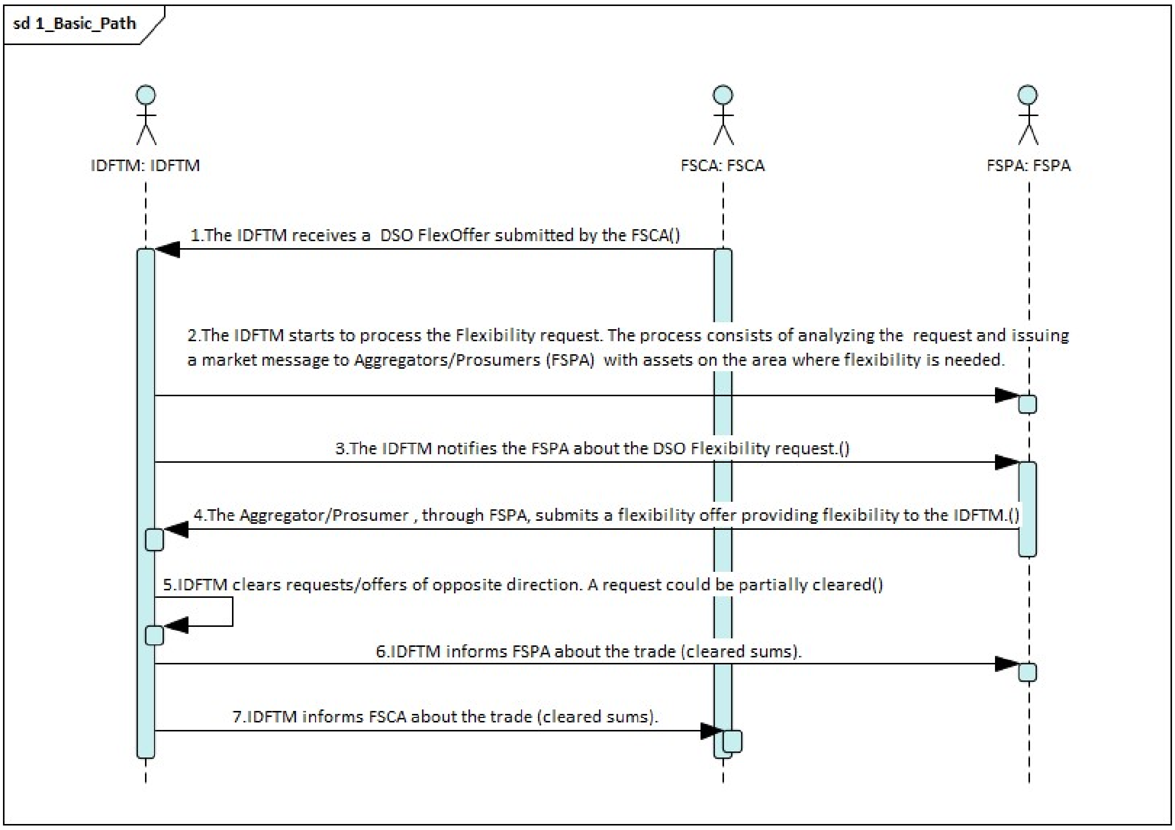


Figure 48 PUC20 Sequence diagram - Scenario 2

6.3.5.7 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
Intra-day Flexibility Trading Mechanism (IDFTM)	Application	Application that will implement the intra-day continuous trading mechanism.	
Flexibility Service Consumer Agent (FSCA)	Application	The agent responsible for packing the flexibility needs of an actor into flexibility bid/request in respect to the requirements imposed by the flexibility markets or the bilateral agreements.	Provides the DSOs' flexibility requests in the 2nd scenario
Flexibility Service Provider Agent (FSPA)	Application	The agent responsible for transforming the available flexibility of an actor to a bidding strategy with respect to the requirements imposed by the	only valid in the second implementation option

		flexibility markets or the bilateral agreements.	
Grid Disturbances Generator	Application	Application that creates random distribution grid disturbances to be solved within the intra-day continuous trading mechanism.	Valid in the 1st scenario

6.3.5.8 References

References						
No.	Type	Reference	Status	Impact	Originator / Organization	URL
1	Publication	Machamint, K. Oureilidis, V. Efthymiou and G. E. Georghiou, "Investigation of the Role of an Aggregator Operating in the European Spot and Balancing Markets; the Case of an Island," 2018 15th International Conference on the European Energy Market (EEM), Lodz, 2018, pp. 1-5. doi: 10.1109/EEM.2018.8469913	Published			
	Publication	Oureilidis, Konstantinos & Malamaki, Kyriaki-Nefeli & Gallos, Konstantinos & Tsitsimelis, Achilleas & Dikaiakos, Christos & Gkavanoudis, Spyros & Cvetkovic, Milos & Mauricio, Juan Manuel & Maza-Ortega, J.M. & Ramos, Jose & Papaioannou, George & Demoulias, Charis. (2020). Ancillary Services Market Design in Distribution Networks: Review and Identification of Barriers. Energies. 13. 917. 10.3390/en13040917.	Published			
2	Platform	GOPACS project				https://gopacs.eu/

6.3.5.9 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Intra-day active/reactive energy flexibility trading with simulated data	Intra-day active/reactive energy flexibility trading through generated data	IDFTM	Grid issue produced by the grid disturbances generator	The generator is operational and can produce critical grid events	A trade is concluded
1	Intra-day active/reactive energy flexibility trading with FEVER tools	Intra-day active/reactive energy flexibility trading with data from FEVER pilots	IDFTM	Grid issue identified by the DSO		A trade is concluded

Scenario							
Scenario name:			Intra-day active/reactive energy flexibility trading				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Continuously	Generation of random grid disturbance and analysis of flexibility need	Grid Disturbances Generator provides random distribution grid disturbances and specific flexibility needs are identified.	Grid Disturbances Generator	Grid Disturbances Generator		
	Continuously	Communication of flexibility need to the IDFTM	The specific flexibility needs are send by the Grid Disturbances Generator in the form of appropriate offers from the generator to the IDFTM	Grid Disturbances Generator	IDFTM	Flexibility request	REQ_PER_01 REQ_SCA_01

6	Continuously	Matching of trades	Different offers providing flexibility are constantly active in the IDFTM. When offers of opposite direction are available in the platform (DSO offers and Aggregator/Prosumer offers) they are instantaneously matched and a trade is concluded. An Offer could be partially cleared however the exact matching rules are to be defined.	IDFTM	IDFTM		REQ_PER_01 REQ_SCA_01

Scenario							
Scenario name:			Intra-day active/reactive energy flexibility trading (simulation that tests compatibility with FEVER tools)				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	Periodic Process	Flexibility request submission	The IDFTM receives a DSO flexibility request submitted by the FSCA.	FSCA	IDFTM	Flexibility request	
2	Periodic Process	Flexibility request processing	The IDFTM starts to process the Flexibility request. The process consists of analyzing the request and issuing a market message to Aggregators/Prosumers (FSPA) with assets on the area where flexibility is needed.	IDFTM	IDFTM		REQ_PER_01 REQ_SCA_01
3	Periodic Process	Message of flexibility request to the FSPA	The IDFTM notifies the FSPA about the DSO Flexibility request.	IDFTM	FSPA	Flexibility request Notification	REQ_PER_01 REQ_SCA_01

4	Periodic Process	Flexibility offer Submission	The Aggregator/Prosumer, through FSPA, submits a flexibility offer providing flexibility to the IDFTM.	FSPA	FSPA	Flexibility offer	REQ_PER_01 REQ_SCA_01
5	Periodic Process	Matching of trades	When requests/offers of opposite direction are available in the platform (DSO offers and Aggregator/Prosumer offers) they are instantaneously matched and a trade is concluded. A request could be partially cleared however the exact matching rules are to be defined.	IDFTM	IDFTM		REQ_PER_01 REQ_SCA_01
6	Periodic Process	Clearing of trades & dispatch instruction	The DSO and Aggregator involved in the trade are informed for the cleared sums.	IDFTM	FSPA, FSCA	Clearing information	REQ_PER_01 REQ_SCA_01

6.3.5.10 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements** **R-ID**
FlexRequest	Flexibility request	A concrete planned realization of a flexibility offer. Submitted by the DSO (FSCA) to the IDFTM for requesting flexibility s (only valid in case of the second implementation option).	IDFTM_REQ_ INR _01
FlexReqNotif	Flexibility request Notification	A notification on the request of flexibility by the DSO send by the IDFTM to the FSPA (only valid in case of the second implementation option)	
FlexOffer	Flexibility offer	An offer providing flexibility submitted by the FSPA to the IDFTM (only valid in case of the second implementation option)	IDFTM_REQ_ INR _01
ClearingInfo	Clearing information	Information on the clearing amounts send by the IDFTM to the FSPA and FSCA (only valid in case of the second implementation option)	

6.3.5.11 Requirements

Requirements ID	Requirement name	Requirement description
IDFTM_REQ_PER_01	IDFTM performance	The process of concluding a trade within the intraday flexibility mechanism should not violate the operating timeline
IDFTM_REQ_SCA_01	IDFTM scalability	IDFTM supports simulation of market mechanisms in medium sized power systems
IDFTM_REQ_ INR _01	Compliant to the FlexOffer protocol	Flexibility information exchanged between parties should comply with the FlexOffer protocol specification

6.3.6 PUC25 Real-time trading of balancing energy & reserve capacity flexibility

6.3.6.1 Scope and objectives of use case

Scope and objectives of the use case	
Scope	The scope of this UC is to incentivize the real-time trading of balancing energy & reserve capacity flexibility located on both the transmission & distribution grid. The prosumer is the main Balance Service Provider actor who sells reserve capacity that the TSO/DSO need to buy, and trades balancing energy to cover the imbalances of non-dispatchable resources. In order to enhance coordination, the transmission & distribution constraints are integrated in the market modelling. This way the dispatch instructions are feasible and instructed deviations can be reduced. The market model yields Locational Marginal Prices at T/D nodes/areas as a means to foster flexible retail pricing schemes.
Objective(s)	1) Build a real-time market platform that integrates flexibility services
Related high-level use case(s)	HLUC 11: Real-time market mechanism incentivizing energy & capacity flexibility trading from BSPs, to address balancing and T&D congestion management, integrating wholesale and retail markets

6.3.6.2 Narrative of use case

Narrative of use case
Short description
The UC implements centralized real-time market mechanisms operated by the IMO for exploiting flexibility from the transmission system and distribution network in order to balance demand with supply and manage congestion. The flexibility is bought by the system operators (TSO/DSO) in the form of balancing energy and reserve capacity on a real-time basis. The flexibility is provided by the Balance Service Entities (BSPs) who offer flexibility located at both the transmission and distribution

level. Locational Marginal Prices at Transmission and Distribution nodes/areas can be used to provide flexible pricing schemes providing a link to the retail market.
Complete description
The real-time balancing market is an integrated balancing / congestion management platform that is used for computing DLMPs and real-time balancing actions. The market is operated by an independent Market Operator who collects all the flexibility offers in both transmission and distribution grid along with imbalances runs the real-time market platform which determines upward and downward activations of real and reactive power. The goal of the real-time market platform is to integrate congestion management and balancing throughout the transmission and distribution system. The resulting price signals provide locational investment signals that attract investment in needed technologies, as well as signals for reinforcing the network wherever this is required. Moreover, the platform promotes economic efficiency by matching orders that benefit from trade, and by coordinating the operations of balancing and congestion management. Finally, the produced DLMPs prevent market manipulation through INC-DEC gaming by exposing agents to a locally uniform price signal and overcoming the well-known manipulation opportunities that result from zonal pricing. The platform incorporates the Real-Time Balancing Market Mechanism (RTBMM), a balancing and congestion management application for computing real-time balancing actions and Distributed Locational Marginal Prices (DLMP) for retail markets. The RTBMM periodically receives bids by different BSPs through the Bidding Application (BA) and also operational constraints from TS and DS SCADA. After receiving the information, the platform clears the market to deduce dispatch instructions. Once the dispatch occurs, after verification through smart meters of consumption and generation, the RTBMM remunerates the different actors according to LMPs.

6.3.6.3 Key performance indicators

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
KPI_PUC25_1	Welfare Maximization	The platform aims at clearing the market while maximizing the profit of each participant. This is what we call welfare maximization.	
KPI_PUC25_2	Lost Opportunity Cost (LOC)	When the market is cleared, if a participant has an incentive to deviate from dispatch instructions sent by the RTBMM, then they should be compensated. The compensation is computed after the welfare maximization and is called LOC. The RTBMM should be able to minimize (or at least limit the effect of) LOC.	
KPI_PUC25_3	Constraints Violation	Optimal power flow equations are nonlinear and nonconvex. Power flow equations might be violated when dispatch occurs. If it's the case,	

		it should be limited and communicated by the platform in order to preserve equipment.	
KPI_PUC25_4	Non-convex orders inclusion	The RTBMM allows for complex bid structure. At certain time-steps, the complexity of the decision-making might lead the platform to omit to remove difficult bid structure. This phenomenon should be as rare as possible.	
KPI_PUC25_5	Run time	One of the constraints regarding real-time dispatch is limitation in time. Indeed, data might be available only 5 to 15 minutes ahead of the decision, and the RTBMM should be able to react within a much slower time frame (max 3-4 minutes).	

6.3.6.4 Use case conditions

Use case conditions
Assumption(s)
• Network is fully known, and relevant data are available from GIS • Grid related operational constraints at transmission and distribution level are provided by the TS SCADA and DS SCADA respectively. • Generation and consumption are measured with smart meters (available through AMI).
Precondition(s)
• Availability of network data (generators technical details, lines technical details) • Generation and consumption measurements are available, even if the measurement is done afterwards

6.3.6.5 Further information to the use case for classification/mapping

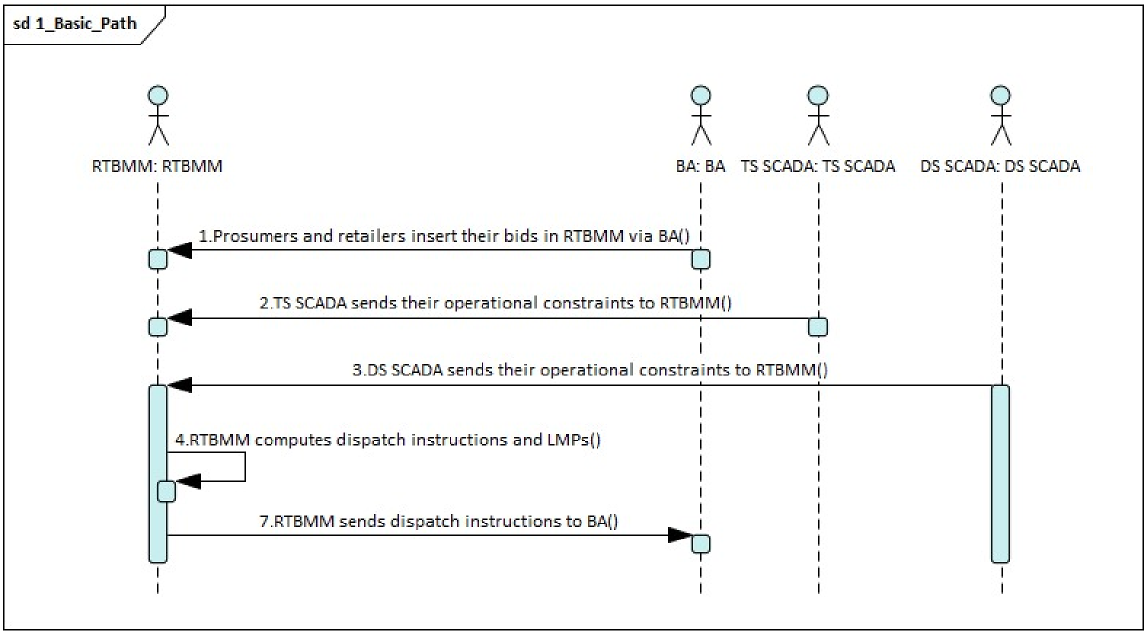
Classification information
Relation to other use cases
HLUC 09: Day-ahead market mechanisms incentivizing energy flexibility trading for mitigating problems of the transmission system & distribution network, integrating wholesale and retail markets **HLUC 10: Intra-day market mechanisms incentivizing active & reactive energy flexibility trading for mitigating problems of the distribution network** **HLUC 11: Real-time market mechanism incentivizing energy & capacity flexibility trading from BSEs, to address balancing and T&D congestion management, integrating wholesale and retail markets** **PUC 14: Processing network data**

PUC 15: Defining Bidding Strategy **PUC 18: Day-ahead market scheduling** **PUC 20: Intra-day active/reactive energy flexibility trading**
Level of Depth
Detailed
Prioritization
High
Generic, regional or national relation
Generic
Nature of the use case
Technical
Further keywords for classification
Real-time balancing, Distribution Locational Marginal Prices

6.3.6.6 General Remarks

General Remarks
As it holds for every electricity markets, the participation in and the operation of the real time balancing market adhere to specific principles and rules. More specifically, the following rules are considered: • The envisioned timeline is based on that of MARI (tertiary reserve platform). • Bidding strategies unveiling: bids are submitted a few minutes prior to real time (e.g. up to 30 minutes prior to the relevant balancing interval). Bids can follow the typical format of EUPHEMIA (e.g. simple curves, interpolated orders, or more complex block orders). • The platform runs for 1-5 minutes. • The resulting prices are recorded in a database, and dispatch instructions are communicated to Flexibility Service Providers, who need to react within their full activation time (eg 12.5 minutes). • Deviations are settled ex post based on the recorded prices using the uniform prices (DLMPs) that are generated by the platform. Participation in the platform is obligatory for Flexibility Service Providers (i.e. BSPs) who have sold reserve capacity in forward (ex. day-ahead auctions). Participation is optional for all other entities (ex. free bids). The platform offers a value stream for flexible resources, but bidding is not mandatory if resources have not committed to offer reserve / flexibility to the DSO or TSO. Thus, for example, bilateral trades can override the platform by being directly submitted as price-inelastic bids into the platform, and do not incur any excess charge or payment if they follow their bilateral schedule.

6.3.6.7 Use case diagram

Diagram(s) of use case
 Figure 49 PUC 25 Sequence Diagram - Market Clearance Scenario

6.3.6.8 Actors

Actors			
Actor name	**Actor type**	**Actor description**	**Further information**
TS SCADA	System	A system in charge of overall monitoring and control of the distribution and transmission grid. It integrates communication, remote monitoring and control, signal processing and logic, and data storage functionalities.	Concerns the SCADA operated by the TSO. Will provide the grid operational constraints at transmission level.
DS SCADA	System	A system in charge of overall monitoring and control of the distribution and transmission grid. It integrates communication, remote monitoring and control, signal processing and logic, and data storage functionalities. It includes a user interface called control center room.	Concerns the SCADA operated by the DSO. Will provide the grid operational constraints at distribution level.
Real-Time Balancing Market Mechanism	Application	It is a balancing and congestion management application for computing real-time balancing actions and Distributed Locational Marginal Prices (DLMP) for retail markets.	The item under design.

(RTBMM)			
Bidding Application (BA)	Application	Application defining the optimal bidding strategy for the wholesale and balancing market participation of BRPs and BSPs.	Will provide the bids and receive the market activation signals.

6.3.6.9 References

References						
No.	**Type**	**Reference**	**Status**	**Impact**	**Originator / Organization**	**URL**
1	Research paper	Caramanis, Michael, et al. "Co-optimization of power and reserves in dynamic T&D power markets with non-dispatchable renewable generation and distributed energy resources." Proceedings of the IEEE 104.4 (2016): 807-836.	Published	Market Design	Caramanis, Michael, et al.	link
2	Research paper	M. Farivar and S. Low, “Branch flow model: Relaxations and convexification—Parts I & II,” IEEE Trans. Power Syst., vol. 28, no. 3, pp. 2554–2564, Aug. 2013.	Published	Operating and clearing the market	M. Farivar and S. Low	link
3	Research paper	Gribik, Paul R., William W. Hogan, and Susan L. Pope. "Market-clearing electricity prices and energy uplift." Cambridge, MA (2007).	Published	Market clearing and pricing	Gribik, Paul R., William W. Hogan, and Susan L. Pope	link

4	Research paper	Hogan, William W. "On an "Energy only" electricity market design for resource adequacy." (2005).	Published	Market design	Hogan, William W.	link
5	Research paper	T. Overbye "Estimating the actual cost of transmission system congestion." 36th Annual Hawaii International Conference on System Sciences, 2003. Proceedings of the. IEEE, 2003.	Published	Congestion pricing	T. Overbye	link
6	Research paper	A. Papavasiliou, I. Mezghani, Coordination Schemes for the Integration of Transmission and Distribution System Operations, 20th Power Systems Computation Conference, Dublin, Ireland, June 11-15, 2018.	Published	Transmission and distribution coordination	A. Papavasiliou, I. Mezghani	link
7	Research paper	A. Papalexopoulos, C. Imparato, and F. Wu. "Large-scale optimal power flow: effects of initialization, decoupling and discretization." IE EE Transactions on Power Systems 4.2 (1989): 748-759	Published	Market clearing	A. Papalexopoulos , C. Imparato, and F. Wu.	link

8	Research paper	A. Papalexopoulos, R. Frowd, A. Birbas, “On the development of Organized Nodal Local Energy Markets and a Framework for the TSO-DSO Coordination”, PSCC 2020.	Published	Market design and T&D coordination	A. Papalexopoulos, R. Frowd, A. Birbas	
9	Research paper	B. Stott, and O. Alsac. "Fast decoupled load flow." IEEE transactions on power apparatus and systems 3 (1974): 859-869	Published	Market clearing	B. Stott, and O. Alsac	link

6.3.6.10 Step by step analysis of use case

Scenario conditions						
No.	**Scenario Name**	**Scenario description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	Market Clearance	The goal is to clear the market: after receiving the bids from the different actors, the RTBMM deduces generation decisions by maximizing the social welfare.	RTBMM	System Imbalance	Bid submission Willingness to share network information	Dispatch instructions
2	Remuneration	Once the dispatch occurred, measurements on generation and consumption are checked and fair remuneration	RTBMM	Financial Settlement	Dispatch occurred	Fair remuneration of TS SCADA, DS SCADA, BSPs

Scenario							
Scenario name:			**Market Clearance**				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	**Balancing market gate closure**	Insertion of bids	Prosumers and retailers insert their bids in RTBMM via BA	BA	RTBMM	Bid (cost & quantity)	
2	**Balancing market gate closure**	TS SCADA constraints communication	TS SCADA sends their operational constraints to RTBMM	TS SCADA	RTBMM	Transmission (operational) constraints	

3	**Balancing market gate closure**	DS SCADA constraints communication	DS SCADA sends their operational constraints to RTBMM	DS SCADA	RTBMM	Distribution (operational) constraints	
4	**T-12.5min: platform launch**	Market Clearing	RTBMM computes dispatch instructions and LMPs	RTBMM	RTBMM	-	
5	**T-12.5min: platform launch**	Dispatch	RTBMM sends dispatch instructions	RTBMM	BA	Dispatch instructions (production and consumption)	

Scenario							
Scenario name:			**Remuneration**				
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Inf. Producer (Actor)**	**Inf. Receiver (Actor)**	**Inf. Exchanged**	**Requirements, R-ID**
1	**Dispatch**	Production Generation Measurements	Through AMI data, we precisely report how much power has been consumed and generated and where.	BSPs and TS/DS SCADA	RTBMM	Energy Measurement Data	
2	**Post-balancing settlements**	Payment BSPs	RTBMM collects payments form BSPs via BA	BA	RTBMM	Payment Information	
3	**Post-balancing settlements**	Remuneration BSPs	RTBMM redistributes payments to BSPs via BA	RTBMM	BA	Payment Information	
4	**Post-balancing settlements**	Remuneration TSO/DSO	RTBMM calculates the lost opportunity cost (if any) for transmission and distribution grid operators.	RTBMM	TSO/DSO		

6.3.6.11 Information exchanged

Information exchanged			
Information exchanged ID	**Name of information**	**Description of information exchanged**	**Requirements R-ID**
Bid	**Bid**	A bid gives the necessary information for generation or consumption. It should come with at least a quantity (for real power) and a cost. It should also be specified if a bid is linked with other bids.	Quantity Cost Optional: links with other bids
TsCons	**Transmission constraints**	The set of operational transmission constraints. Transmission operational constraints only cover transmission flow line limits.	
DsCons	**Distribution constraints**	The set of operational distribution constraints. Distribution operational constraints covers voltage magnitudes limits and apparent flow line limits.	
DispInstr	**Dispatch instructions**	Dispatch instructions are deduced after RTBMM collects all the relevant information to clear the market. The instructions specify whether or not a generator (resp. consumer) should produce (resp. consume) power and if so, how much.	Must meet transmission and distribution constraints as well as consumers' and generators' capacities.
EnergyData	**Energy Measurement Data**	Energy consumption/generation should be carefully measured to preserve the network and accurate remuneration.	
PaymentInfo	**Payment Information**	A certain amount of money is taken/distributed according to the BID submitted.	

7 Conclusions

This document aims to identify a set of requirements that will provide the guidelines which will guide the design of the cyber-physical framework of FEVER project, on the basis of the needs of the different stakeholders.

The work continued the requirement analysis activities of T1.1, towards fine graining the business requirements at a systemic level, detailing the functional and non-functional requirements of systems, as well as usability of FEVER solution from the perspective of the end-user. To achieve this, an agile approach utilizing the concept of user stories was chosen, which proved a useful tool on eliciting usability requirements on top of a high-level design. Furthermore, the established template of IEC62559 was used to capture systems requirements, via documenting fine-grained interactions of the various components of FEVER solution among them and the external environment. The original technical use cases list (PUCs and SUCs) identified in T1.1 was refined: UCs were merged, other were considered out of the boundaries of FEVER implementation, resulting in the current list of analysed systemic use cases presented in chapter 6.

The documentation of the requirement analysis follows different levels of granularity, since on one hand the components of the solution have different maturity levels involving both existing solution that will be evolved and tailored to the need of the project and newly developed ones, as well as “production” level solution vs. solution that will be tested only in simulation environment. The same applies for the business processes envisioned to be offered by FEVER since there exist established business process (e.g. flexibility trading via FlexOffer), whilst other are currently at a more conceptual level seeking for establishing the business framework (e.g. peer to peer trading).

During the analysis concerns were raised regarding the necessary parameters for characterizing flexibility in order to create effective services at the level of the distribution grid for the various stakeholders in the electricity market. In this regard, some crucial characteristics of flexibility were analysed: spatial dimension, time dimension and type of provided flexibility. The fine-grained design of flexibility “products” and the systems exchanging or processing flexibility data will be the work of upcoming tasks.

8 List of tables

9 List of figures

10 List of references

[1] FEVER, “D1.1 Flexibility at the distribution grid: Reference usage scenarios for market and system operation services,” 2020. [Online].

[2] IEC, “IEC 62559-2:2015 “Use case methodology - Part 2: Definition of the templates for use cases, actor list and requirements list”,” [Online].

[3] Eurelectric, “Flexibility and Aggregation Requirements for their interaction in the market,” 2014.

[4] European Distribution System Operators for Smart Grids , “Flexibility: The role of DSOs in tomorrow’s electricity market,” 2014.

[5] SWECO et al., “Study on the effective integration of Distributed Energy Resources for providing flexibility to the electricity system – Final Report to the European Commission,” April 2015.

[6] USEF, “USEF: The Framework Explained,” 2015.

[7] CEDEC, EDSO, ENTSOE, GEODE, EURELECTRIC, “TSO-DSO Report-An Integrated Approach to Active System Management,” 2019. [Online]. Available: https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/Publications/Position%20papers%20and%20reports/TSO-DSO_ASM_2019_190416.pdf. [Accessed August 2020].

[8] MIRABEL, “https://mirabel.daisy.aau.dk/publications/D7.5.pdf,” 2011.

[9] Laurynas Šikšnys, Torben Bach Pedersen, Muhammad Aftab, Bijay Neupane, “Flexibility Modeling, Management, and Trading in Bottom-upCellular Energy Systems”.

[10] Privacy & Us, “D4.1 User Interface Requirements,” 2017. [Online]. Available: https://privacyus.eu/wordpress/wp-content/uploads/2017/10/D4_1.pdf.

[11] “https://www.nngroup.com/articles/ten-usability-heuristics/,” [Online].

11 List of abbreviations

Abbreviation	Term
BRP	Balance Responsible Party
BUC	Business Use Case
DER	Distribution Energy Resources
DLT	Distributed Ledger Technology
DS	Distribution System
DSO	Distribution System Operator
DQ	Data Quality
EV	Electric Vehicle
GMO	Generic Market Operator
FP	Flexible Prosumer
FA	Flexibility Aggregator
FUN	Functionality
HLUC	High Level Use Case
I&C	Integration/ Connectivity
INR	Interoperability
MgR	Microgrid Responsible
OPE	Operational (Requirement)
PED	Power Electronics Device
PER	Performance
P&S	Privacy and Security
PUC	Primary Use Case
REG	Regulations
SCA	Scalability
SUC	Secondary Use Case
TP	Technology Provider
UC	Use case
US	Usability
USEF	Universal Smart Energy Framework