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1.Description of the use case

1.1 Name of use case

Name of the use case:
Frequency control

Area Domain(s)/ Zone(s):
Area: Energy system, Domain: Transmission, DER, Customer Premises Zones: Operation

1.2 Version management

Version No.	Date	Name of author(s)	Changes	Approval status
1	-	Marjolaine Farré (Trialog), Andraž Andolšek (cyberGRID), Elchaysse Soudjae (EDM)Christoph Gutschi (cyberGRID),		Final version

1.3 Scope and objectives of use case

Scope:

The scope of this use case is to examine the use of flexibility to restore system frequency to its nominal value of 50 Hz

Objective(s):

[1] Stabilize the electricity grid of the islands [1.1] Establishing balancing services

Related business case(s):

1.4 Narrative of use case

Short description:

This high-level use case describes different scenarios incl. all required steps for the implementation of a tender based frequency control system. The UC differentiates between FCR (frequency containment reserve) and FRR (frequency restoration reserve) services. The explained approach is technology agnostic and supports any kind of flexibility resource, that can meet the technical requirements for balancing service provision. A common approach to handle different technologies for flexibility provision (industrial demand response, residential demand response aggregated by a VPP, smart charging of electric vehicles, aggregation of renewables (PV) via a VPP, battery energy storage, power-to-hydrogen electrolyser) is explained. The scope of the use case includes dimensioning of balancing service reserves for an islanding system, prequalification of suitable distributed energy assets and intermediary platforms (Virtual Power Plants, VPPs), tendering and contracting balancing services, balancing service activation, monitoring, validation, and

remuneration. All periodic communication between the system operator and the market participants, like biding, monitoring and activation is organized via a Flexibility Management and Trading Platform (FMTP). The use case focuses on the situation on the Island of Mayotte and aims to adapt to the historically grown infrastructure and processes, but also takes into account updates of the system operators SCADA in the near future.

Complete description:

The rising number of PV power plants to be installed and connected to the main grid in Mayotte may increase the difficulty of frequency control as the production is highly dependent on weather conditions challenging to forecast (e.g., a passing cloud leads to a decline in PV production) which may increase the imbalances between generation and consumption. With increasing number of PV generation, partly replacing diesel generators the ratio of spinning machines in the system will be reduced which has negative impact on the synchronous inertia. To avoid reaching low frequency thresholds leading to load shedding (48.5 Hz, 48 Hz and 47.5 Hz), the French Energy Regulatory Commission (CRE) 13 granted an exemption to EDM to operate the grid at a higher frequency. The current mean frequency value is thus of 50.15 Hz, higher than the 50 Hz stipulated in the EU Electricity Network code (see [4]). The main balancing service to cope with the frequency deviation currently applied on the island of Mayotte is the “primary reserve” (covering FCR and FRR), which is estimated at 15% of the daily demand and mainly supported by the EDM diesel generation sets of Longoni and Badamiers. The generators are limited to operate at 80-85% of their maximal capacity. For the past few years, the primary reserve hadn’t exceeded 8 MW, but this will change soon with an expected rising demand and RES integration. To stabilize the frequency in the island and ease the penetration of renewable energy, the French Energy Regulatory Commission CRE launched a call for tender to install a battery for frequency control in July 2018. This 4 MW/2 MWh battery should be installed and be ready to operate in October 2021. Following this installation, the exemption (of higher system frequency) should disappear for the time-being. It is estimated that further investments will be needed to fulfil the requirements that are foreseen in the future. One of the goals when considering the frequency use case is to find a way for moving from the energy assets providing frequency services with the help of fossil fuel to assets using renewable energy sources (RES) and Battery Energy Storage Systems (BESS). To further reduce the primary reserve provided by the EDM’s diesel generation sets new sources for providing frequency regulation services are needed to have a direct impact on reduction of CO2 emissions. The main challenges when implementing the frequency control framework are related to the identification of sufficient assets from RES to reduce the required capacity of fossil fueled generators that are capable to provide similar reliable frequency services. The use case describes the interactions between the main actors and platforms but doesn’t discuss the details of the balancing products. The details of the designed balancing products will be defined Deliverable D4.1 Report detailing the energy market framework and specific product design details. For the MAESHA project, it has been decided to examine how different flexibility sources could support the frequency control on the island: • Industrial Demand Response Industry’s main purpose is manufacturing of goods or provision of other services. Some industrial assets are additionally able to provide a certain help to the system operator by adjusting their internal manufacturing process and thus increase or decrease the consumption for the time being (load shifting) and help minimizing the frequency deviation. Such industrial energy assets usually have some restrictions, such as limited duration of delivery (e.g., max 4 h), poor controllability (e.g., ON-OFF operation), or can provide such action only at a certain time of the day or year. Therefore, industrial demand response is not considered as a primary source for providing balancing services to the power grid, but they may serve as secondary source for additional support when other services are already fully activated (e.g., for emergency measures). • Residential Demand Response managed by a virtual power plant (VPP) Residential customers may have flexible loads that end-users do not necessarily need instantaneously to ensure their comfort, e.g., air-

conditioning units and electric heating, but also dishwashers, washing machines, cloth dryers, etc. Optimally controlling the on/off times of these devices, considering local frequency deviations, can help in ensuring the frequency stability. Depending on the characteristics of the device, the activation time and activation duration differ. Heat pumps or air conditioning units can be used for frequency response, considering the heat storage capacity of the building or heat storage in a hot water tank. The activation duration depends upon the stored heat capacity in the building or the tank and the comfort requirements of the end-users. These units can be activated very fast (remote switch-off) but their availability is difficult to forecast. • Smart Charging of electric vehicles (EV) and vehicle to grid (V2G) Smart charging of EV can be a source of consumption flexibility and theoretically be used even for balancing services. The challenges for provision of FRR by an EV are linked to the prediction of the charging process' time and duration as well as the limited hours per day, when EV charging can be used for load shifting. Nevertheless, the forecasting of consumption and flexibility becomes easier on a fleet of EVs, as such an aggregate of a higher number of EV's can provide ancillary services reliably using a minor share of the predicted consumption. Load reduction in EV charging can be achieved by reducing the charging power (e.g., switch from 3-phase to 1-phase charging) of a certain number of vehicles. Advanced fleet management might also allow downward services by increasing the charging power during the requested period. Feed-in of energy stored in the EV's batteries (V2G) will been investigated as another possibility of upward regulation by EVs but comes with practical drawbacks like possible reduction of battery lifetime and the need for bidirectional inverters. Due to the nature of the fleet management and lower frequency of data acquisition, EV charging will be preferably applied for mFRR than for aFRR or FCR like frequency services. • Virtual Power Plant (VPP) aggregating RES The variability of renewable energy sources, such as wind and solar, are causing continuous, small frequency deviations due to their hard to predict short-term dynamics and their lack of synchronous inertia to stabilize the frequency during disturbances. Lowering the output of PV plants (downward regulation) during high frequency periods can support frequency stabilization. If PVs are operated below their maximal inverter power, PV plants can inject additional power into the grid with different activation times, ranging from seconds to minutes during low frequency periods (upward regulation). The latter will result in a reduction of overall generation or require the installation of PV batteries. The activation duration depends on the amount of reserve kept for upward frequency response and will be the result of a cost-benefit analysis, where the outcome depends on the remuneration of the different frequency response products compared to the value of electric energy fed-in by PV. In the last years, much development effort has been made on virtual inertia provided by PV and wind power, which might become state-of-the-art within the next decades. • Battery Energy Storage System By supplying or absorbing power in response to deviations from the nominal frequency and imbalances between supply and demand, the rapid response of a BESS will provide a frequency stabilizing services. The fast response capability of BESS allows them to participate in all kinds of frequency response (e.g., FCR, FRR) or even a fast or enhanced frequency response markets (activation in less than 5 s). The BESS will also provide virtual inertia by modulating active power as a function of the ROCOF. The duration of the service provision will be determined by the SoC. BESS providing ancillary services will require an additional charge management to maintain the state of charge (SOC) within predefined limits (e.g., 30%<SOC<70%) in order to ensure the continuous availability of upward and downward regulation ability. Load management (consumption or feed-in) is based on schedules and should be communicated with the SO, e.g., via an intraday program. The BESS should be able to provide multiple balancing services and perform load management in parallel. • Power-to-Hydrogen system Proton Exchange Membrane (PEM) electrolysers have the capability of modifying their load rapidly with very high ramps rates (i.e., within seconds) and within a wide operational range up to the nominal power. This flexibility can be utilized for large range of frequency regulation (e.g., FCR, aFRR, mFRR). Despite the hydrogen storage capacity, there is no limit in the duration of the service as the service is provided by reducing/increasing the load of the electrolyser. These DER provide their flexibility to the SO via the FMTP. Functions This Use Case relies on the following functions: •

Asset contraction and technical preparation, incl. pre-qualification • Detection of frequency deviations • Evaluation of flexibility available from different assets or via intermediate platforms • Contracting balancing service products • Calculation of setpoints by the AGC of the SO • Flexibility activation through the Flexibility Management and Trading Platform (FMTP) • Monitoring of service provision • Settlement process to remunerate flexibility activation This Use Case supports a technology-agnostic approach for provision of balancing services by central or decentralized energy assets. In the MAESHA project, the following technologies are aimed to be investigated in the scope of the use case demonstration. Investigated technology options for provision of balancing services The following technology options to provision of balancing services are aimed to be supported by the use case: • Detection of frequency deviations, central by SO or decentral by the DER • Frequency regulation by industrial DR • Frequency regulation by residential DR via VPP • Frequency regulation by Smart charging/V2G • Frequency regulation by RES via VPP • Frequency regulation by BESS • Frequency regulation by P2H system

1.5 Key performance indicators (KPI)

ID	Name	Description	Reference to mentioned use case objectives
Maesha 1.8	Flexibility available	Flexibility available in Mayotte thanks to MAESHA DR solutions Target: 2600 kW	All
Maesha 1.9	Flexibility available	Flexibility available in Mayotte thanks to MAESHA DR solutions Target: 13000 kWh	All
Maesha 1.11	Total flexibility available	Total flexibility available in Mayotte with MAESHA solutions Target: 4 MW	All
Maesha 1.12	Total flexibility available	Total flexibility available in Mayotte with MAESHA solutions Target: 18 MWh	All
Maesha 4.2	Frequency range	Frequency range before and after the project From [49.6;50.6] to [49.8;50.3] Hz	All

1.6 Use case conditions

Assumptions

• Industrial prosumers will be interested in and capable of providing flexibility services to the grid

Residential prosumers will be interested in providing flexibility services to the grid

For residential DR: buildings equipped with heating boilers or air-conditioning units with adequate control system in place

At least one battery for frequency control will be connected to the grid and to the FMTP

Batteries should react upon a control signal to change their power output

EV charging stations will be connected to the grid and operating

The output of the PV plants can be controlled

The PV plants should react upon a control signal to change their power output

EDM can update the AGC to communicate FRR setpoints to distributed assets via the FMTP

All assets providing FCR must be equipped with on-site frequency measurement devices with high precision.

Secure and reliable communication channels supporting bidirectional communication between the distributed assets, intermediate platforms (VPPs, EV charging management), the FMTP and the AGC

Contracts between the assets and EDM to ensure legal security during the test period

Prerequisites

For Smart charging EV: EVs must be plugged to the EV charging stations to participate in frequency control

AGC, FMTP and intermediate platforms are available, functioning, integrated, and tested

1.7 Further information to the use case for classification/mapping

Relation to other use cases

Linked to “Voltage control” UC as potential conflicts within flexibility products could appear.

Level of depth:

High-level use case

Prioritisation:

Obligatory. This UC should be demonstrated under real-life conditions

Generic, regional or national relation:

Regional relation

Nature of the use case:

Technical and business UC

Further keywords for classification:

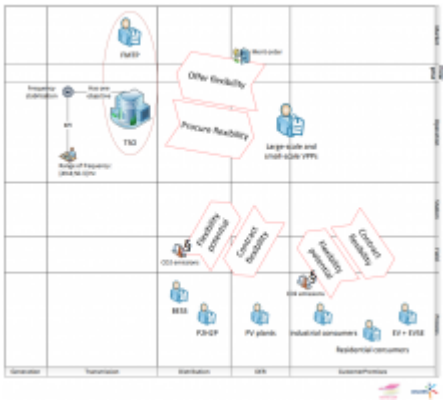
Balancing services, load-frequency control, demand response, flexibility, distributed energy assets (DER)

1.8 General remarks

Remarks:

2.Diagrams of use case

2.1 Diagrams of use case

Diagram name	Diagram image
SGAM Business layer of the frequency control use case-specific architecture	
SGAM Function layer of the frequency control use case-specific architecture	
Use case diagram	

3. Technical details

3.1 Actors

Actor name	Actor type	Actor description
Transmission System Operator (TSO)	Role	According to the Article 2.4 of the Electricity Directive 2009/72/EC (Directive): "a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term Ability of the system to meet reasonable demands for the transmission of electricity". Moreover, the TSO is responsible for connection of all grid users at the transmission level and connection of the DSOs within the TSO control area
Flexibility Operator (FO)	Role	Generic role which links the role customer and its possibility to provide flexibilities to the roles market and grid; generic role that could be taken by many stakeholders, such as a DSO company, an Energy Service Company (ESCO) or an energy supplier
Consumer (ENTSO-E role model)	Role	End user of electricity, gas, water or heat. NOTE: As the consumer can also generate energy using a Distributed Energy Resource, he is sometimes called the "Prosumer".
Industrial consumer	Role	A large consumer of electricity in an industrial / manufacturing industry. May be involved in contract based Demand/Response.
SCADA system	Application	Supervisory Control And Data Acquisition system provides the basic functionality for implementing EMS or DMS, especially provides the communication with the substations to monitor and control the grid.
AGC	Logical actors	Automatic gain control. Process to determine the amount of power needed to bring back the frequency to the nominal values.

Actor name	Actor type	Actor description
Communication Platform	Communication software	Communication software is used to provide remote access to systems and exchange files and messages in text, audio and/or video formats between different computers or users. Communication platform is used to exchange data on network elements outage periods proposals and optimized periods, as well as to confirm/reject optimization solution and to hold conference call in order to harmonize outage periods.
Small-scale virtual power plant	Logical Actor	This is a type of Intermediate platforms. Software platform that aggregates the flexibility of residential prosumers and PV power plants
Large-scale virtual power plant	Logical Actor	This is a type of Intermediate platforms. Software platform that aggregates the flexibility of industrial energy assets and BESS
EV charging management platform	Logical Actor	A platform that manages and aggregates the charging power of multiple EV charging stations
FMTP	Logical Actor	Flexibility Management and Trading Platform
DER		Generic Distributed Energy Resource - "DER devices are generation and energy storage systems that are connected to a power distribution system"
PV power plant	Asset	Renewable energy source able to provide flexibility of feed-in
Battery	Asset	Energy storage system capable of providing different services to the grid
P2H system	Asset	System to convert electricity (optimally from RES) into hydrogen that can be stored to use it eventually for different purposes (feedstock, electricity production, fuel)
Generator	Role	Generating electricity, contributing actively to voltage and reactive power control, required to provide the relevant data (information on outages, forecast, actual production) to the energy marketplace (see also the Articles 2.1 and 2.2 of the Directive).
EV charging station	Device	EV charging station
Frequency meter	Device	Frequency meter, to measure frequency on the entire power network
Smart Meter (SM)	System	The metering end device is a combination of the following meter-related functions from the Smart Metering reference architecture: • Metrology functions including the conventional meter display (register or index) that are under legal metrological control. When under metrological control, these functions shall meet the essential requirements of the MID; • One or more additional functions not covered by the MID. These may also make use of the display; • Meter communication functions.

Actor name	Actor type	Actor description
Distribution System Operator (DSO)	Role	According to the Article 2.6 of the Directive: "a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity". Moreover, the DSO is responsible for regional grid access and grid stability, integration of renewables at the distribution level and regional load balancing.
System Operator (ENTSO-E role model)	Role	A party that is responsible for a stable power system operation (including the organisation of physical balance) through a transmission grid in a geographical area. The SO will also determine and be responsible for cross border capacity and exchanges. If necessary he may reduce allocated capacity to ensure operational stability. Transmission as mentioned above means "the transport of electricity on the extra high or high voltage network with a view to its delivery to final customers or to distributors. Operation of transmission includes as well the tasks of system operation concerning its management of energy flows, reliability of the system and availability of all necessary system services." (definition taken from the UCTE Operation handbook Glossary). Note: additional obligations may be imposed through local market rules.
Flexibility provider	Business Actor	Generic presentation of the energy asset capable of providing flexibility on request (Balancing service provider)

3.2 References

No.	References type	Reference	Status	Impact on use case	Originator/organisation Link
1	Operational guidelines	Operational Handbook P1-Policy 1: Load-Frequency Control and Performance	Final	Medium	ENTSO-E
2	Operational guidelines	French standards about system operation		High	French government

4. Step by step analysis of use case

4.1 Frequency reserve requirements

No.

1

Scenario description

Calculating the amount of FCR and FRR needed

Primary actor

SO

Triggering event

Long term planning (yearly activity)

Pre-condition

Historic data about electricity system mid-term consumption forecasts List of planned new DER installations

Postcondition

Required amount of Inertia, FCR, FRR to be contracted and reserved

4.1 Steps of Frequency reserve requirements

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Periodically (yearly)	Define desired conditions for grid frequency	In a phase of mid-term planning, the SO defines the frequency control strategy, incl. nominal (target) frequency value, frequency bandwidth for operation and frequency thresholds for emergency actions	CREATE	SO (EDM)	N/A	IE-01-01 (frequency bandwidth and emergency thresholds)	R-01-01 Guidelines for operation defined by regulator
2	Periodically (yearly)	Collect data of the power system	The data to describe the power system (system model) and historic measurements (load, frequency) and events (fault statistics)	GET	SCADA	SO (EDM)	IE-01-02 (system model) IE-01-03 (historic measurements) IE-01-04 (fault statistics)	R-01-02 (Historic data about electricity system, load and frequency)
3	Periodically (yearly)	Mid-term & long-term forecasts	The SO generates mid-term and long-term forecasts of the development of consumption and generation	CREATE	SO (EDM)	N/A	IE-01-05 (mid-term & long-term forecasts)	R-01-03 (List of planned new DER installations)

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
4	Periodically (yearly)	Define design scenarios	The SO identifies critical situations (e.g., yearly peak load, separation of parts of the grid, etc.) and defines design scenarios comprising all possible critical situations.	CREATE	SO (EDM)	N/A	IE-01-06 (design scenarios)	IE-01-01, IE-01-02, IE-01-03, IE-01-04, IE-01-05 received.
5	Periodically (yearly)	Calculate the required amount of flexibility-balancing reserve needed on the island - FRR	EDM assesses the amount of flexibility (FCR, FRR balancing reserve) required to perform the load-frequency control of the Mayotte power system.	CREATE	SO (EDM)	N/A	IE-01-07 (required amount of balancing reserve)	IE-01 ... IE-06
6	Step 5 finished	Define balancing service products	Based on the required amount of flexibility the SO defines appropriate balancing products	CREATE	SO (EDM)	N/A	IE-01-08 (definition of balancing products and requirements)	IE-01-07

4.2 Detection of the frequency issues – FCR

No.

2

Scenario description

Detection of the frequency deviations locally on the site of the flexibility provider

Primary actor

Flexibility provider

Triggering event

Continuous activity

Pre-condition

High precision frequency meter

Postcondition

Frequency deviation detected on-site

4.2 Steps of Detection of the frequency issues – FCR

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Periodically (interval of 1 s of faster)	Measure the network frequency	Energy assets (central assets or DER) capable of providing FCR reserve are equipped with an accurate frequency meter to continuously measure frequency of the point of grid connection in real-time	CREATE	Frequency meter	N/A	IE-02-01 (Network frequency)	R-02-01 (frequency meter on-site)
2	New frequency measurement available	Submit the measured frequency to the local controller	The measured frequency must be sent to the local controller capable of receiving freq. measurements in real- time	GET	Frequency meter	Local controller	IE-02-01	R-02-02 (on-site PLC)
3	When freq. measurements arrive to the local controller	Calculate frequency deviation	An algorithm on the PLC compares the measured frequency with the target value and calculates the deviation	CREATE	PLC	N/A	IE-02-02 (frequency deviation)	R-02-02

4.3 Detection of the frequency issues – FRR

No.

3

Scenario description

Detection of the frequency deviations centrally in the SCADA

Primary actor

SO (AGC)

Triggering event

Continuous activity

Pre-condition

High precision frequency meter

Postcondition

Frequency deviation detected by central AGC

4.3 Steps of Detection of the frequency issues – FRR

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Continuously	Measure grid frequency	An accurate (central) frequency meter located in a major substation (e.g., Longoni, Badamiers) measures frequency of the grid in real-time	CREATE	Frequency meter	N/A	IE-03-01 (grid frequency)	R-03-01 (central frequency meter)
2	Continuously	Receive frequency measurement	The measured frequency is received by the AGC embedded in the SCADA.	GET	Frequency meter	AGC	IE-03-01	R-03-02 (AGC)
3	Frequency measurement received by AGC	Measured frequency is stored and available for processing	The frequency measurements need to be persisted and available in real time and for later analysis. The SCADA (where AGC is embedded) saved the measurements in a database.	REPORT	SCADA	AGC	IE-03-01	R-03-03 (data storage)
4	Frequency measurement received by AGC	Calculate the frequency deviation	Calculate the difference between the current measured frequency and the define nominal (target) frequency (e.g., 50 Hz)	CREATE	AGC	N/A	IE-03-02 (frequency deviation)	R-03-02
5	Frequency deviation calculated	Calculate the new FRR setpoint	Based on the actual frequency deviation and its change in time the control algorithm calculates the new FRR setpoint	CHANGE	AGC	N/A	IE-03-03 (updated FRR setpoint)	R-03-04 (P-f-control algorithm)

4.4 Contracting balancing service products

No.

4

Scenario description

Contractual obligations between the SO (EDM) and the flexibility providers

Primary actor

SO

Triggering event

Periodic tender (yearly, monthly, weekly and/or daily)

Pre-condition

Prequalified DER available

Postcondition

List of available flexible capacity and price (merit order)

4.4 Steps of Contracting balancing service products

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	After definition of technical require- ments	Publish technical and market rules for balancing services	The SO publishes the document describing the balancing services, their technical and administrative requirements and tendered products.	CREATE	SO (EDM)	flexibility providers	IE-04-01 (balancing services rules)	IE-01-08

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
			(3 rd party) flexibility providers able to fulfil the SO's requirements prepare for participation via the FMTP, directly or by aggregation via an intermediate platform (e.g., analyse available flexible power, identify suitable flexibility services and products, fulfil technical requirements). Finally, the flexibility provider or aggregator requests the prequalification of the DER (if directly connected to the FMTP).					
2	After reception of balancing service rules	flexibility providers prepare for participation in balancing services		EXECUTE	Flexibility provider	DER	IE-04-02 (Request for prequalification of DER)	I-E04-01
3	After reception of tender announcement	Aggregators prepare for participation in balancing services	Aggregators prepare for balancing service provision, implementing the technical requirements and establishing contracts with flexibility providers. Finally, the aggregator requests the prequalification of the intermediate platform.	EXECUTE	Aggregator	Intermediate platform	IE-04-03 (Request for prequalification of platform)	IE-04-01

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
4	SO received request for prequalification	Prequalify flexibility provider	The SO and flexibility provider (and aggregator if involved) conduct a series of tests to confirm the technical and administrative capability of the DER (and intermediate platform if involved) to provide the balancing services according to the SO's requirements. The step is finalized by issuing the confirmation of prequalification by the SO.	EXECUTE	SO	flexibility provider	IE-04-04 (confirmation of prequalification)	IE-04-02 or IE-04-03
5	Periodically (yearly, monthly, weekly, or daily)	Publish tender for balancing services	The SO details the balancing market products and starts a tendering process and informs all prequalified flexibility providers about the tender	CREATE	SO (EDM)	Intermediate platforms	IE-04-05 (rules and schedules of balancing service tender)	IE-01-08
6	Step 05 finalized	Submit balancing services bids	The prequalified flexibility providers forecast the available power for the tendered balancing service products and calculate the costs of service provision. Then the most suitable balancing products are identified and balancing service bids are submitted via FMTP.	CREATE	flexibility provider or aggregator	SO	IE-04-06 (balancing service bid document)	IE-04-05, R-04-01 (prequalified flexibility providers)

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
7	SO received bid for balancing service provision	Contract balancing services	The SO selects the most favourable bids for flexibility service provision according to the tendering rules and informs the flexibility providers about acceptance or rejection of their bids via the FMTP. The acceptance of a balancing service bid is equivalent to a legal contract between SO and flexibility provider.	EXECUTE	SO (EDM)	Flexibility providers	IE-04-07 (balancing service bid acceptance)	IE-04-06 received

4.5 Flexibility activation through local controller – FCR

No.

5

Scenario description

Activation of the flexibility providers automatically using its local controller

Primary actor

Flexibility provider

Triggering event

Frequency deviation detected on-site

Pre-condition

FCR control algorithm implemented in on-site controller

Postcondition

FCR provision by DER

4.5 Steps of Flexibility activation through local controller – FCR

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Reception of FCR bid acceptance	Enable FCR service	The FCR functionality is unlocked via the PLC of the DER during the timespan defined in the accepted FCR bid.	CREATE	PLC	N/A	IE-05-01 (FCR provision enabled)	IE-04-07 (accepted FCR bid)
2	FCR provision enabled	Calculate FCR setpoint	The PLC calculates the FCR setpoint depending on the frequency deviation (calculated on-site and in real time, see scenario 2) based on an algorithm defined by the SO; e.g., a linear curve P FCR =f(Df)	CREATE	PLC	DER	IE-05-02 (FCR setpoint)	IE-02-02 (frequency deviation) R-05-01 (P(Df) characteristics implemented)
3	FCR setpoint calculated (continuously, e.g., 1 s interval)	Follow new FCR setpoint	The DER adapts the active power feed-in (or consumption) according to the FCR setpoint within the required FAT.	EXECUTE	DER	N/A	IE-05-02 (FCR setpoint)	R-05-02 (DER operative)
4	Continuously (e.g., 1 s interval)	Send monitoring data to FMTP	As long as the FCR service provision is enabled (timespan of the accepted FCR bid), the PLC sends monitoring data to the FMTP, where it is forwarded to the AGC)	CREATE	PLC (DER)	AGC	IE-05-03 FCR monitoring data	R-05-03 (communication channel between PLC and FMTP) R-05-05 active power meter (on-site)
5	Continuously	Validate FCR provision	The AGC receives the FCR monitoring data and compares the measurements with the expected behaviour.	CREATE	AGC	N/A	IE-05-04 FCR validation report	R-05-04 (algorithm to validate FCR performance)
6	FCR malperfor-mance detected	Inform flexibility provider about mal-performance	The SO informs the flexibility provider about the FCR malperformance and orders immediate correction of the behaviour	REPORT	SO	flexibility provider	IE-05-04 FCR validation report	

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
7	FCR validation report received	Remedy FCR malperformance	The flexibility provider updates the DER control algorithms in order to remedy the FCR malperformance and to provide the FCR service according to technical specifications.	EXECUTE	flexibility provider	DER	IE-05-04 FCR validation report	

4.6 Flexibility activation through the Flexibility Management and Trading Platform (FMTP) – FRR

No.

6

Scenario description

Activation of the flexibility providers automatically using centralized platform - FMTP

Primary actor

FMTP

Triggering event

Frequency deviation detected by AGC

Pre-condition

AGC’s control algorithm trained with system characteristics

Postcondition

FRR provision by DER

4.6 Steps of Flexibility activation through the Flexibility Management and Trading Platform (FMTP) – FRR

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Reception of FRR bid acceptance	Enable FRR service	The FRR functionality is unlocked on the intermediate platform and/or the PLC of the DER during the timespan defined in the accepted FRR bid. The PLC starts waiting to receive activation requests from the FMTP or intermediate platform.	CREATE	Intermediate platform	PLC	IE-06-01 (FRR provision enabled)	IE-04-07 (accepted FRR bid)
2	New FRR setpoint available	Dispatch balancing assets	The new FRR setpoint is dispatched between central balancing assets (diesel engines operated by the SO) and distributed balancing assets (DER operated by third party).	CREATE	AGC	DER	IE-06-02 (setpoints for central balancing assets) IE-06-03 (setpoint for DER)	R-06-01 (dispatching algorithm)
3.1	Central assets' FRR setpoint updated	Receive new FRR setpoints	Central balancing assets (operated by the SO) receive their new individual setpoint	GET	SO	Central balancing asset (diesel engines)	IE-06-02	R-06-02 (central balancing asset available)
3.2	Decentral assets' FRR setpoint updated	Receive new FRR setpoints	The updated FRR setpoint is received by the FMTP platform.	GET	SO	FMTP	IE-06-03	R-06-03 (FMTP available) R-06-07 (comm. channel between AGC and FMTP)
4	FMTP received a new FRR setpoint	FMTP dispatches contracted flexibility providers	The FMTP distributes the received FRR setpoint between the contracted flexibility providers (DERs or intermediate platforms) based on predefined rules (pro-rata or according to merit order), and submits the activation requests (direct setpoint or activation schedule).	EXECUTE	FMTP	DERs or intermediate platforms	IE-06-04 (activation requests)	R-06-03 (FMTP available) R-06-06 (communicatio n channel between FMTP and intermediate platforms or large DER)

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
5	Intermediate platform receives activation request	Intermediate platform distributes activation requests	The intermediate platform dis-aggregates the received activation request and forwards the setpoints to the connected DER, which previously indicated availability.	EXECUTE	Intermediate platform	DER	IE-06-05 (individual setpoints)	R-06-04 (DER available) R-06-05 (communicatio n channel between DER and interme-diate platform)
6	DER received the activation request	FRR provision by DER	The DER changes its generation or consumption according to the received setpoint within the required FAT (details see scenario 8).	EXECUTE	DER	N/A	IE-06-05	R-06-04 (DER available)
7	Continuously (e.g., in 2 s interval)	Send monitoring data to intermedia- te platform	As long as the FRR service provision is enabled (timespan of the accepted FRR bid), the DER sends monitoring data to the intermediate platform.	CREATE	PLC (DER)	Intermediate platforms	IE-06-06 (individual FRR monitoring data)	R-06-05 R-05-05 (active power meter, on-site)
8	Continuously (e.g., in 2 s interval)	Send monitoring data to AGC	The intermediate platform receives monitoring data from the connected DER and aggregates the values. The aggregated values are sent to the FMTP. Alternatively, large DER send monitoring data directly to the FMTP, without aggregation via an intermediate platform.	CREATE	Intermediate platform	FMTP	IE-06-07 (aggregated FRR monitoring data)	R-06-06 (communicatio n channel between FMTP and intermediate platforms or large DER)
9.1	Continuously	Validate FRR provision	The FMTP receives the FRR monitoring data and compares the measurements with the expected behaviour.	CREATE	FMTP	N/A	IE-06-08 FRR validation report	R-06-08 (algorithm to validate FRR performance)

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
9.2	Yearly	Validate FRR provision	In case of doubts, the SO compares FRR monitoring data with (public) meter readings.	EXECUTE	SO	N/A	IE-06-08 FRR validation report	R-06-09 (meter data)
10	FRR malperformance detected	Inform flexibility provider about malperformance	The SO informs the flexibility provider about the FRR malperformance and orders immediate correction of the behaviour.	REPORT	SO	flexibility provider	IE-06-08 FRR validation report	
11	FRR validation report received	Remedy FRR malperformance	The flexibility provider updates the DER control algorithms in order to remedy the FRR malperformance and to provide the FRR service according to technical specifications.	EXECUTE	Flexibility provider	DER	IE-06-08 FRR validation report	

4.7 Settlement process to remunerate flexibility activation

No.

7

Scenario description

Validation and settlement of the activation responses

Primary actor

SO

Triggering event

Daily or monthly

Pre-condition

Meter data available

Postcondition

Remuneration of ancillary service provision per DER

4.7 Steps of Settlement process to remunerate flexibility activation

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Daily	Process monitoring data	In the morning hours the energy activated during the previous day is calculated individually for each balancing service contract (accepted bid).	EXECUTE	SO (EDM)	N/A	IE-04-07 (balancing service bid acceptance), IE-06-07 (monitoring data)	IE-06-08 FRR validation report, IE-05-04 FCR validation report
2	After completing previous step	Accounting of balancing service provision	The activated energy and reserved capacity (provided by the aggregator or flexibility provider) is accounted per accepted bid and summarized by flexibility provider.	CREATE	SO (EDM)	Flexibility provider	IE-07-01 (daily balancing service accounting)	IE-04-07 (balancing service bid acceptance),
3	Monthly	Remuneration of flexibility service provision	The daily remuneration of balancing service provision is summarized for the entire past month and remunerated to each flexibility provider	EXECUTE	SO (EDM)	flexibility provider	IE-07-02 (monthly balancing service accounting and remuneration report)	IE-07-01

4.8 Frequency control by flexibility provider

No.

8

Scenario description

The process of flexibility provision by the flexibility provider

Primary actor

Flexibility provider

Triggering event

Reception of activation signal or activation schedule

Pre-condition

Flexibility bid accepted via FMTP

Postcondition

Successful provision of flexibility service

4.8 Steps of Frequency control by flexibility provider

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1	Daily	Forecast flexible capacity for upcoming tender period	The flexibility provider forecasts the amount and costs of the balancing service provision for the next tender period.	CREATE	Flexibility provider (DER)	Aggregator (intermediary platform)	IE-08-01 (forecast of flexible capacity and costs)	R-08-01 (Operational forecast of DER)
2	Previous step finalized	Aggregator receives flexibility forecast	The aggregator receives the flexible capacity & cost forecasts of all contracted flexibility providers (DERs) and creates a merit order of flexibility.	CREATE	Aggregator (intermediary platform)	N/A	IE-08-02 (flexibility merit order)	IE-08-01, R-06-05 (communication channel between DER and intermediate platform)
3	Previous step finalized	Participation in balancing service tender	The aggregator participates in the balancing service tender, creates bids and submits the bids to the FMTP. (See scenario 4)	CREATE	Aggregator	FMTP	IE-04-06 (balancing service bid document)	
4	Bid acceptance message received	Flexibility reservation request	The aggregator informs the connected DER about required flexibility reservation for the next product period and the conditions for balancing service provision.	CREATE	Aggregator	DER	IE-08-02 (Flexibility reservation request)	R-06-05 (communication channel between DER and intermediate platform)
5	Flexibility reservation request received	Flexibility reservation	The DER reserves the requested flexibility for the product period.	EXECUTE	DER	Aggregator	IE-08-02	
6	Continuously	Real-time flexibility calculation	The DER calculates the actual flexibility bandwidth in real time and reports the values to the intermediary platform.	CREATE	PLC (DER)	intermediary platform	IE-08-03 (actual flexibility of DER)	R-06-05 (communication channel between DER and intermediate platform)

Step No.	Event	Name of process/activity	Description of process/activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
7	Continuously	Listen to incoming setpoints	The PLC receives a setpoint to start an activation	GET	Intermediary platform	PLC	IE-06-05 (individual setpoints)	
8	Activation setpoint received by DER	Start activation program	After receiving a new setpoint (see (see scenario 6), the PLC of the DER initiates the activation program (ramp-up) in order to meet the setpoint received from the intermediary platform within the FAT.	EXECUTE	PLC (DER)	N/A	IE-06-05	
9	Continuously	Listen to incoming setpoints	The PLC receives a new setpoint to change the power of an activation.	GET	Intermediary platform	PLC	IE-06-05	
10	New activation setpoint received by DER	Change activation program	The PLC of the DER updates the activation program (ramp-up) in order to meet the new setpoint within the FAT.	EXECUTE	PLC (DER)	N/A	IE-06-05	
11	Continuously	Listen to incoming setpoints	The PLC receives a setpoint of 0 MW to end the ongoing activation.	GET	Intermediary platform	PLC	IE-06-05	
12	Activation end received by DER	End activation program.	The PLC of the DER initiates the end activation program (ramp-down) in order and the balancing energy provision within the FAT.	EXECUTE	PLC (DER)	N/A	IE-06-05	
13	Continuously (e.g., 2 s interval)	Send monitoring data	The DER processes the actual measurements and sends the required monitoring data to the intermediary platform.	CREATE	PLC (DER)	intermediary platform	IE-06-06 (individual FRR monitoring data	R-05-05 active power meter (on-site)

5 Information exchanged

5.1 Information exchanged

Requirement, R-IDs	Information exchanged, ID	Name of information	Description of Information Exchanged
R-05-03	IE-01-01	frequency bandwidth and emergency thresholds	Predefined bandwidth of allowed system frequency, including target value (50 Hz) and thresholds for initiating emergency measures
R-06-07	IE-01-02	System model	Model of the power system supporting dynamic analyses
R-05-03, R-06-05, R-06-06, R-06-07	IE-01-03	historic measurements	Historic timeseries of measured generation, consumption and system frequency
R-05-03	IE-01-04	Fault statistics	Statistics of faults in the power system that are relevant for balancing reserve dimensioning
R-05-03, R-06-05, R-06-06, R-06-07	IE-01-05	Consumption forecasts	Mid-term (timeseries) of the total consumption
R-06-07	IE-01-06	Design scenarios	Expected critical situations (e.g., yearly peak load, separation of parts of the grid, etc.) relevant for balancing reserve dimensioning
R-05-03, R-06-05, R-06-06, R-06-07	IE-01-07	Required amount of balancing reserve	Required number of balancing reserves to ensure a stable operation of the power system, (e.g., 99.975% reliability)
R-05-03, R-06-05, R-06-06, R-06-07	IE-01-08	Balancing products and requirements	Definition of balancing products and requirements comprising: products (duration, min. bid size, direction, tolerances)
R-05-03, R-06-05, R-06-06, R-06-07	IE-02-01	Network frequency	Actual measurements of network frequency measured on-site by DER
R-05-03, R-06-05, R-06-06, R-06-07	IE-02-02	Frequency deviation	Actual frequency deviation detected on-site at DER
R-05-03	IE-03-01	Grid Frequency	Actual measurements of grid frequency centrally acquired by SO
R-05-03	IE-03-02	Frequency deviation	Actual frequency deviation detected centrally by SO
R-06-07	IE-03-03	Updated FRR setpoint	Actual FRR setpoint calculated by AGC, sum for all assets participating in FRR service provision
R-05-03, R-06-05, R-06-06, R-06-07	IE-04-01	Balancing services rules	The document describing the rules for participation in balancing services, their technical and administrative requirements and tendered products, as well as the prequalification procedure
R-05-03, R-06-05, R-06-06, R-06-07	IE-04-02	Request for prequalification of DER	The flexibility provider (DER operator) applies for the prequalification for the balancing service participation.

Requirement, R-IDs	Information exchanged, ID	Name of information	Description of Information Exchanged
R-06-06, R-06-07	IE-04-03	Request for prequalification of platform	The aggregator (intermediate platform operator) applies for the prequalification for the balancing service participation.
R-06-06, R-06-07	IE-04-04	Confirmation of prequalification	The SO confirms the successful prequalification of a DER or platform. Confirmation may need to be renewed after an expiry period.
R-06-06, R-06-07	IE-04-05	Rules and schedules of balancing service tender	The SO publishes the rules and schedules of balancing service tender, including description of tendered balancing service products.
R-06-06, R-06-07	IE-04-06	Balancing service bid document	The aggregator or flexibility provider participates in the tender for balancing services by submitting one or multiple binding bids. Bids contains ID of bidder, date, timespan, product ID, power, capacity price, energy price.
R-06-05, R-06-06, R-06-07	IE-04-07	Balancing service bid acceptance	The SO informs the bidders about acceptance or rejection of the bids submitted in the tender.
R-05-03	IE-05-01	FCR provision enabled	The (PLC of the) DER enabled the FCR functionality and starts detecting the frequency deviations.
R-05-03	IE-05-02	FCR setpoint	FCR setpoint calculated on-site by PLC (DER)
R-06-05, R-06-06	IE-05-03	FCR monitoring data	The FCR monitoring data includes local measurements of frequency, active power, calculated setpoint, actual FCR provision. It is submitted in short intervals (e.g., of 2 s).
R-06-05, R-06-06	IE-05-04	FCR validation report	The FCR validation report summarizes the quality of FCR service provision of a flexibility provider.
R-05-03, R-06-05, R-06-06	IE-06-01	FRR provision enabled	The (PLC of the) DER enabled the FCR functionality and starts listening for incoming setpoints.
R-06-06, R-06-07	IE-06-02	FRR setpoints for central balancing assets	FRR setpoints for central balancing assets (controlled by the SO)
R-06-06	IE-06-03	FRR setpoint for DER	FRR setpoints for central balancing assets (controlled by the SO)
R-06-05, R-06-06	IE-06-04	FRR Activation requests	FRR setpoints for DER (controlled by 3 rd party flexibility providers)
R-06-05	IE-06-05	Individual FRR setpoints	Individual FRR setpoints for DER controlled via an intermedia platform

Requirement, R-IDs	Information exchanged, ID	Name of information	Description of Information Exchanged
R-06-05	IE-06-06	Individual FRR monitoring data	Monitoring data of individual DER, which is sent to an intermediate platform Datapoints: active power, baseline, setpoint, FRR activation, control bandwidth
R-06-05, R-06-06, R-06-07	IE-06-07	Aggregated FRR monitoring data	Aggregated monitoring data of a pool of DER (managed by an intermediary platform), which is sent to the FMTP. Datapoints: active power, baseline, setpoint, FRR activation, control bandwidth
R-05-03, R-06-05, R-06-06, R-06-07	IE-06-08	FRR validation report	The FCR validation report summarizes the quality of FRR service provision of a flexibility provider.
R-06-05, R-06-06, R-06-07	IE-07-01	Daily balancing service accounting	Accounting of provided balancing energy and related costs (according to balancing service bid document), created on d+1
R-06-05, R-06-06, R-06-07	IE-07-02	Monthly balancing service accounting and remuneration report	Monthly sum of Daily balancing service accounting positions, which are used for remuneration of the flexibility provider
R-06-05, R-06-06, R-06-07	IE-08-01	Forecast of flexible capacity and costs	The forecast of flexible capacity and costs of a DER is generated for the entire upcoming product duration, that is tendered.
R-06-05, R-06-06, R-06-07	IE-08-02	Flexibility merit order	The flexibility merit order sorts the DER’s flexibility forecasts according to their costs (from cheapest to most expensive).
R-06-05, R-06-06, R-06-07	IE-08-03	Actual flexibility of DER	The actual flexibility bandwidth of a DER

6 Requirements

6.1 General requirements

Category ID
: Maesha_general_req

Category name for requirements
: General requirements

Category description

All requirements for the implementation of the frequency control use case

Requirement R-ID	Requirement name	Requirement description
R-01-01	Guidelines for system operation	The document describes the technical, organisational and administrative rules for operation of an electricity system. Published by the regulator.
R-01-02	Historic data about electricity system, load and frequency	Historic system configuration and timeseries of historic measurements of total load, total generation and system frequency
R-01-03	List of planned new DER installations	A listing of all new DER (incl. Nominal power, type, connection point and operational characteristics) that have expressed the aim to connect to the public grid
R-02-01	Frequency meter, on-site	A high precision frequency meter installed at the DER site
R-02-02	On-site PLC	A PLC to control the operation of the DER
R-03-01	Central frequency meter	A high precision frequency meter installed at a major central power plant or primary substation
R-03-02	AGC	A system for automatic generation control
R-03-03	Data storage	Performant storage of all incoming monitoring data
R-03-04	P-f- control algorithm	Load-frequency-control algorithm
R-04-01	Prequalified flexibility providers	A flexibility provider (DER and/or intermediary platform) that passed the prequalification procedure with the SO.
R-05-01	P(Df) characteristics implemented	An algorithm defined by the SO; e.g., a linear curve P FCR =f(Df), implemented on a local PLC
R-05-02	DER operative	A DER is available for balancing service provision.
R-05-03	Communication channel between PLC and FMTP	Highly reliable and available communication channel, redundant if needed
R-05-04	Algorithm to validate FCR performance	An algorithm to automatically compare a DER’s (or platform’s) FCR provision with the expected tolerance bandwidth
R-05-05	Active power meter (on-site)	A high precision active power meter installed at the DER
R-06-01	Dispatching algorithm	FRR dispatching algorithm implemented at the AGC
R-06-02	Central balancing asset available	The central balancing asset, operated by the SO, is available for FRR provision.
R-06-03	FMTP available	The FMTP is operative.
R-06-04	DER available	The DER is operative and available for FRR or FCR provision.
R-06-05	Communication channel between DER and interme-diate platform	Highly reliable communication channel
R-06-06	Communication channel between FMTP and intermediate platforms or large DER	Highly reliable communication channel, redundant if needed

Requirement R-ID	Requirement name	Requirement description
R-06-07	Comm. channel between AGC and FMTP	Highly reliable communication channel, redundant
R-06-08	Algorithm to validate FRR performance	An algorithm to automatically compare a DER's (or platform's) FRR provision with the expected tolerance bandwidth
R-06-09	Meter data	Metering data from the calibrated public (utility) meter
R-08-01	Operational forecast of DER	A forecast of the normal operation of the DER (e.g., market schedule)

7 Common terms and definitions

7.1 Common terms and definitions

Term	Definition
aFRR	Automatic Frequency Restoration Reserve
AGC	Automatic Generation Control
BESS	Battery Energy Storage System
CO2	Carbon Dioxide
CRE	Commission de Régulation de l'Energie
DER	Distributed Energy Resources
DR	Demand Response
EDM	Electricité de Mayotte
ENTSO-E	European Network of Transmission System Operators
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FAT	Full Activation Time
FCR	Frequency Containment Reserve
FCR-D	Frequency Containment Reserve for Disturbances
FCR-N	Frequency Containment Reserve for Normal Operation
FMTP	Flexibility Management and Trading Platform
FRR	Frequency Restoration Reserve
mFRR	Manual Frequency Restoration Reserve
P2H	Power-to-Hydrogen
P2H2P	Power-to-Hydrogen-to-Power
PEM	Proton Exchange Membrane
PLC	Power local controller
PV	Photovoltaic
RES	Renewable Energy Sources
ROCOF	Rate of Change of Frequency
SCADA	Supervisory Control and Data Acquisition
SO	System Operator

Term	Definition
SoC	State of Charge
TSO	Transmission System Operator
UC	Use Case
V2G	Vehicle-to-Grid
VPP	Virtual Power Plant

8 Custom information

8.1 Refer to section

Refers to section Value Key

Publisher Organization

Organization name	Organization Acronym	Country
TRIALOG		

Technologies for use cases:
Virtual power plant, flexibility market trading platform, EMSs, flexibility providers

High level Use Case:
HLUC 4: Massive Penetration of RES into the transmission and distribution grid

Related Project:
Maesha

Cordis Link:
https://cordis.europa.eu/project/id/957843

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