Use cases, Requirements and KPIs definition

Deliverable D1.1

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Use cases, Requirements and KPIs definition

Organisation: Trialog

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DEM	Websites, patents filing, press & media actions, videos, etc.	
O	Software, technical diagram, etc.	

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More information on the project can be found at https://www.maesha.eu

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EXECUTIVE SUMMARY

The goal of this document is to detail the outputs of the MAESHA task 1.1 "Use cases and requirements" and the methodology followed. The task 1.1 aims to define the use cases to implement in MAESHA and to demonstrate in the geographical island of Mayotte, in order to decarbonise the energy systems of geographical islands. The document also describes the resulting requirements as well as, for each use case, the specific Key Performance Indicators (KPIs) to be monitored during the project to assess the technical and economic performances of the demonstrated solution.

To select the business use cases relevant for Mayotte, we relied on a set of five generic use cases defined by the Universal Smart Energy Framework (USEF) foundation in its framework, firstly reduced to three generic services by an analysis of the energy system in Mayotte and its foreseen evolution: balancing, constraints management and local optimization. Then, we assessed the relevance of those three generic services for Mayotte by organizing several workshops with local stakeholders (grid operator, local population and relevant local authorities) to understand their specific needs. From this assessment phase, five business use cases were selected. After matching the latter with the core innovations developed by the consortium of MAESHA to assess their feasibility, we described them using the IEC 62559-2 template.

Five use cases have been identified for the pilot of the project in Mayotte:

- Frequency control, which objective is to establish balancing services to maintain the equilibrium between consumption and generation while minimizing the frequency deviations from nominal values (i.e., 50 Hz in Europe).
- Voltage control, which objective is to propose voltage control services to keep voltages within specific safety bands and restore their values to normal range after grid disturbances.
- Minimization of the consumption peak, which objective is to minimize the consumption peak to avoid potential congestion, expensive start-up of peak generators or adequacy issues that may occur in the electricity system of the island.
- Maximization of the use of Renewable Energy Sources, which objective is to implement collective self-consumption operations and to hybridize assets (EV charging stations and air-conditioning units) with photovoltaic panels to maximize the use of Renewable Energy Sources.
- Energy Access, which objective is to respond to the lack of reliable access to electricity in Mayotte, while at the same time offering services to the grid and fostering the involvement of marginalized communities.

This document will be the basis for the implementation of the MAESHA solution in Mayotte. Detailing of the use cases as well as planning of demonstration will be done in WP4 "Energy markets for geographical islands and associated tailored business models". The purpose of the latter is to ensure the commercial viability of the project and to determine the business models and costs implication of the developed solutions.

This document is organized in three main sections:

- A presentation of the demonstration site, Mayotte, and the expectations of the pilot partner as well as the local population towards MAESHA,
- A description of the used methodology,

- The proper description of the five generic use cases, including a high-level definition, Key Performance Indicators (KPIs), actors list, scenarios and information flows, as well as some requirements for the demonstration of the use cases in Mayotte.

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NOTATIONS, ABBREVIATIONS AND ACRONYMS

Table 1: Acronyms used in the document

Acronyms	
AC	Alternating Current
aFRR	automatic Frequency Restoration Reserve
AGC	Automatic Gain Control
BESS	Battery Energy Storage System
BMS	Battery Management System
BUC	Business Use Case
C&I	Commercial & Industrial
CO2	Carbon Dioxide
CPMS	Charging Point Management System
CRE	Commission de Régulation de l'Energie
DC	Direct Current
DER	Distributed Energy Resource
DR	Demand Response
DSO	Distribution System Operator
EDM	Electricité De Mayotte
EMS	Energy Management System
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
GDP	Gross Domestic Product
GHG	Green House Gas
HV	High Voltage
HVAC	Heating, Ventilating and Air-Conditioning
IEC	International Electrotechnical Commission
KPI	Key Performance Indicator
LCOE	Level Cost of Energy
LEC	Local Energy Community
LV	Low Voltage
MAPE	Mean Absolute Percentage Error
mFRR	manual Frequency Restoration Reserve
MV	Medium Voltage
NFC	Near Field Communication
P2H	Power-to-Hydrogen
P2H2P	Power-to-Hydrogen-to-Power
PEM	Proton Exchange Membrane

PLC	Power Local Controller
PV	Photovoltaic
RE	Renewable Energy
RES	Renewable Energy Source
RET	Renewable Energy Technology
RFID	Radio Frequency Identification
ROCOF	Rate of Change of Frequency
SA	Smart Agent
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goal
SGAM	Smart Grid Architecture Model
SO	System Operator
SoC	State of Charge
SUC	System Use Case
TSO	Transmission System Operator
UC	Use Case
V2G	Vehicle-to-Grid
VPP	Virtual Power Plant
WP	Work Package

1. Introduction

1.1. Scope of the document

The goal of this document is to describe the use cases that will be implemented in MAESHA and demonstrated in the pilot site of Mayotte (France).

Use cases consist of a description of what the system will do and how. Usually, it also describes the context of implementation, lists some Key Performance Indicators (KPIs) to ensure that the main objectives of the use case are fulfilled and is accompanied with some diagrams to help its comprehension. Defined at the beginning of a project, use cases set the general orientation of the project. In order to be relevant all along the project, use cases might be updated during the project to ensure that they are aligned with the pilot partner's expectations and the partners' technical considerations.

Five use cases have been defined for Mayotte and are described in this document. The methodology used in MAESHA to define the use cases is also detailed.

This document is public and can be used by the general public to understand what is done in the MAESHA project and internally to ensure a common understanding of the use cases of the project.

1.2. About MAESHA

There are more than 2 200 inhabited islands in the European Union, many of which depend on expensive fossil fuel imports for their energy supply. The large-scale deployment of local renewable energy sources and storage systems would contribute to decarbonizing the energy system. However, this endeavour requires flexible solutions, new tools and efficient frameworks that can be adapted to local needs. The EU-funded MAESHA project will develop smart and flexible methods of storage and energy management as well as modelling tools and technical systems with the aim of promoting the transition towards sustainable energy. Designed with respect to the interests of the local communities, adapted to the market and ready to be disseminated, the new approaches will serve as a demonstration for the future decarbonization of Mayotte and other European islands.

2. Demonstration site

This section presents the demonstration site of Mayotte (France), its energy and transport system, the expectations of the local system operator, Electricité de Mayotte, and of the local population towards MAESHA as well as the reasons for choosing Mayotte as the main demonstration site for MAESHA. Please note that the MAESHA project will also assess thoroughly the replicability of the different solutions on a large pool of follower islands in WP10:

- Wallis & Futuna, France
- Saint-Barthélémy, France
- Gran Canaria, Spain
- Favignana, Italy
- Gozo, Malta

2.1. Mayotte

Mayotte is a French overseas territory situated in the Indian Ocean near Madagascar and the coast of Mozambique. It is composed of two main islands, Petite Terre and Grande Terre, and is locally administrated by the elected Departmental Council. The declared population is 300 000 people, but there is an important proportion of migrants estimated at 200 000 people that has to be considered. The economy is at the same time very dynamic with an annual growth rate of 9% in recent years but has a high unemployment rate of 35%.

Despite officially being part of the European Union, existing socio-economic differences should be considered when implementing a technological innovation project such as MAESHA in Mayotte. Official statistics illustrate the contextual differences of the island compared to mainland Europe (see [2]). With an annual population-growth of 3.8 per cent, on average 5 children per woman, and a Gross Domestic Product comparable to that of Djibouti, Mayotte stands out compared to many other European regions. In comparison, the GDP of La Réunion, another European oversea department, is more than double of the GDP of Mayotte (Mayotte ann. GDP p.c.: 13 000 $, Réunion: 27 000$). Compared to France with 16 per cent, a staggering 70-84 per cent of people in Mayotte live below the poverty line. Conservative estimates state that 25.9 per cent of the population is unemployed and half of the population is younger than 18 years old. Due to this lack of perspectives for young people, many who have the possibility leave the island.

2.2. Energy and Transport system

The electricity distribution on the island is managed by Electricité de Mayotte (EDM), who is in a situation of monopole. 95% of the electricity production comes from Diesel generators, and the remaining 5% come from recently installed RE plants, mainly solar (23MWp with a 4% annual growing rate). The potential for PV development is high as opposed to wind, because the wind deposit is very low, and not workable with the actual wind power technologies. Land availability is one of the main limits for large-scale expansion of solar PV plants. As for the grid, it is not conforming to European standards and illegal connection is a severe issue. The share of the population without access to electricity was indeed of 10% in 2017 (see [3]). All this results in a very polluting energy sector and in very high electricity generation prices, which, however, do not directly impact the local population as the electricity tariffs proposed by EDM are aligned with those proposed in metropolitan France. (This should however be qualified by taking into account that the GDP of Mayotte is three times lower compared to metropolitan France.)

Regarding the transport system, which is the primary source of GHG emissions on the territory, it is almost exclusively based on thermal vehicles although the first slow EV charging stations have recently been installed, and only one car dealership offers electric vehicles. However, given the size of the island, the electric vehicles, if they are recharged with non-carbonized electricity, could provide significant reductions in CO2 emissions and air pollutants.

In April 2017, the current "Programmation Pluriannuelle de l'Energie" for Mayotte was released; a document setting the objectives as well as listing the challenges for the energy policy of the island at different time horizons. To help Mayotte in its energy transition and its decarbonization, the document recommends the following (see [4], [5]):

- To promote a significant development of RES, especially PV plants, with a multiplication by almost 10 of their share in the electricity mix. Electricité de Mayotte has currently received many requests from stakeholders for connection of new PV plants to the grid, for a total capacity of 43,9 MWp (8% of which for a connection to the MV grid).
- To promote the development of thermal renewable energy, which are likely to avoid nearly 20 GWh of electricity consumption annually. The measures include an ambitious development of individual and collective solar water heaters.
- To install storage systems for a total capacity of 29,4 MW by 2023. In this context, two batteries of 7,4 MW and 4 MW for load transfer and frequency control respectively will be installed in 2021.
- To develop innovative projects based on renewable energy coupled with storage facilities
- To secure the electricity supply of the island, by:
  - Keeping a non-intermittent power plant in Petite Terre, as the island hosts sensitives facilities such as the airport and the hospital
  - Diversifying the generation facilities in Grande Terre and working on the stability of the electricity system. A proposition is to create a 44MW production facility by 2025. The objective is to cover part of this need with a biomass power plant project (12 MW) and a project combining photovoltaic installations and storage (13 MW), with the remainder covered by a power plant running on light fuel or liquefied petroleum gas
- To promote clean and sustainable mobility (e-mobility, public transit, maritime transport)

Please note that the document is currently under revision.

2.3. Expectations from pilot partner towards MAESHA

Electricity production in Mayotte is today essentially based on fossil fuel engines. The share of renewable energies (mainly Photovoltaic) in the electricity mix is low compared to most other non-interconnected island. It amounts to 5%. Thus, the challenges are considerable to green the electricity mix and reduce the territory's CO_2 emissions. With a low potential identified for the other sectors, photovoltaic energy appears to be the best way for the development of renewable energy on the island.

Despite considerable technical progress in solar technology, a massive introduction of photovoltaic power plants into Mayotte's energy mix raises the question of the reliability and quality of the distributed energy. Indeed, solar power plants do not contribute to the stability of the grid like conventional sources (no inertia, no power reserve, intermittence). For this reason, an instantaneous penetration limit of 36% is currently in effect. Above this value, the grid operator (EDM) has the right to disconnect PV generation installations. With the increase of PV production, the disconnection threshold should be increased.

EDM faces the challenge of improving the reliability and robustness of its electricity system in order to integrate a maximum of renewable energy. It is in this context that EDM has embarked on the MAESHA project.

EDM operates its electricity network at a frequency of 50.15 Hz. It should be noted that, in a normal situation, the electricity network must operate at 50 Hz. The intermittency of renewable energies associated with the lack of flexibility of the network, forces EDM to raise the frequency of the network. EDM’s aim is to stabilise the frequency at 50 Hz thanks to the solutions that will be developed in the MAESHA project.

The electrification of Mayotte began in the 1980s. Within 15 years, all the communes of Mayotte were connected to the electricity network. Despite considerable work on rural electrification, there are still some remote areas where access to electricity is difficult for technical and administrative reasons. This is particularly the case in agricultural areas. Some solutions could be provided within the MAESHA project to allow access to energy in these areas.

2.4. Mayotte and MAESHA

All these elements make Mayotte the perfect demonstration site for MAESHA. The territory needs an energy transition to tackle the high energy generation prices and the very emitting production sector, and there is a strong local political will to boost this transition as shown by the involvement of EDM in MAESHA and the relations established with the local government. There is also an important potential for RE penetration although the grid and more globally the energy sector, needs to be properly shaped to welcome these changes. Through its variety of local needs and situation, Mayotte is the adequate laboratory to test all the flexibility solutions that this project provides.

Mayotte holds very specific circumstances within the EU. Its economic development and conclusively the development of the energy system is lower than EU standards. Considering the rapid growth of population and electric appliances used, it is foreseeable that the energy system will increase in scale in the next decades. The establishment of a flexibility platform, which enables large scale deployment of RE causes even greater future impact than in a well-developed economy, steering the whole energy system development for the next decades.

3. USE CASE DEFINITION PROCESS

This section describes the methodology followed to define the use cases to implement in MAESHA as well as the tool used. The main steps of this methodology are shown in Figure 1 below.

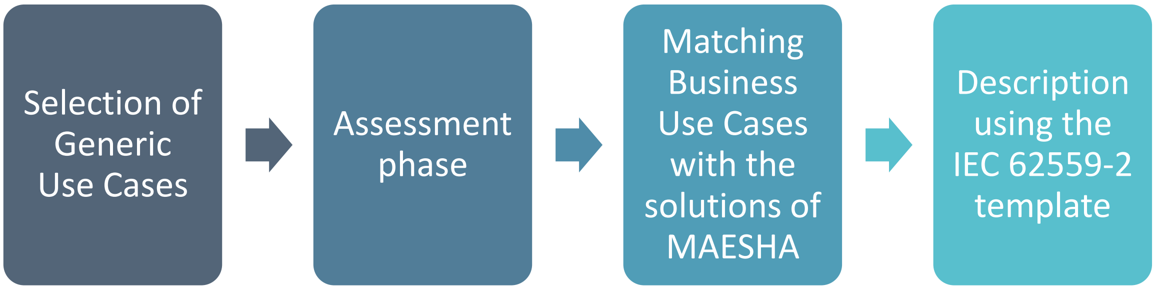

Figure 1: Methodology followed for the use case definition in MAESHA

3.1. SELECTION OF GENERIC USE CASES

After an analysis of the energy situation in Mayotte, it has been decided to rely on a set of generic and technology-agnostic use cases for the Smart Grid domain to outline state of the art insights on demand response systems. Those use cases were presented to ensure an effective discussion, with common terminology, between pilot partner, local stakeholders and partners of the consortium and for comprehensiveness purposes, to ensure that most common challenges encountered by system operators were analysed for MAESHA.

3.1.1. USEF flexibility services

The specific positioning of Electricité de Mayotte on the electricity value chain – EDM is indeed an energy supplier, a Transmission System Operator (TSO), a Distribution System Operator (DSO) and a Balance Responsible Party (BRP) at the same time – led us to consider a wide selection of generic and technology-agnostic use cases covering many roles, defined in the ENTSO-E Harmonized Electricity Market role model. For comprehensiveness, we decided to rely on the flexibility services developed by the Universal Smart Energy Framework (USEF) and depicted in Figure 2 and Figure 3 below (see [6]).

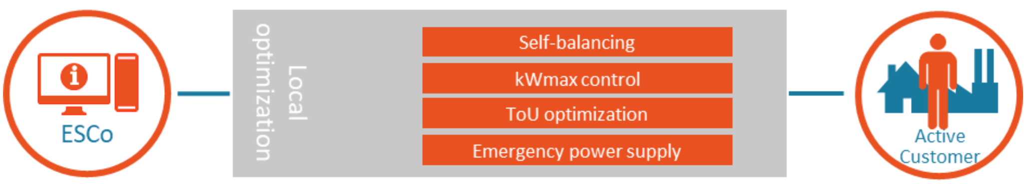

Figure 2: Implicit Demand Response (USEF, 2021)

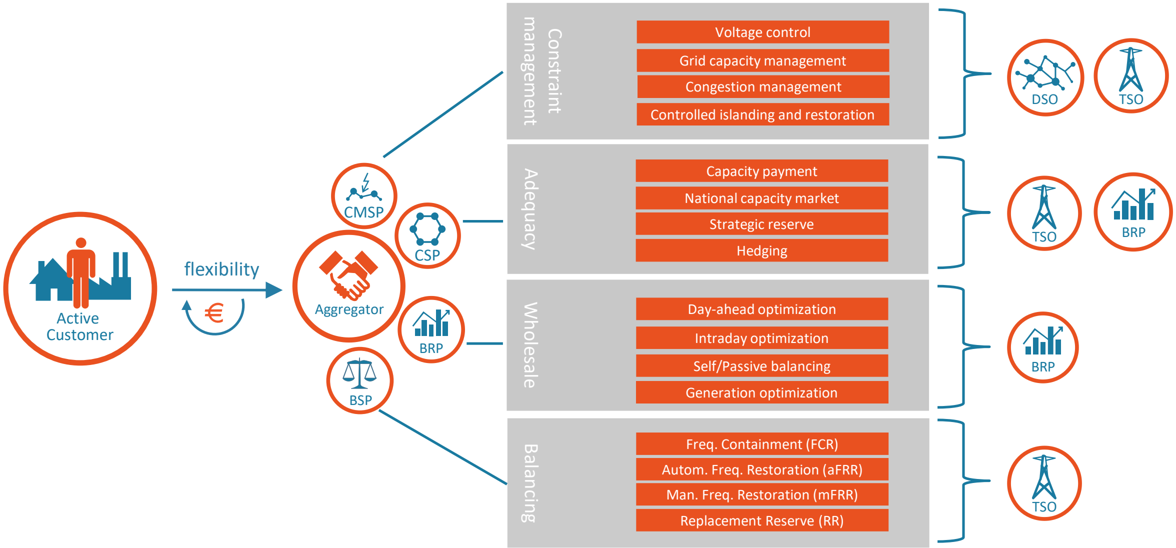

Figure 3: Explicit Demand Response (USEF, 2021)

The following chapter briefly presents the five flexibility services.

3.1.1.1. Local optimization

Local optimization refers to all services for local optimization (in-home, in-factory), provided by implicit Demand Response, which can be offered to Active Customers (e.g., self-balancing, control of the maximum load, Time-of-Use optimization, emergency power supply).

3.1.1.2. Constraint management

According to USEF (see [6]), constraint management services help grid operators (TSO and DSO) **to optimize grid operation for physical and market constraints** (e.g., voltage control, congestion management, grid capacity management, controlled islanding and black start).

3.1.1.3. Adequacy

According to USEF (see [6]), adequacy is the planning of required generation capacities for all hours of the year, usually focusing on critical moments, e.g., winter peak load in Europe (link to heating demand) or late afternoon in a tropical area (link to demand for air conditioning). Adequacy services aim thus **to increase security of supply by organizing sufficient long-term peak and non-peak generation capacity** (e.g., capacity markets, capacity payments, strategic reserves, hedging).

3.1.1.4. Wholesale

Wholesale markets are the main place for interaction between generators and suppliers, both can be balance responsible parties (BRPs). While the majority of procurement relies on long-term contracts, the day-ahead (DA) market is used to clear remaining open positions and react on changes in forecasts. Due to the volatile nature of the renewable generators, the Intraday (ID) markets gain more importance and gate closure times are reduced steadily and move close to real-time operation. Imbalances are caused by deviations of the actual load or generation from the forecasted behaviour and are a main cause for frequency balancing needs. BRPs causing the imbalances are penalized in order to cover the expenses for frequency balancing. Therefore, BRPs are motivated to reduce their imbalances by means of short-term intraday trading and self-balancing. Final consumers but also suppliers and generators can reduce sourcing costs by optimisation of energy consumption and generation schedule with respect to the forecasted market prices (e.g., day-ahead optimization, intraday optimization).

In case of a single-buyer situation, e.g., in an isolated system with limited amount of customers, the wholesale trading can be used to minimize procurement cost of the system operator, which also holds the role of a BRP. The SO tries to minimize risky intraday trades by putting emphasis on the forecasting quality.

3.1.1.5. Balancing

According to the European Network Code, balancing services aim to restore system frequency to its nominal frequency, for example 50 Hz, and to avoid any lengthy (a few minutes) excursions outside of this normal range as well as any very high or low (exceeding nominal by more than 0.2 Hz) excursions (e.g., Frequency Containment Reserve - FCR, automatic and manual Frequency Restoration Reserve - FRR, Replacement Reserve - RR) (see [9]).

3.1.2. Selection of three generic use cases

From our initial analysis of the energy system in Mayotte, two flexibility services proposed by USEF were discarded - adequacy and wholesale:

- The electricity demand seasonality of Mayotte is indeed low as its climate is characterised by small variations of daily and annual temperatures. Moreover, the total generation capacity of the two diesel power plants (106 MW) largely exceeds the daily electricity demand (a maximum consumption peak of 61.5 MW has been measured in February 2021). And as a reference scenario for Mayotte, EDM assessed that the consumption peak should reach 84 MW in 2028: here again, the security of supply is guaranteed. For all those reasons, adequacy as the organisation of sufficient long-term peak and non-peak generation capacity has not been further analysed in MAESHA. However, please note that the “Minimization of the consumption peak” use case, further described in section 4.1.3, can support adequacy as it can also provide economic and environmental optimization by avoiding the expensive start-up of polluting peak generators.
- The current wholesale market implemented in Mayotte by its System Operator (EDM) is a so called “Running program” which starts at a day-ahead delivery program. Matching relies on the existing forecasting of the production and demand. It has been identified by EDM that forecasting tools need to be updated to meet the current and future needs to improve the forecasting results. When the demand and production match, the internal merit-order is created based on the availabilities, economics, and environmental considerations of the existing diesel generators, while fully utilising the PV production potential. As the separate ongoing project of EDM called SAWA will focus on the improvement of the existing “Running program” to meet the SO’s goals, such as CO2 reduction by introducing more RES and their maximum utilization, wholesale services have not been further analysed in MAESHA.

During the next step - the assessment phase - only three generic flexibility services were thus analysed for Mayotte:

- local optimization benefitting local population,
- constraint management benefitting DSOs and TSOs,
- adequacy benefitting TSOs.

3.2. Assessment phase

The flexibility services presented above are generic. It is important to assess their relevance to Mayotte. This second phase was thus composed of two different assessments. First, we conducted several workshops with the system operator, Electricité de Mayotte (EDM), to better understand the energy situation of the island and the challenges they face or might face in the near future considering the evolution of the energy system. Secondly, HUDARA partners visited Mayotte and met local stakeholders and communities to assess their needs and to ensure that the MAESHA project will perfectly fit in the ecosystem of the island.

3.2.1. Results from discussion with the system operator

From several discussions with different departments of EDM, including the grid department in charge, among other thing, of the dispatching, the following results were extracted:

Table 2: Assessment of EDM needs

Flexibility service	Subcategories of services	Relevance for EDM
Constraint management	Voltage control	Some specific voltage issues have already been identified by the system operator in Mayotte: • Some consumers located at the end of long feeders (e.g., the one supplying the south of the island) are complaining about non-working induction cookers because of low voltage level. EDM is thus assuming some voltage drops along its lines. • The undergrounding of overhead cables currently performed by EDM leads to an increase in reactive power levels in the cables and may cause transient overvoltage and resonant behaviour due to the energization or switching of transformers in the system.
	Congestion management	EDM has really low visibility on the LV grid due to the lack of measuring equipment and smart meters. The electricity company is thus not aware of any congestion on the distribution grid. However, with new ways of consuming (e.g., Electric Vehicles charging and datacenter[1]) and an overall overloading of grid equipment (e.g., transformers, feeders), EDM is interested in examining how market mechanisms can minimize the consumption peak.
	Controlled islanding and restoration	Even if controlled islanding might have sense for Mayotte as the territory is divided in two islands – Petite Terre and Grande Terre – electrically connected by three MV submarine cables, this service was not deeper analysed. Electricité de Mayotte has indeed a diesel power plant on each island capable of meeting the demand of the specific island: Badamiers power plant in Petite Terre (composed of Badamiers I, 8 MW and Badamiers II, 25 MW) and Longoni power plant in Grande Terre (composed of Longoni I, 39 MW and Longoni II, 34 MW).

[1] A new datacentre will be installed in Mamoudzou in 2022

Balancing	FCR, FRR	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. Indeed, PV production is highly dependent on weather conditions that are challenging to forecast (e.g., a passing cloud leads to a decline in PV production), which may finally increase the imbalances between generation and consumption. With increasing number of PV generation, that will partly replace diesel generators, the ratio of spinning machines in the system will be reduced which also has negative impact on the synchronous inertia. 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 based on the expected rising demand and increasing RES generation. For those reasons, frequency control has been selected for MAESHA.

From this first assessment, three different use cases were selected:

- Voltage control
- Minimization of the consumption peak
- Frequency control

3.2.2. Results from discussion with local population and stakeholders

Local optimization services were analyzed with the help of local stakeholders (local authorities, EDM, local population):

Table 3: Assessment of local population needs

Flexibility service	Subcategories of services	Relevance for Mayotte
Local optimization	Self-balancing	As the connection of intermittent renewable energy sources is a cause of instability for the grid, another way of maximizing the use of RES in the island is to foster self-consumption operations (individual and collective) and thus to look at self-balancing.
	kWmax control	Control of the maximum load was not considered as relevant for the project, as there is no power tariff component – proportional to the consumption peak of the household - in the electricity tariff in Mayotte.

	Time-of-Use optimization	As no dynamic tariff is currently proposed to consumers in Mayotte, Time-of-Use optimization was discarded.
	Emergency power supply	Local stakeholders sensitive to power outages are already equipped with emergency power supply in the island (e.g., the hospital).

From our discussion with local population in the context of WP3 "User-centered approach for Local Energy Communities", it appears that many people in Mayotte are living in precarious living situations with sometimes no access to running water or electricity. The community-based approach lies at the heart of the MAESHA project and it is crucial for the projects' success, impact and sustainability. This also means that relevant community needs, such as the demand for better energy-access, must be considered from an early stage on. More insights into the citizens' perspectives on Renewable Energy Technology and Local Energy Communities will be given in D3.1 "Baseline-Assessment", carried out by HUDARA. Disregarding the local context and de-emphasizing community needs bares the risk of MAESHA being seen as intellectual or elitist project which is dedicated only to wealthy and educated individuals. That's why it has been decided to consider a final use case focusing on the energy access for marginalized communities. Please note that this service is not considered in the USEF framework as the latter is focused on continental Europe.

From this second assessment, two use cases were selected:

- Maximization of the use of Renewable Energy Sources
- Energy access

3.3. Matching Business Use Cases with the solutions of MAESHA

The five selected use cases – frequency control, voltage control, minimization of the consumption peak, maximization of the use of Renewable Energy Sources and energy access – are business use case and technology-agnostic. It was then important to assess their feasibility with regards to the core innovations developed by the consortium of MAESHA. Experts of the consortium thus assessed the capabilities of their solution to support each of the aforementioned use cases. The result of this analysis is shown Table 4 below.

Table 4: Solutions implemented in each use case

Solution	Frequency control	Voltage control	Minimization of the consumption peak	Maximization of the use of RES	Energy Access
RES Virtual Power Plant	X	X			
Collective self-consumption			X	X	X
Industrial Demand Response	X	X	X		
Residential Demand Response	X	X	X		
Smart Charging/V2G	X		X	X	

Hybridization of PV production and EV charging				X	
Battery storage	X	X			
Power to Hydrogen	X	X			X
Flexibility Management and Trading Platform	X		X		

As all use cases could be supported by the core innovations of MAESHA and thus demonstrated in Mayotte, it has been decided to continue with the five aforementioned use cases and to extensively describe them with the IEC 62559-2 template.

3.4. Description using the IEC 62559-2 template

The IEC 62559-2 standard [1] aims to set a methodology and a template for detailing a use case. It includes the description of objectives, actors, requirements (including KPI), and the relation between them. This template is designed for the definition of smart grid use cases, though it can be used as well for other energy systems such as e-mobility. It is therefore perfectly suitable for MAESHA use cases.

The IEC 62559-2 template is depicted Figure 4 below. It is a Microsoft Word format document that provide a way to dispatch each use case specified information into dedicated chapters and tables in a formatted manner:

1. Narrative of the use case (context and objectives)
2. Diagrams of the use case
3. Technical details, including the extensive description of all the actors
4. Step by step analysis of the use case: defines the main scenarios of the use case, and for each of them it details the processes and relations between actors, step by step.
5. Information exchanged
6. Requirements
7. Common terms and definitions

It enables to place the use-case as a whole in its context, describe the processes thoroughly within the scenarios, and define each component, information or requirement, while referring to them in the whole document. It therefore drives towards a very comprehensive and detailed description of the use-case.

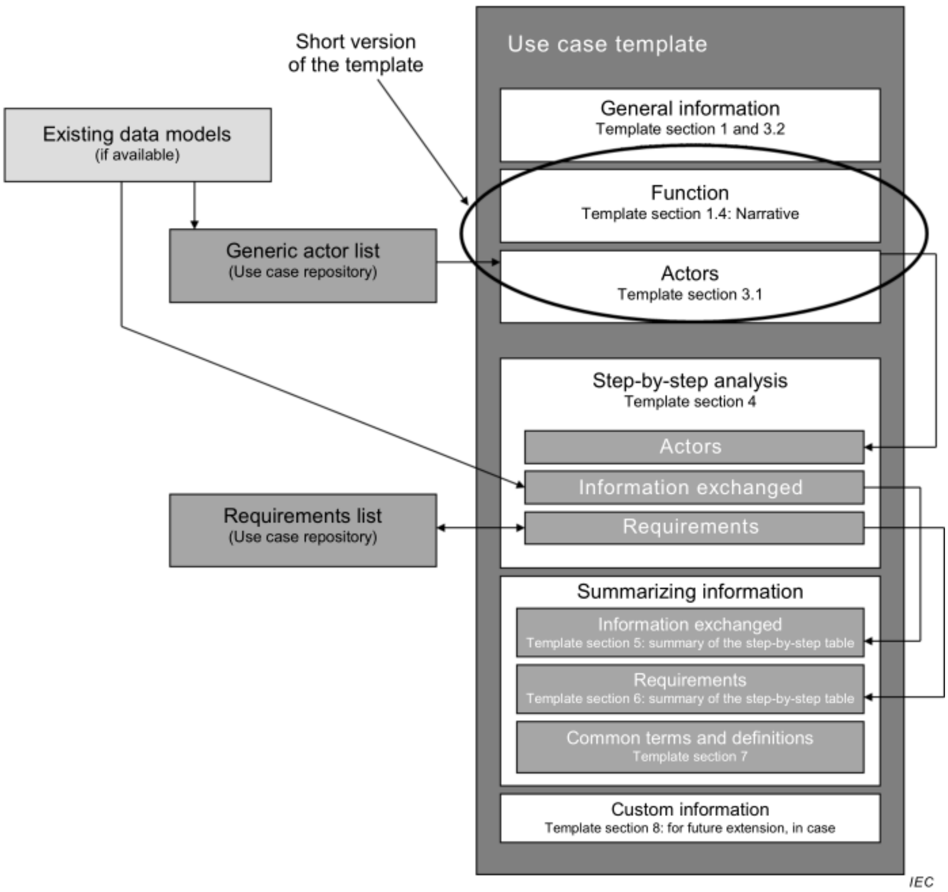

Figure 4: Overview of the IEC 62559-2 template

Additional information was added when relevant such as:

- A SGAM Business layer providing a high-level presentation of the major stakeholders or the major (business) domains in the system and their interactions
- A SGAM Function layer depicting the arrangement of functions and interfaces (internal and external) that defines the execution sequencing, the condition for control or data flow
- A SGAM Information layer representing the information exchanges between components to support this use case

Please refer to deliverable D1.2 for further details on the Smart Grid Architecture Model (SGAM) and on the system architecture.

4. USE CASES

4.1. USE CASES DESCRIPTION

This section presents the generic and high-level specifications of the five use cases to demonstrate in MAESHA: frequency control, voltage control, minimization of the consumption peak, maximization of the use of Renewable Energy Sources and energy access. The main beneficiary of each use case is recalled in Table 5 and the solutions implemented to support each use case are shown in Table 4 above.

Table 5: Use cases and their main beneficiary

Use case	Main beneficiary
Frequency control	TSO
Voltage control	DSO
Minimization of the consumption peak	DSO
Maximization of the use of Renewable Energy Sources	Local population, local authorities
Energy Access	Marginalized communities

If use cases are adjusted or modified along the project (e.g., for complete alignment with pilot partners expectations), the use cases definition will be updated accordingly. Please note that this section provides a complete description of the narrative of the use cases as well as their objectives only. Specific system architecture, list of actors, scenarios, KPIs and information flows can be found in annex of this document to ease its reading.

4.1.1. Frequency control

Scope and objective of use case

Scope and objectives of the 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)	The main objective of this use case is to stabilize the electricity grid of the islands by establishing balancing services. Implementing the balancing services framework will help system operators to maintain the equilibrium between consumption and generation while minimizing the frequency deviation from the nominal values.

Narrative of use case

Narrative of use case
Short description
This 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) balancing 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 DR aggregated by a VPP, smart charging of electric vehicles, aggregation of renewables 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 organised 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 operator's SCADA in the near future.

Complete description

Reminder on frequency control:

The system operator Electricité de Mayotte (EDM), responsible for grid operation and supply of electric energy, needs to maintain the network frequency within a narrow bandwidth (+300 / -200 mHz) around 50 Hz. Frequency deviation is a consequence of an imbalance between generation (feed-in to the grid) and consumption (extraction from the grid) including losses of the grid itself. These imbalances are mainly caused by unpredictable fluctuations of the load (low impact on the grid frequency), general imprecisions in the load forecasting that cause improper generation schedules (medium impact) or rare fault-induced disconnection of entire branches or substations or even unexpected loss of generation (high impact). Until now, the electricity system in Mayotte relied on fast adaption of the generation of spinning diesel engines to balance the load fluctuations. These diesel engines also cover for the main generation schedule.

The mechanisms to maintain the grid frequency within a narrow bandwidth can be distinguished between three main types of control, as shown in Figure 5. After an incident like the unexpected outage of a generator, the imbalance between load and generation causes an immediate decrease of the grid frequency, which is mainly limited by the kinetic energy stored in spinning machines (synchronous inertia). The higher the inertia of the rotating machines connected to the grid, the lower the gradient of frequency change (Df/Dt), also known as rate of change in frequency (ROCOF). The frequency stabilization by inertia is a physical effect, responding spontaneously to any frequency gradient and acting in both directions. New generations of inverters can provide a frequency gradient dependent feed-in (with a minor time lag), which can be considered as "virtual inertia".

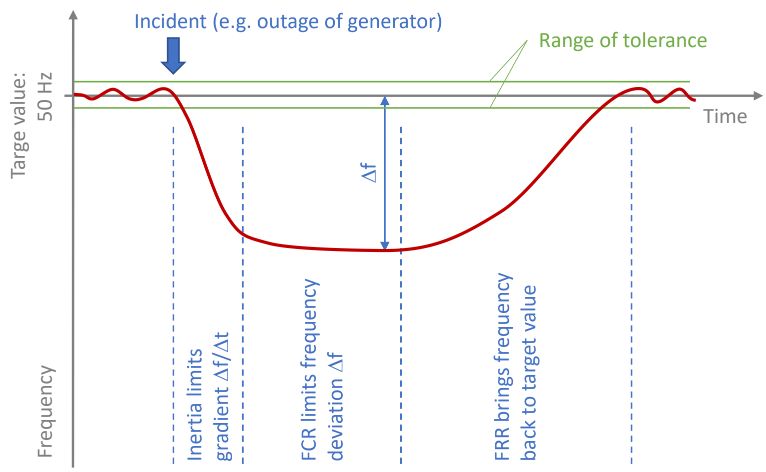

Figure 5: Overview of phases of frequency control after a major outage

The frequency containment reserve (FCR), also known as primary control, provides a variable feed-in linearly depending on the deviation of the frequency (Df) from the target value of 50 Hz. FCR is required to act very fast. The required full activation time (FAT) is determined by the considered maximum imbalance (e.g., due to loss of the largest generation unit in the system), the maximum allowed frequency deviation and the typical inertia of the system. FCR is a very fast service that requires frequency measurements and control logic directly at the providing asset, usually a generator or battery. Some loads controlled by power electronics might also be feasible to provide FCR. Usually, FCR is a symmetric service that acts in both directions. The linear function of FCR power only depending on the frequency deviation enables a fast response to limit the frequency deviation but does not allow to bring the frequency back to the target value.

Some transmission system operators (TSO), e.g., in the NORDPOOL, differentiate between Frequency Containment Reserve for Normal Operation (FCR-N) and Frequency Containment Reserve for Disturbances (FCR-D). FCR-N is a symmetric service providing upregulation and downregulation with a linear characteristic while FCR-D differentiate between upward (increase feed-in or decrease consumption) and downward (decrease feed-in or increase consumption) regulation. FCR-D is only activated after exceeding a threshold value of frequency deviation.

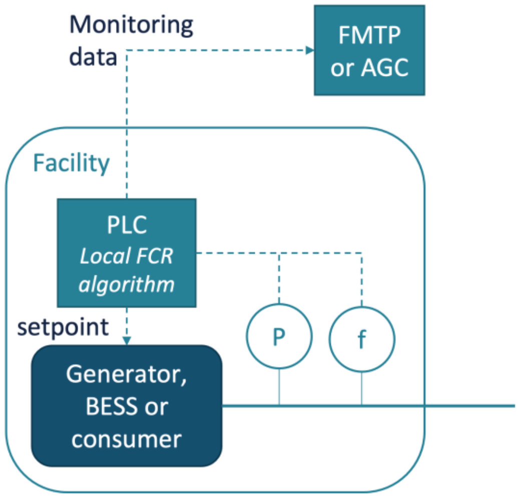

Figure 6: FCR architecture overview

The frequency restoration reserve FRR is managed by the system operator (SO) using the automatic generation control (AGC). The AGC calculates setpoints for multiple balancing providing assets (generators, batteries but also fast and precisely controllable loads like electrolysers). After reception of the setpoint the assets will adapt the power output within a defined FAT that may be longer than required for FCR. The AGC aims to bring the system frequency back to the target value. FRR requires reliable communication between the central AGC and the distributed assets. FRR can be divided into positive products for upward control and negative products for downward control. European TSO differentiate between faster, automatically controlled reserves (aFRR), that follow to instantaneous setpoints, and slower reserves that might be manually controlled (mFRR) and follow to received schedules.

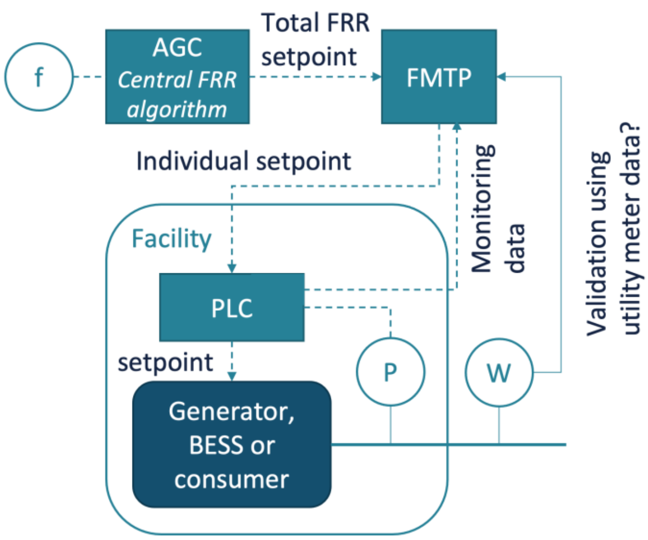

Figure 7: FRR architecture overview

FCR and FRR provision in Europe usually require active power measurements with high precision (e.g., 0.5% error class) and submission of data points to the SO in short intervals (e.g., 1-2 s) for the purpose of real-time monitoring of provision and ex-post validation of the provided services.

Additional Emergency measures will be activated in case that the frequency regulation system failed, and the frequency deviation exceeds defined thresholds. Emergency measure can include load shedding, disconnection of large, robust consumers or disconnection of generators. The rules for frequency protection devices to disconnect sensible assets in case of high frequency deviations must be defined accordingly to support system frequency stabilization and to avoid negative feedback on the frequency control mechanisms.

Context of Mayotte:

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. Indeed, the production is highly dependent on weather conditions, that are 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)[2] 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.

MAESHA and frequency control:

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 CO_2 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 fuelled 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., manual ON-OFF operation), or can provide such action only at a certain time of the day or year. Therefore, industrial

[2] The French Energy Regulatory Commission is the organization in charge of ensuring that the electricity and gas markets in France function smoothly for the benefit of end users and in line with energy policy objectives

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 be 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, as indicated in Figure 8 below.

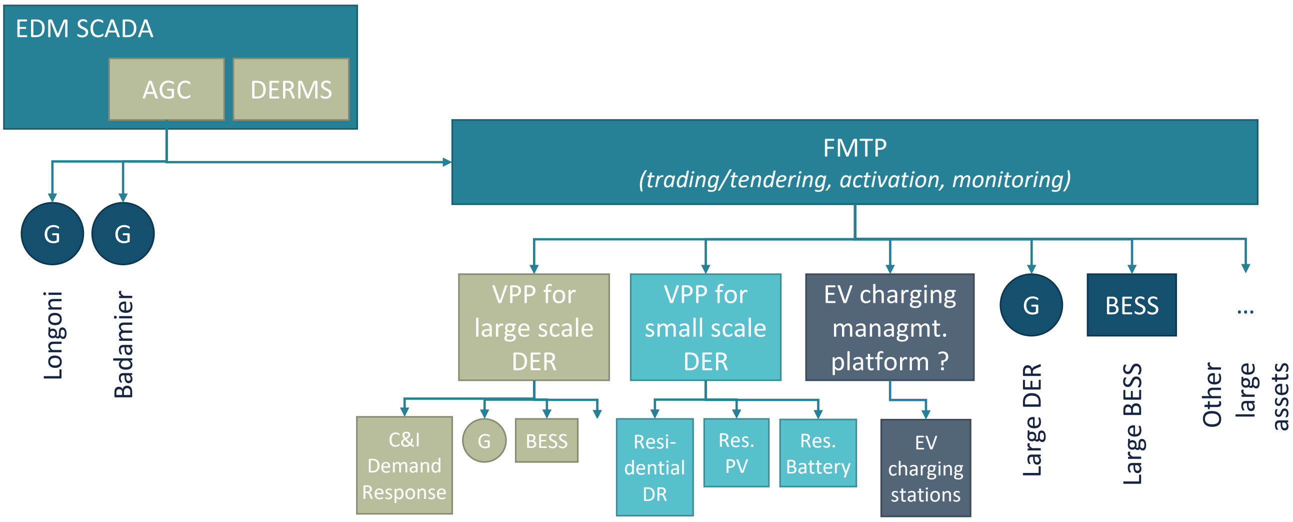

Figure 8: Architecture overview for frequency control in MAESHA

Functions supporting the use case:
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.

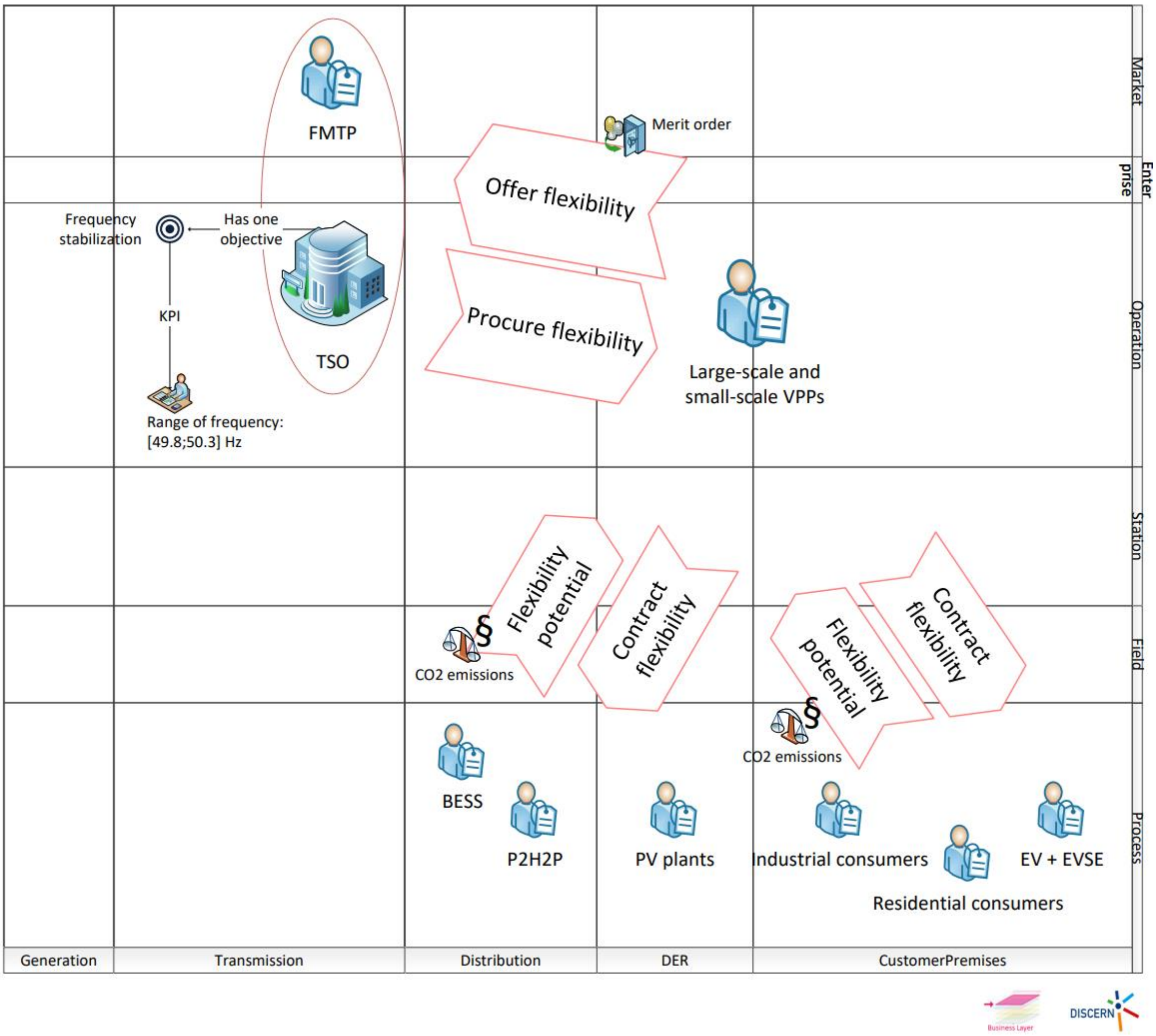

Figure 9: SGAM business layer of the frequency control use case-specific architecture

This SGAM business layer depicts the MAESHA solution in the context of the use case and provides a conceptual view, a high-level presentation of the major stakeholders or the major domains in the system and their interactions. Please refer to deliverable D1.2 for further information on this layer and on the SGAM methodology.

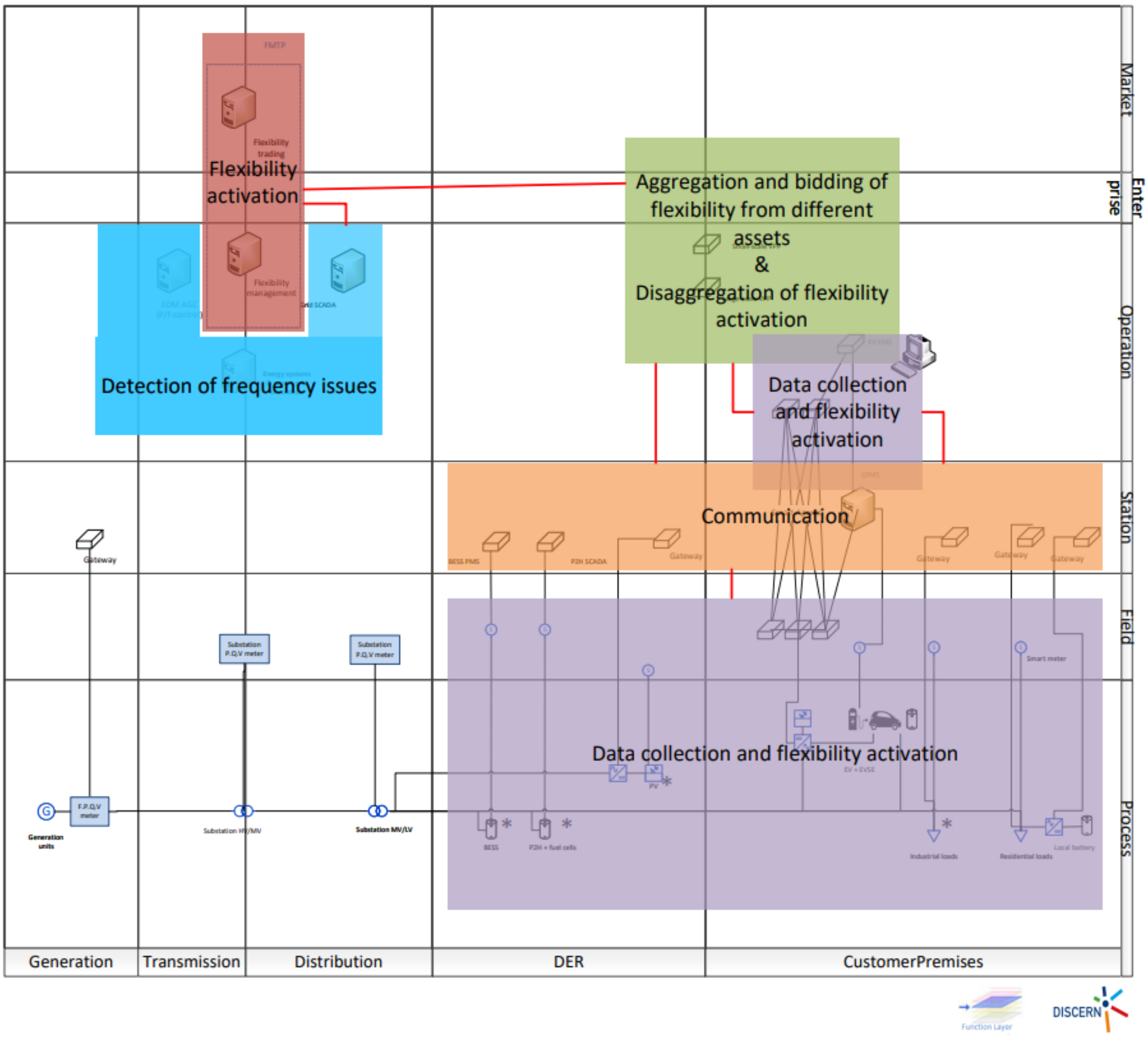

Figure 10: SGAM function layer of the frequency control use case-specific architecture

This SGAM function layer describes the functions and services including their relationships that support the frequency control use case.

The description of this use-case is continued in the annex (page 64).

4.1.2. Voltage control

Scope and objective of use case

Scope and objectives of the use case	
Scope	The scope of this use case is to examine the use of flexibility resources connected to the distribution grid to ensure the voltage stability of the power system
Objective(s)	The main objective of this use case is to stabilize the electricity grid of the island by proposing voltage control services. Voltage control services aim at keeping voltages within specific safety bands and restore their values to the normal range after grid disturbances occur, to minimize reactive power flows, investments and technical losses.

Narrative of use case

Narrative of use case
Short description
The voltage control use case aims at using new flexibility assets, such as battery energy storage systems, renewable energy virtual power plants, power-to-hydrogen facilities or demand response, to support system operators in improving the voltage profile. This use case will focus on voltage control using static voltage control curves.
Complete description
Reminder on voltage control: Voltage stability is a responsibility of the system operator to ensure the secure and reliable operation of the power system. The voltage level at all points of delivery should be equal to 230 V for single-phase power and at 400 V for three-phase power in low voltage grid and equal to 20 kV in medium voltage grid, with a margin of acceptability of [-10%, +10%], both in steady-state and transient conditions (see [10]). Typical voltage issues experienced by system operators are voltage drops or rises at the end of feeders, caused by high demand for power or supply by local renewable energy production units at these locations. On top of changes in voltage magnitudes, voltage should remain stable at all times, even during large and small disturbances, denoted as large-disturbance voltage stability and small-disturbance voltage stability: • To ensure large-disturbance voltage stability, system operators need to ensure that voltage levels remain within limits even if a generator or a transmission line goes out of service. The outage of a transmission line or generator causes a variation in the system reactance, which lowers the voltage generation characteristic, resulting in a lower voltage or possibly unstable operating point. • Small-disturbance voltage stability focuses on the continuous small changes in the system due to imbalances between demand and supply, e.g., initiated by the variability of load and renewable energy sources. • On top of the system and operational planning procedures for large and small disturbances, power systems should have additional defence facilities in place to prevent voltage collapse following extreme disturbances, but these are out of scope of this use case. The voltage stability also strongly depends upon the demand characteristics. If the active power load is steadily increasing, the reactive power supply curve, which expresses the reactive power supply as a function of the voltage, decreases. An increase of the reactive power load, which may go with the increase of the active power load, will raise the reactive power load curve. As a consequence, the stable operating point moves towards smaller voltage levels and the steady increase of the load may ultimately result in a voltage collapse, when the demand for reactive power becomes larger than the supply. This process has been illustrated in [11]. Moreover, the voltage stability depends upon the voltage control capabilities of the generators.

Context of Mayotte:

Some specific voltage issues have already been identified by the system operator in Mayotte:

- Some consumers located at the end of long feeders (e.g., the one supplying the south of the island) are complaining about non-working induction cookers because of low voltage level. EDM is thus assuming some voltage drops along its lines.
- The undergrounding of overhead cables currently performed by EDM leads to an increase in reactive power levels in the cables and may cause transient overvoltage and resonant behaviour due to the energization or switching of transformers in the system.
- A too high voltage level can be observed on high voltage lines between April and October, when the demand is lower (e.g., high voltage lines sometimes reach 94kV instead of 90kV). This case is more difficult to treat for EDM because there is less margin for compensation.

To ensure voltage stability, system operators need to ensure during the network planning stage that reliability criteria are satisfied for all possible N-1 contingencies, i.e., that the maximum allowable voltage drops or rises are not exceeded and that the stability margins for real and reactive power are large enough for each composite load and load area. To ensure this, system operators should monitor the capabilities of individual assets as represented in Q-U-ranges, such as the example in Figure 11.

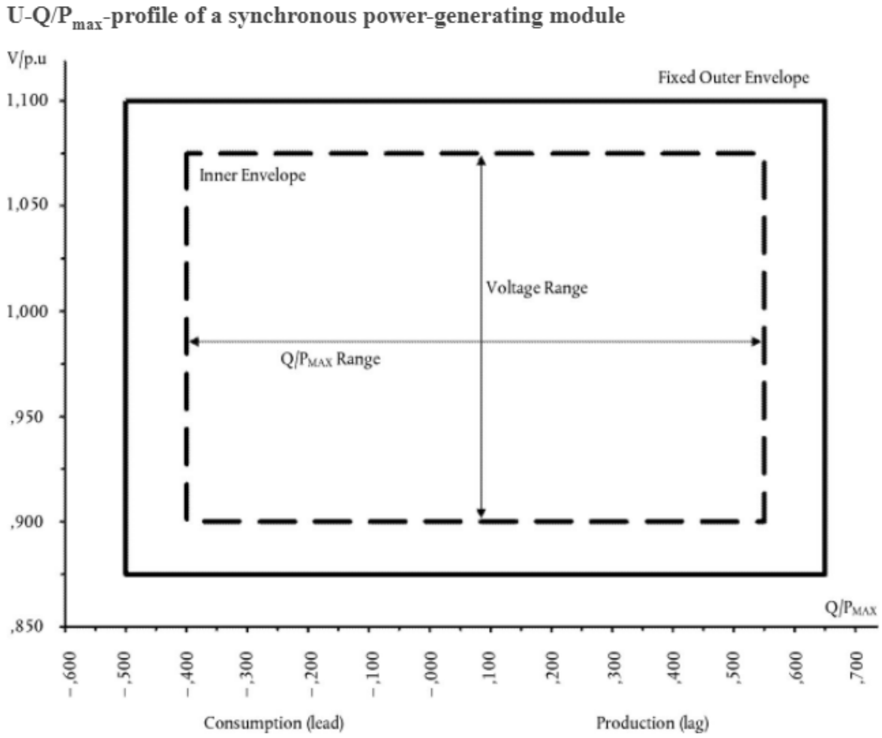

Figure 11: Voltage/reactive power range of asset (Source: ENTSO-E, see [7])

During operational planning and real-time monitoring and control, the system operator should continuously maintain a desired voltage profile. Currently, EDM controls the voltage profile through manual activation of appropriate reactive power compensation devices, such as capacitor banks, manual and automatic tap-changing of transformers and control of the available Diesel generators (Longoni and Badamiers). An adequate reserve of real and reactive power should be maintained at the generators. Reserve is the amount of power by which generators in operation can be additionally loaded without exceeding the reactive power capability curve. Note that voltage control can be performed through active and reactive power control. However, active power control is related to far higher costs and efforts than reactive power control. And as active power is also extensively used in other use cases, reactive power reserve is particularly important from a voltage stability perspective. This reactive power reserve can be activated to quickly deal with a reactive power deficit when voltage deviations are detected. The amount of reactive power to be supplied by a particular asset depends upon the control architecture in place, i.e., based on a voltage setpoint, possibly combined with a voltage droop curve to adequately deal with load transients, a reactive power setpoint or a power factor setpoint. The setpoints can be static or may change dynamically over time but should always satisfy the asset's capabilities as specified in the capabilities ranges illustrated in Figure 11 above. An example of static voltage droop curve is available in Figure 12.

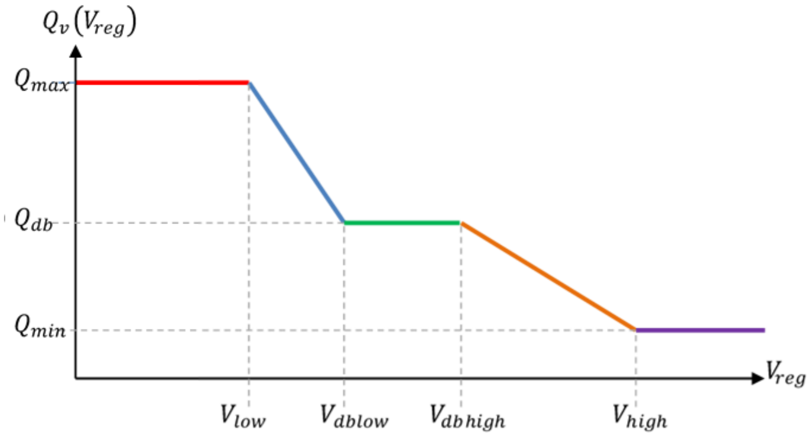

Figure 12: Example of a static voltage droop curve

Voltage control has specific characteristics, which strongly determine the suitability of acquiring mechanisms to apply in the voltage control setting. First of all, voltage control should resolve **local** issues, i.e., in contrast to frequency control, the location of the assets is more important and assets connected close to the need should be used. Given the small number of assets combined with the fact that flexibility assets are restricted to specific locations for a particular need, the market liquidity is low, and the efficiency of market-based mechanisms may not be guaranteed. Alternatively, bilateral contracts or obligation may be possible acquiring solutions that will be considered. Second, it is **hard to predict long in advance the location and extent of the voltage issue**, unless it depends on structural deficits or known (periodic) behaviour of generation or demand. Third, the effectiveness of the voltage control services **depends upon the visibility of the system operator**. Currently, Electricité de Mayotte (EDM) only has access to real-time voltage measurements at the three HV/MV substations in the system.

MAESHA and voltage control:

In MAESHA, the voltage control use case aims at using new flexibility assets, such as battery energy storage systems, renewable energy virtual power plants, power-to-hydrogen system or demand response, to support system operators in improving the voltage profile. This use case will exclusively focus on reactive power control. However, please note that active power control, as a measure of last resort, is still feasible using the mechanisms introduced by the next use case (see section 4.1.3). In the pilot test, a dedicated location in EDM's system will be chosen with specific voltage issues where flexibility from the aforementioned assets will be used to support EDM in their voltage control. The voltage control use case focuses initially on voltage control using static voltage control curves, giving the limited visibility of the system operator in its system that block the case for a more complex dynamic approach at this stage.

Renewable Energy Virtual Power Plant

Adequate control of the AC/DC inverters of PV plants offers the possibility to control the reactive power and voltage in the system.

Battery Energy Storage System

Battery Energy Storage System (BESS)s are devices able to store and manage electric energy. The main subsystems are the Battery Management System (BMS), converter, auxiliary systems and main control system. Amongst other capabilities, BESS can perform voltage support to the bus it is connected by delivering a variable amount of active and reactive power according to the control algorithms of the BESS control system. The power dispatch is managed by 4-quadrant power electronics (BESS converter).

Power-to-Hydrogen system

Power to hydrogen systems are plants that convert electricity into hydrogen than can be stored and subsequently utilized as feedstock, fuel or to produce electricity in a fuel cell. The flexible operating capabilities of the electrolyser can contribute to reduce the voltage fluctuations at the point of interconnection.

Industrial and Residential Demand Response

Buildings equipped with inverter-interfaced demand or generation (e.g., PV installation, heat pumps, electric boilers) can participate in voltage control services through the reactive power control of those assets. However, active power control of those assets is more effective in the framework of other grid services (e.g., minimization of the consumption peak use case) and we might not be able to demonstrate this solution in MAESHA.

Please note that industrial and residential consumers equipped with inverter-interfaced demand or generation assets can theoretically propose voltage control services. However, the service is quite specific – the control of the inverter will be further detailed in task 5.2 "Technologies to increase grid inertia and improve power quality" – and the ability to demonstrate it in MAESHA still needs to be evaluated.

Functions supporting the use case:

This use case relies on the following functions:

- Determination of static voltage control curves by the system operator for assets capable of reactive power control/voltage support based on asset's capability curves and the capabilities of traditional solutions (e.g., by using tap changing transformers, capacitor banks or voltage support of Diesel generators)
- Local voltage and power measurements
- Control logic: determination of reactive power setpoints to follow according to local voltage and power measurements and static voltage control curve of the asset
- Validation process

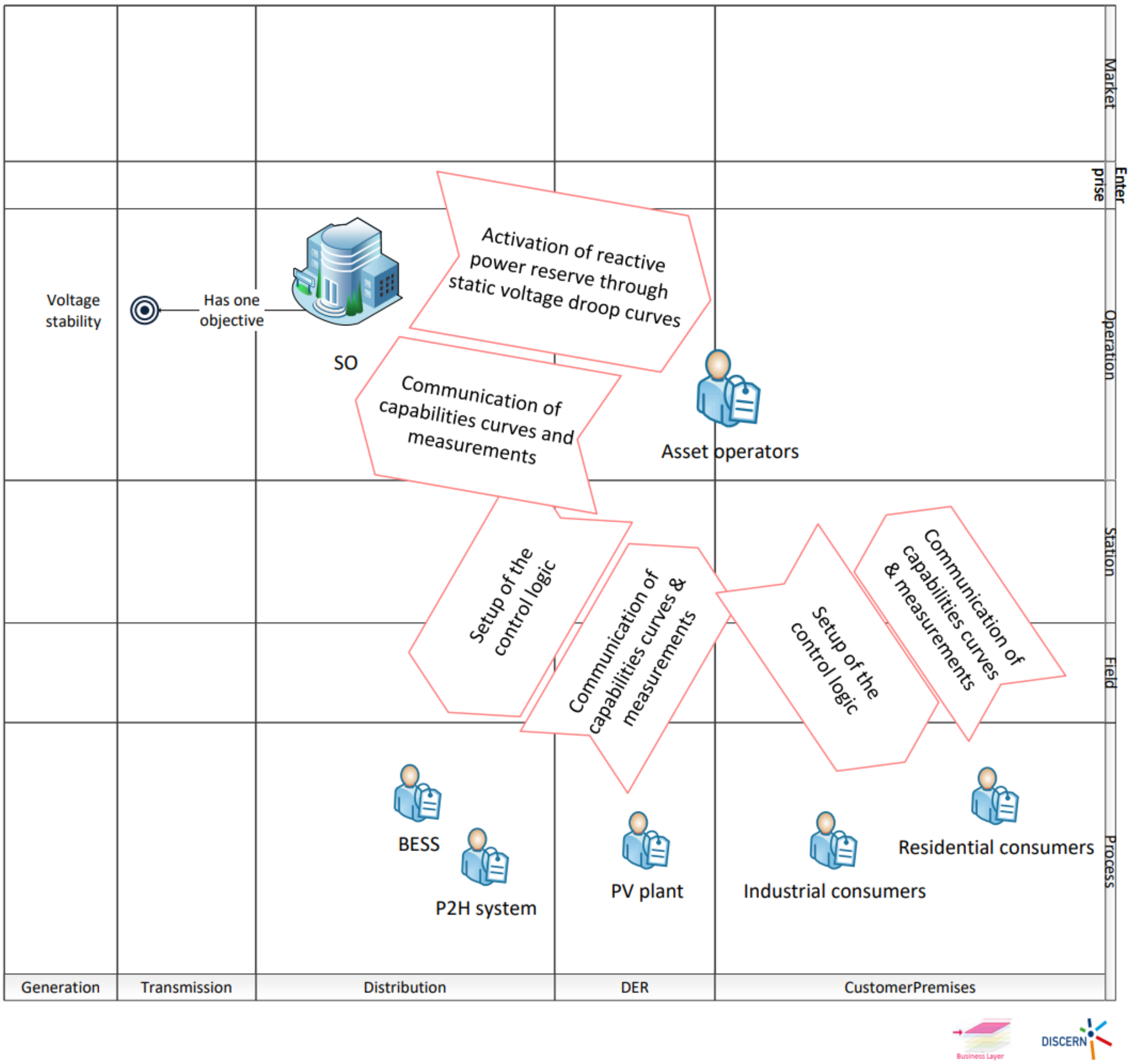

Figure 13: SGAM business layer of the voltage control use case-specific architecture

This SGAM business layer depicts the MAESHA solution in the context of the use case and provides a conceptual view, a high-level presentation of the major stakeholders or the major domains in the system and their interactions.

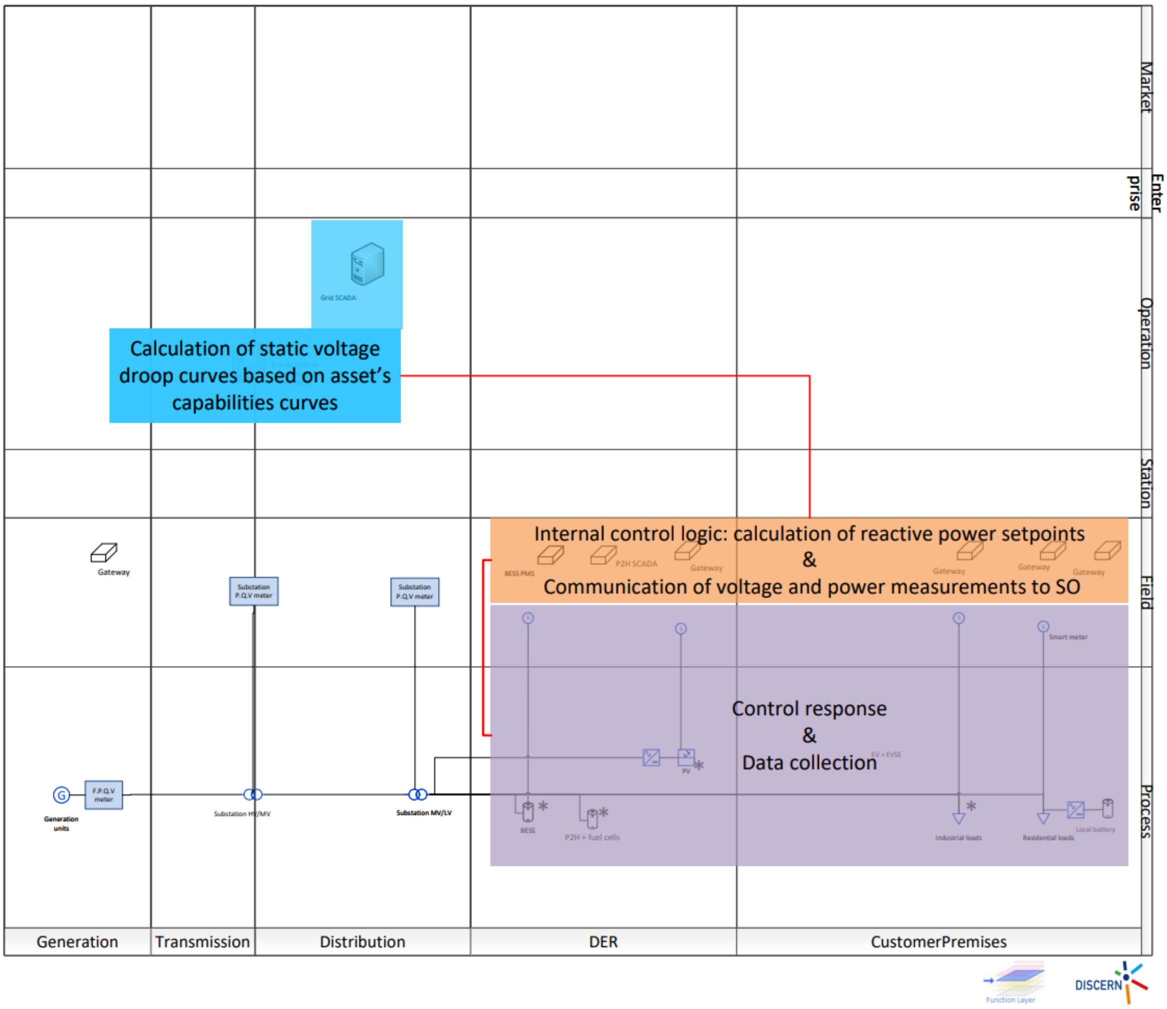

Figure 14: SGAM function layer of the voltage control use case-specific architecture

This SGAM function layer describes the functions and services including their relationships that support the voltage control use case. Please note that the communication of voltage and power measurements to the SO can be performed automatically on a daily basis if smart meters are deployed. Otherwise, the communication will go through a local controller that will log those data and send them to the SO regularly.

The description of this use-case is continued in the annex (page 85).

4.1.3. Minimization of the consumption peak

Scope and objective of use case

Scope and objectives of the use case	
Scope	The scope of this use case is to examine how the MAESHA system can minimize the consumption peak to avoid potential congestion, expensive start-up of peak generators or adequacy issues that may occur in the electricity system of the island
Objective(s)	The main objectives of this use case are to: • Minimize the consumption peak by proposing load shifting, load shedding or increase of distributed generation (behind the meter) to the SO through the Flexibility Management and Trading Platform (FMTP) • Minimize the consumption peak on a daily basis by following the EV signal set by Electricité de Mayotte (EDM) on its Open Data to advertise favourable periods of consumption • Maximize self-consumption for EV charging to reduce the peak load (link w/ UC "Maximisation of the use of Renewable Energy Sources") If extended to congestion management, a subobjective could be to: • Control consumption and/or production to avoid congestion in the distribution network

Narrative of use case

Narrative of use case
Short description
This use case aims at minimizing the consumption peak by implementing a flexibility market for load shedding and/or load shifting to enable new flexibility assets to support the system operator in operating the grid and by following, on a daily basis, the EV signal set by EDM to advertise favourable periods of consumption.
Complete description
<u>Reminder on consumption peak:</u> Consumption peak – also named peak load – refers to the highest electrical power demand that has occurred over a specific time period. In Mayotte, where the climate is characterised by small variations of daily and annual temperatures as well as heavy rainfalls, the electricity demand seasonality is low. The demand is indeed quite stable all around the year and the daily consumption peak occurs early morning (from 5 a.m. to 8 a.m.) when people wake up and, in the evening, (from 6 p.m. to 10 p.m.) when people get back from work. *<u>Context of Mayotte:</u>* However, the System Operator (SO) of Mayotte, Electricité de Mayotte (EDM), is expecting changes in the near future. As a reference scenario for Mayotte, EDM assessed that the total demand should reach 540 GWh with a consumption peak of 84MW in 2028 (to compare with the 370 GWh of electricity supplied in 2019 and the maximum consumption peak of 61.5 MW reached in February 2021). This increase can partly be explained by the penetration of electric vehicles – personal cars but also renewed C&I fleets – and improving living conditions for the population, which relies more and more on air-conditioning units. To deal with the increasing demand which may happen at a higher pace than grid reinforcements can cope with, EDM is interested in evaluating how flexibility can solve potential congestion. Grid congestion occurs when the capacity of the electricity grid is insufficient to transport the volumes of electric power required to meet the demand. EDM has currently too low visibility on its grid to measure any congestion. However, EDM knows that some equipment (transformers and feeders) is overloaded by comparing the capacity of the equipment with the total power capacity subscribed by the end-users located downstream from this equipment. EDM is currently performing reinforcement work such as: • the creation of a new HV/MV substation in SADA to transport electricity to the south of the island using a high voltage line (90 kV) and propose a better repartition of the end-users on the different feeders

* the replacement of old transformers

In addition to this reinforcement work, EDM has also set an EV signal, available on its Open Data to advertise favourable periods of Electric Vehicles charging – to promote Smart Charging and to not add any burden on the electricity grid of the island. This signal is binary:

* 1 means that the period is favourable and that EV charging is recommended at 7.4 kW maximum
* 0 means that the period is not favourable and that the charging is to avoid or to limit at 3.7 kW maximum

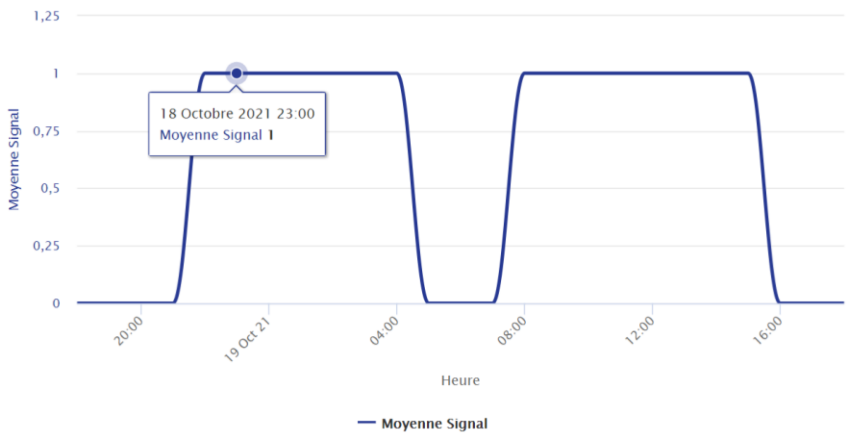

Figure 15: EV signal available on EDM Open Data

MAESHA and minimization of the consumption peak:

To extend EDM's reach on the management of the consumption peak, it has been decided within MAESHA to examine how different flexibility sources could propose load shifting or load shedding through the Flexibility Management and Trading Platform on a day-ahead flexibility market[4]. The flexibility market will have priority over the daily optimization: it means that a flexibility activation order sent by the DSO through the FMTP will have priority over the EV signal advertised on the Open Data. Please note that the minimization of the consumption peak should also be able to resolve **local** issues (e.g., overloaded MV/LV transformers), i.e., as in the voltage control use case, the location of the assets is important and assets close to the need should be used. The efficiency of the flexibility market will thus highly depend on its liquidity, the specific locations of the needs and of the flexibility assets involved.

Partners of MAESHA have assessed the potential indirect impacts of such flexibility markets:

* First, it will help EDM in future decision-making processes. By defining a merit order[5] for load shifting and load shedding, the MAESHA solution will evaluate the cost of consumption reduction. EDM will thus have the ability to compare such prices with internal generation options (in the short-term) and new projects (e.g., installation of new batteries, reinforcement work) and evaluate the relevance of the latter (in the mid-term).
* Then, this flexibility market will help assessing consumer's behaviour which might be useful if EDM decides to implement specific Time-of-Use tariffs based on consumer segmentation in the future.
* Finally, this market can also lead to CO_2 emissions reduction if EDM favours load shifting or load shedding to the operation of peak power plants[6], which are usually very polluting.

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[4] Through the forecast of typical patterns of EV charging, the MAESHA solution will be able to propose flexibility extracted from EV on a day-ahead flexibility market (if provided the access to the market. Otherwise, EV can participate in intraday flexibility market)

[5] The merit order will be calculated based on customers incentivization (e.g., financial compensation for switching off its air-conditioning unit)

[6] Peak power plants refer to power plants that run only when there is a high demand for electricity. They are usually small power plants fuelled by gas or diesel

The benefits of this use case are thus spread over time for EDM: on a short-time scale, the flexibility market will help EDM in minimizing the cost for electricity supply and on a longer time scale, help EDM in decision-making.

The different sub-systems in MAESHA supporting this use case are described in the following sections.

Residential Demand Response

Residential customers may have flexible loads that end-users do not necessarily need instantaneously to ensure their comfort, e.g., dishwashers, washing machines, cloth dryers, air-conditioning units or electric heating. Typically, these devices are used simultaneously during the consumption peak, e.g., when customers come home in the evening. Optimally controlling the on/off times of these devices can reduce the consumption peak. Dishwashers, washing machines or cloth dryers may be activated through the day, whereas heating can rely upon the thermal buffer of the building and/or a hot water tank to delay or prepone its activation.

Industrial Demand Response

Industry's main purpose is manufacturing of the certain goods and/or service. Some industrial assets on the other hand are 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 consumption peak. Those energy assets within the industry have usually some restrictions, such as limited time-frame of delivery (e.g., max 4 h) or can provide such action only at the certain time of the day or year.

Industry is usually the biggest energy consumption. Reducing the peak at the point of usage is a perfect candidate to be used within this use case.

Decentralized Energy Management within Local Energy Community

Most commonly, Local Energy Communities (LECs) are legal entities such as associations or cooperatives which are involved in generation and self-consumption of renewable energy. Often, LECs consist of prosumers, meaning members who both produce and consume renewable energy. These may own generation assets, practice self-consumption, share electric vehicles or are active in the local energy market through selling excess energy or being engaging in flexibility services. By offering local energy arbitration based on individual's needs, the energy management system developed within MAESHA will assess locally-aggregated flexibility to help the system operator in operating the distribution grid.

Smart Charging/V2G

Smart charging is the process by which Electric Vehicles (EVs) connected to charging stations are charged/discharged, taking into account various factors such as consumption peak, renewable energy production or low/high tariff periods. Upon request from an aggregator or a system operator, the Charging Point Management System can reduce or increase the consumption of the EVs, while respecting the EV driver's preferences (desired state of charge at its departure time).

Battery for peak load coverage

We would also like to integrate the battery for peak load coverage that will be installed on the island by the end of 2021. This battery can indeed contribute to the use case by providing additional electricity supply to meet the consumption peak, without running polluting and expensive peak power plants.

Function supporting the use case:

Considering the flexibility market, the use case relies on the following functions:

- Contracting flexibility products
- Forecast and operational planning – detection of a consumption peak
- Aggregation and bidding of flexibility from different assets by the intermediate platforms (VPPs and EV EMS)
- Activation of flexibility through the Flexibility Management and Trading Platform
- Disaggregation of flexibility activation and control dispatching
- Settlement process to validate flexibility activation
- Minimization of the consumption peak by Smart Charging/V2G

Considering the daily optimization, only EVs and potentially Local Energy Communities (LEC) will be able to synchronize the operation period of their respective assets with period advertised by EDM in its Open Data.

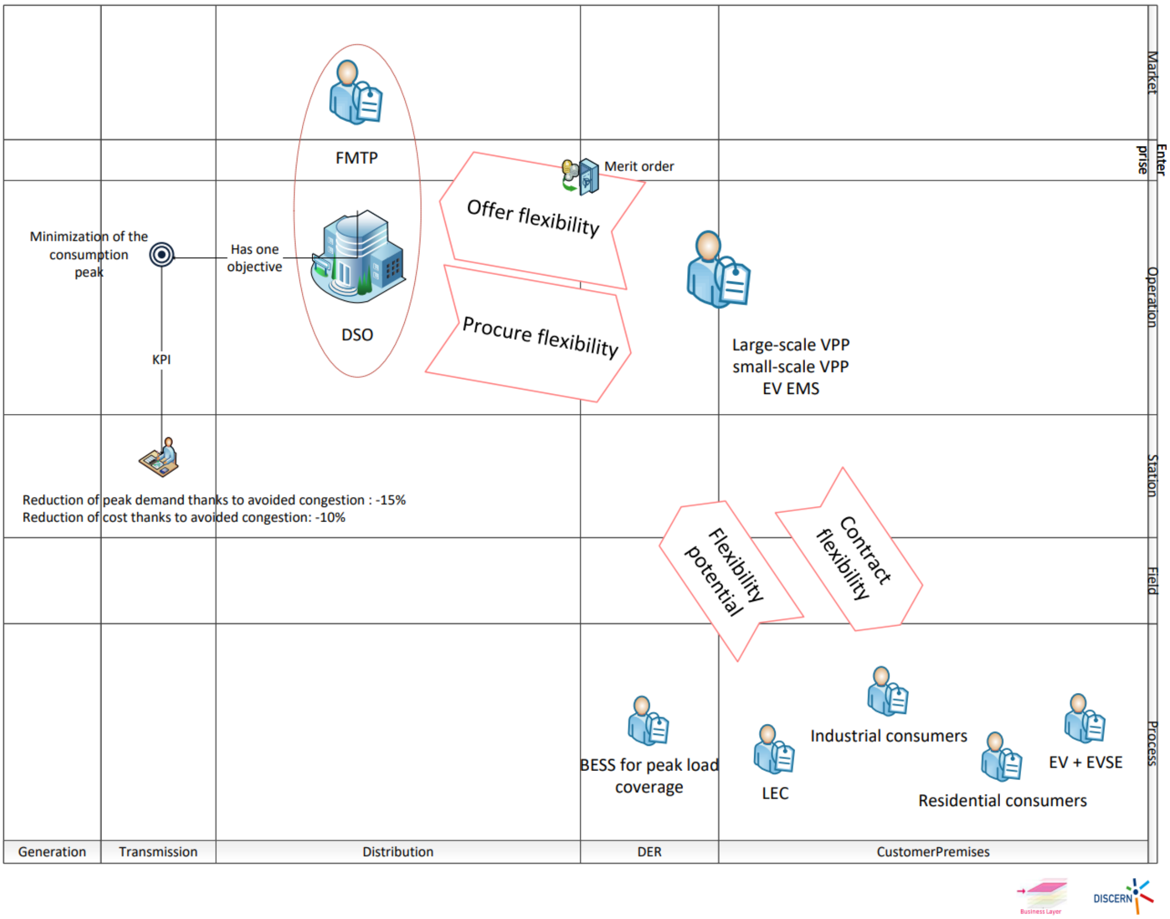

Figure 16: SGAM business layer of the minimization of the consumption peak use case-specific architecture (flexibility market)

This SGAM business layer depicts the MAESHA solution in the context of the use case and provides a conceptual view, a high-level presentation of the major stakeholders or the major domains in the system and their interactions.

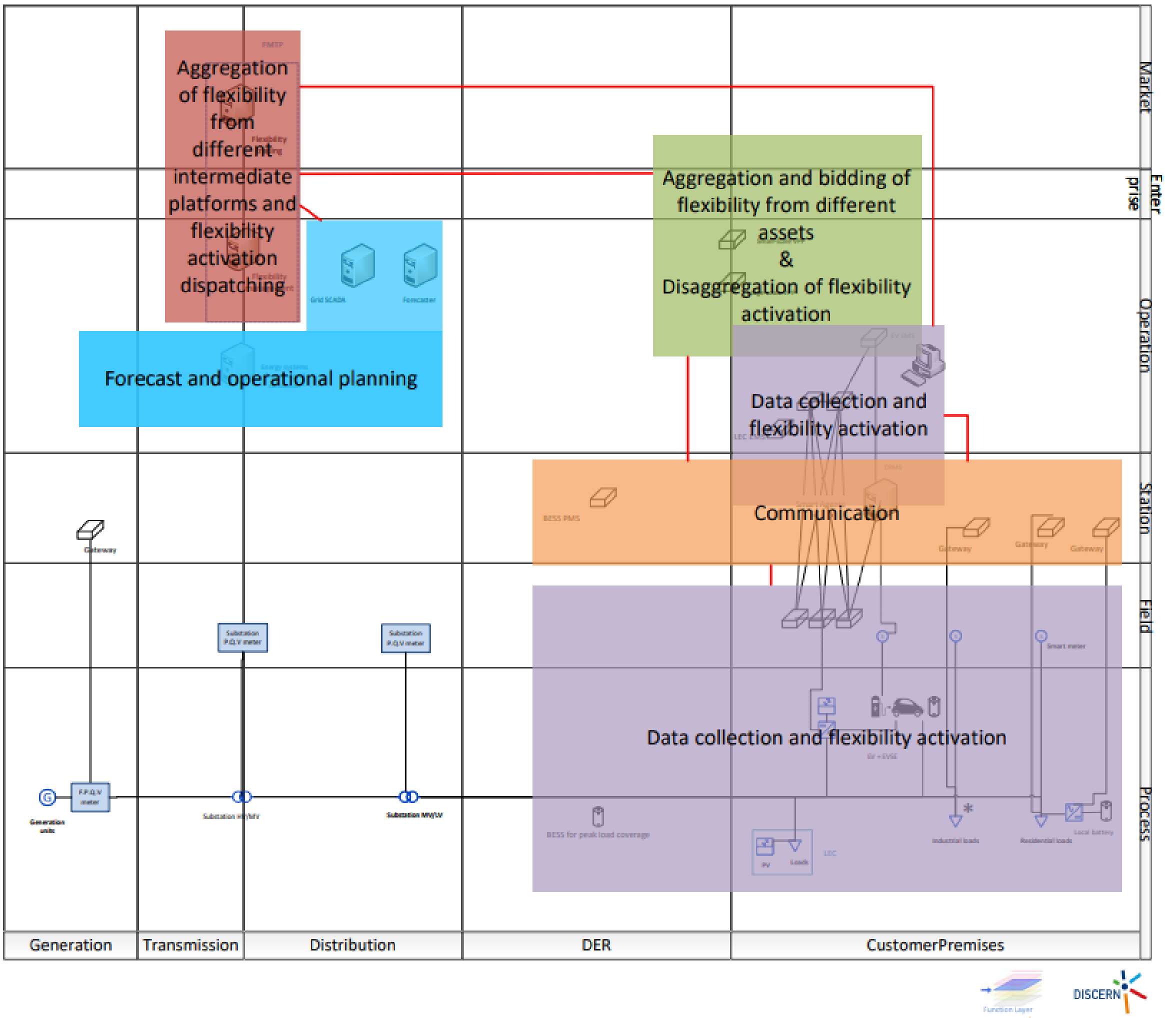

Figure 17: SGAM function layer of the minimization of the consumption peak use case-specific architecture (flexibility market)

This SGAM function layer describes the functions and services including their relationships that support the minimization of the consumption peak use case.

The description of this use-case is continued in the annex (page 96).

4.1.4. Maximization of the use of Renewable Energy Sources

Scope and objective of use case

Scope and objectives of the use case	
Scope	The scope of this use case is to maximize the use of Renewable Energy Sources in the daily life through collective self-consumption operations, local energy communities and hybridization of assets
Objective(s)	The main objective of this use case is to maximize the use of Renewable Energy Sources through: • The decentralization of renewable energy production and empowerment of citizens using collective self-consumption operations or energy communities • Higher levels of solar energy for charging electric vehicles to lower emissions in the transport sector • Higher levels of solar energy in climatization (HVAC) devices

Narrative of use case

Narrative of use case
Short description
This use case aims at implementing collective self-consumption operations and hybridizing assets (EV charging station and air-conditioning units) with photovoltaic panels to maximize the use of Renewable Energy Sources.
Complete description
The main objective of MAESHA is to decarbonise the energy systems of geographical islands, with two specific objectives relevant for this use case: **1. Reach up to 70 to 100% of Renewable Energy penetration with close collaboration between Local Energy utilities, communities, modellers and flexibility solutions providers** The potential for PV is high in Mayotte. With an electricity grid not fully conforming to European standards yet and many PV installations waiting for a connection to the main grid, many prosumers install small PV production units (e.g., rooftop panels) to use a local and renewable electricity production. Those operations are named individual self-consumption. In MAESHA, we will examine how those operations could be extended to a community level through the development of **collective self-consumption** and the creation of multiple Local Energy Communities. **2. Create synergies between electricity and other networks** The transport system in Mayotte, which is the primary source of GHG emissions on the territory (36%), is almost exclusively based on thermal vehicles. Very few Electric Vehicles are being deployed (of the order of a few tens of units (see [4])). However, if charged with carbonized electricity, as the one produced by the EDM diesel power plants, the benefit for the environment is small (approximately equivalent to a recent thermal vehicle of the same category, see [4]). The law on the orientation of mobilities, published in the official gazette on December 26, 2019, includes a ban on the sale of cars using carbon-based energy by 2040. Thus, it is necessary to engage an ambitious transition on the department of Mayotte. The Multi-Annual Energy Programming objective is migrating to 10% of electric vehicle until 2030. The first electric vehicles have been purchased by dealers to meet the demand of companies or local authorities for the replacement of their fleet in 2019. Indeed, the TECV law (article L. 224-7 and L. 224-8 of the environment code) fosters local authorities to integrate vehicles with lower GHG emissions into their fleet. A call for projects from ADEME has made it possible to launch the first recharging infrastructure development projects. Thus, on the territory of the Community of Communes of the South (CCSUD), 5 stations, each coupled with a photovoltaic power station, will be equipped to recharge about ten vehicles of the CCSUD and supply the 4 town halls of the territory. A similar project exists on the territory of the Community of Communes of Petite Terre (CCPT). It is important to highlight that those charging stations will be limited to 3.7 kVA or 7.4 kVA when supplied by electricity coming from the grid, depending on the EV signal (see section 4.1.3), and to 22 kVA when supplied by local solar electricity. *Local authorities are thus really interested in the MAESHA solution to maximize the use of Renewable Energy Sources to charge their EVs.*

In MAESHA, to foster the deployment of a more sustainable way of travelling across the island and to improve air quality, it has thus been decided to examine the **hybridization of the Electric Vehicles charging stations with PV production** and to synchronize the period of charging with period of local and renewable production.

Additionally, in the tropical climate of Mayotte, many consumers are relying on air-conditioning units or cooling systems to deal with the high temperatures. An EDM study reveals that the importation of air-conditioning units has increased by 77% in three years (2017-2019), with approximatively 60% of the population in Mayotte being equipped with such systems. With an average number of 2.3 air-conditioning units per household, the number of such systems is evaluated at 87000 (November 2020). The electricity consumption of this equipment is intensive and has a direct impact on the electricity system of the island. As air-conditioning units are mostly used during the warmer (and the sunnier) hours of the day, it has been decided to examine the **coupling of such systems with PV production**.

MAESHA and the maximization of the use of Renewable Energy Sources:

The different sub-systems in MAESHA supporting this use case are:

Collective self-consumption

The French Energy code defines individual and collective self-consumption in 2015 and 2016. The self-consumption operation is collective when the supply of electricity is carried out between one or more (PV) producers and one or more final consumers linked together within a legal entity and whose consumption and injection points are located in the same building, including residential buildings[7]. This framework is a way to involve citizens in the energy transition subject and to empower them. Collective self-consumption scheme allows to free PV producers from the limits of individual self-consumption such as the absence of outputs for the local production not consumed (in case of surplus, the local production is lost). It also pushes back the need for a battery to store electricity as most of it is consumed by the PV owner and the different consumers involved in the self-consumption operation.

Decentralized Energy Management within Local Energy Community

Local Energy Communities (LECs) are, most commonly, legal entities such as associations or cooperatives which are involved in generation and self-consumption of renewable energy. Often, LECs consist of prosumers, meaning members who both produce and consume renewable energy. These may own generation assets, practice self-consumption, share electric vehicles supply equipment or are active in the local energy market through selling excess energy or being engaging in flexibility services. By offering local energy arbitration based on individual's needs, the energy management system developed within MAESHA will maximize the self-consumption of the LEC by aggregating the loads and the supply of the community.

Hybridization of EV stations with PV production

EV charging stations coupled with PV production units allow for the recharging of EVs with renewable solar energy, allowing for the growing number of EVs in Mayotte to be powered with clean energy sources when solar production is available, reducing the GHG emissions generated by the charging through carbonized electricity. In addition, when there is an excess of PV production (perhaps due to a low number of EVs being charged at a particular moment), the energy can be fed to the grid to avoid curtailment and provide further services for the maximization of RES in the island. The benefits of this hybridization can be extended by smart charging as presented below.

In MAESHA, it has been decided to renew the DSO's fleet of vehicles with EVs and to install a charging station coupled with a PV production for the usage of EDM.

Smart Charging/V2G

Smart charging is the process by which Electric Vehicles (EVs) connected to charging stations are charged/discharged, taking into account various factors such as consumption peak, renewable energy production or low/high tariff periods. Upon analysis of the renewable energy generation forecast, the Charging Point Management System can synchronize the charging of the EV with periods of local generation, while respecting the EV driver's preferences (desired state of charge at its departure time). By implementing Vehicle-to-Grid, EV batteries can be used as distributed storage units to store solar electricity when plugged to a hybridized charging station during sunny hours and to discharge during darker hours for

[7] Source: French Energy Code (Art. 315-2) (see [8])

different purposes (charging of other EVs, avoiding the start-up of polluting peak power plants, etc.). It thus maximizes the use of Renewable Energy Sources and the environmental impact of this use case.

Hybridization of cold production with PV production

As air-conditioning units are mostly used during the warmer (and the sunnier) hours of the day, it has been decided to examine the coupling of such systems with PV production.

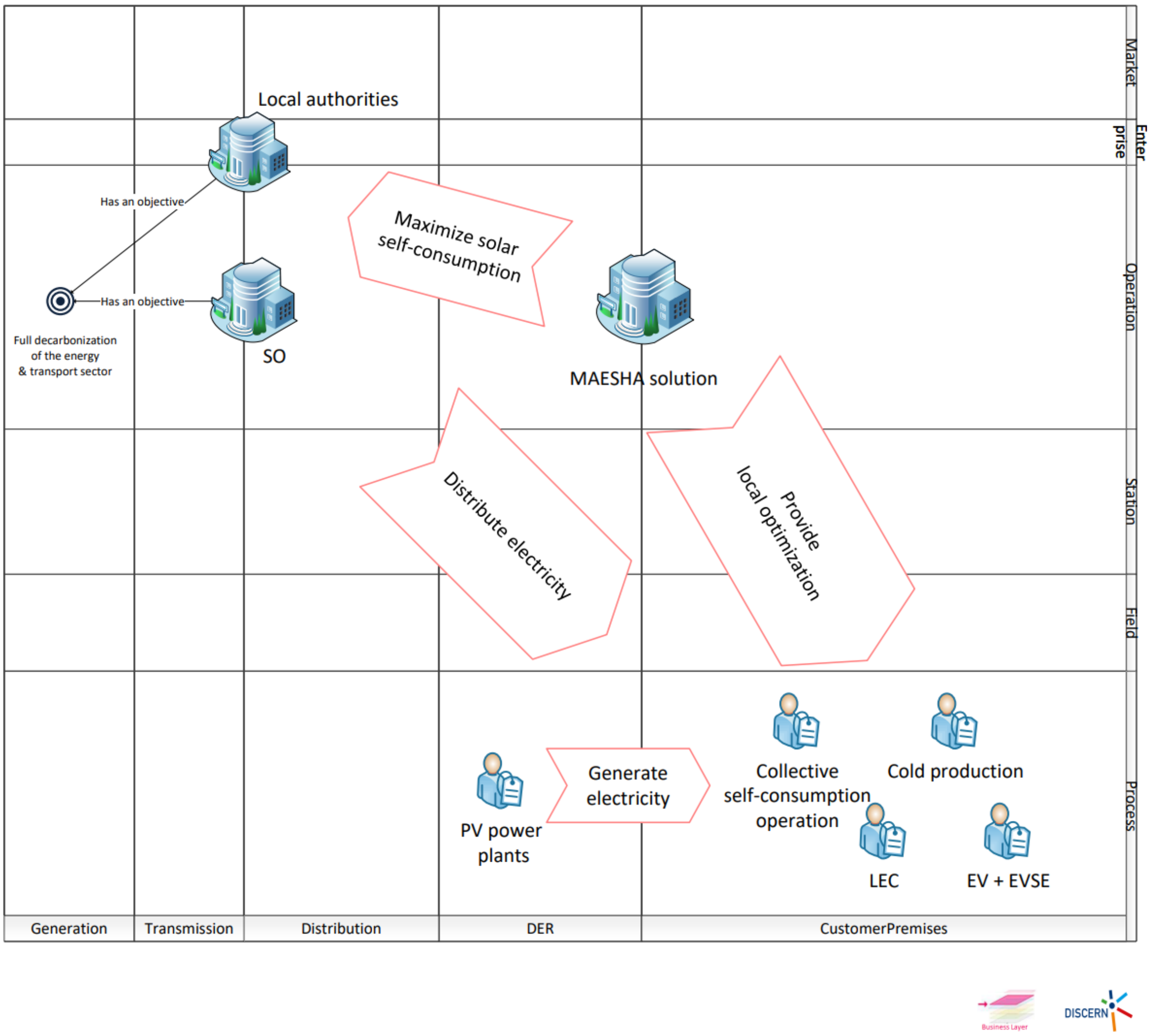

Figure 18: SGAM business layer of the maximization of RES use case-specific architecture

This SGAM business layer depicts the MAESHA solution in the context of the use case and provides a conceptual view, a high-level presentation of the major stakeholders or the major domains in the system and their interactions. Local authorities and SO are represented in this illustration as the MAESHA solution will provide them with a service of self-consumption maximization when charging their EVs fleets.

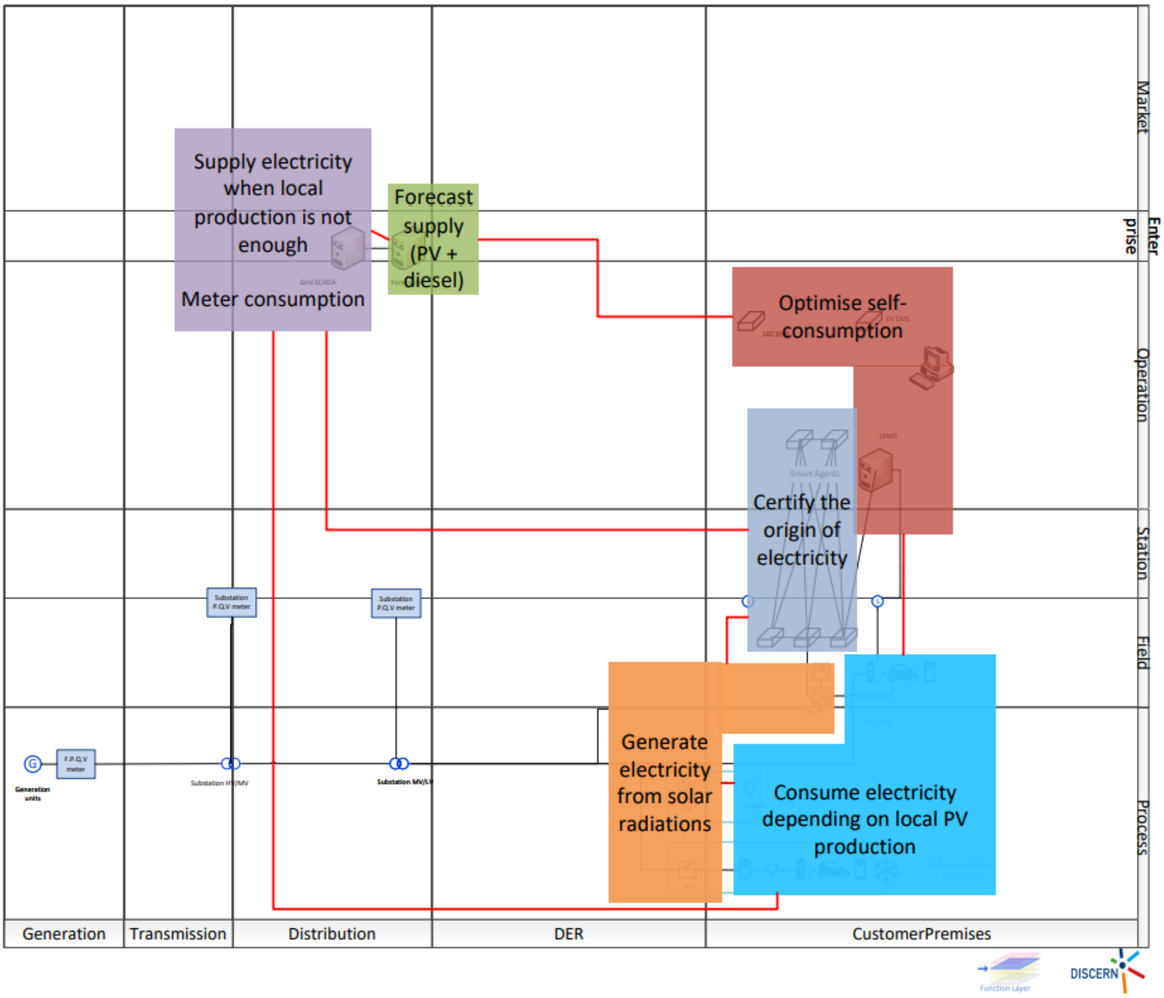

Figure 19: SGAM function layer of the maximization of RES use case-specific architecture

This SGAM function layer describes the functions and services including their relationships that support the maximization of RES use case.

The description of this use-case is continued in the annex (page 115).

4.1.5. Energy Access

Scope and objective of use case

Scope and objectives of the use case	
Scope	Provision of reliable and affordable access to electricity
Objective(s)	The objective of the use case is to respond to the lack of reliable access to electricity in Mayotte, thus fostering higher community involvement and support for renewable energy technology.

Narrative of use case

Narrative of use case
Short description
The objective of the use case is to respond to the lack of reliable access to electricity in Mayotte. The use case builds on Sustainable Development Goal (SDG) 7, to "ensure access to affordable, reliable, sustainable and modern energy for all", while at the same time offering services to the grid and fostering the involvement of (marginalized) communities.
Complete description
Context of Mayotte: Despite officially being part of the European Union, existing socio-economic differences should be considered when implementing a technological innovation project such as MAESHA in Mayotte. Official statistics illustrate the contextual differences of the island compared to many of the follower islands and of mainland Europe[8]. With an annual population-growth of 3.8 per cent, on average 5 children per woman, and a Gross Domestic Product comparable to that of Djibouti, Mayotte stands out compared to many other European regions. In comparison, the GDP of La Réunion, another European oversea department, is more than double of the GDP of Mayotte (Mayotte ann. GDP p.c.: 13 000 $, Réunion: 27 000$). Compared to France with 16 per cent, a staggering 70-84 per cent of people in Mayotte live below the poverty line. Conservative estimates state that 25.9 per cent of the population is unemployed and half of the population is younger than 18 years old. Due to this lack of perspectives for young people, many of those who have the possibility leave the island, resulting in a brain-drain. It is estimated that around half of Mayotte's 500 000 residents do not hold a valid legal status. Official statistics suggest that 30 per cent of the population have insufficient access to running water and 40 per cent live in sheet metal houses, often without clearly defined property rights of the inhabited land and without connection to the main grid. Ultimately, the local energy infrastructure suffers from a growing number of illegal connections and energy theft is posing a major challenge to the local Distribution System Operator (DSO)/Transmission System Operator (TSO). The reduction of these illegal connections as one goal of MAESHA (see KPI 3.6) and the necessity to consider the local context and requirements of the local population have led to the formation of the Energy Access Use-Case which is described in this chapter. The community-based approach lies at the heart of the MAESHA project and it is crucial for the projects' success, impact and sustainability. This also means that relevant community needs, such as the demand for better energy-access, must be considered from an early stage on. Disregarding the local context and de-emphasizing community needs bares the risk of MAESHA being seen as intellectual or elitist project which is dedicated only to wealthy and educated individuals. Hence, a fair and just distribution of the benefits reaped from the project serve as benchmark for accomplishments of MAESHA in the region. Further, according to community representatives, the level of awareness for Renewable Energy Technology (RET) is low. For many, RET is expensive and only for wealthy people. While the issue of climate change has gained much relevance in central Europe and in educated circles, the topic is given much less importance to by communities who struggle to meet their basic needs. Demonstration sites which focus on the better provision of energy to residents, especially those who

8 INSEE, 2021. See [2]

find themselves in precarious living conditions, can have a major impact. They serve as good examples for the accessibility and potential benefits of renewable energy and to help establish trust into local authorities and even into the European Union. Visible examples of RET in vulnerable and marginalized communities are key for their further adoption and ultimately for combating climate change and energy poverty. The Use Case Energy Access also builds on the Sustainable Development Goal set by the United Nations, namely SDG7, to "ensure access to affordable, reliable, sustainable and modern energy for all."

Due to legal constraints, some of the area's most affected by energy poverty are difficult to include in the project, as residents often do not own the property rights of the land they live on. Considering this barrier, we identified three possible target groups who may benefit from the Energy Access use case:

1. Legal communities with no connection to the main grid. Note, however, that most legal settlers are already connected to the main grid.
2. Legal communities who are connected to the main grid, but an upgrade of the connection is needed e.g., if existing lines are congested.
3. Farms or agricultural areas with no energy access/connection to the main grid.

MAESHA and the energy access:

Perspectives for solar community/collective self-consumption

A first assessment related to Energy Access has revealed that there is high potential for residential solar technology, possibly in combination with social housing and resettlement programs, set up by municipalities.

Example of a potential Local Energy Community (LEC) in Majicavo Koropa (City of Koungou):

The city of Koungou is currently carrying out a resettlement program, to relocate marginalized communities from sheet-metal settlements to low-cost houses (See Figure 20 below). These houses can be equipped with solar panels which can be maintained and managed by the inhabitants of the houses. By forming a Local Energy Community, inhabitants can exert agency under the umbrella of some legal entity, such as an association. Thus, they can collectively decide over investments and other relevant issues.

Local Energy Communities can be involved in a variety of different tasks and come in different legal forms and constellations. Most common are Energy Co-operatives who are involved in collective self-consumption. Public-Private-Partnerships are also frequently found, where a public institution such as the municipality can support the LEC either financially or by other means such as legal counseling. Further, LECs can set up awareness campaigns on energy savings, provide energy services such as demand side mechanisms[9] and energy auditing or reinvest generated income in a neighborhood electric vehicle fleet. Thus, they play an important part in the transition to a green energy infrastructure and enable citizens to become an active part of the energy system.

In the case of marginalized communities such as in Majicavo Koropa, the collaboration with local public actors is crucial to overcome different entry-barriers to Local Energy Communities. The nature of these barriers stem from financial restraints or the lack of education, trust and/or other capacities. It also helps overcoming some of the substantial legal issues around informal settlements. This scenario is a step towards introducing marginalized communities to Renewable Energy Technologies and helps building capacities for active energy citizenship. At the same time, it empowers vulnerable communities to harvest the potential economic and social benefits of innovative technologies introduced by MAESHA, bringing them at the forefront of the broader social and energy transition aimed for in MAESHA. Ultimately, these communities can become role models in the region and inspire others to follow their example.

[9] Energy communities can provide services to system operators only if connected to the main grid (second category of identified target groups)

Figure 20: Majicavo Koropa resettlement program

Within MAESHA and to assist the development of a demonstration site in Majicavo Koropa in the city of Koungou, it is proposed to call upon a French metropolitan association called Sol Solidaire which develops solar projects in self-consumption[10] in social housing. This association helps to fight against energy poverty by financially supporting the installation and operation of photovoltaic power plants of social landlords, on the site of low-rent buildings, with the aim of supplying the occupants with free solar electricity produced on site.

Membership to this association is in the form of candidatures to a call for tenders launched every year between September and December. Candidates (usually landlords and/or public authorities) commit to supply the energy of the installation to their tenants. The city of Koungou could apply for this call for tenders. However, the PV power capacity installed should be between 10 and 250 kW_p to be eligible for the call for tenders.

Installation and operation of PV power plants are financially supported by the association, which funds are supplied by sponsors. Funds are collected in metropolitan France but can be used for projects located in Mayotte. For our project, the sponsor could indirectly be local authorities of Mayotte through various companies. Local authorities of Mayotte (Department and Region) can subsidize companies if the objective of the subsidy concerns the development of renewable energies (like installation of PV panels). This subsidy would then be conditioned to the payment of a part of the profits of these companies to the association Sol Solidaire. It should be noted that the association Sol Solidaire does not carry out any economic activities, so this aid does not fall within the scope of the regulations on state aid.

Perspectives for Power to Hydrogen to Power (P2H2P)

Another perspective is the use of Power to Hydrogen to Power (P2H2P) Technology where communities with insufficient access to electricity are provided with a fuel-cell and hydrogen supply which ideally is produced from RES (Renewable Energy Sources) in an electrolyser connected to the main grid. Note that the energy mix in Mayotte is still heavily based on fossil fuels which means that the hydrogen cannot be considered green yet. However, as the transition to Renewable Energy in Mayotte progresses, the produced hydrogen becomes greener as a result. In the best case, the installation of the P2H2P technology will be accompanied by the installation of a solar plant, which compensates for the additional use of electricity.

As it is the case for residential solar energy, the provision of P2H2P can be accompanied with the formation of different legal entities forming Local Energy Communities. Both residential solar panels and P2H2P can bring benefits to localities which are not connected to the grid, e.g., agricultural areas. Besides, P2H can provide flexibility services to the main grid (e.g., frequency control), by taking advantage of the quick ramp-ups and ramp-downs and the power range of operation of the electrolyser.

This works as follows: A fuel cell is installed in an area where there is no connection to the main-grid, or it needs to be upgraded. The fuel cell would then be fueled with hydrogen which is transported from the production site where the electrolyser is connected to the main grid. Local people can be trained in the maintenance of the fuel cells, or even the transport of the hydrogen from the electrolyser to the fuel cell. This opens many opportunities to combine the provision of electricity through innovative technology and the community-based approach and formation of Energy Communities in MAESHA.

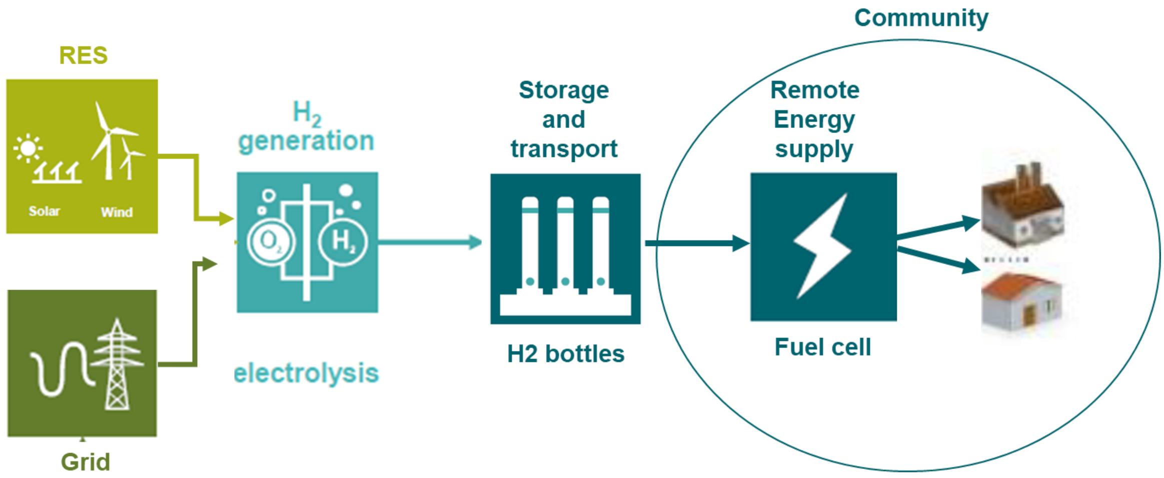

Figure 21: P2H2P process diagram

[10] The collective self-consumption regime, defined in article L.315-2 of Code de l'Energie, authorizes one or more electricity generators to provide electricity, for free or against payment, to one or more consumers.

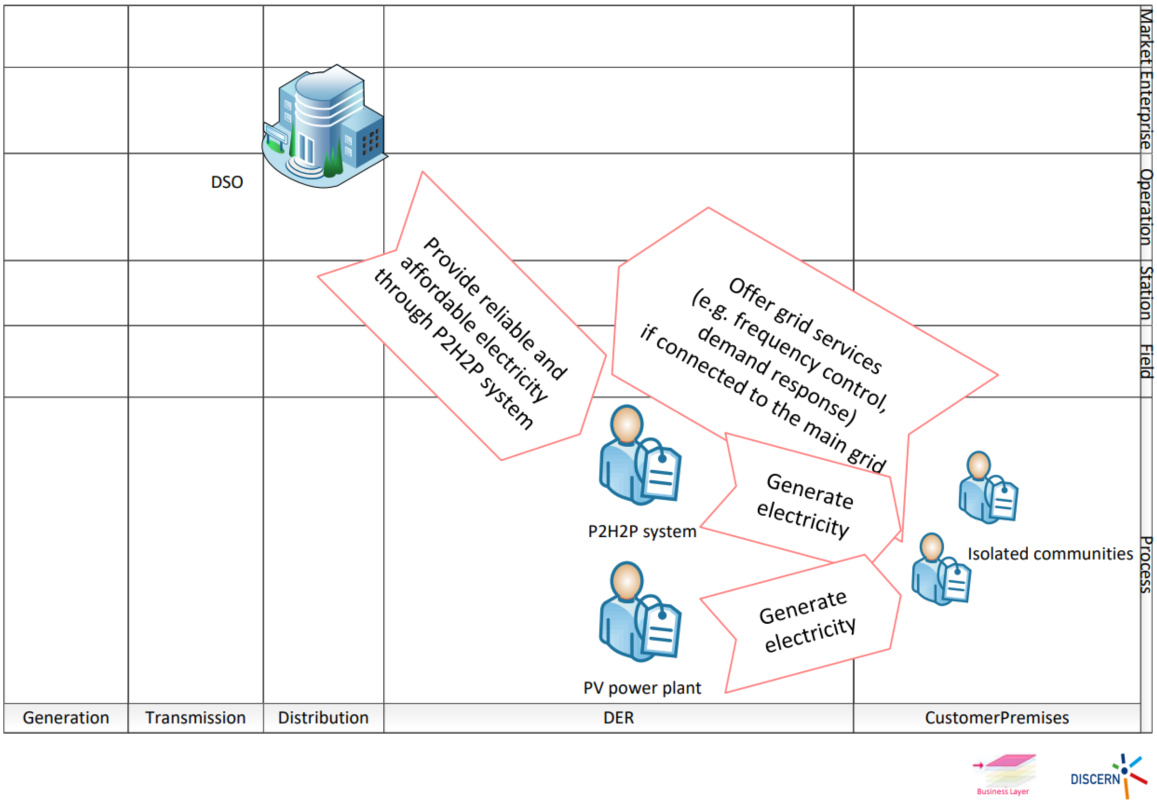

Figure 22: SGAM business layer of the energy access use case-specific architecture

This SGAM business layer depicts the MAESHA solution in the context of the use case and provides a conceptual view, a high-level presentation of the major stakeholders or the major domains in the system and their interactions.

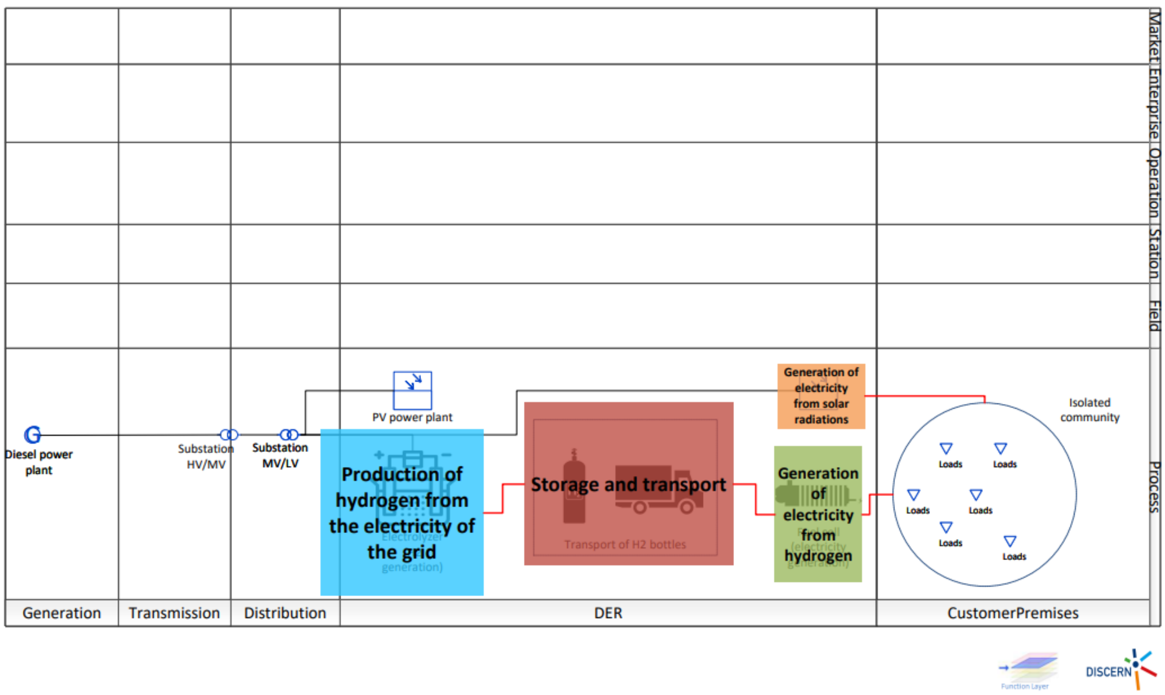

Figure 23: SGAM function layer of the energy access use case-specific architecture

This SGAM function layer describes the functions and services including their relationships that support the energy access use case.

The description of this use-case is continued in the annex (page 127).

4.2. Requirements

To properly demonstrate the different use cases in Mayotte, partners in the consortium defined a list of requirements to be met. Those requirements are also relevant for the replicability study for follower islands and expansion to more islands as they are essential for the proper implementation of each use case and solution. Those requirements can be divided into three main categories – general requirements for the project, use case-specific requirements and solution-specific requirements - further detailed in Table 7 below.

Table 6: Requirements

Requirements category	Requirements	Description
General requirements for MAESHA	Prosumers recruitment and engagement	To foster long-term engagement of prosumers in Demand Response schemes and flexibility services, it is important to find appropriate business models and financial schemes benefitting them. Those models will be defined in task 4.2.
	Cybersecurity, privacy and data protection	Data used in the project needs to be handled with precautions in order to ensure the respect of the privacy of the users and the confidential data of companies. Those concerns will be tackled in task 7.3.
Use case specific	Location	Voltage control and minimization of the consumption peak are localized use cases, meaning that they tackle local issues. The flexibility sources (external [11] and internal[12] to MAESHA) should thus be localized at specific locations for a particular need (e.g., voltage deviations or overloaded equipment).
	Data availability and access	Use cases benefitting the system operator (frequency control, voltage control and minimization of the consumption peak) highly relies on data (e.g., metering and measurement data) for the detection of the issue, for the baseline and flexibility forecast as well as for the settlement process: measuring devices as well as smart meters should thus be installed for the proper implementation of those use cases. Collected data should also be accessible to MAESHA partners to run their solutions.
	Communication	The SO and the different components of the MAESHA solution should effectively communicate to exchange the

[11] External flexibility sources: PV plants, existing batteries, industrial and residential consumers involved in Demand Response, existing charging stations

[12] Internal flexibility sources: battery, power-to-hydrogen system, charging stations

		information needed for the proper implementation of the use cases.
Solution specific	Interoperability	Defined as "the ability of two or more system or components to exchange information and to use the information that has been exchange" in the IEEE Standard Computer Dictionary, interoperability is a critical enabler of the smart grid potential and should be considered from the very beginning in the project development lifecycle. Interoperability requirements will be further detailed in deliverable D1.4.
	Technical requirements	To support the use cases described in section 4.1, solutions should meet some technical requirements further described in Table 7.

Table 7: Solution-specific technical requirements

Solution	Requirements
RES Virtual Power Plant	• Existing RES power plant must be able to communicate data to the gateways via Modbus TCP protocol or REST webservices. • The inverter-control of PV plants must allow for reactive power control to participate in voltage control. • Local voltage measurements and current measurements (possibly power measurements if grid-forming inverter-control) must be available to inform the local logic and inverter-control.
Community self-consumption	• Communities must be structured into Local Energy Communities or into any other form of legal entities.
Industrial & Residential Demand Response	• Residential end-users must have a battery, electric boiler, heat pump, air conditioning unit and/or electric vehicle to be eligible for residential demand-response. • Gateways must be installed in locations where an internet connection (e.g., via cellular network) is available. • Local measurements (e.g., active power, voltage) to inform the local logic and measure the response of the asset must be available.
Smart charging/V2G & hybridization PV/EV	• Charging stations must be equipped with the EV Energy Management System (EMS, which is used for the optimization of charging stations by smart charging and V2G integration) and with the Charge Point Management System (CPMS, which is a cloud based/standalone application – OCPP Server – used for managing the charging stations). • Existing charging stations must be able to communicate using OCPP 1.6 or 2.0 to connect to the MAESHA solution. • PV panels must be connected to EVSEs to maximize the use of renewable energy for EV charging and thus enable a better carbon footprint.

	• Energy consumption and generation forecasts must be available. • To perform the relevant energy transactions, Bovlabs Smart Agents must have access to metering data from the SO, the BESS and/or the RES plants. • EV drivers must have a smartphone to use the EV charging mobile app.
Battery storage	• Conditioned area available for the equipment: the location of the asset should present some characteristics related to safety, accessibility and security. Those characteristics will be further defined in task 6.3.
Power to Hydrogen	• Conditioned area available for the deployment of the equipment: the location of the asset should present some characteristics related to safety, accessibility and security. Those characteristics will be further defined in task 6.4. • The purchased inverter must be capable of voltage control • The purchased electrolyser must be able to work in a 0-100% nominal load range and quickly modify the load (in seconds)

4.3. Key Performance Indicators

The following KPIs have been designed in the Grant Agreement. These are global KPIs, which need to be fulfilled during the scope of the project, including both pilot and follower demonstration sites. Therefore, some of the KPIs listed below are not covered within this document, such as KPI 2 "Large scale uptake of MAESHA solutions", which are only relevant for follower demonstration sites. The partners that will be responsible for the measurement of these KPIs are indicated in the last column.

The responsibilities of the responsible partner are as followed:

- Check, at early stages of the project, that the KPI is reachable in the context of Mayotte and MAESHA,
- Regularly check that everything is done to reach the KPI target and warn the consortium partners of any deviations that may occur,
- Propose a measurement or calculation method,
- Measure the KPI at the end of the project.

Some measurement and calculation methods are already available in Annex.

Please note that the relevant KPIs for each use case are listed in the section 1.5 of each use case description that can be found in annex.

Table 8: Key Performance Indicators of the MAESHA project

Key Performance Indicator	Target	Responsible partners
1. Reduction of fossil fuel consumption and development of renewable energy-based systems		

1.1	Share of electricity production from fossil fuels in Mayotte at the beginning of MAESHA	95%	EDM
1.2	Share of electricity production from fossil fuels in Mayotte at the end of MAESHA	70%	EDM
1.3	Share of electricity production from fossil fuels in Mayotte 10 years after MAESHA	40%	EDM
1.4	Renewable energy capacity installed in Mayotte thanks to MAESHA solutions	20 MW	EDM
1.5	Reduction of km travelled with combustion engine cars in Mayotte 10 years after MAESHA	50%	EDM
1.6	Storage power installed in Mayotte during MAESHA	1400 kW	COBRA/EDM
1.7	Storage energy capacity installed in Mayotte during MAESHA	3000 kWh	COBRA/EDM
1.8	Flexibility available in Mayotte thanks to MAESHA DR solutions	2600 kW	CENTRICA
1.9	Flexibility available in Mayotte thanks to MAESHA DR solutions	13000 kWh	CENTRICA
1.10	Electricity load adaptability level	15%	CENTRICA
1.11	Total flexibility available in Mayotte with MAESHA solutions	4 MW	CyberGRID
1.12	Total flexibility available in Mayotte with MAESHA solutions	18 MWh	CyberGRID
1.13	Horizon for full decarbonisation of the transport sector in Mayotte	2040	EDM
1.14	Horizon for full decarbonisation of the energy sector in Mayotte	2050	EDM
2. Large scale uptake of MAESHA solutions			
2.1	Number of follower islands and deep replicability studies	5	TUB
2.2	Number of relevant islands touched by the communication and dissemination activities	>200	GTI/EQY
2.3	Number of replication manuals training sessions and workshops	>30	WP10 partners
2.4	Number of technological partners giving recommendations for replication	10	TUB
2.5	Population of overseas islands directly impacted by MAESHA solutions	>1 000 000	GTI/EQY
2.6	Number of EU islands that could use MAESHA solutions	>400	GTI

3. Local Energy Communities			
3.1	Number of Local Energy Communities created in Mayotte	>10	HUD
3.2	Number of LEC created in follower islands	>6	HUD
3.3	Number of LEC created from the project	>15	HUD
3.3	Number of people involved in a LEC	>100	HUD
3.4	Total number of people involved in MAESHA LEC	>2000	HUD
3.5	Total energy produced by LECs in self-consumption during MAESHA	>5 MWh	Trialog/Tecsol
3.6	Decrease of illegal connections thanks to LEC development	-30%	EDM
4. Stability of the grid for islands			
4.1	Shortages duration before and after the project	From 6.6 to 2.2 h/year/consumer	EDM
4.2	Frequency range before and after the project	From [49.6;50.6] to [49.8;50.3] Hz	EDM
4.3	Reduce exchanged energy between island and mainland (when interconnection exists)	>15%	To be discussed
5. Reduction GHG emissions and improvement air quality			
5.1	Reduction of GHG emissions for electricity sector in Mayotte at the end of MAESHA	-30%	EDM
5.2	Reduction of GHG emissions for electricity sector in Mayotte 10 years after MAESHA	-60%	EDM
5.3	Reduction of GHG emissions for mobility sector in Mayotte at the end of MAESHA	-10%	EDM
5.4	Reduction of GHG emissions for mobility sector in Mayotte 10 years after MAESHA	-50%	EDM
5.5	Reduction of particulate matter emissions from mobility sector in Mayotte at the end of MAESHA	-20%	EDM
5.6	Reduction of particulate matter emissions from mobility sector in Mayotte 10 years after MAESHA	-70%	EDM
6. Electricity costs reduction and upgrade grid infrastructure			

6.1	Reduction of cost thanks to avoided congestion	-10%	EDM
6.2	Reduction of peak demand thanks to avoided congestion	-15%	EDM
6.3	Distribution grid stability through responsiveness of flexibility services (Time required to activate portion of available load flexibility through DR services)	30 min (>25%DR) 1h (>50%DR) 24hrs (>100%DR)	CyberGRID
6.4	Likelihood of prediction of congestion (voltage/power-flow limit violation)	>90%	TUB/HIVE
6.5	Accuracy of forecasts at prosumer, MV/LV transformer or substation level (energy demand, generation, flexibility)	<20% MAPE	HIVE
6.6	Overall effectiveness of complete system in kWh for DSO - avoided curtailment	>50%	EDM
6.7	Average LCOE variation before/after the demonstration	-5%	EDM
7. Socio-economic impact			
7.1	Share of income of households spent on electricity bill in LEC	<15%	HUD
7.2	Net job creation from the project	100	EDM
7.3	Number of people involved in training activities	500	WP10 partners
7.4	Number of potential investors reached through the project	50	EQY
7.5	Number of investors arising from the project	10	EDM
7.6	Amount of investment arising from the project	50M €	EDM
7.7	Direct and indirect job creation from the project	>100	EDM
7.8	Green tourism development in Mayotte	20%	EDM
8. Higher involvement of the population			
8.1	Number of local people involved in Mayotte through community-based approach	>2000	HUD
8.2	Number of workshops organised in Mayotte	>20	HUD

8.3	Number of workshops organised in each follower island	>3	GTI
8.4	Total number of people reached by workshops, events and dissemination	>10 000	EQY

5. Conclusion and next steps

This document presents the demonstration site, its energy situation and the expectations of the pilot partner, Electricité de Mayotte, towards the MAESHA project. It also describes the five use cases that have been selected for a demonstration in Mayotte, based on the needs of the pilot partner and of the local population:

- Frequency control
- Voltage control
- Minimization of the consumption peak
- Maximization of the use of RES
- Energy access

The document also lists some requirements for the proper demonstration of the MAESHA solution in Mayotte: general requirements for the project, use case-specific requirements as well as solution-specific requirements. Finally, KPIs were identified and linked to relevant use cases to assess the good completion of the project.

The five use cases described in this document pave the way for the implementation of the MAESHA solution in Mayotte. The description of the flexibility products, the exact location for demonstration of the use cases, as well as the location of the assets to install will be addressed in WP4 “Energy markets for geographical islands and associated tailored business models”. The purpose of the latter is to ensure the commercial viability of the project and to determine the business models and costs implication of the developed solutions by setting up an underlying market design and business models for the different market players, aligning the solutions with the local regulatory framework and providing policy and regulatory recommendations for an efficient market uptake in islands. If use cases are adjusted or modified along the project, the use cases definition will be updated accordingly.

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ANNEX

KPIs MEASURING METHODS

Table 9: KPIs measuring methods

KPIs	Measuring method
1.6	Sum of power capacity of the energy storage systems deployed in Mayotte during the MAESHA project period. For the Hydrogen systems, the highest power value between electrolyser and fuel cell
1.7	Sum of energy capacity of the energy storage systems deployed in Mayotte during the MAESHA project period.

USE CASE DESCRIPTION USING IEC 62669-2 TEMPLATE

Frequency control

1. Description of the use case
1.1 Name of the use-case

Use case identification		
ID	***Area/Domain/Zone(s)***	***Name of the use case***
UC1	Area: Energy system, Domain: Transmission, DER, Customer Premises Zones: Operation	Frequency control

1.2 Version management

Version management				
Version No.	***Date***	***Name of author(s)***	***Changes***	***Approval status***
0.0	15/07/2021	Marjolaine Farré (Trialog)	Initial creation	Draft
0.1	10/09/2021	Andraž Andolšek (cyberGRID)	Update	Draft
0.2	21/09/2021	Christoph Gutschi (cyberGRID)	Finalization	Final Draft
1.0	08/10/2021	Elchaysse Soudjae (EDM)	Review by EDM	Final version

1.3 Scope and objective of use case

Scope and objectives of the 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)	The main objective of this use case is to stabilize the electricity grid of the islands by establishing balancing services. Implementing the balancing services framework will help system operators to maintain the equilibrium between consumption and generation while minimizing the frequency deviation from the nominal values.

1.4 Narrative of use case

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
<u>Introduction to balancing services for frequency control</u> The system operator Electricité de Mayotte (EDM), responsible for grid operation and supply of electric energy, needs to maintain the network frequency within a narrow bandwidth (+300 / -200 mHz) around 50 Hz. Frequency deviation is a consequence of an imbalance between generation (feed-in to the grid) and consumption (extraction from the grid) including losses of the grid itself. These imbalances

are mainly caused by unpredictable fluctuations of the load (low impact on the grid frequency), general imprecisions in the load forecasting that cause improper generation schedules (medium impact) or rare fault-induced disconnection of entire branches or substations or even unexpected loss of generation (high impact). Until now, the electricity system in Mayotte relied on fast adaption of the generation of spinning diesel engines to balance the load fluctuations. These diesel engines also cover for the main generation schedule.

The mechanisms to maintain the grid frequency within a narrow bandwidth can be distinguished between three main types of control, as shown in Figure 24. After an incident like the unexpected outage of a generator, the imbalance between load and generation causes an immediate decrease of the grid frequency, which is mainly limited by the kinetic energy stored in spinning machines (synchronous inertia). The higher the inertia of the rotating machines connected to the grid, the lower the gradient of frequency change (Df/Dt), also known as rate of change in frequency (ROCOF). The frequency stabilization by inertia is a physical effect, responding spontaneously to any frequency gradient and acting in both directions. New generations of inverters can provide a frequency gradient dependent feed-in (with only a minor time lag), which can be considered as "virtual inertia".

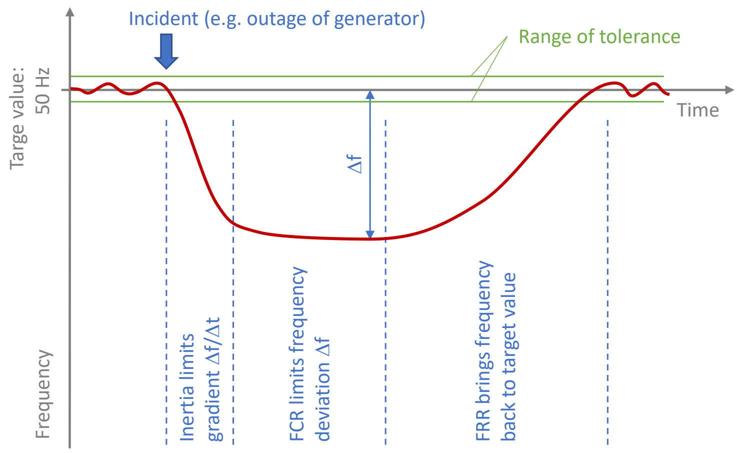


Figure 24: Overview of phases of frequency control after a major outage

The frequency containment reserve (FCR), also known as primary control, provides a variable feed-in linearly depending on the deviation of the frequency (Df) from the target value of 50 Hz. FCR is required to act very fast. The required full activation time (FAT) is determined by the considered maximum imbalance (e.g., due to loss of the largest generation unit in the system), the maximum allowed frequency deviation and the typical inertia of the system. FCR is a very fast service that requires frequency measurements and control logic directly at the providing asset, usually a generator or battery. Some loads controlled by power electronics might also be feasible to provide FCR. Usually, FCR is a symmetric service that acts in both directions. The linear function of FCR power only depending on the frequency deviation enables a fast response to limit the frequency deviation but does not allow to bring the frequency back to the target value.

Some transmission system operators (TSO), e.g., in the NORDPOOL, differentiate between Frequency Containment Reserve for Normal Operation (FCR-N) and Frequency Containment Reserve for Disturbances (FCR-D). FCR-N is a symmetric service providing upregulation and downregulation with a linear characteristic while FCR-D differentiate between upward (increase feed-in or decrease consumption) and downward (decrease feed-in or increase consumption) regulation. FCR-D is only activated after exceeding a threshold value of frequency deviation.

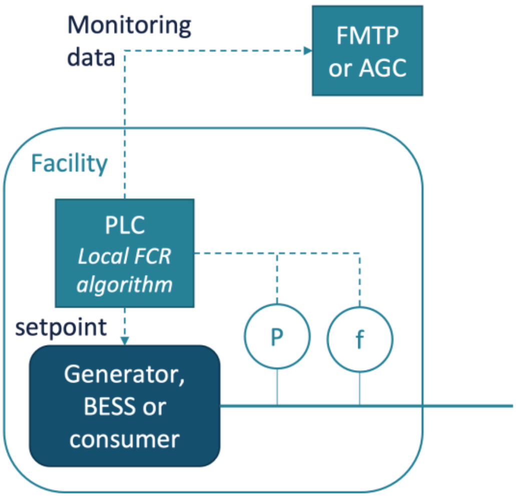


Figure 25: FCR architecture overview

The frequency restoration reserve FRR is managed by the system operator (SO) using the automatic generation control (AGC). The AGC calculates setpoints for multiple balancing providing assets (generators, batteries but also fast and precisely controllable loads like electrolyser). After reception of the setpoint the assets will adapt the power output within a defined FAT that may be longer than required for FCR. The AGC aims to bring the system frequency back to the target value. FRR requires reliable communication between the central AGC and the distributed assets. FRR can be divided into positive products for upward control and negative products for downward control. European TSO differentiate between faster, automatically controlled reserves (aFRR), that follow to instantaneous setpoints, and slower reserves that might be manually controlled (mFRR) and follow to received schedules.

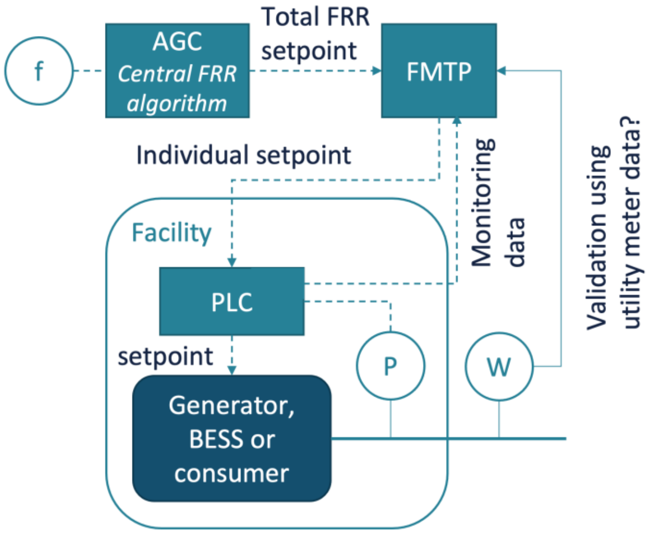


Figure 26: FRR architecture overview

FCR and FRR provision in Europe usually require active power measurements with high precision (e.g., 0.5% error class) and submission of data points to the SO in short intervals (e.g., 1-2 s) for the purpose of real-time monitoring of provision and ex-post validation of the provided services.

Additional Emergency measures will be activated in case that the frequency regulation system failed, and the frequency deviation exceeds defined thresholds. Emergency measure can include load shedding, disconnection of large, robust consumers or disconnection of generators. The rules for frequency protection devices to disconnect sensible assets in case of high frequency deviations must be defined accordingly to support system frequency stabilization and to avoid negative feedback on the frequency control mechanisms.

Context

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

[13] The French Energy Regulatory Commission is the organization in charge of ensuring that the electricity and gas markets in France function smoothly for the benefit of end users and in line with energy policy objectives

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, as indicated in Figure 27 below.

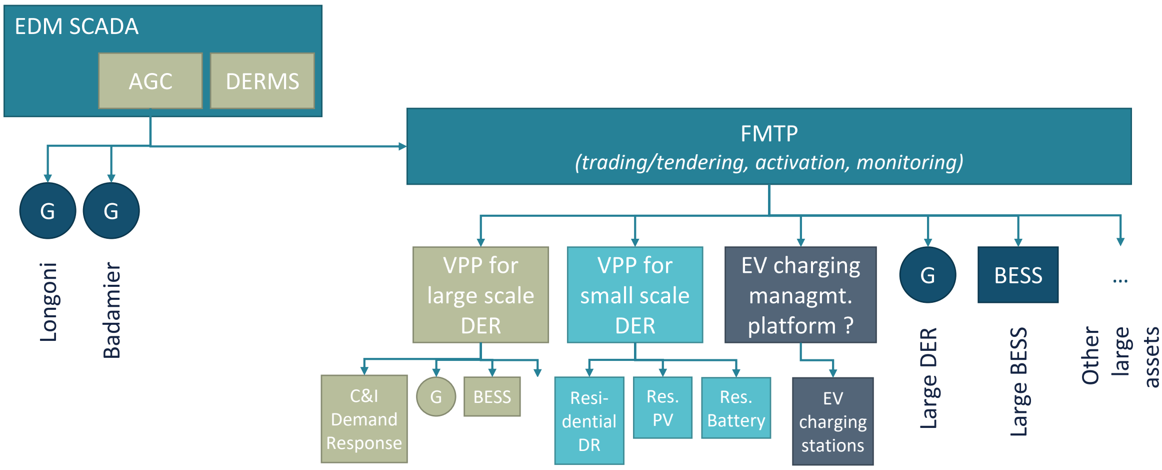


Figure 27: Architecture overview for frequency control in MAESHA

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

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
1.6	Storage power installed in Mayotte during MAESHA	Target: 1400 kW	Extracted from the Grant Agreement
1.7	Storage energy capacity installed in Mayotte during MAESHA	Target: 3000 kWh	Extracted from the Grant Agreement
1.8	Flexibility available in Mayotte thanks to MAESHA DR solutions	Target: 2600 kW	Extracted from the Grant Agreement
1.9	Flexibility available in Mayotte thanks to MAESHA DR solutions	Target: 13000 kWh	Extracted from the Grant Agreement
1.11	Total flexibility available in Mayotte with MAESHA solutions	Target: 4 MW	Extracted from the Grant Agreement
1.12	Total flexibility available in Mayotte with MAESHA solutions	Target: 18 MWh	Extracted from the Grant Agreement
4.2	Frequency range before and after the project	From [49.6;50.6] to [49.8;50.3] Hz	Extracted from the Grant Agreement
6.5	Accuracy of forecasts at prosumer, MV/LV transformer or substation level (energy demand, generation, flexibility)	<20% MAPE	Extracted from the Grant Agreement

1.6 Use case conditions

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

Classification information
Relation to the other use cases
Linked to "Voltage control" UC as potential conflicts within flexibility products could appear.
Level of depth
High-level use case
Prioritization
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)

2 Diagrams of use case

Diagram(s) of use case

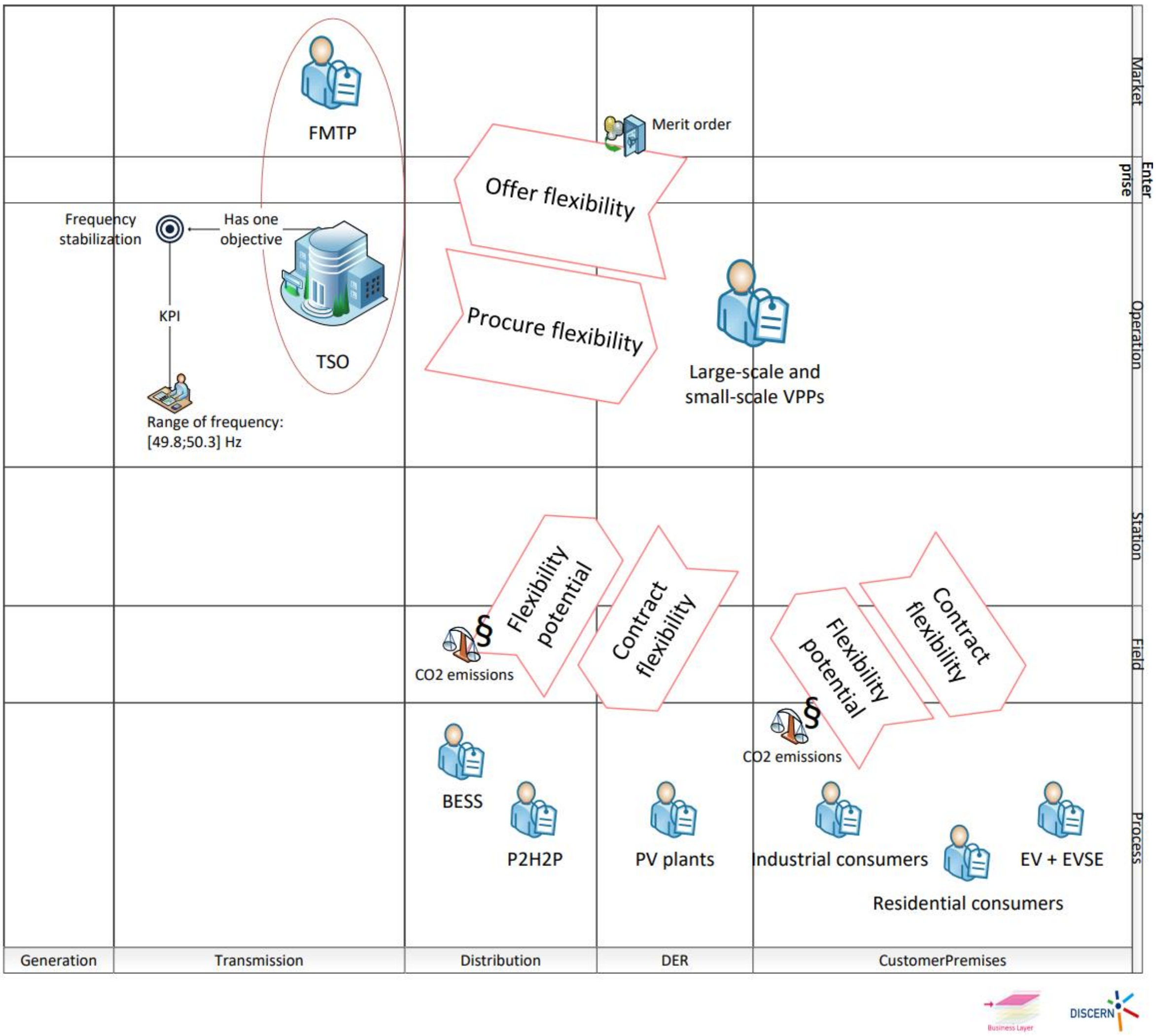


Figure 28: SGAM business layer of the frequency control use case-specific architecture

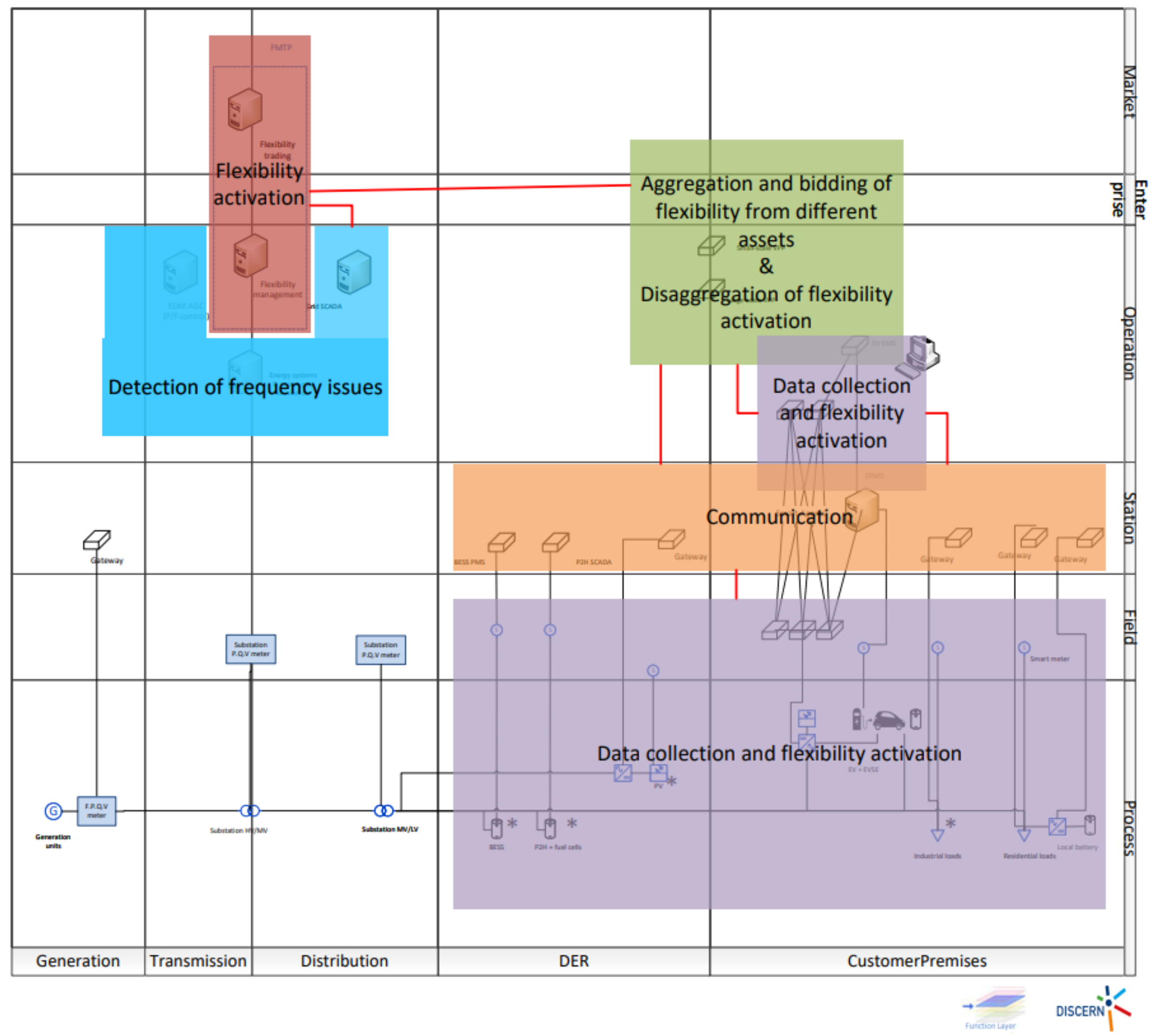


Figure 29: SGAM function layer of the frequency control use case-specific architecture

3 Technical details

3.1 Actors

Actors			
Grouping		***Group Description***	
Business Actor		Physical or legal person that has his own interests, defined as "Business Goals"	
Operator		Business Actor that operates a system	
Logical Actor		Technical entity that takes part in the execution of a use case. A logical actor can be mapped to a physical component	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
Business actors			
SO (TSO)	Business Actor	(Transmission) System Operator	Electricité de Mayotte (EDM)
Flexibility provider	Business Actor	Generic presentation of the energy asset capable of providing flexibility on request (Balancing service provider)	
Residential prosumer	Business Actor	A residential party that consumes electricity (Resource Provider)	
Industrial prosumer	Business Actor	An industrial party that consumes electricity (Resource Provider)	
Logical actors			
SCADA	Logical Actor	Supervisory Control and Data Acquisition – a supervisory computerized system that gathers and processes data and applies operational controls for transmission side systems used to control dispersed assets	EDM SCADA

AGC	Logical Actor	Automatic gain control. Process to determine the amount of power needed to bring back the frequency to the nominal values.	EDM SCADA
Intermediate platform	Logical Actor	Platform that aggregates flexibility energy assets (virtual power plant, EV charging management platform)	
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	Developed by Centrica
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	Developed by cyberGRID
EV charging management platform	Logical Actor	A platform that manages and aggregates the charging power of multiple EV charging stations	Developed by Bovlabs
FMTP	Logical Actor	Flexibility Management and Trading Platform	Platform developed by CyberGRID
Assets			
Distributed Energy Resource (DER)	Asset	Generic presentation of the energy asset providing flexibility	
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)	
Diesel generator	Asset	Synchronous generators	Electricité de Mayotte (EDM)
Devices			
EV charging station	Device		
Frequency meter	Device	Frequency meter, to measure frequency on the entire power network	EDM SCADA
Local controller (PLC) Active power meter	Device	Calibrated power meter to continuously measure the active power exchange with the public grid.	Installed at the DER and controlled via PLC.
Public meter	Device	Calibrated utility meter for energy metering, providing data in the settlement interval (e.g., 30 min)	

3.2 References

References						
No.	***Reference type***	***Reference***	***Status***	***Impact on use case***	***Originator, organization***	***Link***
Ref-1	Operational guidelines	Operational Handbook P1-Policy 1: Load-Frequency Control and Performance	Final	Medium	ENTSO-E	https://eepublicdownloads.entsoe.eu/clean-documents/pre2015/publications/entsoe/Operation_Handbook/Policy_1_final.pdf
Ref-2	Operational guidelines	French standards about system operation		High	French government	https://codes.droit.org/PDF/Code%20de%20l'%C3%A9nergie.pdf
Ref-3	Role model	The Harmonized Role Model	Version 2020-01	Medium	ENTSO-E	https://www.entsoe.eu/digital/cim/role-models/#harmonised-electricity-role-model

4 Step by step analysis of use case

4.1 Overview of scenarios

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

Sc1	**Frequency reserve requirements**	Calculating the amount of FCR and FRR needed	SO	Long term planning (yearly activity)	Historic data about electricity system mid-term consumption forecasts List of planned new DER installations	Required amount of Inertia, FCR, FRR to be contracted and reserved
Sc2	**Detection of the frequency issues – FCR**	Detection of the frequency deviations locally on the site of the flexibility provider	Flexibility provider	Continuous activity	High precision frequency meter	Frequency deviation detected on-site
Sc3	**Detection of the frequency issues – FRR**	Detection of the frequency deviations centrally in the SCADA	SO (AGC)	Continuous activity	High precision frequency meter	Frequency deviation detected by central AGC
Sc4	**Contracting balancing service products**	Contractual obligations between the SO (EDM) and the flexibility providers	SO	Periodic tender (yearly, monthly, weekly and/or daily)	Prequalified DER available	List of available flexible capacity and price (merit order)
Sc5	**Flexibility activation through local controller – FCR**	Activation of the flexibility providers automatically using its local controller	Flexibility provider	Frequency deviation detected on-site	FCR control algorithm implemented in on-site controller	FCR provision by DER
Sc6	**Flexibility activation through the Flexibility Management and Trading Platform (FMTP) – FRR**	Activation of the flexibility providers automatically using centralized platform - FMTP	FMTP	Frequency deviation detected by AGC	AGC's control algorithm trained with system characteristics	FRR provision by DER
Sc7	**Settlement process to remunerate flexibility activation**	Validation and settlement of the activation responses	SO	Daily or monthly	Meter data available	Remuneration of ancillary service provision per DER
Sc8	**Frequency control by flexibility provider**	The process of flexibility provision by the flexibility provider	Flexibility provider	Reception of activation signal or activation schedule	Flexibility bid accepted via FMTP	Successful provision of flexibility service

4.2 Steps – Scenarios

Scenario							
Scenario name		**Sc1-Frequency reserve requirements**					
Step No.	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***
St1	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)	IE-01-01 (frequency bandwidth and emergency thresholds)	R-01-01 Guidelines for operation defined by regulator
St2	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	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)

St3	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)	IE-01-05 (mid-term & long-term forecasts)	R-01-03 (List of planned new DER installations)
St4	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)	IE-01-06 (design scenarios)	IE-01, IE-02, IE-03, IE-04, IE-05 received.
St5	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)	IE-01-07 (required amount of balancing reserve)	IE-01 … IE-06
St6	Step 5 finished	Define balancing service products	Based on the required amount of flexibility the SO defines appropriate balancing products	CREATE	SO (EDM)	IE-01-08 (definition of balancing products and requirements)	IE-01-07

Scenario name	**Sc2-Detection of the frequency issues – Frequency containment reserve (FCR)**						
Step No.	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***
St1	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	IE-02-01 (Network frequency)	R-02-01 (frequency meter on-site)
St2	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	IE-02-01	R-02-02 (on-site PLC)
St3	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	IE-02-02 (frequency deviation)	R-02-02

Scenario name	**Sc3-Detection of the frequency issues – Frequency restoration reserve (FRR)**						
Step No.	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***
St1	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	IE-03-01 (grid frequency)	R-03-01 (central frequency meter)
St2	Continuously	Receive frequency measurement	The measured frequency is received by the AGC embedded in the SCADA.	GET	Frequency meter	IE-03-01	R-03-02 (AGC)
St3	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	IE-03-01	R-03-03 (data storage)

St4	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	IE-03-02 (frequency deviation)	R-03-02
St5	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	CHANG E	AGC	IE-03-03 (updated FRR setpoint)	R-03-04 (P-f- control algorithm)

Scenario name	**Sc4-Contracting balancing service products**						
Step No.	***Event***	***Name of process/ activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***
St1	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)	IE-04-01 (balancing services rules)	IE-01-08
St2	After reception of balancing service rules	flexibility providers prepare for participation in balancing services	(3rd 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).	EXECUTE	Flexibility provider	IE-04-02 (Request for prequalifi-cation of DER)	I-E04-01
St3	After reception of tender announce-ment	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	IE-04-03 (Request for prequalifi-cation of platform)	IE-04-01
St4	SO received request for prequalifica tion	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	IE-04-04 (confirma-tion of pre-qualification)	IE-04-02 or IE-04-03
St5	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)	IE-04-05 (rules and schedules of balancing service tender)	IE-01-08
St6	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	IE-04-06 (balancing service bid document)	IE-04-05, R-04-01 (prequalified flexibility providers)
St7	SO received bid for balancing	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	EXECUTE	SO (EDM)	IE-04-07 (balancing service bid acceptance)	IE-04-06 received

	service provision		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.				
Scenario name	**Sc5- Flexibility activation through local controller - FCR**						
Step No.	***Event***	***Name of process/ activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***
St1	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	IE-05-01 (FCR provision enabled)	IE-04-07 (accepted FCR bid)
St2	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	IE-05-02 (FCR setpoint)	IE-02-02 (frequency deviation) R-05-01 (P(Df) characteristics implemented)
St3	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	IE-05-02 (FCR setpoint)	R-05-02 (DER operative)
St4	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)	IE-05-03 FCR monitoring data	R-05-03 (communication channel between PLC and FMTP) R-05-05 active power meter (on-site)
St5	Continuously	Validate FCR provision	The AGC receives the FCR monitoring data and compares the measurements with the expected behaviour.	CREATE	AGC	IE-05-04 FCR validation report	R-05-04 (algorithm to validate FCR performance)
St6	FCR malperformance 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	IE-05-04 FCR validation report	
St7	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	IE-05-04 FCR validation report	
Scenario name	**Sc6-Flexibility activation through the Flexibility Management and Trading Platform - FRR**						
Step No.	***Event***	***Name of process/ activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***
St1	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)
St2	New FRR setpoint available	Dispatch balancing assets	The new FRR setpoint is dispatched between central balancing assets (diesel engines operated by the SO) and	CREATE	AGC	IE-06-02 (setpoints for central	R-06-01 (dispatching algorithm)

			distributed balancing assets (DER operated by third party).			balancing assets) IE-06-03 (setpoint for DER)	
St3a	Central assets' FRR setpoint updated	Receive new FRR setpoints	Central balancing assets (operated by the SO) receive their new individual setpoint	GET	Central balancing asset (diesel engines)	IE-06-02	R-06-02 (central balancing asset available)
St3b	Decentral assets' FRR setpoint updated	Receive new FRR setpoints	The updated FRR setpoint is received by the FMTP platform.	GET	FMTP	IE-06-03	R-06-03 (FMTP available) R-06-07 (comm. channel between AGC and FMTP)
St4	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	IE-06-04 (activation requests)	R-06-03 (FMTP available) R-06-06 (communication channel between FMTP and intermediate platforms or large DER)
St5	Intermediate platform receives activation request	Intermedia-te 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	IE-06-05 (individual setpoints)	R-06-04 (DER available) R-06-05 (communication channel between DER and interme-diate platform)
St6	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	IE-06-05	R-06-04 (DER available)
St7	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)	IE-06-06 (individual FRR moni-toring data)	R-06-05 R-05-05 (active power meter, on-site)
St8	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	IE-06-07 (aggregated FRR monitoring data)	R-06-06 (communication channel between FMTP and intermediate platforms or large DER)
St9a	Continuously	Validate FRR provision	The FMTP receives the FRR monitoring data and compares the measurements with the expected behaviour.	CREATE	FMTP	IE-06-08 FRR validation report	R-06-08 (algorithm to validate FRR performance)

St9b	Yearly	Validate FRR provision	In case of doubts, the SO compares FRR monitoring data with (public) meter readings.	EXECUTE	SO	IE-06-08 FRR validation report	R-06-09 (meter data)
St10	FRR malperfor-mance detected	Inform flexibility provider about malperfor-mance	The SO informs the flexibility provider about the FRR malperformance and orders immediate correction of the behaviour.	REPORT	SO	IE-06-08 FRR validation report	
St11	FRR validation report received	Remedy FRR malperfor-mance	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	IE-06-08 FRR validation report	

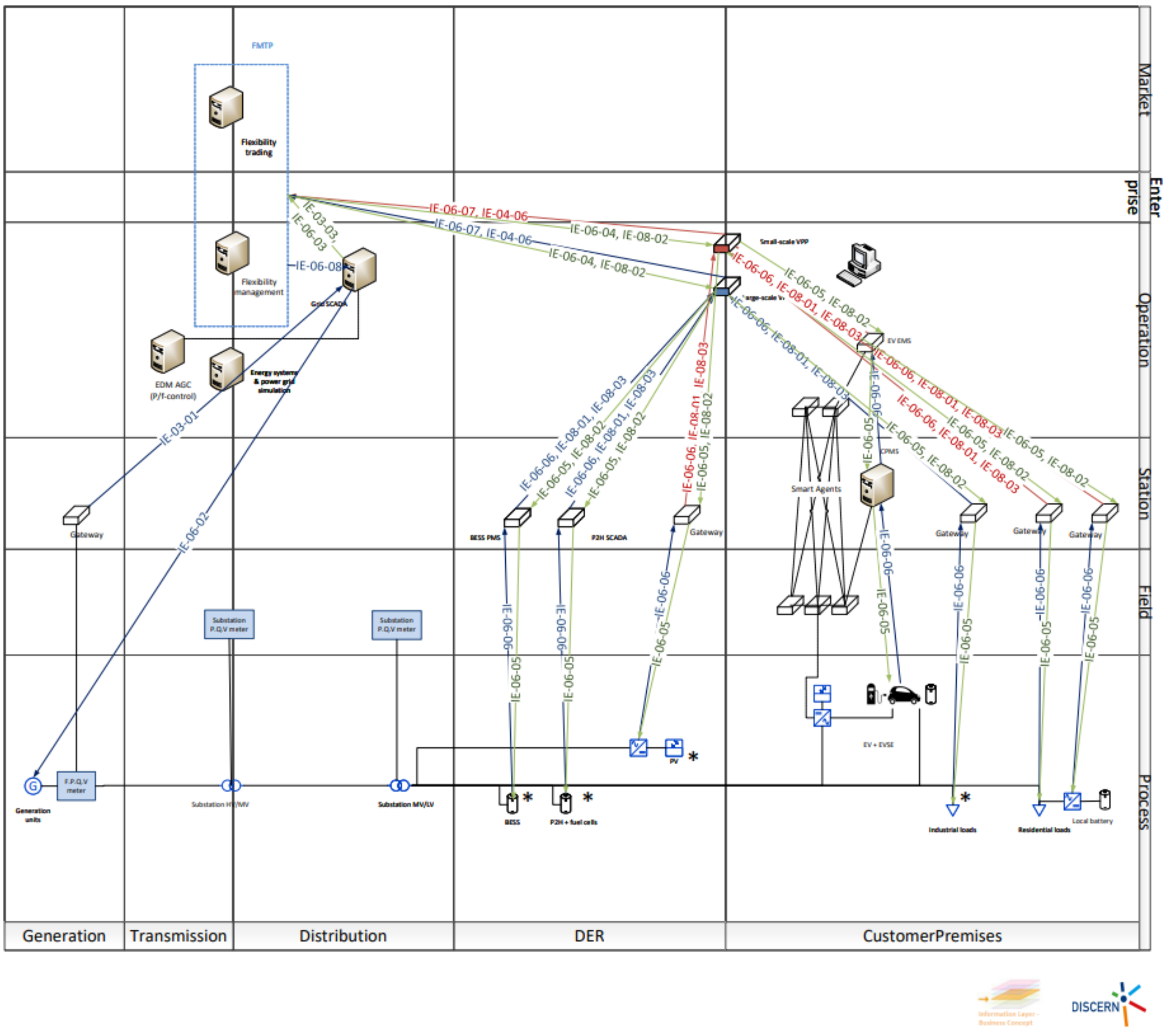


Figure 30: SGAM information layer of the frequency control use-case specific architecture

Scenario name	Sc7-Settlement process to remunerate flexibility activation						
Step No.	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***
St1	Daily	Process monitoring data	In the morning hours the energy activated during the previous day is calculated	EXECUTE	SO (EDM)	IE-04-07 (balancing service bid acceptance),	IE-06-08 FRR validation report

			individually for each balancing service contract (accepted bid).			IE-06-07 (monitoring data)	IE-05-04 FCR validation report
St2	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)	IE-07-01 (daily balancing service accounting)	IE-04-07 (balancing service bid acceptance),
St3	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)	IE-07-02 (monthly balancing service accounting and remuneration report)	IE-07-01

Scenario name	**Sc8-Frequency control by flexibility provider**						
Step No.	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***
St1	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)	IE-08-01 (forecast of flexible capacity and costs)	R-08-01 (Operational forecast of DER)
St2	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)	IE-08-02 (flexibility merit order)	IE-08-01, R-06-05 (communication channel between DER and interme-diate platform)
St3	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	IE-04-06 (balancing service bid document)	
St4	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	IE-08-02 (Flexibility reservation request)	R-06-05 (communication channel between DER and interme-diate platform)
St5	Flexibility reservation request received	Flexibility reservation	The DER reserves the requested flexibility for the product period.	EXECUTE	Aggregator	IE-08-02	
St6	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)	IE-08-03 (actual flexibility of DER)	R-06-05 (communication channel between DER and interme-diate platform)
St7	Continuously	Listen to incoming setpoints	The PLC receives a setpoint to start an activation	GET	Intermediary platform	IE-06-05 (individual setpoints)	
St8	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)	IE-06-05	
St9	Continuously	Listen to incoming setpoints	The PLC receives a new setpoint to change the power of an activation.	GET	Intermediary platform	IE-06-05	

St10	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)	IE-06-05	
St11	Continuously	Listen to incoming setpoints	The PLC receives a setpoint of 0 MW to end the ongoing activation.	GET	Intermediary platform	IE-06-05	
St12	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)	IE-06-05	
St13	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)	IE-06-06 (individual FRR moni-toring data	R-05-05 active power meter (on-site)

5 Information exchanged

Information exchanged			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE-01-01	frequency band-width and emer-gency thresholds	Predefined bandwidth of allowed system frequency, including target value (50 Hz) and thresholds for initiating emergency measures	
IE-01-02	System model	Model of the power system supporting dynamic analyses	
IE-01-03	historic measurements	Historic timeseries of measured generation, consumption and system frequency	
IE-01-04	Fault statistics	Statistics of faults in the power system that are relevant for balancing reserve dimensioning	
IE-01-05	Consumption forecasts	Mid-term (timeseries) of the total consumption	
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	
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)	
IE-01-08	Balancing products and requirements	Definition of balancing products and requirements comprising: products (duration, min. bid size, direction, tolerances)	
IE-02-01	Network frequency	Actual measurements of network frequency measured on-site by DER	
IE-02-02	Frequency deviation	Actual frequency deviation detected on-site at DER	
IE-03-01	Grid Frequency	Actual measurements of grid frequency centrally acquired by SO	
IE-03-02	Frequency deviation	Actual frequency deviation detected centrally by SO	
IE-03-03	Updated FRR setpoint	Actual FRR setpoint calculated by AGC, sum for all assets participating in FRR service provision	
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	
IE-04-02	Request for prequalification of DER	The flexibility provider (DER operator) applies for the prequalification for the balancing service participation.	
IE-04-03	Request for prequalification of platform	The aggregator (intermediate platform operator) applies for the prequalification for the balancing service participation.	
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.	

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.	
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.	
IE-04-07	Balancing service bid acceptance	The SO informs the bidders about acceptance or rejection of the bids submitted in the tender.	
IE-05-01	FCR provision enabled	The (PLC of the) DER enabled the FCR functionality and starts detecting the frequency deviations.	
IE-05-02	FCR setpoint	FCR setpoint calculated on-site by PLC (DER)	
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).	
IE-05-04	FCR validation report	The FCR validation report summarizes the quality of FCR service provision of a flexibility provider.	
IE-06-01	FRR provision enabled	The (PLC of the) DER enabled the FCR functionality and starts listening for incoming setpoints.	
IE-06-02	FRR setpoints for central balancing assets	FRR setpoints for central balancing assets (controlled by the SO)	
IE-06-03	FRR setpoint for DER	FRR setpoints for central balancing assets (controlled by the SO)	
IE-06-04	FRR Activation requests	FRR setpoints for DER (controlled by 3rd party flexibility providers)	
IE-06-05	Individual FRR setpoints	Individual FRR setpoints for DER controlled via an intermedia platform	
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	
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	
IE-06-08	FRR validation report	The FCR validation report summarizes the quality of FRR service provision of a flexibility provider.	
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	
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	
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.	
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).	
IE-08-03	Actual flexibility of DER	The actual flexibility bandwidth of a DER	

6 Requirements (optional)

Requirements (optional)		
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(Δf) characteristics implemented	An algorithm defined by the SO; e.g., a linear curve $P_{FCR}=f(\Delta f)$, 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
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

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

Voltage control

1. Description of the use case

1.1 Name of the use-case

Use case identification		
ID	***Area/Domain/Zone(s)***	***Name of the use case***
UC3	Area: Energy system, Domain: Distribution, DER, Customer Premises Zones: Operation	Voltage control

1.2 Version management

Version management				
Version No.	***Date***	***Name of author(s)***	***Changes***	***Approval status***
0.0	20/07/2021	Marjolaine Farré (Trialog)	Initial creation	Draft
0.1	06/08/2021	Evelyn Heylen (Centrica)	Update	Draft
0.2	28/09/2021	Evelyn Heylen (Centrica), Marjolaine Farré (Trialog)	Finalization	Final version

1.3 Scope and objective of use case

Scope and objectives of the use case	
Scope	The scope of this use case is to examine the use of flexibility resources connected to the distribution grid to ensure the voltage stability of the power system
Objective(s)	The main objective of this use case is to stabilize the electricity grid of the islands by proposing voltage control services. Voltage control services aim at keeping voltages within specific safety bands and restore their values to the normal range after grid disturbances occur, to minimize reactive power flows, investments and technical losses.
Related business case(s)	

1.4 Narrative of use case

Narrative of use case
Short description
The voltage control use case aims at using new flexibility assets, such as battery energy storage systems, renewable energy virtual power plants, power-to-hydrogen facilities or demand response, to support system operators in improving the voltage profile. This use case will focus on voltage control using static voltage control curves.
Complete description
Voltage stability is a responsibility of the system operator to ensure the secure and reliable operation of the power system. The voltage level at all points of delivery should be equal to 230 V for single-phase power and at 400 V for three-phase power in low voltage grid and equal to 20 kV in medium voltage grid, with a margin of acceptability of [-10%, +10%], both in steady-state and transient conditions (see [10]). Typical voltage issues experienced by system operators are voltage drops or rises at the end of feeders, caused by high demand for power or supply by local renewable energy production units at these locations. On top of changes in voltage magnitudes, voltage should remain stable at all times, even during large and small disturbances, denoted as large-disturbance voltage stability and small-disturbance voltage stability: • To ensure large-disturbance voltage stability, system operators need to ensure that voltage levels remain within limits even if a generator or a transmission line goes out of service. The outage of a transmission line or generator causes a variation in the system reactance, which lowers the voltage generation characteristic, resulting in a lower voltage or possibly unstable operating point. • Small-disturbance voltage stability focuses on the continuous small changes in the system due to imbalances between demand and supply, e.g., initiated by the variability of load and renewable energy sources.

- On top of the system and operational planning procedures for large and small disturbances, power systems should have additional defence facilities in place to prevent voltage collapse following extreme disturbances, but these are out of scope of this use case.

The voltage stability also strongly depends upon the demand characteristics. If the active power load is steadily increasing, the reactive power supply curve, which expresses the reactive power supply as a function of the voltage, decreases. An increase of the reactive power load, which may go with the increase of the active power load, will raise the reactive power load curve. As a consequence, the stable operating point moves towards smaller voltage levels and the steady increase of the load may ultimately result in a voltage collapse, when the demand for reactive power becomes larger than the supply. This process has been illustrated in [11]. Moreover, the voltage stability depends upon the voltage control capabilities of the generators.

Some specific voltage issues have already been identified by the system operator in Mayotte:

- Some consumers located at the end of long feeders (e.g., the one supplying the south of the island) are complaining about non-working induction cookers because of low voltage level. EDM is thus assuming some voltage drops along its lines.
- The undergrounding of overhead cables currently performed by EDM leads to an increase in reactive power levels in the cables and may cause transient overvoltage and resonant behaviour due to the energization or switching of transformers in the system.
- A too high voltage level can be observed on high voltage lines between April and October, when the demand is lower (e.g., high voltage lines sometimes reach 94kV instead of 90kV). This case is more difficult to treat for EDM because there is less margin for compensation.

To ensure voltage stability, system operators need to ensure during the network planning stage that reliability criteria are satisfied for all possible N-1 contingencies, i.e., that the maximum allowable voltage drops or rises are not exceeded and that the stability margins for real and reactive power are large enough for each composite load and load area. To ensure this, system operators should monitor the capabilities of individual assets as represented in Q-U-ranges, such as the example in Figure 31.

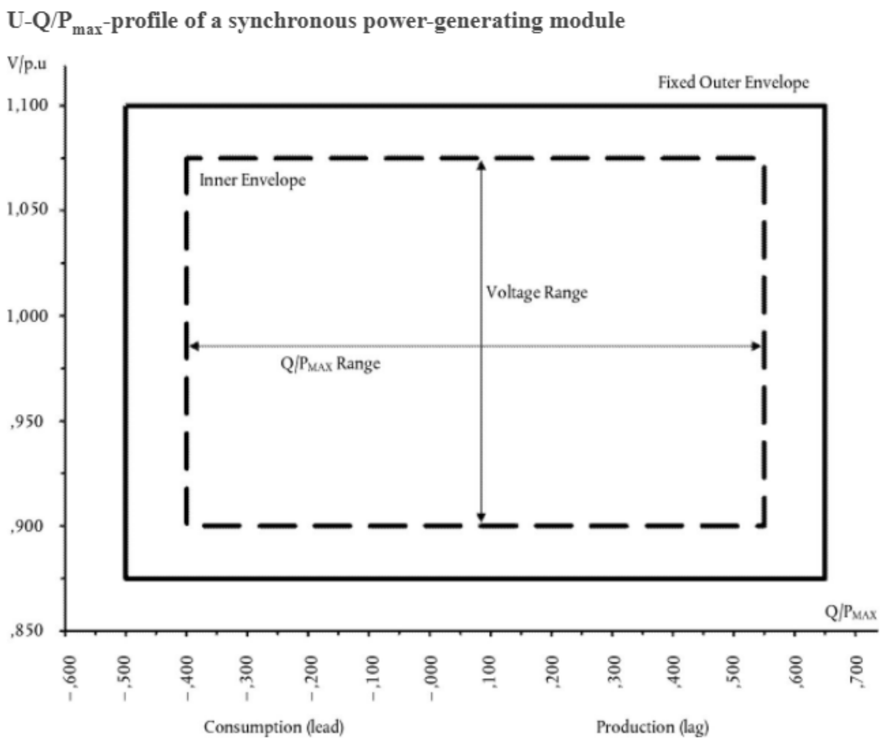


Figure 31: Voltage/reactive power range of asset (Source: ENTSO-E, see [7])

During operational planning and real-time monitoring and control, the system operator should continuously maintain a desired voltage profile. Currently, EDM's controls the voltage profile through manual activation of appropriate reactive power compensation devices, such as capacitor banks, manual and automatic tap-changing of transformers and control of the available Diesel generators (Longoni and Badamiers). An adequate reserve of real and reactive power should be maintained at the generators. Reserve is the amount of power by which generators in operation can be additionally loaded without exceeding the reactive power capability curve. Note that voltage control can be performed through active and reactive power control. However, active power control is related to far higher costs and efforts than reactive power control. As active power is also extensively used in other use cases, reactive power reserve is particularly important from a voltage stability perspective. This reactive power reserve can be activated to quickly deal with a reactive power deficit when voltage deviations are detected. The amount of reactive power to be supplied by a particular asset depends upon the control architecture in place, i.e., based on a voltage setpoint, possibly combined with a voltage droop curve to adequately deal with load transients, a reactive power setpoint or a power factor setpoint. The setpoints can be static or may change dynamically over time but should always satisfy the asset's capabilities as specified in the capabilities ranges illustrated in Figure 31 above. An example of static voltage droop curve is available in Figure 32 below.

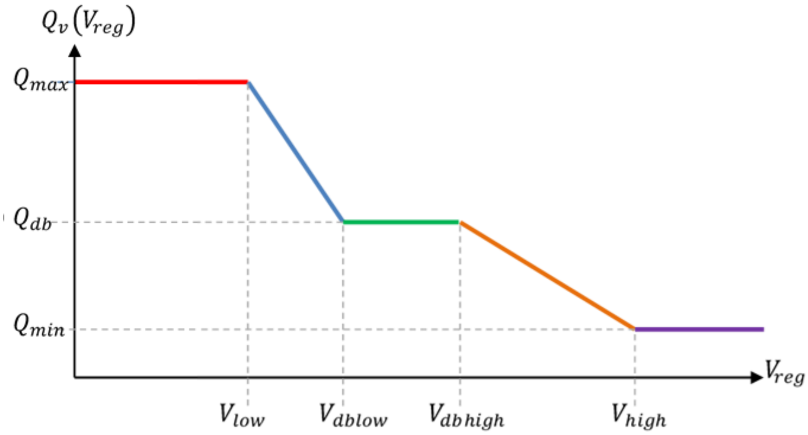


Figure 32: Example of a static voltage droop curve

Voltage control has specific characteristics, which strongly determine the suitability of acquiring mechanisms to apply in the voltage control setting. First of all, voltage control should resolve **local** issues, i.e., in contrast to frequency control, the location of the assets is more important and assets connected close to the need should be used. Given the small number of assets combined with the fact that flexibility assets are restricted to specific locations for a particular need, the market liquidity is low, and the efficiency of market-based mechanisms may not be guaranteed. Alternatively, bilateral contracts or obligation may be possible acquiring solutions that will be considered. Second, it is **hard to predict long in advance the location and extent of the voltage issue**, unless it depends on structural deficits or known (periodic) behaviour of generation or demand. Third, the effectiveness of the voltage control services **depends upon the visibility of the system operator**. Currently, Electricité de Mayotte (EDM) only has access to real-time voltage measurements at the three HV/MV substations in the system.

In MAESHA, the voltage control use case aims at using new flexibility assets, such as battery energy storage systems, renewable energy virtual power plants, power-to-hydrogen system or demand response, to support system operators in improving the voltage profile. This use case will exclusively focus on reactive power control. However, please note that active power control, as a measure of last resort, is still feasible using the mechanisms introduced by the next use case (see section 4.1.3). In the pilot test, a dedicated location in EDM's system will be chosen with specific voltage issues where flexibility from the aforementioned assets will be used to support EDM in their voltage control. The voltage control use case focuses initially on voltage control using static voltage control curves, giving the limited visibility of the system operator in its system that block the case for a more complex dynamic approach at this stage.

Within MAESHA, it has been decided to examine how different flexibility sources could support the voltage control of the island:

- **<u>Renewable Energy Virtual Power Plant</u>**

Adequate control of the AC/DC inverters of PV plants offers the possibility to control the reactive power and voltage in the system.

- **<u>Battery Energy Storage System</u>**

Battery Energy Storage System (BESS)s are devices able to store and manage electric energy. The main subsystems are the Battery Management System (BMS), converter, auxiliary systems and main control system. Amongst other capabilities, BESS can perform voltage support to the bus it is connected by delivering a variable amount of active and reactive power according to the control algorithms of the BESS control system. The power dispatch is managed by 4-quadrant power electronics (BESS converter).

- **<u>Power-to-Hydrogen system</u>**

Power to hydrogen systems are plants that convert electricity into hydrogen than can be stored and subsequently utilized as feedstock, fuel or to produce electricity in a fuel cell. The flexible operating capabilities of the electrolyser can contribute to reduce the voltage fluctuations at the point of interconnection.

- **<u>Industrial and Residential Demand Response</u>**

Buildings equipped with inverter-interfaced demand or generation (e.g., PV installation, heat pumps, electric boilers) can participate in voltage control services through the reactive power control of those assets. However, active power control of those assets is more effective in the framework of other grid services (e.g., minimization of the consumption peak use case) and we might not be able to demonstrate this solution in MAESHA.

This Use Case relies on the following functions:

- Determination of static voltage control curves by the system operator for assets capable of reactive power control/voltage support based on asset's capability curves and the capabilities of traditional solutions (e.g., by using tap changing transformers, capacitor banks or voltage support of Diesel generators)

• Local voltage and power measurements • Control logic: determination of reactive power setpoints to follow according to local voltage and power measurements and static voltage control curve of the asset • Validation process

1.5 Key performance indicators

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
KPI 6.4	Likelihood of prediction of congestion (voltage/power-flow limit violation)	Target: >90%	Extracted from the Grant Agreement
KPI 6.6	Overall effectiveness of complete system in kWh for DSO – avoided curtailment	Target: >50%	Extracted from the Grant Agreement

1.6 Use case conditions

Use case conditions
Assumptions
• Assuming industrial prosumers will be interested in providing flexibility services to the grid • Assuming residential prosumers will be interested in providing flexibility services to the grid • Assuming those prosumers will be equipped with inverter-interfaced demand or generation (e.g., PV installation) capable of adequate control for reactive power control[15] • Assuming PV producers will be interested in providing flexibility services to the grid • Assuming that gateways for local logic, control setting and for communication will be installed and capable of communicating with inverter controls • Assuming the battery for voltage control will be connected to the grid • Local voltage measurements and current measurements (possibly power measurements if grid-forming inverter control) should be available to inform the local logic and inverter control
Prerequisites

1.7 Further information to the use case for classification/mapping

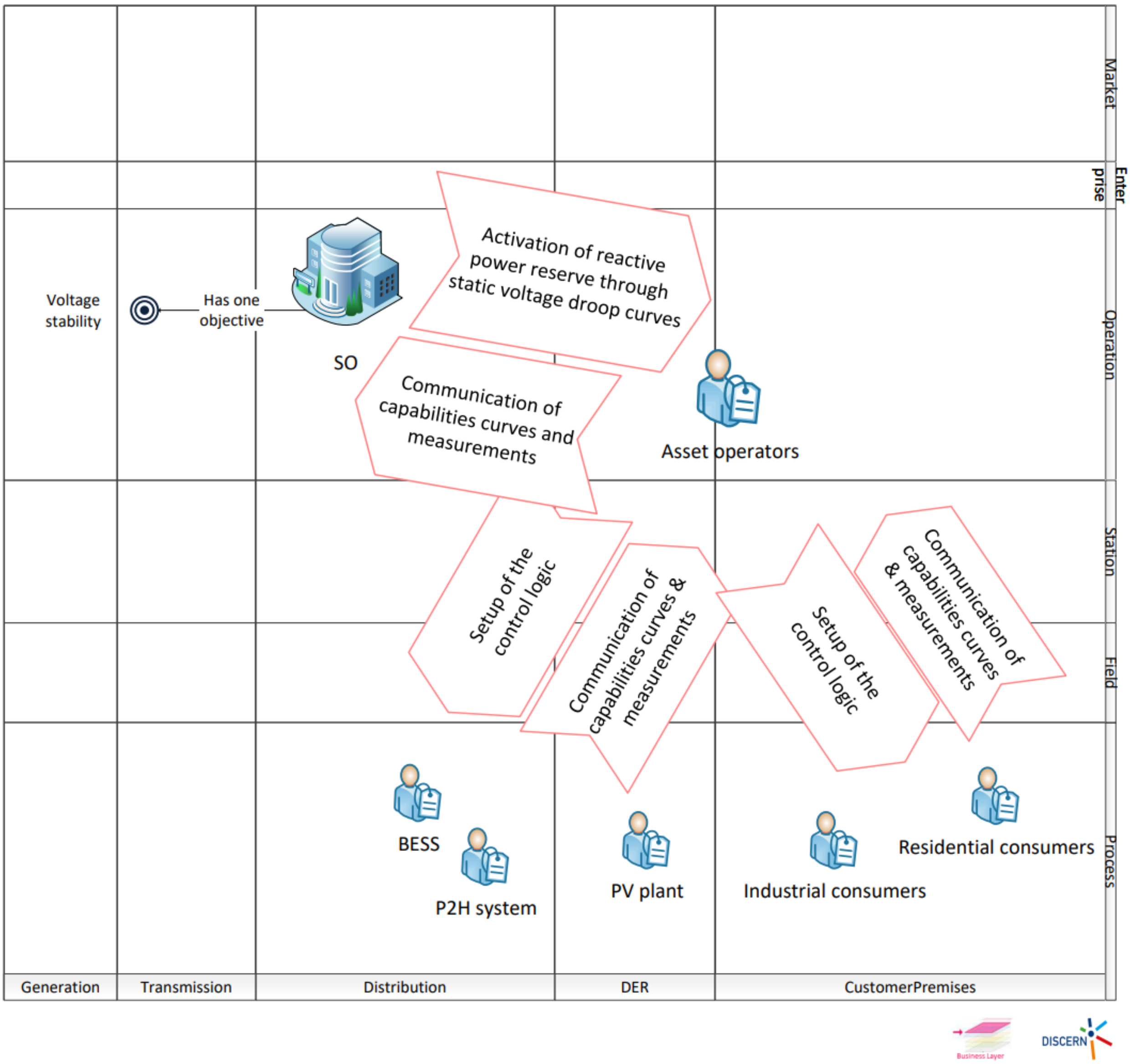
Classification information
Relation to the other use cases
Level of depth
High-level
Prioritization
Generic, regional or national relation
Generic
Nature of the use case
Further keywords for classification
Flexibility, Voltage control

1.8 General remarks

General remarks

[15] Please note that the control of the inverter will be detailed in task 5.2 "Technologies to increase grid inertia and improve power quality"

2 Diagrams of use case

Diagram(s) of use case
 Figure 33: SGAM business layer of the voltage control use case-specific architecture

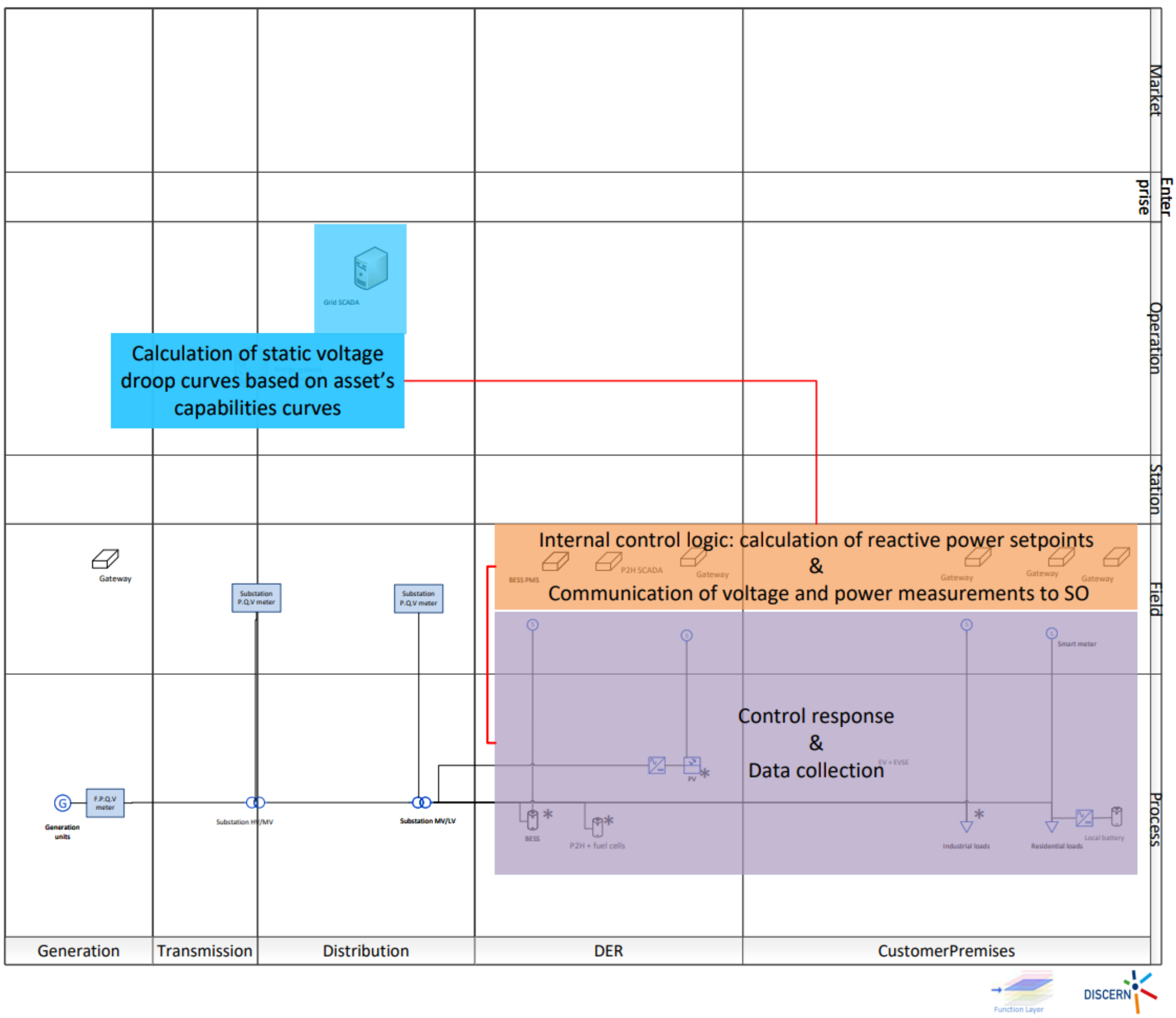


Figure 34: SGAM function layer of the voltage control use case-specific architecture

The functions supporting this use case are displayed in below.

3 Technical details

3.1 Actors

Actors			
Grouping		***Group Description***	
Business Actor		Physical or legal person that has his own interests, defined as “Business Goals”	
Operator		Business Actor that operates a system	
Logical Actor		Technical entity that takes part in the execution of a use case. A logical actor can be mapped to a physical component	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
(D)SO	System Operator	Operator of the Distribution System, in this case also the operator of the entire system on the island.	Electricité de Mayotte (EDM)
SCADA	Logical Actor	Supervisory Control and Data Acquisition – a supervisory computerized system that gathers and processes data and applies operational controls for transmission side systems used to control dispersed assets	EDM SCADA
Residential prosumer	Business Actor	A residential party that consumes electricity	
Industrial prosumer	Business Actor	An industrial party that consumes electricity	

RES generator	Logical Actor	Small units which generate electricity from renewable sources (e.g., solar) and which is connected to the distribution grid	
Battery	Logical Actor	Energy storage system capable of providing different services to the grid	
P2H system	Logical Actor	System to convert electricity (optimally from RES) into hydrogen that can be stored to use it eventually for different purposes (feedstock, electricity production, fuel)	
Measurement device	Device	A local measurement device to continuously measure the grid voltage at the connection point	
Local controller	Device	A local, programmable controller (PLC) that controls the operation of the power plant. It has got the droop curve implemented.	
Smart meter	Device	A Smart meter is an electronic device that records information such as consumption of electric energy, voltage levels, current and power factor. Smart meters communicate the information to the consumer for greater clarity of consumption behavior and to electricity suppliers for system monitoring and customer billing.	

3.2 References

References						
No.	***Reference type***	***Reference***	***Status***	***Impact on use case***	***Originator/organization***	***Link***

4 Step by step analysis of use case
4.1 Overview of scenarios

Scenario conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
Sc1	Bilateral agreement (D)SO/asset owner and prequalification for voltage control services	This scenario describes the bilateral agreement between the (D)SO and the asset owner for participation in voltage control services and the prequalification process with the calculation of the static voltage droop curve of the asset	(D)SO and individual asset owner	Request for connection of the asset to the grid or request for participation in voltage control services	/	Asset qualified to provide voltage control services received static voltage droop curve from the (D)SO
Sc2	Voltage control by RES generator as an example	This scenario describes how a generator of renewable energy sources, such as PV plants, can provide voltage support to the electricity system	RES generator	Voltage deviations due to imbalances between demand and supply	The (D)SO has decided upon the reactive power reserve of the power plant The (D)SO has decided upon the static voltage response curve of the power plant	The voltage profile of the assets stays within limits
Sc3	Validation process	This scenario describes how the (D)SO validates the voltage control services provided by the individual assets	(D)SO	Voltage control services provided by the individual assets		Voltage control services are validated by the (D)SO

4.2 Steps – Scenarios

Scenario	
Scenario name	**Sc1 - Bilateral agreement (D)SO/asset owner and prequalification for voltage control services**

Step No.	*Event*	*Name of process/activity*	*Description of process/activity*	*Service*	*Information producer (actor)*	*Information exchanged (IDs)*	*Requirements, R-IDs*
St1	Request for connection or request for participation in voltage control services	Request for connection or participation in voltage control services	An asset owner requests the connection of its new asset to the grid (e.g., new PV power plant, new battery) or requests its participation in voltage control services to the (D)SO	CREATE	Asset owner	IE-01-01	
St2	Previous request approved	Connection and/or participation approval	After analysis of the request, the (D)SO accepts the connection of the asset to the grid and/or its participation in voltage control services and informs the asset owner	EXECUTE, REPORT	(D)SO	IE-01-01	
St3	After completing previous step	Communication of capabilities curves to the (D)SO	The asset owner communicates the capabilities curve of its asset to the (D)SO	REPORT	Asset owner	IE-01-02	R-01-01
St4	After completing previous step	Calculation of the static voltage droop curve for the asset	Based on the capabilities curve received, the (D)SO calculates the static voltage droop curve of the asset	EXECUTE	(D)SO	IE-01-03	
St5	After completing previous step	Communication of the static voltage droop curve to asset owner	The (D)SO communicates the static voltage droop curve to the asset owner	REPORT	(D)SO	IE-01-03	R-01-01
St6	After completing previous step	Voltage support	Asset owner provides voltage control services, as described in scenario 2	EXECUTE	Asset owner		
Scenario name		**Sc2 - Voltage control by RES generator as an example**					
Step No.	*Event*	*Name of process/activity*	*Description of process/activity*	*Service*	*Information producer (actor)*	*Information exchanged (IDs)*	*Requirements, R-IDs*
St1	Continuous voltage measurement	Continuous voltage measurement	The power plant is equipped with measurement equipment which continuously measures the local voltage level	GET	Measurement device	IE-02-01	R-02-01
St2	After completing previous step	Calculation of the reactive power setpoint	The local controller of the asset in charge of the control logic translates the voltage measurement in an reactive power setpoint/response based on the static voltage droop curve provided by the (D)SO	EXECUTE	Local controller	IE-02-02	
St3	After completing previous step	Control of the inverter	The local controller communicates the setpoints to the inverter to generate the requested reactive power	REPORT	Local controller	IE-02-02	
St4	After completing previous step	Modification of the reactive power output	The reactive power outputs at the terminals of the power plant are modified to change the voltage profile	EXECUTE	Power plant		
St5	After completing	Measurement	The voltage and power outputs at the terminals are measured	EXECUTE	Measurement device	IE-02-03	R-02-01

	previous step						
St6	After completing previous step	Data logging	Measurements of voltage, active and reactive power are logged for later validation (see Sc3) Please note that this step might disappear if smart meters are deployed in each individual asset: in that case, voltage, active and reactive power data will be automatically communicated to the (D)SO	REPORT	Local controller (or Smart meters)	IE-02-03	R-02-02
Scenario name		**Sc3 - Validation process**					
Step No.	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***
St1	Periodic control (e.g., yearly)	(D)SO requests data logs	The (D)SO requests logged measurements (see Sc2) for validation purposes from the power plant operator.	GET	(D)SO	IE-03-02	
St2	Data request for validation received	Submission of validation data	The asset operator submits the validation data to the (D)SO via email	REPORT	Asset operators	IE-03-01	R-03-01
Please note that the first two steps of this scenario, described above, are unnecessary if smart meters are deployed in each individual asset. In that case, data are indeed automatically and regularly (daily basis) communicated to the (D)SO.							
St3	Validation data received	Validation of reactive power support	Logged measurements are validated to ensure the proper provision of the voltage supply service.	EXECUTE	(D)SO	IE-03-03	
St4	Validation check failed	Correction of control behaviour	In case of deviation from the required behaviour, the asset operator is prompted to immediately correct the behaviour of the reactive power control.	EXECUTE	Asset operator		
St5	A predefined period after the correction	Repeat validation	The validation process (St1-St3) is repeated after a predefined period (e.g., 2 months). In case of ignorance of the (D)SO's request, a penalty can be allocated to the asset operator	EXECUTE	(D)SO		

5 Information exchanged

Information exchanged			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE-01-01	Request for connection or participation in voltage control services	Document requesting a connection of the asset to the grid or requesting the participation of the asset in voltage control services	
IE-01-02	Capabilities curve	This curve represents the capabilities of individual assets as represented in Q-U-ranges (see Figure 31).	
IE-01-03	Static voltage droop curve	This curve is a voltage-to-power response curve that translates local voltage measurements to active and reactive power response. This curve is specific to an individual asset.	
IE-02-01	Voltage data	Local voltage level measured at the asset level	
IE-02-02	Reactive power setpoint	This setpoint is the reactive power response calculated by the gateway in charge of the control logic based on the static voltage droop curve of the asset (see Figure 32).	

IE-02-03 IE-03-01	Validation data	Those data is needed for the validation process. It includes the baseline, power and voltage measurements and is submitted in a format predefined by the (D)SO.	
IE-03-02	Request for validation data	A formal request of the (D)SO to submit the validation data	
IE-03-03	Validation report	A document issued by the (D)SO reporting the result of the validation process	

Figure 35 below represents the information exchanges between the different components.

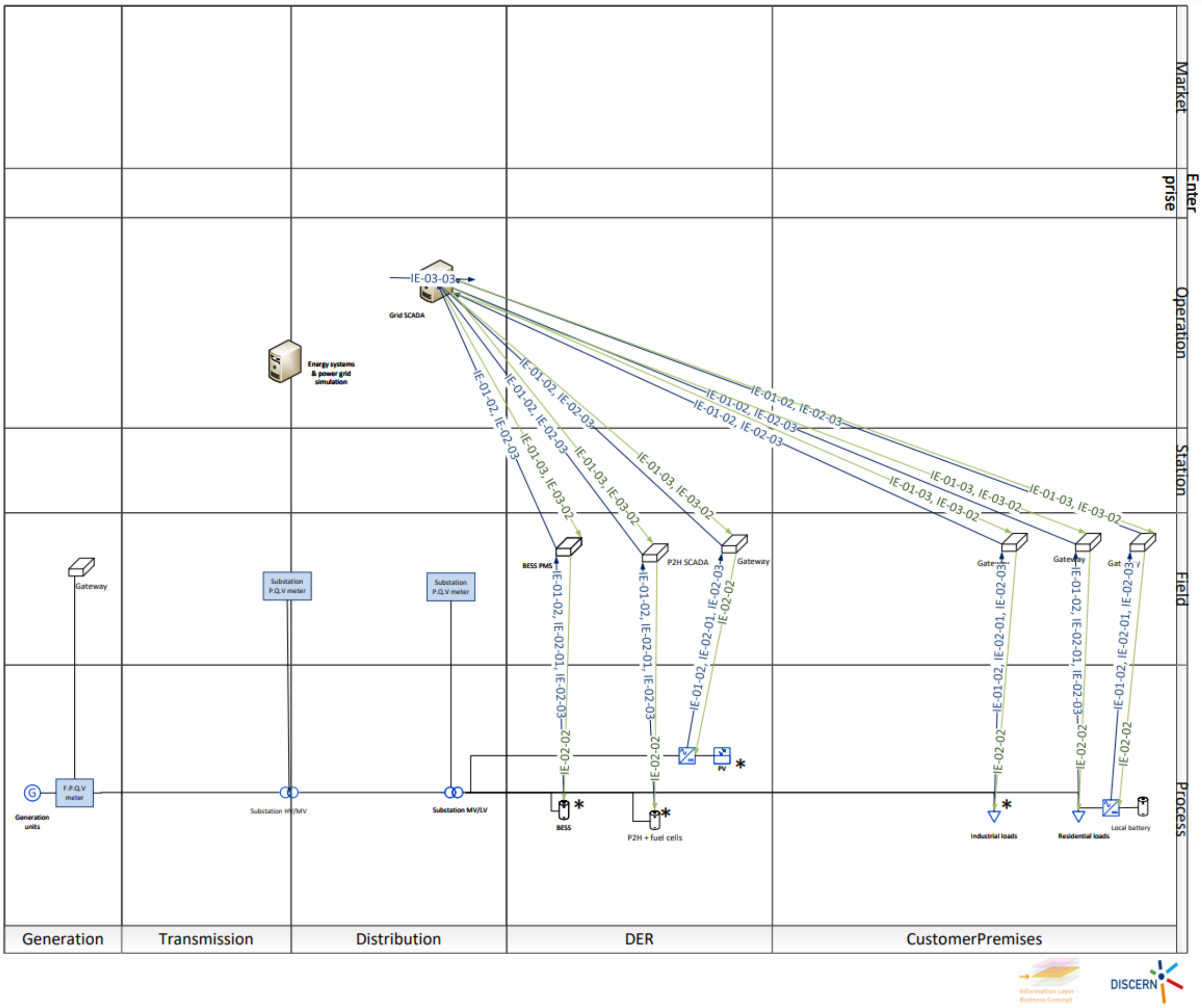


Figure 35: SGAM information layer of the voltage control use case-specific architecture

6 Requirements (optional)

Requirements (optional)		
Requirement R-ID	***Requirement name***	***Requirement description***
R-01-01 R-02-02	Formal way of business communication	The communication between the individual asset operators and the (D)SO must be operational, following the communication channels (e.g., email, postal mail) stated in the operator's terms and conditions.
R-02-01	Sufficient and accurate voltage measurements	Voltage and power meters with sufficient measurement accuracy should be installed at each asset.
R-03-01	Local data storage	The local controller must be able to log measurements for a period of up to 12 months.

7 Common terms and definitions

Common terms and definitions

Term	*Definition*
AC	Alternating Current
BESS	Battery Energy Storage System
BMS	Battery Management System
DC	Direct Current
DER	Distributed Energy Resource
DR	Demand Response
DSO	Distribution System Operator
EDM	Electricité de Mayotte
FMTP	Flexibility Management and Trading Platform
HV	High Voltage
MV	Medium Voltage
P2H	Power-to-Hydrogen
PV	Photovoltaic
RES	Renewable Energy Sources
SCADA	Supervisory Control and Data Acquisition
SGAM	Smart Grid Architecture Model
SO	System Operator
UC	Use Case
VPP	Virtual Power Plant
WP	Work Package

8 Custom information (optional)

Custom information (optional)		
Key	***Value***	***Refers to section***

Minimization of the consumption peak

1. Description of the use case

1.1 Name of the use-case

Use case identification		
ID	***Area/Domain/Zone(s)***	***Name of the use case***
UC5	Area: Energy system, Domain: Distribution, DER, Customer Premises Zones: Operation	Minimizing the consumption peak (Can be extended to congestion management)

1.2 Version management

Version management				
Version No.	***Date***	***Name of author(s)***	***Changes***	***Approval status***
0.0	20/07/2021	Marjolaine Farré (Trialog)	Initial creation	Draft
0.1	05/08/2021	Christoph Gutschi, Andraz Andolsek (CyberGRID), Jk Pillai (Bovlabs), Evelyn Heylen (Centrica), Elchaysse Soudjae (EDM), Juan Varo Lopez, Pablo Gonzalez Reed (Creara), Marjolaine Farré (Trialog)	Definition of objectives Description of the context Listing of indirect impacts Listing of the functions performed by the system to support the UC	
0.2	03/09/2021	Juan Varo Lopez, Pablo Gonzalez Reed (Creara), Jk Pillai (Bovlabs)	Description of scenario 3	
0.3	10/09/2021	Marjolaine Farré (Trialog)	Description of remaining scenarios	
0.4	15/09/2021	Christoph Gutschi (CyberGRID), Jk Pillai (Bovlabs), Evelyn Heylen (Centrica), Elchaysse Soudjae (EDM), Juan Varo Lopez, Pablo Gonzalez Reed (Creara), Marjolaine Farré (Trialog)	Review of the scenarios	

1.3 Scope and objective of use case

Scope and objectives of the use case	
Scope	The scope of this use case is to examine how the MAESHA system can minimize the consumption peak to avoid potential congestion, expensive start-up of peak generators or adequacy issues that may occur in the electricity system of the island
Objective(s)	The main objectives of this use case are to: ● Minimize the consumption peak by proposing load shifting, load shedding or increase of distributed generation (behind the meter) to the SO through the Flexibility Management and Trading Platform (FMTP) ● Minimize the consumption peak on a daily basis by following the EV signal set by Electricité de Mayotte (EDM) on its Open Data to advertise favourable periods of consumption ● Maximize self-consumption for EV charging to reduce the peak load (link w/ UC "Maximization of the use of Renewable Energy Sources") If extended to congestion management, a subobjective could be to:

	• Control consumption and/or production to avoid congestion in the distribution network
Related business case(s)	

1.4 Narrative of use case

Narrative of use case
Short description
This use case aims at minimizing the consumption peak by implementing a flexibility market for load shedding and/or load shifting to enable new flexibility assets to support the system operator in operating the grid and by following, on a regular basis, the EV signal set by EDM to advertise favourable periods of consumption.
Complete description

Consumption peak – also named peak load – refers to the highest electrical power demand that has occurred over a specific time period. In Mayotte, where the climate is characterised by small variations of daily and annual temperatures as well as heavy rainfalls, the electricity demand seasonality is low. The demand is indeed quite stable all around the year and the daily consumption peak occurs early morning (from 5 a.m. to 8 a.m.) when people wake up and, in the evening, (from 6 p.m. to 10 p.m.) when people get back from work.

However, the System Operator (SO) of Mayotte, Electricité de Mayotte (EDM), is expected changes in the near future. As a reference scenario for Mayotte, EDM assessed that the total demand should reach 540 GWh with a consumption peak of 84MW in 2028 (to compare with the 370 GWh of electricity supplied in 2019 and the maximum consumption peak of 61.5 MW reached in February 2021). This increase can partly be explained by the penetration of electric vehicles – personal cars but also renewed C&I fleets – and improving living conditions for the population, which relies more and more on air-conditioning units. To deal with the increasing demand which may happen at a higher pace than grid reinforcements can cope with, EDM is interested in evaluating how flexibility can solve potential congestion.

Grid congestion occurs when the capacity of the electricity grid is insufficient to transport the volumes of electric power required to meet the demand. EDM has currently too low visibility on its grid to measure any congestion. However, EDM knows that some equipment (transformers and feeders) is overloaded by comparing the capacity of the equipment with the total power capacity subscribed by the end-users located downstream from this equipment. EDM is currently performing reinforcement work such as:

- the creation of a new HV/MV substation in SADA to transport electricity to the south of the island using a high voltage line (90 kV) and propose a better repartition of the end-users on the different feeders
- the replacement of old transformers

In addition to this reinforcement work, EDM has also set an EV signal, available on its Open Data to advertise favourable periods of Electric Vehicles charging – to promote Smart Charging and to not add any burden on the electricity grid of the island. This signal is binary:

- 1 means that the period is favourable and that EV charging is recommended at 7.4 kW maximum
- 0 means that the period is not favourable and that the charging is to avoid or to limit at 3.7 kW maximum

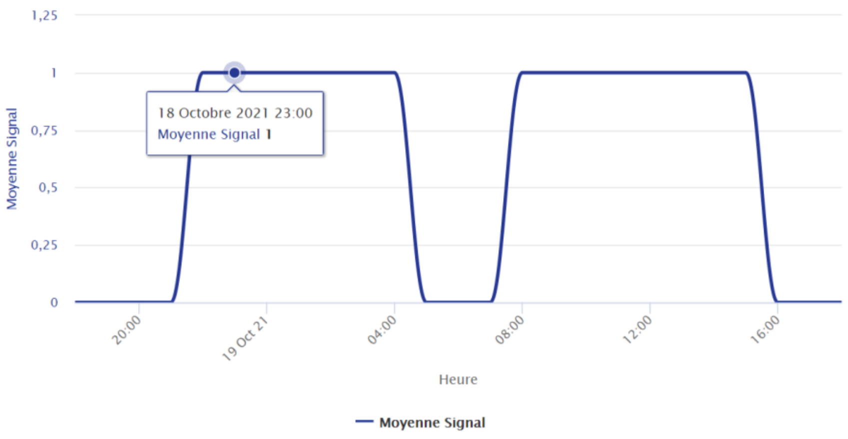


Figure 36: EV signal available on EDM Open Data

To extend EDM's reach on the management of the consumption peak, it has been decided within MAESHA to examine how different flexibility sources could propose load shifting or load shedding through the Flexibility Management and Trading Platform on a day-ahead flexibility market[16]. The flexibility market will have priority over the daily optimization: it means that a flexibility activation order sent by the DSO through the FMTP will have priority over the EV signal advertised on the Open Data. Please note that the minimization of the consumption peak should also be able to resolve local issues (e.g., overloaded MV/LV transformers), i.e., as in the voltage control use case, the location of the assets is important and assets close to the need should be used. The efficiency of the flexibility market will thus highly depend on its liquidity, the specific locations of the needs and of the flexibility assets involved.

Partners of MAESHA have assessed the potential indirect impacts of such flexibility markets:

- First, it will help EDM in future decision-making processes. By defining a merit order[17] for load shifting and load shedding, the MAESHA solution will evaluate the cost of consumption reduction. EDM will thus have the ability to compare such prices with internal generation options (in the short-term) and new projects (e.g., installation of new batteries, reinforcement work) and evaluate the relevance of the latter (in the mid-term).
- Then, this flexibility market will help assessing consumer's behaviour which might be useful if EDM decide to implement specific Time-of-Use tariffs based on consumer segmentation in the future.
- Finally, this market can also lead to CO_2 emissions reduction if EDM favour load shifting or load shedding to the operation of peak power plants[18], which are usually very polluting.

The benefits of this use case are thus spread over time for EDM: on a short-time scale, the flexibility market will help EDM in minimizing the cost for electricity supply and on a longer time scale, help EDM in decision-making.

The different sub-systems in MAESHA supporting this use case are:

- **Residential Demand Response**

Residential customers may have flexible loads that end-users do not necessarily need instantaneously to ensure their comfort, e.g., dishwashers, washing machines, cloth dryers, air-conditioning units or electric heating. Typically, these devices are used simultaneously during the consumption peak, e.g., when customers come home in the evening. Optimally controlling the on/off times of these devices can reduce the consumption peak. Dishwashers, washing machines or cloth dryers may be activated through the day, whereas heating can rely upon the thermal buffer of the building and/or a hot water tank to delay or prepone its activation.

- **Industrial Demand Response**

Industry's main purpose is manufacturing of the certain goods and/or service. Some industrial assets on the other hand are 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 consumption peak. Those energy assets within the industry have usually some restrictions, such as limited time-frame of delivery (e.g., max 4 h) or can provide such action only at the certain time of the day or year.

Industry is usually the biggest energy consumption. Reducing the peak at the point of usage is a perfect candidate to be used within this use case.

- **Decentralized Energy Management within Local Energy Community**

Most commonly, Local Energy Communities (LECs) are legal entities such as associations or cooperatives which are involved in generation and self-consumption of renewable energy. Often, LECs consist of prosumers, meaning members who both produce and consume renewable energy. These may own generation assets, practice self-consumption, share electric vehicles or are active in the local energy market through selling excess energy or being engaging in flexibility services. By offering local energy arbitration based on individual's needs, the energy management system developed within MAESHA will assess locally-aggregated flexibility to help the system operator in operating the distribution grid.

- **Smart Charging/V2G**

Smart charging is the process by which Electric Vehicles (EVs) connected to charging stations are charged/discharged, taking into account various factors such as consumption peak, renewable energy production or low/high tariff periods. Upon request from an aggregator or a system operator, the Charging Point Management System can reduce or increase the consumption of the EVs, while respecting the EV driver's preferences (desired state of charge at its departure time).

- **Battery for peak load coverage**

[16] Through the forecast of typical patterns of EV charging, the MAESHA solution will be able to propose flexibility extracted from EV on a day-ahead flexibility market (if provided the access to the market. Otherwise, EV can participate in intraday flexibility market).

[17] The merit order will be calculated based on customers incentivization (e.g., financial compensation for switching off its air-conditioning unit)

[18] Peak power plants refer to power plants that run only when there is a high demand for electricity. They are usually small power plants fuelled by gas or diesel.

We would also like to integrate the battery for peak load coverage that will be installed on the island by the end of 2021. This battery can indeed contribute to the use case by providing additional electricity supply to meet the consumption peak, without running polluting and expensive peak power plants.

Considering the flexibility market, the Use Case relies on the following functions:

- Contracting flexibility products
- Forecast and operational planning – detection of a consumption peak
- Aggregation and bidding of flexibility from different assets by the intermediate platforms (VPPs and EV EMS)
- Activation of flexibility through the Flexibility Management and Trading Platform
- Disaggregation of flexibility activation and control dispatching
- Settlement process to validate flexibility activation
- Minimization of the consumption peak by Smart Charging/V2G

Considering the daily optimization, only EVs and potentially Local Energy Communities (LEC) will be able to synchronize the operation period of their respective assets with period advertised by EDM in its Open Data.

1.5 Key performance indicators

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
KPI 1.8	Flexibility available in Mayotte thanks to MAESHA DR solutions	Target: 2600 kWh	Extracted from the Grant Agreement
KPI 1.9	Flexibility available in Mayotte thanks to MAESHA DR solutions	Target: 13000 kWh	Extracted from the Grant Agreement
KPI 1.10	Electricity load adaptability level	Target: 15%	Extracted from the Grant Agreement
KPI 1.11	Total flexibility available in Mayotte with MAESHA solutions	Target: 4 MW	Extracted from the Grant Agreement
KPI 1.12	Total flexibility available in Mayotte with MAESHA solutions	Target: 18 MWh	Extracted from the Grant Agreement
KPI 3.1	Number of Local Energy Communities created in Mayotte	Target: >10	Extracted from the Grant Agreement
KPI 3.2	Number of LEC created in follower islands	Target: >6	Extracted from the Grant Agreement
KPI 3.3	Number of LEC created from the project	Target: >15	Extracted from the Grant Agreement
KPI 3.4	Number of people involved in a LEC	Target: >100	Extracted from the Grant Agreement
KPI 3.5	Total number of people involved in MAESHA LEC	Target: >2000	Extracted from the Grant Agreement
KPI 6.1	Reduction of cost thanks to avoided congestion	Target: -10%	Extracted from the Grant Agreement
KPI 6.2	Reduction of peak demand thanks to avoided congestion	Target: -15%	Extracted from the Grant Agreement
KPI 6.3	Distribution grid stability through responsiveness of flexibility services (Time required to activate portion of available load flexibility through DR services)	30 min (>25%DR) 1h (>50%DR) 24hrs (>100%DR)	Extracted from the Grant Agreement
KPI 6.4	Likelihood of prediction of congestion (voltage/power-flow limit violation)	Target: >90%	Extracted from the Grant Agreement
KPI 6.6	Overall effectiveness of complete system in kWh for DSO - avoided curtailment	Target: >50%	Extracted from the Grant Agreement

1.6 Use case conditions

Use case conditions
Assumptions
• Assuming industrial prosumers will be interested in providing flexibility services to the grid • Assuming residential prosumers will be interested in providing flexibility services to the grid • Assuming residential prosumers will be interested in forming a Local Energy Community • Assuming EV stations will be connected to the grid and operating • Assuming V2G-compatible EVs will be deployed in Mayotte at the time of the demonstration • Assuming the battery manager will be interested in integrating the MAESHA project and participating in this Use Case
Prerequisites
• For residential and industrial Demand Response: consumers should consume electricity when congestion occurs to shift load and thus participate in this Use Case • For Smart Charging: EVs should be plugged when congestion occurs

1.7 Further information to the use case for classification/mapping

Classification information
Relation to the other use cases
Directly linked to "Maximize the use RES" as it may also lead to a reduction of consumption peak
Level of depth
High-level
Prioritization
Generic, regional or national relation
Generic
Nature of the use case
Further keywords for classification
Congestion management, Lower consumption peak, Demand Response

1.8 General remarks

General remarks

2 Diagrams of use case

Diagram(s) of use case
The "flexibility market" and "EV signal" mechanisms, described in section 1.4 "Narrative of the use case" are quite independent from each other. That's why we built two different specific architectures for this use case. • Flexibility market

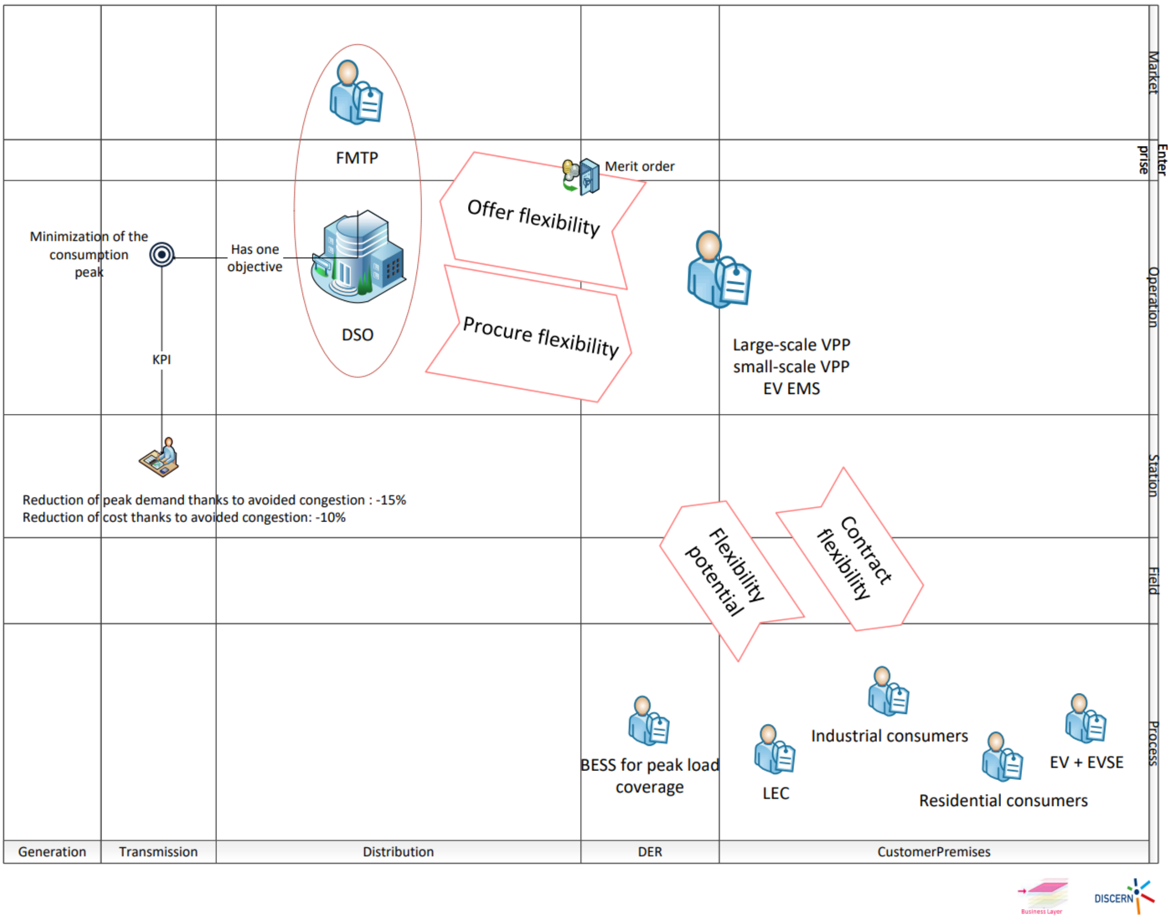


Figure 37: SGAM business layer of the minimization of the consumption peak use case-specific architecture (flexibility market)

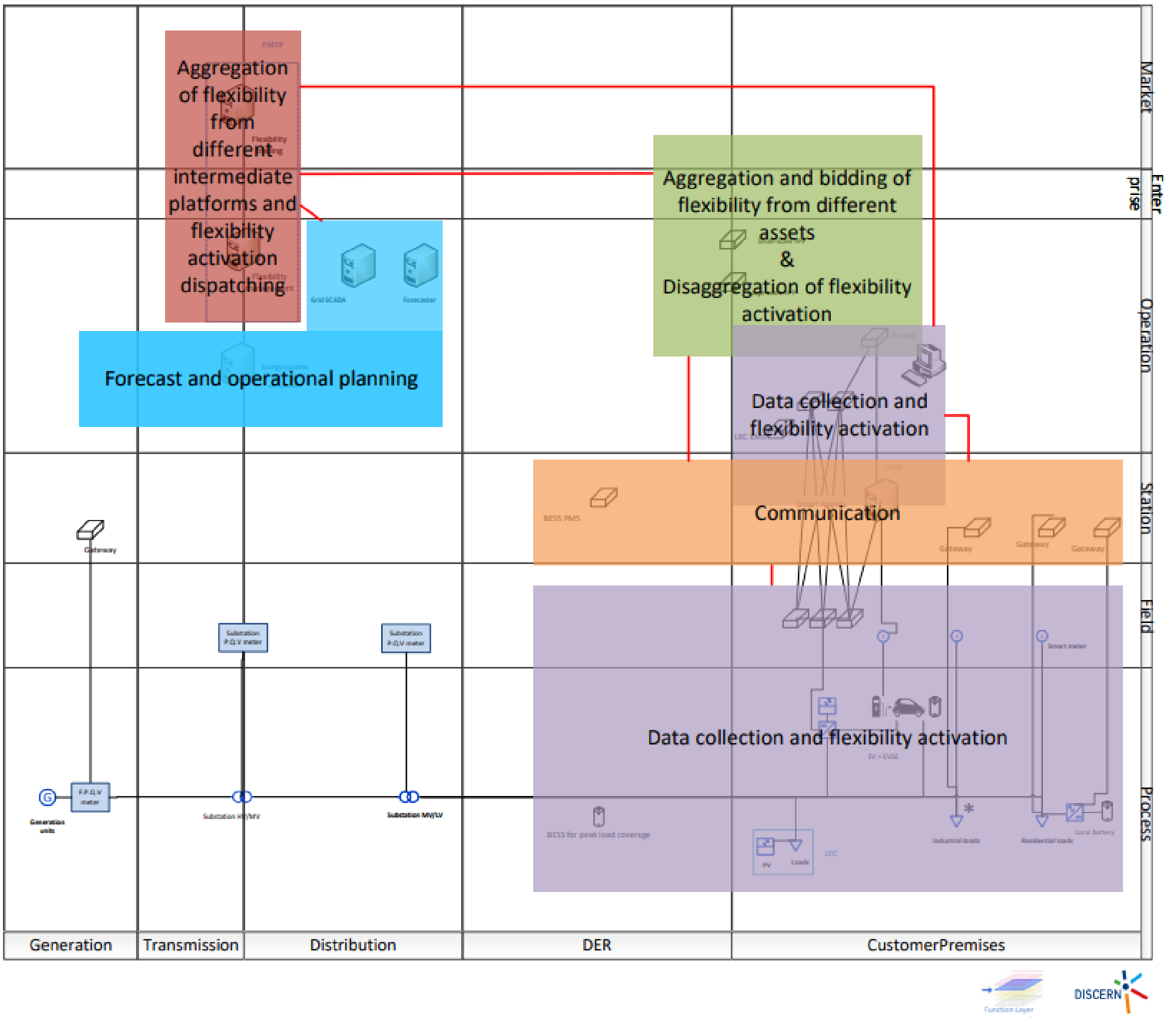


Figure 38: SGAM function layer of the minimization of the consumption peak use case-specific architecture (flexibility market)

- EV signal

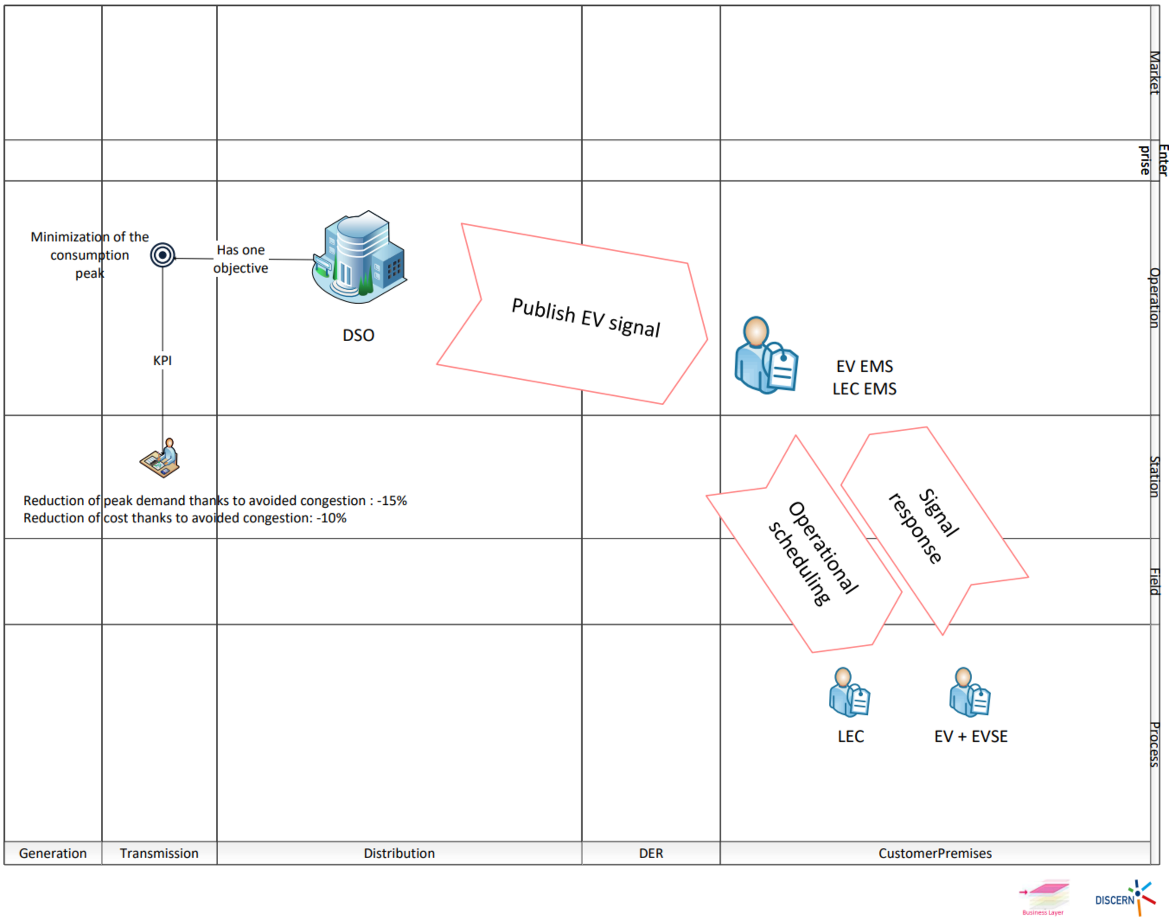


Figure 39: SGAM business layer of the minimization of the consumption peak use case-specific architecture (EV signal)

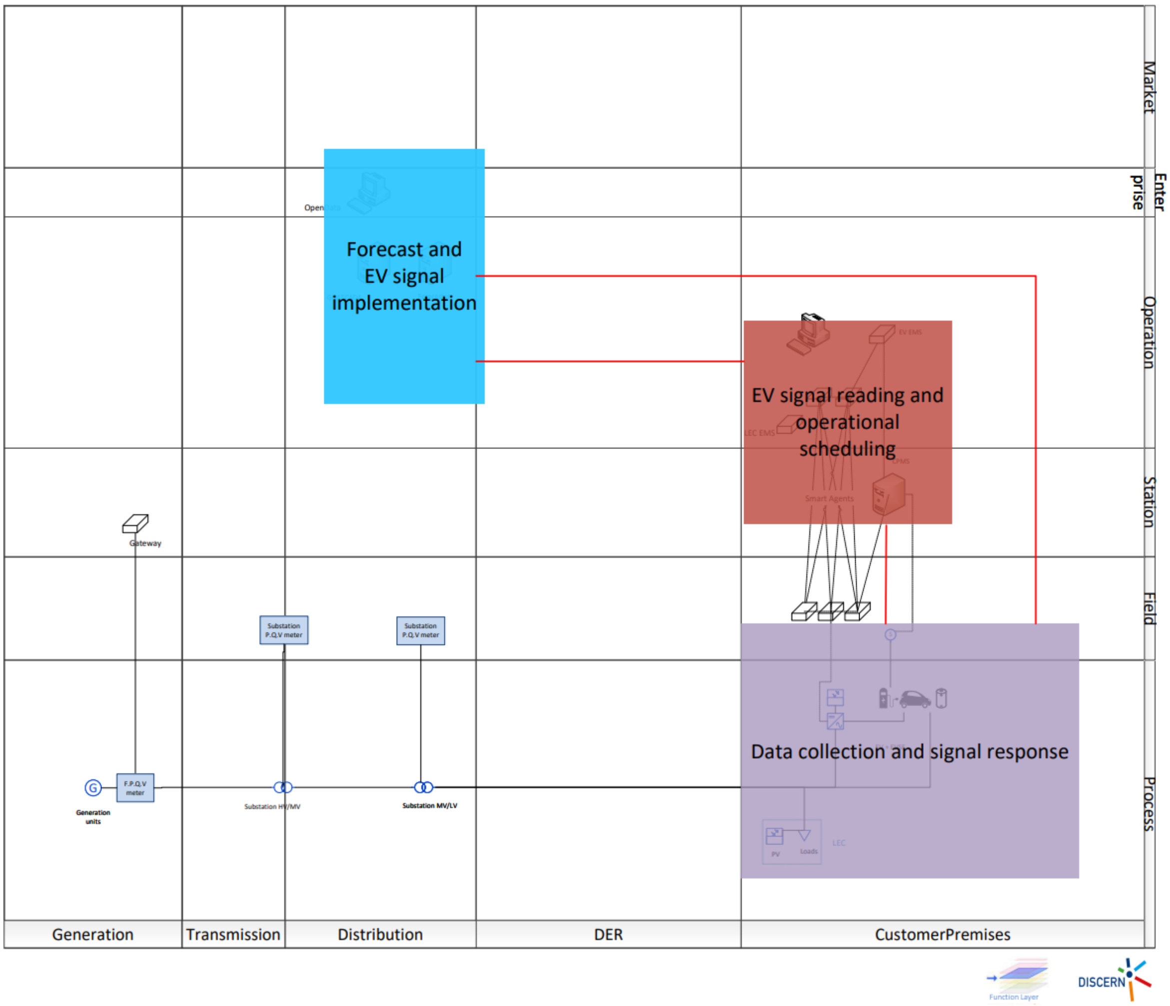


Figure 40: SGAM function layer of the minimization of the consumption peak use case-specific architecture (EV signal)

3 Technical details

3.1 Actors

Actors			
Grouping		***Group Description***	
Business Actor		Physical or legal person that has his own interests, defined as “Business Goals”	
Operator		Business Actor that operates a system	
Logical Actor		Technical entity that takes part in the execution of a use case. A logical actor can be mapped to a physical component	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
System Operator (SO)	Logical Actor	Operator of the Electricity System	Electricité de Mayotte (EDM)
Residential prosumer	Business Actor	A residential party that consumes electricity	
Industrial prosumer	Business Actor	An industrial party that consumes electricity (including also farmers and EV drivers)	
Local Energy Community (LEC)	Business Actor	An organisation based on open and voluntary participation of civil society, which owns and controls its operations in market activities such as generation, distribution, supply, consumption, aggregation, energy storage, energy efficiency, or charging services for electric vehicles	
Electric Vehicle (EV)	Logical Actor	Automobile which is powered completely or in part by electricity and whose battery can be charged from an EVSE	
Electric Vehicle Supply	Logical Actor	Electric Vehicles charger	

Equipment (EVSE)			
Charging Point Management System (CPMS)	Logical Actor	This application is used for managing the charging stations. The back-office systems support standard protocols like OCPP 1.6, 2.0 to integrate with charging stations.	Developed by Bovlabs
EV Energy Management System (EV EMS)	Logical Actor	This application is used for optimisation of charging stations by smart charging and V2G integration bringing in resilience to the Grid.	Developed by Bovlabs
EVSE Smart Agents (EVSE SA)	Logical Actor	Smart Agents are used for communicating the meters and recording P2P energy transactions related to EVSE and EV. They could also provide intelligence at edges to enable smart charging and V2G	Developed by Bovlabs
LEC Energy Management System (EMS)	Logical Actor	Technical module allowing decentralized energy management within local energy communities. This module offers local energy arbitration (including DER, stationary storage, V1G, V2G, etc.) based on users' needs, maximization of collective self-consumption and assessment of potential "locally-aggregated flexibility" (i.e., the flexibility that the LEC can offer)	Developed by Trialog
Flexibility Management and Trading Platform (FMTP)	Logical Actor	Flexibility management platform that acts as a conductor for the flexibility orchestra	Developed by CyberGRID
Battery for peak load coverage	Logical Actor	Battery dedicated for peak load coverage	Extern to MAESHA

3.2 References

References						
No.	***Reference type***	***Reference***	***Status***	***Impact on use case***	***Originator/organization***	***Link***

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
Sc1	Participation in flexibility market contracting	This scenario describes the process of contracting participation of flexibility providers in flexibility market	SO, flexibility providers	Publication of the flexibility market description	/	Participation in flexibility market contracted with the SO
Sc2	Flexibility market for minimizing the consumption peak	This scenario describes the operation of the flexibility market for minimizing the consumption peak. It relies on the following main functions: • Data collection from assets involved in the flexibility market (e.g., EVs, industrial and residential loads) • Forecasting of the consumption baseline and of the flexibility potential • Aggregation of flexibility by intermediate platforms	SO, FMTP, large-scale VPP, small-scale VPP, EV EMS and assets involved in the flexibility market	The provision of flexibility offers to the SO is done regularly, on a 30 minutes basis	Flexibility providers have contracted their participation in flexibility markets with the SO (Sc1)	Upon flexibility activation requested by the SO, the consumption peak is minimized

		• Sending flexibility offers/bids to the SO through the FMTP • Flexibility activation order by the SO upon detection of a consumption peak • Disaggregation of the flexibility activation order by intermediate platforms • Load shifting or load shedding of the assets according to the flexibility activation requested by the SO (through direct control, indirect control or through the provision of a schedule) • Validation process to validate the flexibility activation • Settlement process: incentivization of the flexibility providers				
Sc3	Minimization of the consumption peak by following the EV signal used to advertise favorable periods of consumption	This scenario describes how, on a daily basis, EVs and potentially Local Energy Communities (LEC) synchronize the operation period of their respective assets with period advertised by EDM in its Open Data	SO, EV EMS and LEC EMS	The synchronization is done continuously when possible	The EV signal used to advertise favorable periods of consumption is available on EDM Open Data	/
Sc4	Smart charging/V2G for congestion management	This scenario describes how the EV EMS and the smart charging/V2G infrastructure can reduce the congestion of the grid and minimize consumption during peak hours. The EVs connected to the EVSEs are charged/discharged considering several factors such as the forecasted consumption peak times, the availability of renewable energy generation, and high/low tariff periods. The CPMS can either reduce or increase the consumption of the EVs upon requests from aggregators or system operators, supporting the consumption minimization use case, whilst also respecting the EV driver's preferences on EV state of charge and departure time	EVs, EV EMS	As soon as an EV is plugged into its EVSE, the EV EMS will charge / discharge the EVs according to consumption and generation forecasts. Additionally, CPMS controls charging upon request from aggregators and system operators	• The Charging Station should be equipped with the EV EMS, CPMS and at least, one EV should be plugged to the EVSE. • Energy consumption and generation forecasts must be available.	Flexibility activation and control dispatching upon requests from the aggregator
Hybridization of EV charging stations with PV plants (described in UC4 "Maximization of the use of RES") is also highly relevant to this use case. For further details, please refer to scenario 2 of UC4.						

4.2 Steps – Scenarios

Scenario							
Scenario name		**Sc1 – Participation in flexibility markets contracting**					
Step No.	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***

St1	Flexibility market description ready	Publication of the flexibility market description	The SO publishes the public document describing the flexibility market, its products and the related requirements	CREATE	SO	IE-01-01	
St2	After completing previous step	Compliance to the flexibility market requirement	Flexibility providers willing to participate in the flexibility market implement what is necessary to meet the requirements advertised in the flexibility market description (IE-01-01) (e.g., to properly connect the asset to the FMTP or to an intermediate platform)	EXECUTE	Flexibility providers		
St3	After completing previous step	Prequalification process	Flexibility providers take the prequalification process set by the SO to ensure that all requirements are met	EXECUTE	Flexibility providers		
St4	Prequalification process passed	Participation approval	If the prequalification process is passed, flexibility providers receive approval from the SO to participate in the flexibility market	GET	SO, flexibility providers	IE-01-02	
St5	After completing previous step	Participation in flexibility market	Flexibility providers participate in flexibility market, as described in Scenario 2	EXECUTE	Flexibility providers		
Scenario name		**Sc2 – Flexibility market for minimizing the consumption peak**					
Step No.	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***
St1	(Regularly)	Data collection from the assets involved in the flexibility market	Consumption data from the different assets involved in the flexibility market (EVs, LEC loads, residential loads and industrial loads) are collected by a utility meter (see related requirements)	CREATE	Assets involved in the flexibility market	IE-02-01	R-02-01
St2	After completing previous step	Data communication to the intermediate platforms (large-scale VPP, small-scale VPP, EV EMS)	Consumption data are communicated to the intermediate platforms (large-scale VPP, small-scale VPP and EV EMS) through gateways	REPORT	Gateways	IE-02-01	R-02-02
St3	After completing previous step	Forecasting	Intermediate platforms and various EMS forecast the consumption, the generation (if relevant) and the flexibility potential of the asset based on the forementioned data (IE-02-01) for the next day Note that the baseline forecast (estimate of the future demand based on historical demand) is needed for the validation process (St13)	CREATE	Large-scale VPP, small-scale VPP, EV EMS, LEC EMS	IE-02-02 IE-02-03	
St4	After completing previous step	Aggregation of flexibility	Intermediate platforms aggregate the flexibility potential of their connected assets: • Large-scale VPP aggregates the flexibility potential from industrial loads and BESS for load transfer	CREATE	Large-scale VPP, small-scale VPP and EV EMS	IE-02-04	

			• Small-scale VPP aggregates the flexibility potential from residential and LEC loads • EV EMS aggregates the flexibility potential from EVs connected to their charging stations Please note that the aggregation might consider specificities related to the asset (e.g., location, alternative source of electricity)				
St5	After completing previous step	Sending of aggregated flexibility bids to the FMTP	Intermediate platforms send the aggregated flexibility bids (for the next day) to the FMTP. Note that all flexibility bids are priced	REPORT	Large-scale VPP, small-scale VPP, EV EMS and FMTP	IE-02-04	
St6	After completing previous step	Order of the flexibility bids	The FMTP orders the flexibility bids. Note that the criteria to define the order will be discussed in WP4	CHANGE	FMTP	IE-02-04	
St7	After completing previous step	Flexibility bids communication to the SO	The FMTP shares the ordered flexibility bids (for the next day) to the SO	REPORT	FMTP	IE-02-04	
St8	During operational planning	Flexibility bids order by the SO	Upon detection of a consumption peak challenging the operational planning of the electricity system, the SO orders flexibility bids (for the next day) to the FMTP, detailing the energy reduction required for each time frame	CREATE	SO, FMTP	IE-02-05	
St9	After completing previous step	Flexibility activation communication to the intermediate platforms	The FMTP sends the flexibility bids order to the relevant intermediate platforms	REPORT	FMTP, large-scale VPP, small-scale VPP and EV EMS	IE-02-05	
St10	After completing previous step	Flexibility activation disaggregation	The intermediate platforms disaggregate the flexibility bids order into flexibility activation dedicated for each connected asset	CREATE	Large-scale VPP, small-scale VPP and EV EMS	IE-02-06	
Note that the load shifting/shedding can then be performed in three different ways: through direct control of the asset (e.g., residential DR), through indirect control (e.g., industrial DR) or through the provision of an operating schedule (e.g., EV). The following step is thus tripled according to the control performed							
St11-1	After completing previous step	Direct control: flexibility activation communication to the assets	The small-scale VPP stores the flexibility bids order and the following day, directly send control commands to the assets connected to the small-scale VPP. Please note that the command cannot be overridden by the residential consumers. However, they can provide feedback on the control performed by the VPP	EXECUTE	Small-scale VPP and residential consumers	IE-02-06	
St11-2	After completing previous step	Indirect control: flexibility activation communication to the assets	The large-scale VPP sends the flexibility activation signal for the next day to the local controller of the industry. Please note that direct control of the industrial assets is not possible as too sensitive for the industry	REPORT	Large-scale VPP and industrial consumers	IE-02-06	
St11-3	After completing	Provision of an operating schedule:	Intermediate platforms send operating schedules (e.g., charging/discharging schedules) extracted from the	REPORT	EV EMS and EVs, large-scale VPP and BESS	IE-02-06	

	previous step	flexibility activation communication to the assets	flexibility bids order of the SO to the connected assets				
St12	After completing previous step	Flexibility activation by the assets involved in the flexibility market	After reception of the flexibility activation signal and at the requested time frame, assets perform the load shifting or load shedding needed to minimize the consumption peak	EXECUTE	Assets involved in the flexibility market		
St13	After completing previous step	Validation process	The SO verifies the good completion of the flexibility activation by comparing the baseline forecast (IE-02-03) and the consumption profile of the assets (IE-02-07).	EXECUTE	SO	IE-02-03, IE-02-07	
St14	After completing previous step	Rewards and penalties	The SO rewards the flexibility providers according to their participation in the flexibility market. If the flexibility activation is not followed, penalties can be considered	EXECUTE		IE-02-08	

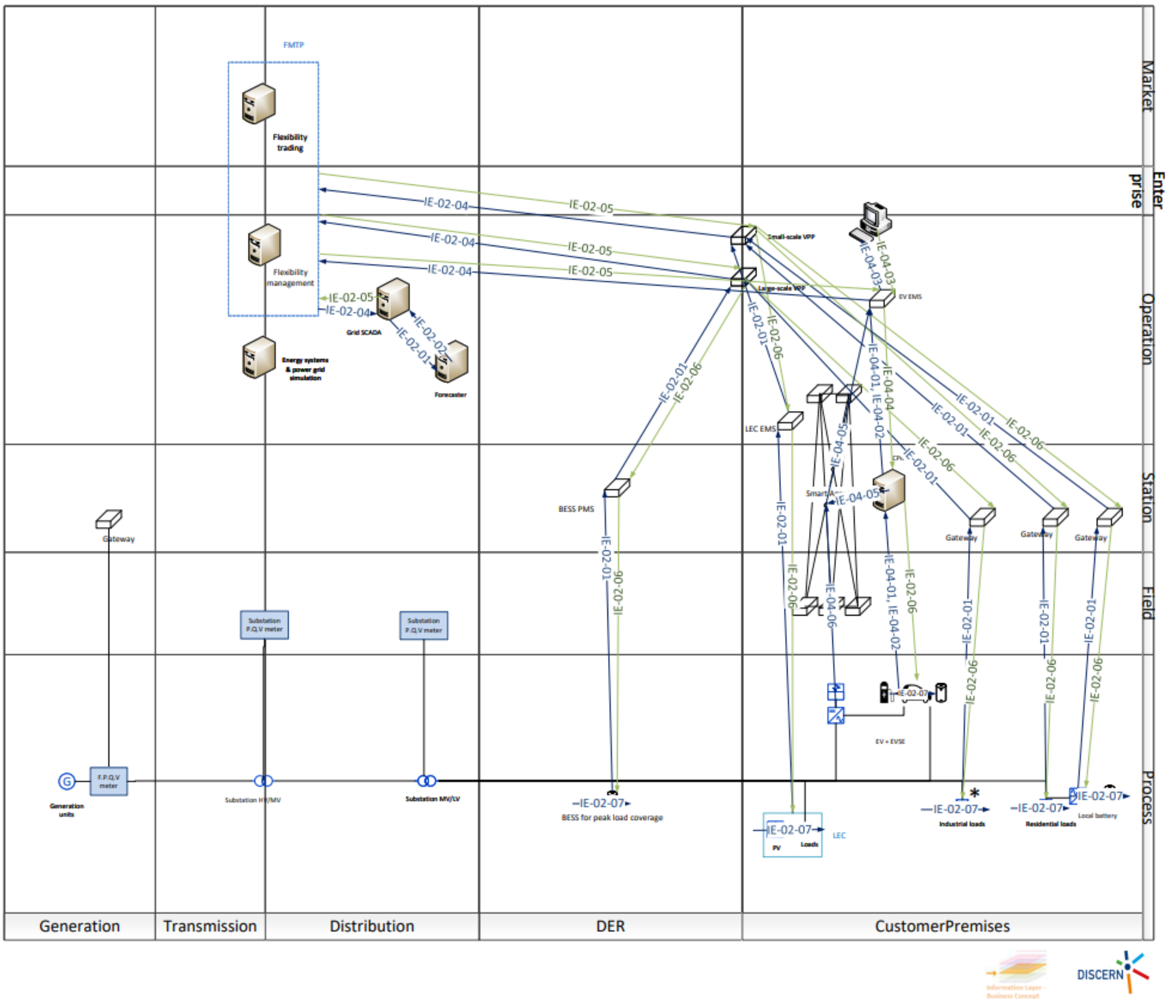


Figure 41: SGAM information layer of the minimization of the consumption peak use case-specific architecture (flexibility market)

Scenario name	**Sc3 – Minimization of the consumption peak by following the EV signal used to advertise favourable periods of consumption**						
Step No.	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***

St1	(Regularly, on a daily basis)	Development of the EV signal	The SO estimates the favourable and unfavourable periods of consumption for the next day by analysing the demand forecast	CREATE	SO	IE-03-01	
St2	(Regularly, on a daily basis)	Reading of the EV signal	EV EMS and LEC EMS read the EV signal advertised by EDM on its Open Data to advertise favourable periods of consumption through the API proposed on the Open Data (GET request)	GET	EV EMS, LEC EMS	IE-03-01	
St3	After completing previous step	Control dispatching upon analysis of the EV signal	EV EMS and LEC EMS perform the proper control dispatching according to the EV signal read: • 1 means that the period is favourable and that EV charging is recommended at 7.4kW max • 0 means that the period is not favourable and that the charging is to avoid or to limit at 3.7kW max Note that consumer's preferences have the priority. For instance, the EV EMS will propose a charging/discharging schedule respecting the EV driver's preferences on EV state of charge and departure time.	EXECUTE	EV EMS, LEC EMS	IE-03-02	

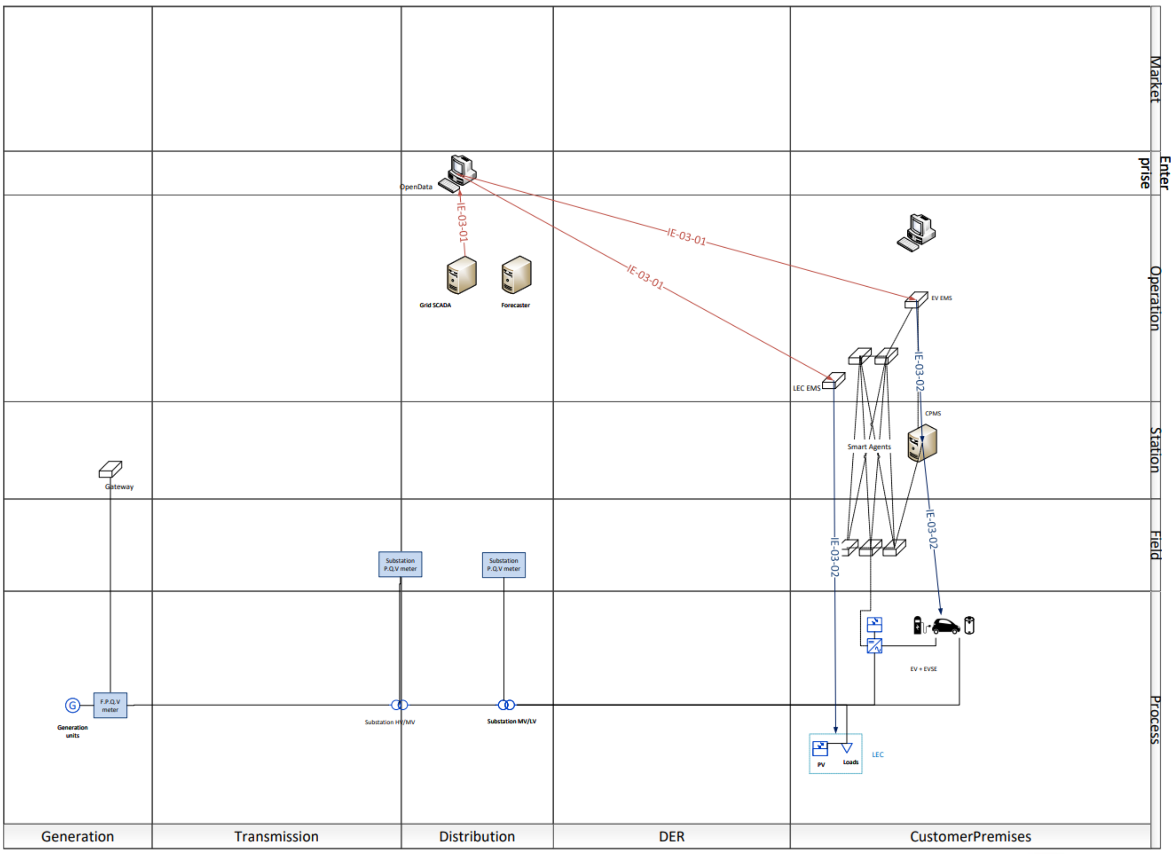


Figure 42: SGAM information layer of the minimization of the consumption peak use case-specific architecture (EV signal)

Scenario name	**Sc4 - Smart charging/V2G for congestion management**						
Step No.	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***

St1	EV driver's will to charge its car	Plug of the EV to the Charging Point	EV driver connects the vehicle to its EV charger and authenticates using RFID/NFC tag	CREATE, REPORT	EV driver	IE-04-01	St1
St2	Completion of previous step	Authentication		EXECUTE	Charging Point	IE-04-01	
St3	Completion of previous step	Communication of event St1 to the EV EMS	The Charging Point Management System (CPMS) communicates with EV EMS information about connected charger and ID tag of the EV driver	REPORT	Charging Point Management System (CPMS)	IE-04-01 IE-04-02	
St4	Completion of previous step	Request for EV driver information	The EV EMS sends a notification to EV driver's mobile app asking driver's preferences, such as initial state of charge, desired state of charge, departure time, etc. and if he wants to engage in smart charging	GET	EV EMS and mobile app	IE-04-03	
St5	The EV driver reacts to the notification and sets its preferences	Receive EV driver information	The EV driver sets its preferences in the mobile app, which sends it back to the EV EMS	REPORT	Mobile app and EV EMS	IE-04-03	
St6	Completion of previous step	Smart charging profile calculation	EV EMS calculates the smart charging profile considering the EV driver's preferences and other input parameters provided by energy generation and demand forecasts	EXECUTE	EV EMS	IE-04-04	
St7	Completion of previous step	EV EMS communicates smart charging profile with CPMS	EV EMS communicates the smart charging profile to CPMS every minute	REPORT	EV EMS	IE-04-04	
St8	Completion of previous setup	Charge / discharge is communicated to the EVSE	The CPMS communicates with the EVSE to charge based on the received smart charging profile	REPORT	CPMS	IE-04-04	
St9	Completion of previous step	EVSE begins charge / discharge	Based on the information received from the CPMS, the EVSE begins to charge / discharge the EV	EXECUTE	EVSE and CPMS	IE-04-04	
St10	Completion of previous step	EV EMS recalculates the entire charging profile	The EV EMS recalculates the entire smart charging profile in relation to the load profiles of other cars every 15 minutes, effectively charging / discharging the EV considering grid congestion data, energy prices, consumption peaks, and local renewable energy production	EXECUTE	EV EMS	IE-04-04	
St11	Completion of previous step	Incentives are transferred to EV driver for allowing flexibility using smart charging	EV EMS transfers the incentives to EV driver's token wallet based on his/her participation in smart charging and V2G flexibility participation. Note that EV drivers receive incentives only when they participate in smart charging. Also, those tokens are not public crypto currencies that can be traded on the exchange. It is loyalty point that can be linked to services such as the reduction of parking fees or discount for the rental of a shared vehicle.	EXECUTE	EV EMS		

St12	Periodically	Charge points meter readings	Charge point meter readings are received from the CPMS and communicated to the EV EMS, tracking each kWh of energy charged and discharged in the smart charge points	REPORT	Smart Agents	IE-04-05	
St13	Periodically	Solar PV production meter readings	Meter readings of the solar PV energy production (kWh) are performed, auditing its source of origin and sharing information to prevent double spending	REPORT		IE-04-06	
St14	Periodically upon completion of energy transactions (St12 & St13)	Smart Agents perform energy transactions	Bovlabs Smart Agents perform energy transactions with the continuous information gathered in St12 and St13, using a Proof of Authority consensus algorithm and light blockchain architecture	EXECUTE	Smart Agents	IE-04-07	

5 Information exchanged

Information exchanged			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE-01-01	Flexibility market description	Public document describing the flexibility market, the products and the related requirements. This document will be described in WP4.	
IE-01-02	Participation in flexibility market approval	Document certifying that a specific flexibility provider is allowed to participate in the flexibility market described in IE-01-01	
IE-02-01	Consumption data	Various consumption data collected from the assets involved in the flexibility market for minimizing the consumption peak. Those data are highly linked to R-02-01: At least one utility meter should be installed in each of the facility involved in the flexibility market and should communicate consumption/generation data at the facility level. At least, data should present a 30-minute granularity and be pushed to the SO once per day.	
IE-02-02	Baseline forecast	Estimate of the future demand that is based on the historical demand	
IE-02-03	Flexibility potential forecast	Estimate of the flexibility potential of the asset (by load shedding or load shifting)	
IE-02-04	Flexibility bid	A flexibility bid consists of the aggregation of the flexibility potentials of the different assets connected to an intermediate platform. They usually come with a pricing.	
IE-02-05	Flexibility activation request	A flexibility activation is a request from the SO to modify the load profile at a specific location by reducing the consumption.	
IE-02-06	Disaggregated flexibility activation	Flexibility activation request is disaggregated for control dispatching of the different assets connected to the intermediate platforms.	
IE-02-07	Consumption profile	Consumption profile of the assets involved in the flexibility market. Ideally, if a flexibility activation has been requested by the SO, it should be different from the baseline forecast (IE-02-02) as the assets has performed load shifting/shedding to minimize the consumption peak.	
IE-02-08	Flexibility reward	Reward of the flexibility providers for its participation in the flexibility market. Note that this reward can be transformed in penalties if the flexibility providers did not follow the flexibility activation requested by the SO.	

IE-03-01	EV signal	EV signal, available on EDM Open Data to advertise favourable periods of Electric Vehicles charging – to promote Smart Charging and to not add any burden on the electricity grid of the island. This signal is binary: • 1 means that the period is favourable and that EV charging is recommended at 7.4kW. • 0 means that the period is not favorable and that the charging is to avoid or to limit at 3.7kW.	
IE-03-02	Control dispatching	Control dispatching proposed after analysis of the EV signal. It has the form of a charging/discharging schedule in the case of EV.	
IE-04-01	ID Tag	Authentication of EV using RFID/NFC tag	
IE-04-02	New EV connection signal	The Charging Point Management System (CPMS) communicates with EV EMS information about connected charger and EV driver data.	
IE-04-03	EV driver's preferences	Through the mobile app, the EV driver indicates its preferences for the EV parking status, such as desired state of charge, departure time, etc. and if he wants to engage in smart charging.	
IE-04-04	Smart charging profile	Charging/discharging profile to be performed by an individual EV connected to the EVSE (and related to a specific ID Tag), based upon various parameters such as EV driver's preferences, renewable energy generation forecast, energy prices and potential grid constraints	
IE-04-05	energy consumption – kWh	Charge point meter readings are received from the CPMS and communicated to the EV EMS, tracking each kWh of energy charged and discharged in the smart charge points.	
IE-04-06	Solar energy generation - kWh	Meter readings of the solar PV energy production (kWh) are performed, auditing its source of origin and sharing information to prevent double spending	
IE-04-07	Smart Agents energy transactions	Blockchain Smart Agents perform energy transactions with the continuous information gathered in St12 and St13, using a Proof of Authority consensus algorithm and light blockchain architecture.	

6 Requirements (optional)

Requirements (optional)		
Requirement R-ID	***Requirement name***	***Requirement description***
R-02-01	Communicating utility meters should be installed	At least one utility meter should be installed in each of the facility involved in the flexibility market and should communicate consumption/generation data at the facility level. At least, data should present a 30-minute granularity and be pushed to the SO once per day.
R-02-02	Access to consumption data should be granted to partners	Partners should have access to consumption data for the proper operation of their solution (forecasting step). Related cybersecurity and privacy issues should be tackled.

7 Common terms and definitions

Common terms and definitions	
Term	***Definition***
C&I	Commercial and Industrial
CPMS	Charging Point Management System
DER	Distributed Energy Resource
DR	Demand Response
EDM	Electricité de Mayotte
EMS	Energy Management System
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment

FMTP	Flexibility Management and Trading Platform
HV	High Voltage
LEC	Local Energy Community
LV	Low Voltage
MV	Medium Voltage
NFC	Near Field Communication
RFID	Radio Frequency Identification
SA	Smart Agent
SO	System Operator
UC	Use Case
V2G	Vehicle-to-Grid
VPP	Virtual Power Plant

Maximization of the use of RES

1. Description of the use case

1.1 Name of the use-case

Use case identification		
ID	***Area/Domain/Zone(s)***	***Name of the use case***
UC4	Area: Energy system, Domain: DER, Customer Premises Zones: Operation	Maximizing the use of Renewable Energy Sources

1.2 Version management

Version management				
Version No.	***Date***	***Name of author(s)***	***Changes***	***Approval status***
0.0	16/07/2021	Marjolaine Farré (Trialog)	Initial creation	Draft
0.1	11/08/2021	Nicolas Peiffer (Tecsol)	• Scope and objectives • Complete description	
0.2	10/09/2021	Marjolaine Farré (Trialog), Juan Varo Lopez, Pablo Gonzalez Reed (Creara), Jk Pillai (Bovlabs)	Description of scenarios	
0.3	04/10/2021	Nicolas Peiffer (Tecsol)	Finalization	

1.3 Scope and objective of use case

Scope and objectives of the use case	
Scope	The scope of this use case is to maximize the use of Renewable Energy Sources in the daily life through collective self-consumption operations, local energy communities and hybridization of assets
Objective(s)	The main objective of this use case is to maximize the use of Renewable Energy Sources through: • The decentralization of renewable energy production and empowerment of citizens using collective self-consumption operations or energy communities • Higher levels of solar energy for charging electric vehicles to lower emissions in the transport sector • Higher levels of solar energy in climatization (HVAC) devices

1.4 Narrative of use case

Narrative of use case
Short description
This use case aims at implementing collective self-consumption operations and hybridizing assets (EV charging station and air-conditioning units) with photovoltaic panels to maximize the use of Renewable Energy Sources.
Complete description
The main objective of MAESHA is to decarbonise the energy systems of geographical islands, with two specific objectives relevant for this use case: 1. **Reach up to 70 to 100% of Renewable Energy penetration with close collaboration between Local Energy utilities, communities, modellers and flexibility solutions providers** The potential for PV is high in Mayotte. With an electricity grid not fully conforming to European standards yet and many PV installations waiting for a connection to the main grid, many prosumers install small PV production units (e.g., rooftop panels) to use a local and renewable electricity production. Those operations are named individual self-consumption. In MAESHA, we will examine how those operations could be extended to a community level through the development of **collective self-consumption** and the creation of multiple Local Energy Communities. 2. **Create synergies between electricity and other networks**

The transport system in Mayotte, which is the primary source of GHG emissions on the territory (36%), is almost exclusively based on thermal vehicles. Very few Electric Vehicles are being deployed (of the order of a few tens of units (see [4])). However, if charged with carbonized electricity, as the one produced by the EDM diesel power plants, the benefit for the environment is small (approximately equivalent to a recent thermal vehicle of the same category, see [4]).

The law on the orientation of mobilities, published in the official gazette on December 26, 2019, includes a ban on the sale of cars using carbon-based energy by 2040. Thus, it is necessary to engage an ambitious transition on the department of Mayotte. The Multi-Annual Energy Programming objective is migrating to 10% of electric vehicle until 2030. The first electric vehicles have been purchased by dealers to meet the demand of companies or local authorities for the replacement of their fleet in 2019. Indeed, the TECV law (article L. 224-7 and L. 224-8 of the environment code) fosters local authorities to integrate vehicles with lower GHG emissions into their fleet. A call for projects from ADEME has made it possible to launch the first recharging infrastructure development projects. Thus, on the territory of the Community of Communes of the South (CCSUD), 5 stations, each coupled with a photovoltaic power station, will be equipped to recharge about ten vehicles of the CCSUD and supply the 4 town halls of the territory. A similar project exists on the territory of the Community of Communes of Petite Terre (CCPT). It is important to highlight that those charging stations will be limited to 3.7 kVA or 7.4 kVA when supplied by electricity coming from the grid, depending on the EV signal (see section 4.1.3), and to 22 kVA when supplied by local solar electricity. *Local authorities are thus really interested in the MAESHA solution to maximize the use of Renewable Energy Sources to charge their EVs.*

In MAESHA, to foster the deployment of a more sustainable way of travelling across the island and to improve air quality, it has thus been decided to examine **the hybridization of the Electric Vehicles charging stations with PV production** and to synchronize the period of charging with period of local and renewable production.

Additionally, in the tropical climate of Mayotte, many consumers are relying on air-conditioning units or cooling systems to deal with the high temperatures. An EDM study reveals that the importation of air-conditioning units has increased by 77% in three years (2017-2019), with approximatively 60% of the population in Mayotte being equipped with such systems. With an average number of 2.3 air-conditioning units per household, the number of such systems is evaluated at 87000 (November 2020). The electricity consumption of this equipment is intensive and has a direct impact on the electricity system of the island. As air-conditioning units are mostly used during the warmer (and the sunnier) hours of the day, it has been decided to examine the **coupling of such systems with PV production**.

The different sub-systems in MAESHA supporting this use case are:

Collective self-consumption

The French Energy code defines individual and collective self-consumption in 2015 and 2016. The self-consumption operation is collective when the supply of electricity is carried out between one or more (PV) producers and one or more final consumers linked together within a legal entity and whose consumption and injection points are located in the same building, including residential buildings[19]. This framework is a way to involve citizens in the energy transition subject and to empower them. Collective self-consumption scheme allows to free PV producers from the limits of individual self-consumption such as the absence of outputs for the local production not consumed (in case of surplus, the local production is lost). It also pushes back the need for a battery to store electricity as most of it is consumed by the PV owner and the different consumers involved in the self-consumption operation.

Decentralized Energy Management within Local Energy Community

Local Energy Communities (LECs) are, most commonly, legal entities such as associations or cooperatives which are involved in generation and self-consumption of renewable energy. Often, LECs consist of prosumers, meaning members who both produce and consume renewable energy. These may own generation assets, practice self-consumption, share electric vehicles supply equipment or are active in the local energy market through selling excess energy or being engaging in flexibility services. By offering local energy arbitration based on individual's needs, the energy management system developed within MAESHA will maximize the self-consumption of the LEC by aggregating the loads and the supply of the community.

Hybridization of EV stations with PV production

EV charging stations coupled with PV production units allow for the recharging of EVs with renewable solar energy, allowing for the growing number of EVs in Mayotte to be powered with clean energy sources when solar production is available, reducing the GHG emissions generated by the charging through carbonized electricity. In addition, when there is an excess of PV production (perhaps due to a low number of EVs being charged at a particular moment), the energy can be fed to the grid to avoid curtailment and provide further services for the maximization of RES in the island. The benefits of this hybridization can be extended by smart charging as presented below.

In MAESHA, it has been decided to renew the DSO's fleet of vehicles with EVs and to install a charging station coupled with a PV production for the usage of EDM.

Smart Charging/V2G

[19] Source: French Energy Code (Art. 315-2) (see [8])

Smart charging is the process by which Electric Vehicles (EVs) connected to charging stations are charged/discharged, taking into account various factors such as consumption peak, renewable energy production or low/high tariff periods. Upon analysis of the renewable energy generation forecast, the Charging Point Management System can synchronize the charging of the EV with periods of local generation, while respecting the EV driver's preferences (desired state of charge at its departure time). By implementing Vehicle-to-Grid, EV batteries can be used as distributed storage units to store solar electricity when plugged to a hybridized charging station during sunny hours and to discharge during darker hours for different purposes (charging of other EVs, avoiding the start-up of polluting peak power plants, etc.). It thus maximizes the use of Renewable Energy Sources and the environmental impact of this use case. **Hybridization of cold production with PV production** As air-conditioning units are mostly used during the warmer (and the sunnier) hours of the day, it has been decided to examine the coupling of such systems with PV production. It's a practical way to use the surplus of a PV installation.

1.5 Key performance indicators

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
KPI 1.4	Renewable energy capacity installed in Mayotte thanks to MAESHA solutions	Target: 20 MW	Extracted from the Grant Agreement
KPI 1.13	Horizon for full decarbonisation of the transport sector in Mayotte	Target: 2040	Extracted from the Grant Agreement
KPI 1.14	Horizon for full decarbonisation of the energy sector in Mayotte	Target: 2050	Extracted from the Grant Agreement
KPI 3.1	Number of Local Energy Communities created in Mayotte	Target: >10	Extracted from the Grant Agreement
KPI 3.2	Number of LEC created in follower islands	Target: >6	Extracted from the Grant Agreement
KPI 3.3	Number of LEC created from the project	Target: >15	Extracted from the Grant Agreement
KPI 3.4	Number of people involved in a LEC	Target: >100	Extracted from the Grant Agreement
KPI 3.5	Total number of people involved in MAESHA LEC	Target: >2000	Extracted from the Grant Agreement
KPI 3.6	Total energy produced by LECs in self-consumption during MAESHA	Target: >5 MWh	Extracted from the Grant Agreement
KPI 5.1	Reduction of GHG emissions for electricity sector in Mayotte at the end of MAESHA	Target: -30%	Extracted from the Grant Agreement
KPI 5.2	Reduction of GHG emissions for electricity sector in Mayotte 10 years after MAESHA	Target: -60%	Extracted from the Grant Agreement
KPI 5.3	Reduction of GHG emissions for mobility sector in Mayotte at the end of MAESHA	Target: -10%	Extracted from the Grant Agreement
KPI 5.4	Reduction of GHG emissions for mobility sector in Mayotte 10 years after MAESHA	Target: -50%	Extracted from the Grant Agreement
KPI 5.5	Reduction of particulate matter emissions from mobility sector in Mayotte at the end of MAESHA	Target: -20%	Extracted from the Grant Agreement
KPI 5.6	Reduction of particulate matter emissions from mobility sector in Mayotte 10 years after MAESHA	Target: -70%	Extracted from the Grant Agreement
KPI 7.1	Share of income of households spent on electricity bill in LEC	Target: <15%	Extracted from the Grant Agreement

1.6 Use case conditions

Use case conditions
Assumptions

• Assuming residential prosumers will be interested in joining a collective self-consumption operation • Assuming residential prosumers will be interested in forming a Local Energy Community • Assuming EV stations coupled with PV production will be installed and operating • Assuming V2G-compatible EVs will be deployed in Mayotte at the time of the demonstration • Assuming cold production and PV panels will be installed and operating in a collective self-consumption operation
Prerequisites
• For hybridization of EV charging station with PV production: EVs should be plugged to EV charging station during sunny hours • For collective self-consumption operations: smart meters (i.e., Linky meters) should be installed in each household

1.7 Further information to the use case for classification/mapping

Classification information
Relation to the other use cases
Linked to “Minimize the consumption peak” UC as this use case may also lead to a reduction of the consumption peak for the DSO
Level of depth
High-level Use Case
Prioritization
Generic, regional or national relation
Generic
Nature of the use case
Further keywords for classification
Self-consumption, hybridization, Local Energy Community

1.8 General remarks

General remarks

2 Diagrams of use case

Diagram(s) of use case

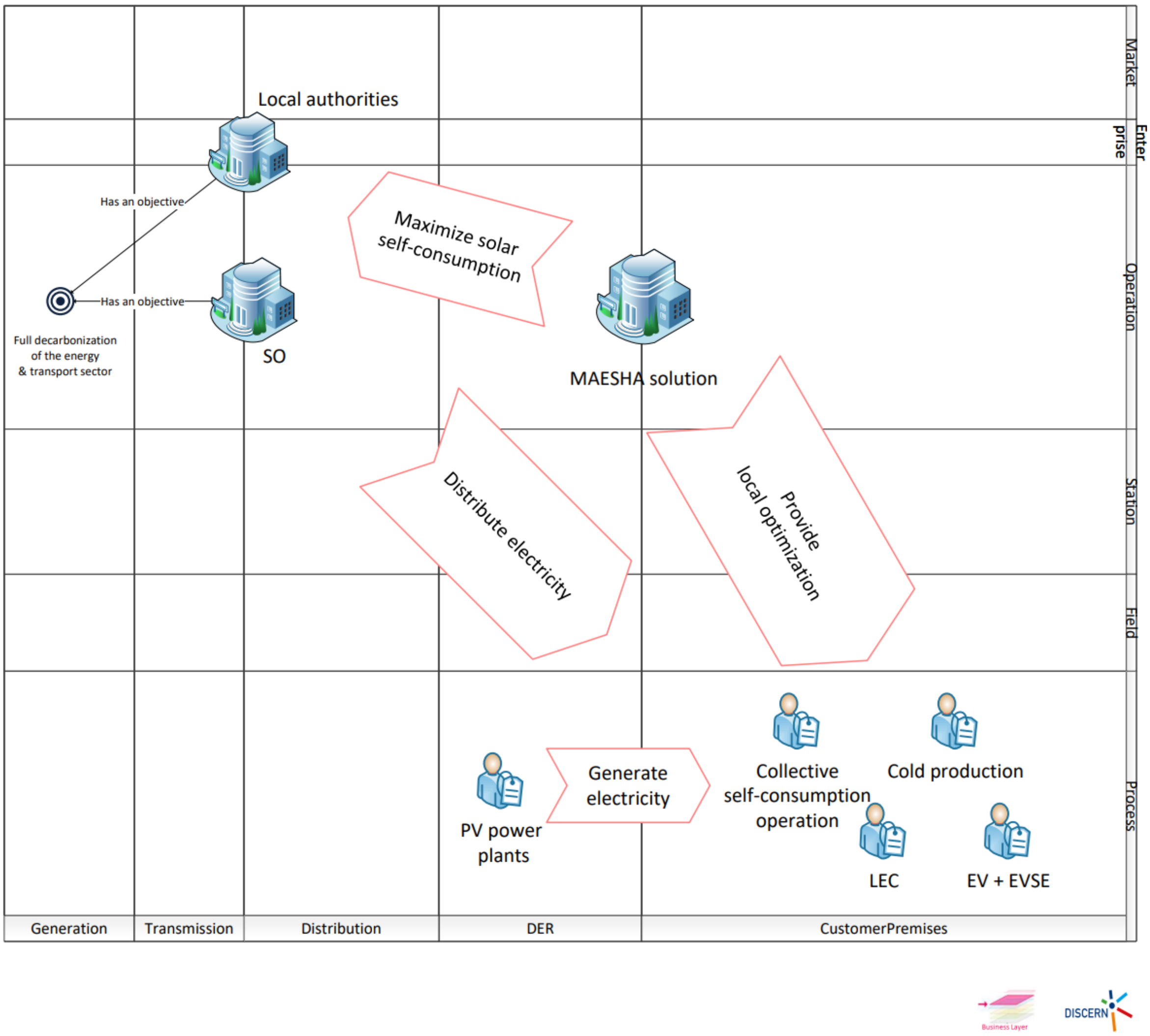


Figure 43: SGAM business layer of the maximization of RES use case-specific architecture

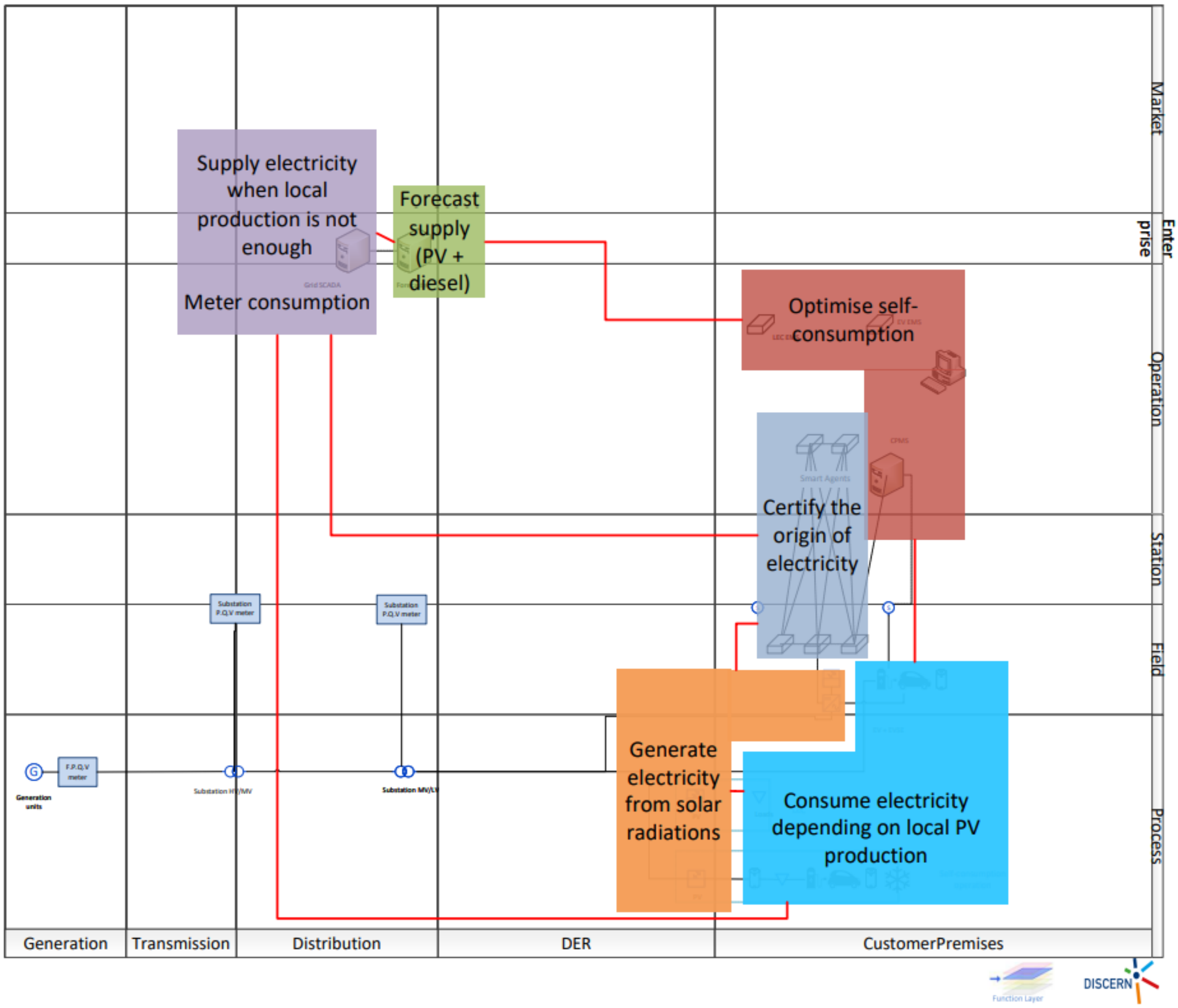


Figure 44: SGAM function layer of the maximization of RES use case-specific architecture

Local authorities and SO are represented in this illustration as the MAESHA solution will provide them with a service of self-consumption maximization when charging their EVs fleets.

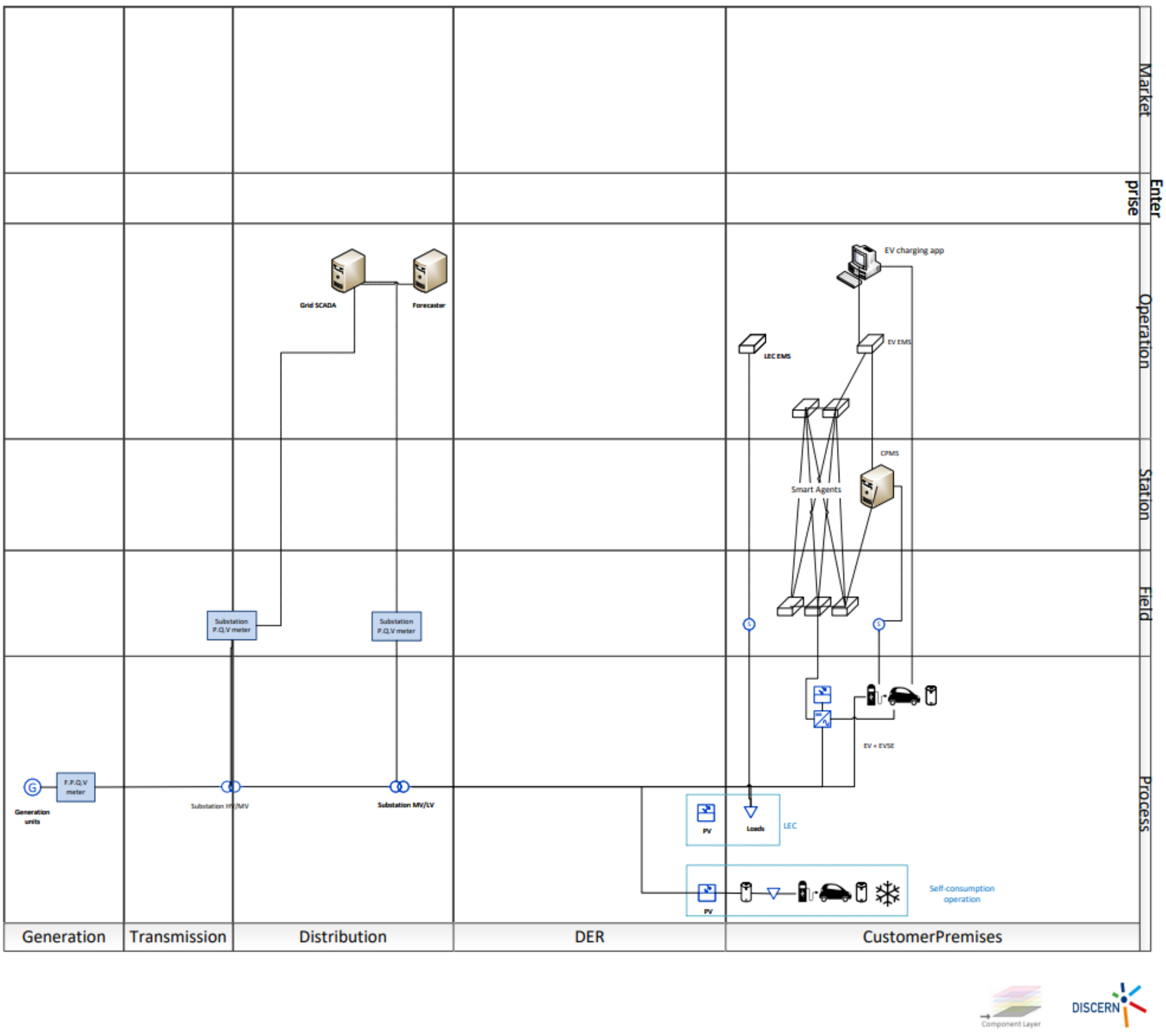


Figure 45: SGAM component layer of the maximization of RES use case-specific architecture

3 Technical details

3.1 Actors

Actors			
Grouping		***Group Description***	
Business Actor		Physical or legal person that has his own interests, defined as "Business Goals"	
Logical Actor		Technical entity that takes part in the execution of a use case. A logical actor can be mapped to a physical component	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
Forecaster	Logical Actor	A system that forecasts the energy demand as well as the generation	
Residential prosumer	Business Actor	A residential party that consumes electricity	
Local Energy Community (LEC)	Business Actor	An organisation based on open and voluntary participation of civil society, which owns and controls its operations in market activities such as generation, distribution, supply, consumption, aggregation, energy storage, energy efficiency, or charging services for electric vehicles	
Electric Vehicle (EV)	Logical Actor	Automobile which is powered completely or in part by electricity and whose battery can be charged from an EVSE	
Electric Vehicle Supply Equipment (EVSE)	Logical Actor	Electric Vehicles charger	

Charging Point Management System (CPMS)	Logical Actor	This application is used for managing the charging stations. The back-office systems support standard protocols like OCPP 1.6, 2.0 to integrate with charging stations.	Developed by Bovlabs
EV Energy Management System (EV EMS)	Logical Actor	This application is used for optimization of charging stations by smart charging and V2G integration bringing in resilience to the Grid.	Developed by Bovlabs
EVSE Smart Agents (EVSE SA)	Logical Actor	Smart Agents are used for communicating the meters and recording P2P energy transactions related to EVSE and EV. They could also provide intelligence at edges to enable smart charging and V2G	Developed by Bovlabs
PV production units	Logical Actor	Small unit which generates energy from solar sources and which is connected to the distribution grid	
Cold production	Logical Actor	Process of removing heat and controlling the humidity of air in an enclosed space to achieve a more comfortable interior environment by use of powered 'air conditioners' or a variety of other methods including passive cooling and ventilative cooling	
LEC Energy Management System (EMS)	Logical Actor	Technical module allowing decentralized energy management within local energy communities. This module offers local energy arbitration (including DER, stationary storage, V1G, V2G, etc.) based on users' needs, maximization of collective self-consumption and assessment of potential "locally-aggregated flexibility" (i.e., the flexibility that the LEC can offer)	Developed by Trialog

4 Step by step analysis of use case
4.1 Overview of scenarios

Scenario conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
Sc1	Collective self-consumption	This scenario describes the concept of collective self-consumption	Community			
Sc2	Optimization of the EV charging (Smart charging/V2G)	This scenario describes how the MAESHA solution synchronized the EV charging with period of local renewable electricity generation	EV			

4.2 Steps – Scenarios

Scenario							
Scenario name		**Sc1 – Collective self-consumption**					
Step No.	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***
The French Energy code define individual and collective self-consumption in 2015 and 2016. The self-consumption operation is collective when the supply of electricity is carried out between one or more (PV) producers and one or more final consumers linked together within a legal entity and whose consumption and injection points are located in the same building, including residential buildings20. This framework is a way to involve citizens in the energy transition subject and to empower them. Collective self-consumption scheme allows to free PV producers from the limits of individual self-consumption such as the absence of outputs for the local production not consumed (in case of surplus, the local production is lost). It also allows, by multiplying the consumption, to push back the recourse to batteries to store electricity and limit the ecological impact of self-consumption. In this framework, it is possible to imagine an operation at a building scale or neighbourhood scale, within a radius of 1km. Please note that prosumers can be behind different MV/LV substations and connected to MV and/or LV grid. All the participants are linked together inside a legal entity, led by an Organizing Moral Entity (OME or PMO in French, for "Personne Morale Organisatrice"). This entity is the contact person of the DSO and choose the solar production breakdown. This solar production breakdown represents the share of solar production allocated to each participant of the LEC. There are 3 types of breakdowns: – Static							

[20] Source: French Energy Code (Art. 315-2) (see [8])

- Dynamic by default
- Dynamic customized

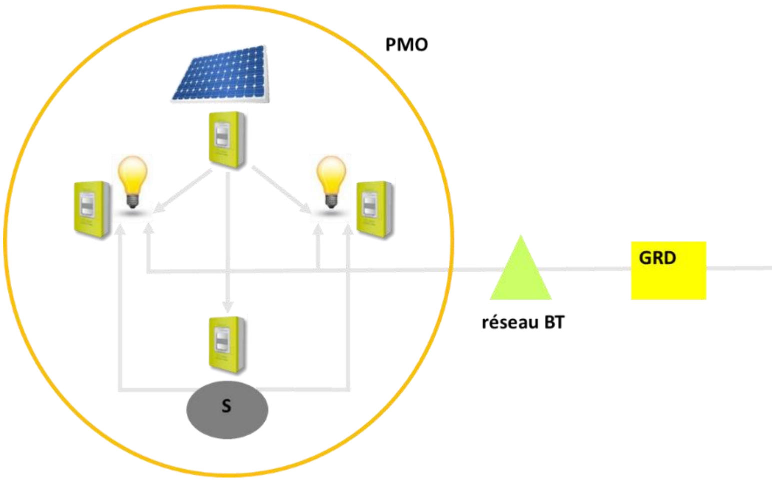


Figure 46: Collective self-consumption actors

Note that "PMO" stands for "Personne Morale Organisatrice" (or OME in English), "reseau BT" for "low-voltage grid" and GRD for DSO.

Scenario name	**Sc2 – Optimization of the EV charging (Smart charging/V2G)**						
Step No.	***Event***	***Name of process/activity***	***Description of process/activity***	***Service***	***Information producer (actor)***	***Information exchanged (IDs)***	***Requirements, R-IDs***
St1	EV driver's will to charge its car	Plug of the EV to the Charging Point	EV driver connects the vehicle to its EV charger and authenticates using RFID/NFC tag	CREATE, REPORT	EV driver	IE-02-01	
St2	Completion of previous step	Authentication		EXECUTE	Charging Point	IE-02-01	
St3	Completion of previous step	Communication of event St1 to the EV EMS	The Charging Point Management System (CPMS) communicates with EV EMS information about connected charger and ID tag of the EV driver	REPORT	Charging Point Management System (CPMS)	IE-02-01 IE-02-02	
St4	Completion of previous step	Request for EV driver information	The EV EMS sends a notification to EV driver's mobile app asking driver's preferences, such as initial state of charge, desired state of charge, departure time, etc. and if he wants to engage in smart charging	GET	EV EMS and mobile app	IE-02-03	
St5	The EV driver reacts to the notification and sets its preferences	Receive EV driver information	The EV driver sets its preferences in the mobile app, which sends it back to the EV EMS	REPORT	Mobile app and EV EMS	IE-02-03	
St6	Completion of previous step	Request for renewable energy generation forecast	The EV EMS requests the renewable energy generation forecast to the Forecaster. Please note that the Forecaster will provide a generation forecast for the whole island. For local optimization, this forecast might thus be a bit inaccurate.	GET	EV EMS	IE-02-04	

St7	Completion of previous step	Receive renewable energy generation forecast	The Forecaster sends the renewable energy generation forecast to the EV EMS	REPORT	Forecaster	IE-02-04	
St8	Completion of previous step	Smart charging profile calculation	EV EMS calculates the smart charging profile considering the EV driver's preferences and the renewable energy generation forecast	EXECUTE	EV EMS	IE-02-05	
St9	Completion of previous step	EV EMS communicates smart charging profile with CPMS	EV EMS communicates the smart charging profile to CPMS every minute	REPORT	EV EMS	IE-02-05	
St10	Completion of previous setup	Charge / discharge is communicated to the EVSE	The CPMS communicates with the EVSE to charge based on the received smart charging profile	REPORT	CPMS	IE-02-05	
St11	Completion of previous step	EVSE begins charge / discharge	Based on the information received from the CPMS, the EVSE begins to charge / discharge the EV	EXECUTE	EVSE and CPMS	IE-02-05	
St12	Completion of previous step	EV EMS recalculates the entire charging profile	The EV EMS recalculates the entire smart charging profile in relation to the load profiles of other cars every 15 minutes, effectively charging / discharging the EV considering grid congestion data, energy prices, consumption peaks and local renewable energy production	EXECUTE	EV EMS	IE-02-05	
St13	Periodically	Charge points meter readings	Charge point meter readings are received from the CPMS and communicated to the EV EMS, tracking each kWh of energy charged and discharged in the smart charge points	REPORT	Smart Agents	IE-02-06	
St14	Periodically	Solar PV production meter readings	Meter readings of the solar PV energy production (kWh) are performed, auditing its source of origin and sharing information to prevent double spending	REPORT		IE-02-07	
St15	Periodically upon completion of energy transactions (St12 & St13)	Smart Agents perform energy transactions	Bovlabs Smart Agents perform energy transactions with the continuous information gathered in St12 and St13, using a Proof of Authority consensus algorithm and light blockchain architecture	EXECUTE	Smart Agents	IE-02-08	

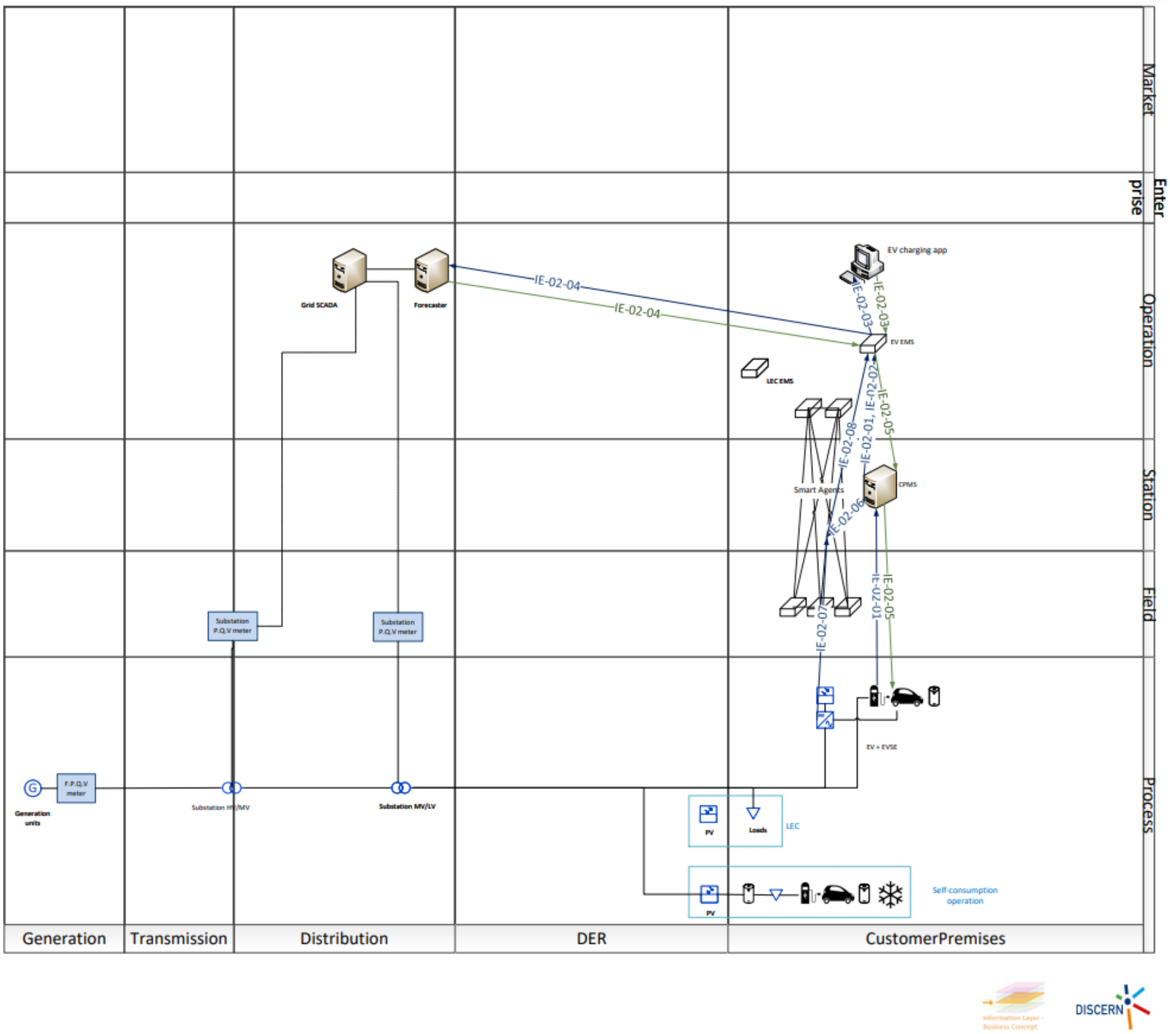


Figure 47: SGAM information layer of the maximization of self-consumption and hybridization use case-specific architecture

5 Information exchanged

Information exchanged			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
IE-02-01	ID Tag	Authentication of EV using RFID/NFC tag	
IE-02-02	New EV connection signal	The Charging Point Management System (CPMS) communicates with EV EMS information about connected charger and EV driver data.	
IE-02-03	EV driver’s preferences	Through the mobile app, the EV driver indicates its preferences for the EV parking status, such as desired state of charge, departure time, etc.	
IE-02-04	Renewable energy generation forecast	Local renewable energy generation forecast, calculated by the Forecaster	
IE-02-05	Smart charging profile	Charging/discharging profile to be performed by an individual EV connected to the EVSE (and related to a specific ID Tag), based upon various parameters such as EV driver’s preferences, renewable energy generation forecast, energy prices and potential grid constraints	
IE-02-06	Energy consumption – kWh	Charge point meter readings are received from the CPMS and communicated to the EV EMS, tracking each kWh of energy charged and discharged in the smart charge points.	

IE-02-07	Renewable energy generation - kWh	Meter readings of the renewable energy generation (kWh) are performed, auditing its source of origin and sharing information to prevent double spending	
IE-02-08	Smart Agents energy transactions	Blockchain Smart Agents perform energy transactions with the continuous information gathered in St13 and St14, using a Proof of Authority consensus algorithm and light blockchain architecture	

Common terms and definitions

Common terms and definitions	
Term	***Definition***
CPMS	Charging Point Management System
DER	Distributed Energy Resource
DSO	Distribution System Operator
EDM	Electricité de Mayotte
EMS	Energy Management System
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
GHG	Greenhouse Gas
KPI	Key Performance Indicator
LEC	Local Energy Community
NFC	Near Field Communication
OCPP	Open Charge Point Protocol
P2P	Peer-to-Peer
PV	Photovoltaic
RES	Renewable Energy Sources
RFID	Radio Frequency Identification
SA	Smart Agent
SGAM	Smart Grid Architecture Model
SO	System Operator
TECV	Transition Energétique pour la Croissance Verte
UC	Use Case
V2G	Vehicle-to-Grid

Energy access

1. Description of the use case

1.1 Name of the use-case

Use case identification		
ID	***Area/Domain/Zone(s)***	***Name of the use case***
UC5	Area: Energy Domain: DER, Customer Premises Zones: Operation	Energy Access

1.2 Version management

Version management				
Version No.	***Date***	***Name of author(s)***	***Changes***	***Approval status***
0.0	10/08/2021	Tidian Baerens (HUD)	Initial Version	Draft
0.1	13/08/2021	Lucia González Cuadrado (COBRA)	Update	Draft 2
0.2	01/09/2021	Marjolaine Farré (Trialog)	Update	Draft 3
0.3	02/09/2021	Tidian Baerens (HUD)	Update	Draft 4
1.0	06/09/2021	Tidian Baerens (HUD)/Marjolaine Farré/Lucia González	Update	Draft 5
1.1	01/10/2021	Nicolas Peiffer (TECSOL)	Finalized version	Draft 6

1.3 Scope and objective of use case

Scope and objectives of the use case	
Scope	Provision, reliable and affordable access to electricity, ideally from renewable energy sources
Objective(s)	The objective of the use case is to respond to the lack of (reliable) access to electricity in Mayotte, thus fostering higher community involvement and support for renewable energy technology.
Related business case(s)	

1.4 Narrative of use case

Narrative of use case
Short description
The objective of the use case is to respond to the lack of reliable access to electricity in Mayotte. The use case builds on Sustainable Development Goal (SDG) 7, to “ensure access to affordable, reliable, sustainable and modern energy for all”, while at the same time offering services to the grid and fostering the involvement of (marginalized) communities.
Complete description
Despite officially being part of the European Union, existing socio-economic differences should be considered when implementing a technological innovation project such as MAESHA in Mayotte. Official statistics illustrate the contextual differences of the island compared to many of the follower islands and of mainland Europe[21]. With an annual population-growth of 3.8 per cent, on average 5 children per woman, and a Gross Domestic Product comparable to that of Djibouti, Mayotte stands out compared to many other European regions. In comparison, the GDP of La Réunion, another European oversea department, is more than double of the GDP of Mayotte (Mayotte ann. GDP p.c.: 13 000 $, Réunion: 27 000$). Compared to France with 16 per cent, a staggering 70-84 per cent of people in Mayotte live below the poverty line. Conservative estimates state that 25.9 per cent of the population is unemployed and half of the population is younger than 18 years old. Due to this lack of perspectives for young people, many of those who have the possibility leave the island, resulting in a brain-drain. It is estimated that around half of Mayotte’s 500 000 residents do not hold a valid legal status. Official statistics suggest that 30 per cent of the population have insufficient access to running water and 40 per cent live in sheet metal houses, often without clearly defined

21 INSEE, 2021. See [2]

property rights of the inhabited land and without connection to the main grid. Ultimately, the local energy infrastructure suffers from a growing number of illegal connections and energy theft is posing a major challenge to the local Distribution System Operator (DSO)/Transmission System Operator (TSO). The reduction of these illegal connections as one goal of MAESHA (see KPI 3.6) and the necessity to consider the local context and requirements of the local population have led to the formation of the Energy Access Use-Case which is described in this chapter.

The community-based approach lies at the heart of the MAESHA project and it is crucial for the projects' success, impact and sustainability. This also means that relevant community needs, such as the demand for better energy-access, must be considered from an early stage on. Disregarding the local context and de-emphasizing community needs bares the risk of MAESHA being seen as intellectual or elitist project which is dedicated only to wealthy and educated individuals. Hence, a fair and just distribution of the benefits reaped from the project serve as benchmark for accomplishments of MAESHA in the region.

Further, according to community representatives, the level of awareness for Renewable Energy Technology (RET) is low. For many, RET is expensive and only for wealthy people. While the issue of climate change has gained much relevance in central Europe and in educated circles, the topic is given much less importance to by communities who struggle to meet their basic needs. Demonstration sites which focus on the better provision of energy to residents, especially those who find themselves in precarious living conditions, can have a major impact. They serve as good examples for the accessibility and potential benefits of renewable energy and to help establish trust into local authorities and even into the European Union. Visible examples of RET in vulnerable and marginalized communities are key for their further adoption and ultimately for combating climate change and energy poverty. The Use Case Energy Access also builds on the Sustainable Development Goal set by the United Nations, namely SDG7, to "ensure access to affordable, reliable, sustainable and modern energy for all."

Due to legal constraints, some of the area's most affected by energy poverty are difficult to include in the project, as residents often do not own the property rights of the land they live on. Considering this barrier, we identified three possible target groups who may benefit from the Energy Access use case.

1. Legal communities with no connection to the main grid. Note however that most legal settlers are already connected to the main grid
2. Legal communities who are connected to the main grid, but an upgrade of the connection is needed, e.g., if existing lines are congested
3. Farms or agricultural areas with no anergy access/connection to the main grid

Perspectives for solar community / collective self-consumption

A first assessment related to Energy Access has revealed that there is high potential for residential solar technology, possibly in combination with social housing and resettlement programs, set up by municipalities.

Example of a potential Local Energy Community (LEC) in Majicavo Koropa (City of Koungou):

The city of Koungou is currently carrying out a resettlement program, to relocate marginalized communities from sheet-metal settlements to low-cost houses (See image below). These houses can be equipped with solar panels which can be maintained and managed by the inhabitants of the houses. By forming a Local Energy Community, inhabitants can exert agency under the umbrella of some legal entity, such as an association. Thus, they can collectively decide over investments and other relevant issues.

Local Energy Communities can be involved in a variety of different tasks and come in different legal forms and constellations. Most common are Energy Co-operatives who are involved in collective self-consumption. Public-Private-Partnerships are also frequently found, where a public institution such as the municipality can support the LEC either financially or by other means such as legal counseling. Further, LECs can set up awareness campaigns on energy savings, provide energy services such as demand side mechanisms[22] and energy auditing or reinvest generated income in a neighborhood electric vehicle fleet. Thus, they play an important part in the transition to a green energy infrastructure and enable citizens to become an active part of the energy system.

In the case of marginalized communities such as in Majicavo Koropa, the collaboration with local public actors is crucial to overcome different entry-barriers to Local Energy Communities. The nature of these barriers stem from financial restraints or the lack of education, trust and/or other capacities. It also helps overcoming some of the substantial legal issues around informal settlements. This scenario is a step towards introducing marginalized communities to Renewable Energy Technologies and helps building capacities for active energy citizenship. At the same time, it empowers vulnerable communities to harvest the potential economic and social benefits of innovative technologies introduced by MAESHA, bringing them at the forefront of the broader social and energy transition aimed for in MAESHA. Ultimately, these communities can become role models in the region and inspire others to follow their example.

[22] Energy communities can provide services to system operators only if connected to the main grid (second category of identified target groups)

Figure 48: Majicavo Koropa resettlement program

Within MAESHA and to assist the development of a demonstration site in Majicavo Koropa in the city of Koungou, it is proposed to call upon a French metropolitan association called Sol Solidaire which develops solar projects in self-consumption[23] in social housing. This association helps to fight against energy poverty by financially supporting the installation and operation of photovoltaic power plants of social landlords, on the site of low-rent buildings, with the aim of supplying the occupants with free solar electricity produced on site.

Membership to this association is in the form of candidatures to a call for tenders launched every year between September and December. Candidates (usually landlords and/or public authorities) commit to supply the energy of the installation to their tenants. The city of Koungou could apply for this call for tenders. However, the PV power capacity installed should be between 10 and 250 kWp to be eligible for the call for tenders.

Installation and operation of PV power plants are financially supported by the association, which funds are supplied by sponsors. Funds are collected in metropolitan France but can be used for projects located in Mayotte. For our project, the sponsor could indirectly be local authorities of Mayotte through various companies. Local authorities of Mayotte (Department and Region) can subsidize companies if the objective of the subsidy concerns the development of renewable energies (like installation of PV panels). This subsidy would then be conditioned to the payment of a part of the profits of these companies to the association Sol Solidaire. It should be noted that the association Sol Solidaire does not carry out any economic activities, so this aid does not fall within the scope of the regulations on state aid.

Perspectives for Power to Hydrogen to Power P2H2P

Another perspective is the use of Power to Hydrogen to Power (P2H2P) Technology where communities with insufficient access to electricity are provided with a fuel-cell and hydrogen supply which ideally is produced from RES (Renewable Energy Sources) in an electrolyser connected to the main grid. Note that the energy mix in Mayotte is still heavily based on fossil fuels which means that the hydrogen cannot be considered green yet. However, as the transition to Renewable Energy in Mayotte progresses, the produced hydrogen becomes greener as a result. In the best case, the installation of the P2H2P technology will be accompanied by the installation of a solar plant, which compensates for the additional use of electricity.

As it is the case for residential solar energy, the provision of P2H2P can be accompanied with the formation of different legal entities forming Local Energy Communities. Both residential solar panels and P2H2P can bring benefits to localities which are not connected to the grid, e.g., agricultural areas. Besides, P2H can provide flexibility services to the main grid (e.g., frequency control), by taking advantage of the quick ramp-ups and ramp-downs and the power range of operation of the electrolyser.

This works as follows: A fuel cell is installed in an area where there is no connection to the main-grid, or it needs to be upgraded. The fuel cell would then be fueled with hydrogen which is transported from the production site where the electrolyser is connected to the main grid. Local people can be trained in the maintenance of the fuel cells, or even the transport of the hydrogen from the electrolyser to the fuel cell. This opens many opportunities to combine the provision of electricity through innovative technology and the community-based approach and formation of Energy Communities in MAESHA.

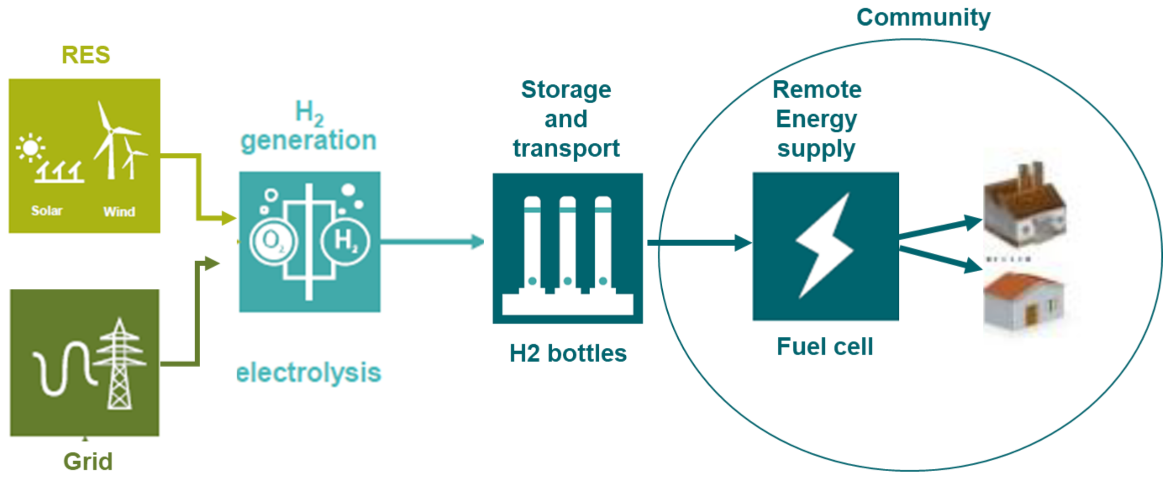


Figure 49: P2H2P process diagram

1.5 Key performance indicators

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
KPI 3.1	Number of LECs created in Mayotte	>10	Extracted from the Grant Agreement
KPI 3.6	Decrease of illegal connections thanks to LEC development	- 30 %	Extracted from the Grant Agreement
KPI 7.1	Share of income of households spent on electricity bill in LEC	<15 %	Extracted from the Grant Agreement
KPI 7.2	Direct and indirect job creation from the project	>100	Extracted from the Grant Agreement
KPI 8.1	Number of local people involved in Mayotte through community-based approach	>2000	Extracted from the Grant Agreement

1.6 Use case conditions

Use case conditions
Assumptions
• At least, one local community should be interested in taking part in MAESHA (demonstration) • Communities should be structured into a Local Energy Community • PV panels should be installed in the community • Electrolyzer should be connected to the main grid to produce hydrogen • Fuel cell should be installed in the community to turn hydrogen back into electricity • Transport of the hydrogen from the electrolyzer to the fuel cell should be organized • Electrical installation from the fuel cell to the dwellings • Best case: community is enabled to independently take care of the maintenance of the fuel-cell/solar panels • Best case: Add renewable energy to the grid in the same amount as required by the electrolyser to have green hydrogen
Prerequisites

[23] The collective self-consumption regime, defined in article L.315-2 of Code de l'Energie, authorizes one or more electricity generators to provide electricity, for free or against payment, to one or more consumers.

1.7 Further information to the use case for classification/mapping

Classification information
Relation to the other use cases
The “Energy Access” UC is quite independent from other UCs as it mainly benefits the local population, but the P2H2P system can also participate in the “Frequency Control” UC and both solutions (PV and P2H systems) in the “Minimizing Consumption Peak” UC. The benefits for the LEC can thus be extended (e.g., financial rewards) if it takes part in the stabilisation of the electricity system.
Level of depth
High-level Use Case
Prioritization
Generic, regional or national relation
Generic
Nature of the use case
Further keywords for classification
Access to electricity, electrification

1.8 General remarks

General remarks

2 Diagrams of use case

Diagram(s) of use case

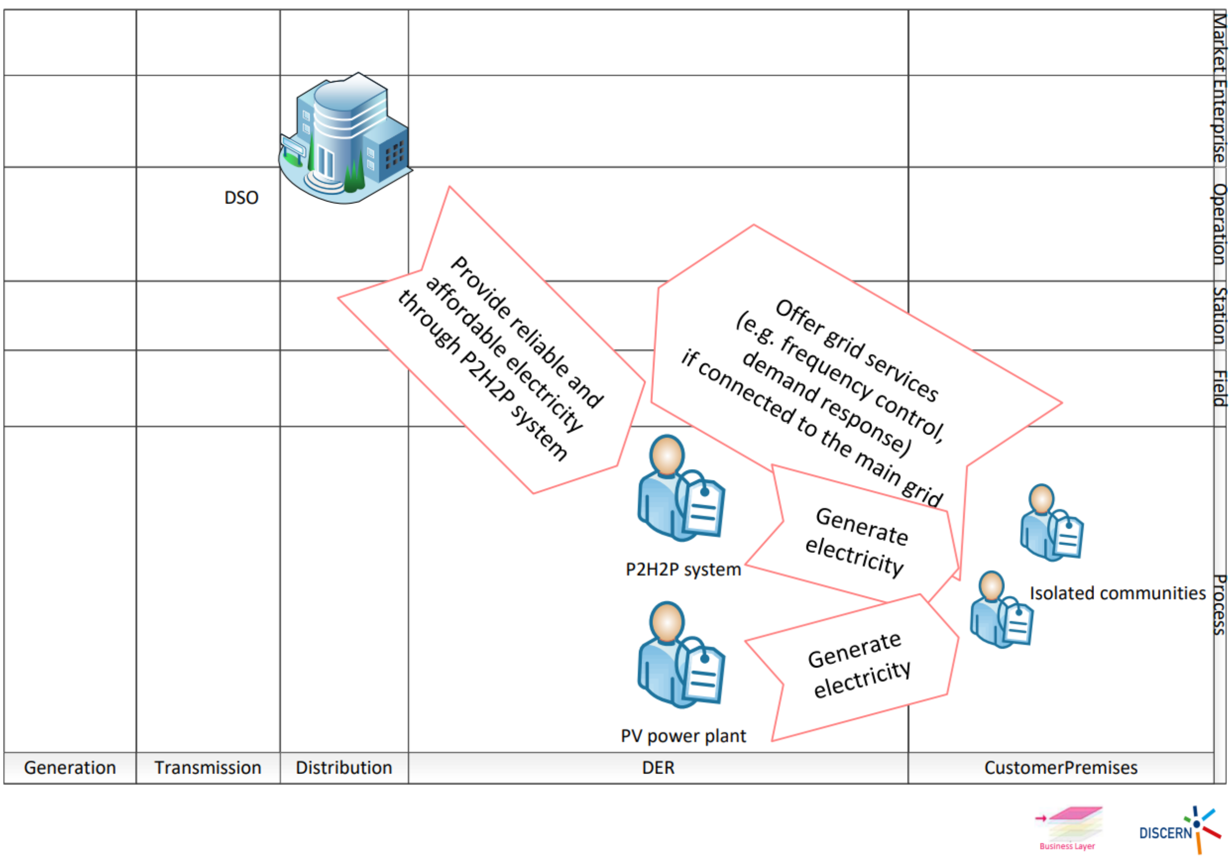


Figure 50: SGAM business layer of the energy access use case-specific architecture

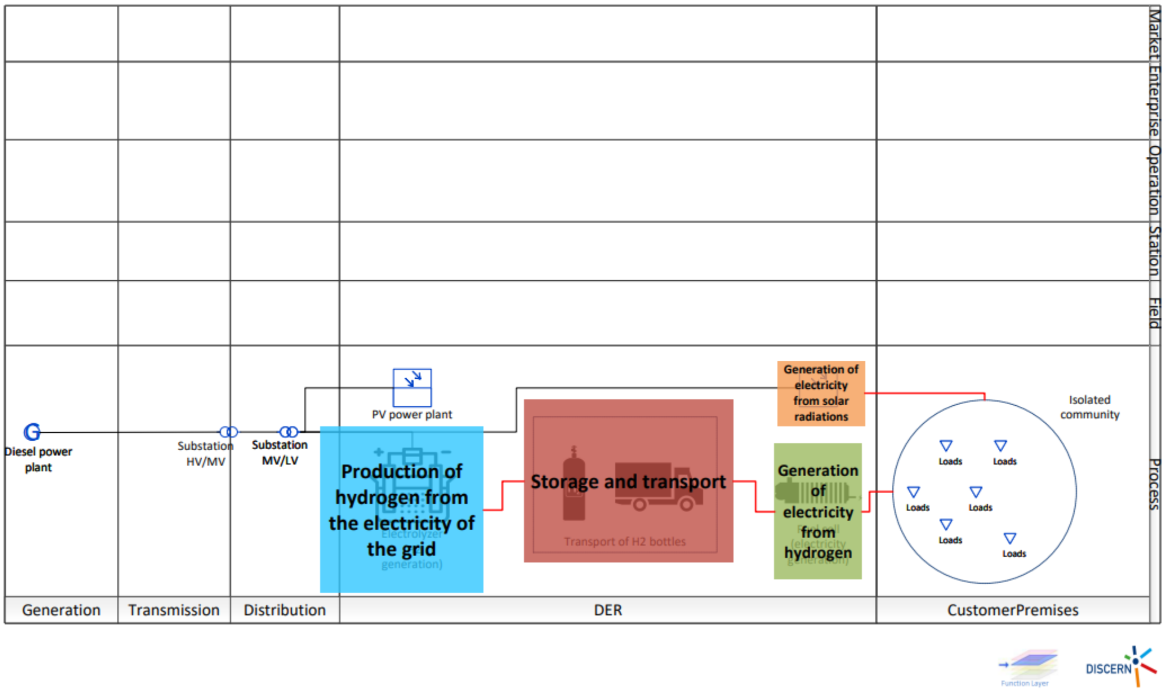


Figure 51: SGAM function layer of the energy access use case-specific architecture

3 Technical details

3.1 Actors

Actors			
Grouping		***Group Description***	
Business Actor		Physical or legal person that has his own interests, defined as "Business Goals"	
Logical Actor		Technical entity that takes part in the execution of a use case. A logical actor can be mapped to a physical component	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
LEC	Business Actor	A Local Energy Community (LEC) is defined as a legal entity which is involved in the production and/or self-consumption of (renewable) energy. The LEC may be involved in the maintenance of solar plants or the Fuel Cell, as well as in the transport of hydrogen bottles from the electrolyser to the fuel cell.	
DSO	Business Actor	The Distribution System Operator is responsible for the management and maintenance of the distribution grid. At the same time, it will be responsible for the management and maintenance of the electrolyser.	
Municipality	Business Actor	The municipality may be a relevant actor which mediates between the LEC and the DSO, and can act as a partner of the LEC, offering support and financial means.	
Solar Plant	Logical Actor	A solar plant is a production asset, allowing the transformation from solar energy to electricity.	
Electrolyser	Logical Actor	The electrolyser converts electricity to hydrogen. It is placed near the main grid and can provide different flexibility services to the main grid, e.g., frequency control.	
Fuel Cell	Logical Actor	The fuel cell re-converts hydrogen to electricity. It is fed with air and hydrogen which is transported from the electrolyser to the fuel-cell in pressurised bottles.	

Please note that the scenarios, information exchanged and requirements sections were not filled for this use case, as it mostly relies on electrical processes.

Common terms and definitions

Common terms and definitions

Term	*Definition*
DER	Distributed Energy Resource
DSO	Distribution System Operator
GDP	Gross Domestic Product
KPI	Key Performance Indicator
LEC	Local Energy Community
P2H	Power-to-Hydrogen
P2H2P	Power-to-Hydrogen-to-Power
PV	Photovoltaic
RES	Renewable Energy Sources
RET	Renewable Energy Technology
SDG	Sustainable Development Goal
SGAM	Smart Grid Architecture Model
TSO	Transmission System Operator
UC	Use Case