FLEXERGY

Deliverable DV2 – Use cases and requirements identification

Activity 1:

Preliminary Studies

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FLEXERGY ABSTRACT

The FLEXERGY project aims at the development of an advanced management solution, highly innovative and provided of artificial intelligence, for the management of assets of battery energy storage systems, integrated with renewable energy sources or for application within a microgrid

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Disclosure

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01.00	2018-10-03	Document release	Ismael Miranda
01.01	2019-01-15	Use cases 1 and 2 description	Marta Ribeiro
01.02	2019-03-29	Minor corrections and changes	Marta Ribeiro

Executive Summary

The FLEXERGY project is promoted by Efacec's Automation unit which growing strategy is based on keeping the forefront of technological. FLEXERGY is a research and technological development project to be developed in order to achieve the growth and strength of energy storage solutions.

The aim of the project is the development of an advanced management solution, highly innovative and provided of artificial intelligence, for the management of assets of battery energy storage systems, integrated with renewable energy sources or for application within a microgrid.

In order to support the definition of functionalities, actors and processes of the FLEXERGY project, the use case methodology has been used. The System Use Cases included in the present document have been developed using the Use Case template proposed by IEC/PAS 62559, that is the most widely accepted within the Smart Grid community. This document aims at defining the use cases to be demonstrated under the scope of the FLEXERGY project by identifying the interactions between different systems and actors to achieve particular objectives.

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Glossary

BESS – Battery Energy Storage System

DER - Distributed Energy Resources

DSO – Distribution System Operator

ECP – Electrical Connection Point

EPPC – Energy Power Plant Controller

ESC – Energy Storage Controller

ESCO – Energy Service Company

EV – Electric Vehicle

GUI – Graphical User Interface

HVAC – Heating, Ventilation and Air Conditioning

KPI – Key Performance Indicator

PCC – Point of Common Coupling

PV - Photovoltaic

SCADA – Supervisory Control and Data Acquisition

SGAM – Smart Grid Architecture Model

SG-CG/RA - Smart Grid Coordination Group/Reference Architecture Working Group

SOC – State of Charge

RES – Renewable Energy Resources

TSO – Transmission System Operator

1. Introduction

The FLEXERGY project aims at developing an advanced and highly innovative management solution, enabled by artificial intelligence, suitable for managing battery-based energy storage assets, integrated with renewable energy sources or meant to be applied in micro grids. This platform will be developed according to the intrinsic features of this kind of systems, being suitable for adaptation to different scopes of integration.

In this document it will be defined the use cases enhanced by the integration of Battery Energy Storage Systems equipped with the ES Manager product – management platform, developed in the scope of the FLEXERGY project.

The use cases are related to the identified application contexts – for example renewable energy integration, system service provision and flexibility management in the presence of distributed energy resources. The definition of the Use Cases (UC) that will be addressed within the FLEXERGY project aim to express in a straightforward way the main actors and interactions among them to accomplish the goals of each functionality, identifying as well the key performing indicators for a post-analysis. Once the use cases are defined, the identification of requirements to be met in the context of each of these use cases will also be provided in the scope of this task.

This task will result in the deliverable DV2, about the defined use cases and the identification of their associated requirements.

2. Smart Grid Architecture Model

The FLEXERGY system architecture has been mapped into the three-dimensional cube defined within the scope of the Smart Grid Architecture Model (SGAM).

The SGAM has been developed by the Smart Grid Coordination Group/Reference Architecture Working Group (SG-CG/RA) in the context of the European Commission's Standardisation Mandate M/490 as a holistic viewpoint of an overall architecture of a Smart Grid domain.

The SGAM framework consists of five layers representing business objectives and processes, functions, information exchange and models, communication protocols and components. Each layer covers the smart grid plane, which is spanned by electrical domains and information management zones. The intention of this model is to represent on which zones of information management interactions between domains take place. It allows the presentation of the current state of implementations in the electrical grid, but furthermore to depict the evolution to future smart grid scenarios by supporting the principles universality, localization, consistency, flexibility and interoperability.

2.1 SGAM Interoperability Layers

In order to allow a clear presentation and simple handling of the architecture model, the interoperability categories are aggregated into five abstract interoperability layers (refer to Figure 1).

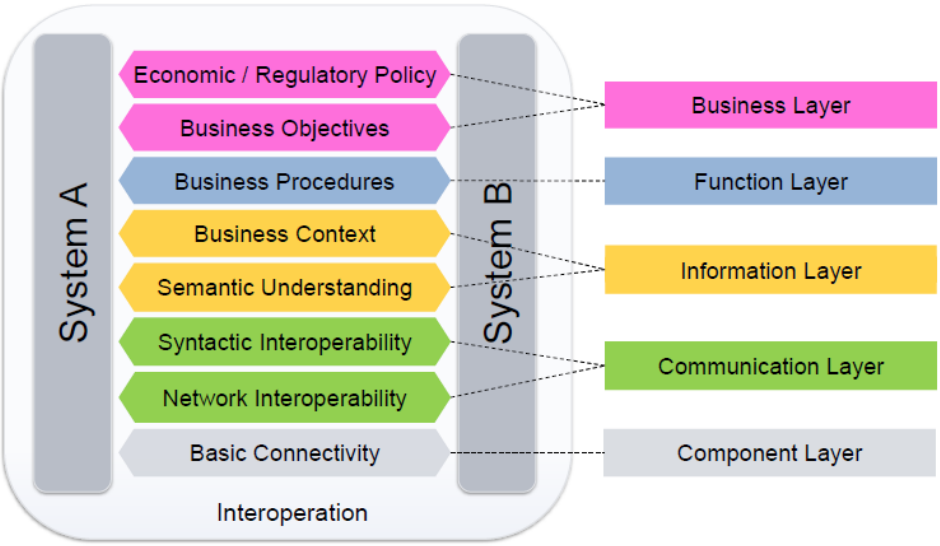


Figure 1- Grouping into interoperability layers

2.2 SGAM Domains

The smart grid domains are directly related to the electrical grid (Bulk Generation, Transmission, Distribution, Distributed Energy Resources (DER) and Costumer) and are organised according to the electrical energy conversion chain.

The Smart Grid Plane covers the complete electrical conversion chain. This includes the domains listed below:

Table 1- SGAM domains

Domain	Description
Bulk Generation	Representing generation of electrical energy in bulk quantities, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale solar power plant (i.e. PV, CSP)– typically connected to the transmission system.
Transmission	Representing the infrastructure and organization which transports electricity over long distances.
Distribution	Representing the infrastructure and organization which distributes electricity to customers.

Domain	Description
DER	Representing distributed electrical resources directly connected to the public distribution grid, applying small-scale power generation technologies (typically in the range of 3 kW to 10.000 kW). These distributed electrical resources may be directly controlled by DSO.
Customer Premises	Hosting both - end users of electricity, also producers of electricity. The premises include industrial, commercial and home facilities (e.g. chemical plants, airports, harbors, shopping centers, homes). Also generation in form of e.g. photovoltaic generation, electric vehicles storage, batteries, micro turbines are hosted.

The SGAM zones represent the hierarchical levels of power system management. These zones reflect a hierarchical model which considers the concept of aggregation and functional separation in power system management.

Table 2- SGAM Zones

Zone	Description
Process	Including the physical, chemical or spatial transformations of energy (electricity, solar, heat, water, wind…) and the physical equipment directly involved. (E.g. generators, transformers, circuit breakers, overhead lines, cables, electrical loads any kind of sensors and actuators which are part or directly connected to the process,…).
Field	Including equipment to protect, control and monitor the process of the power system, e.g. protection relays, bay controller, any kind of intelligent electronic devices which acquire and use process data from the power system.
Station	Representing the areal aggregation level for field level, e.g. for data concentration, functional aggregation, substation automation, local SCADA systems, plant supervision…
Operation	Hosting power system control operation in the respective domain, e.g. distribution management systems (DMS), energy management systems (EMS) in generation and transmission systems, microgrid management systems, virtual power plant management systems (aggregating several DER), electric vehicle (EV) fleet charging management systems.
Enterprise	Includes commercial and organizational processes, services and infrastructures for enterprises (utilities, services providers, energy traders…), e.g. asset management, logistics, work force management, staff training, costumer relation management, billing and procurement, etc.
Market	Reflecting the market operations possible along the energy conversion chain, e.g. energy trading, mass market, retail market.

In order to assess the interoperability of the systems involved and the applicability of the architecture within the European context, a general representation of the overall system has been carried out and is depicted on Figure 2.

FLEXERGY follows a hierarchical structure, as its actuation scope covers different layers/levels of electrical power systems - Field and Process levels - where all the installed devices on the field are presented, namely the local controller and communication infrastructures. The local controllers are responsible for ensuring a bidirectional information flow with the assets present at the component layer and with the ES Manager present at the Station/Function layer.

The ES Manager shall be capable of managing several Controllers, in a scalable concept (up to multi MW scale, eventually geographically dispersed). The ES Manager shall also be capable of managing:

- Multiple battery energy storage systems which may comprise different battery technologies;
- Several PV/wind generation assets power plants belonging to a same plant (same point of common coupling), through their respective controllers/management systems (or through the ES Controller);
- Multiple gensets belonging to a same microgrid;
- Aggregated management of multiple flexible loads (e.g. EV chargers) through their respective controller, considering technical and economical specific conditions;

The ES Manager is responsible for interacting with corporate systems such as SCADA systems, Energy Services Companies (ESCOs), Web services, Transmission System Operator, EV charging manager and Assets Controllers.

Through the information gathered from the Controllers, and taking in consideration the information received from the other entities (SCADA, ESCOs), the ES Manager will be able to perform multiple functionalities simultaneously through the development of advanced management algorithms that allow the optimal allocation and management of the energy storage capacity combined with the management of common DER assets and controllable loads.

FLEXERGY goes beyond the technical operation and foresees the relevance of a market environment, with costumer oriented advanced energy services to establish economic relationships among several players on the electrical system value chain.

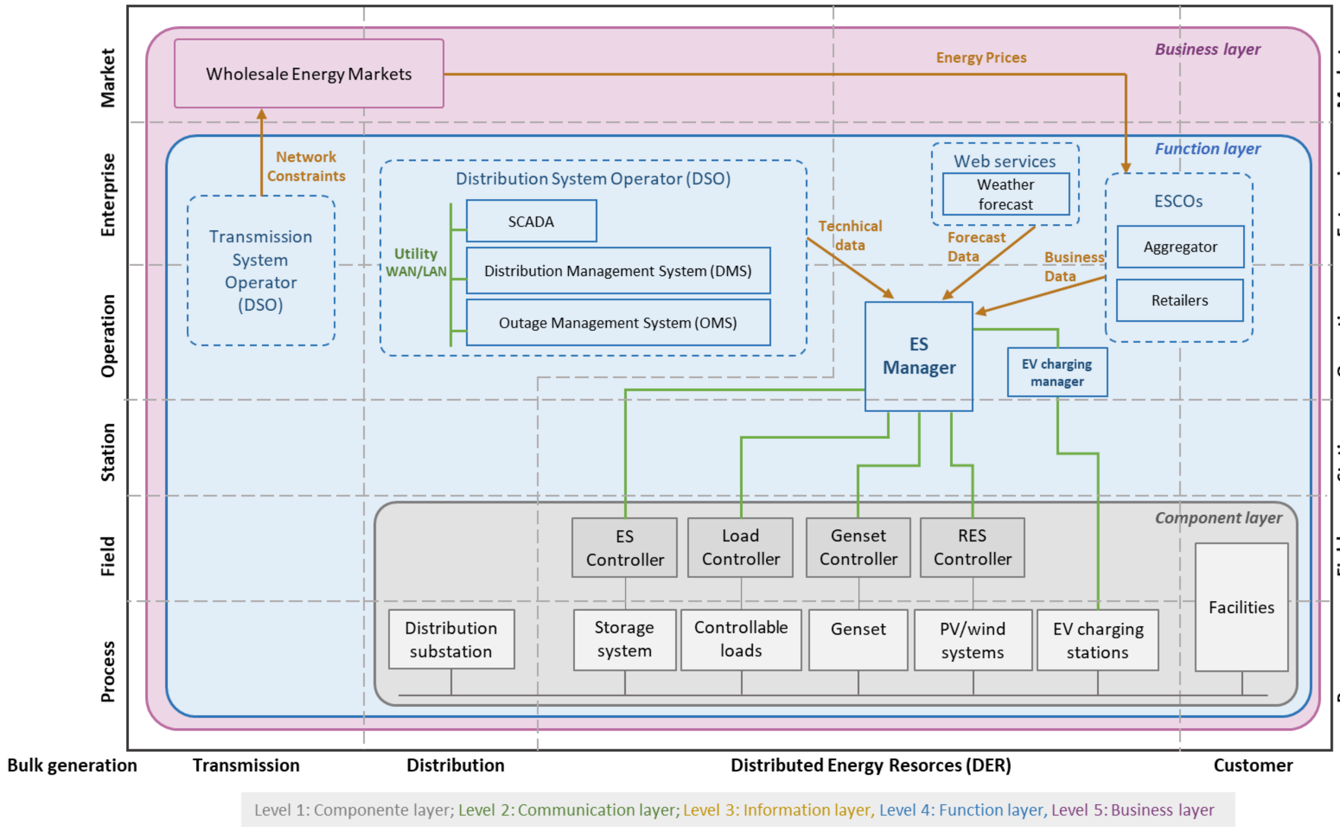


Figure 2- SGAM of FLEXERGY project

3. FLEXERGY Use Cases

In order to support the definition of functionalities, actors and processes of the FLEXERGY project the use case methodology has been used based on the IEC 62559 Methodology. This methodology has extensively been used within the power supply industry for Smart Grid standardisation purposes by international and European Standardisation Organisations and projects.

A definition of the use case is given in ISO/IEC 19505-2:2012 as following "A use case is a specification of a set of actions performed by a system, which yields an observable result that is, typically, of value for one or more actors or other stakeholders of the systems".

The System Use Cases developed within the FLEXERGY project are described in the following section of the present document. The Use Case template proposed by IEC/PAS 62559 has been used, that is the most widely accepted within the Smart Grid community. This document also contains the project requirements, presented for each use case.

For the FLEXERGY project, five (5) use cases are identified and detailed, namely:

- Technical and economic optimization of hybrid park (PV/ Wind/ Storage) supported by battery energy storage system
- Battery Energy Storage System as a buffer for Electric Vehicles (EVs) integration
- Holistic optimization of microgrids integrating energy storage
- Maximizing distributed storage net profit through the provision of multiple services
- Maximization of batteries useful time through Life Cycle Assessment (LCA)

The use cases are not independent from each other. Figure 3 depicts the interactions between use cases.

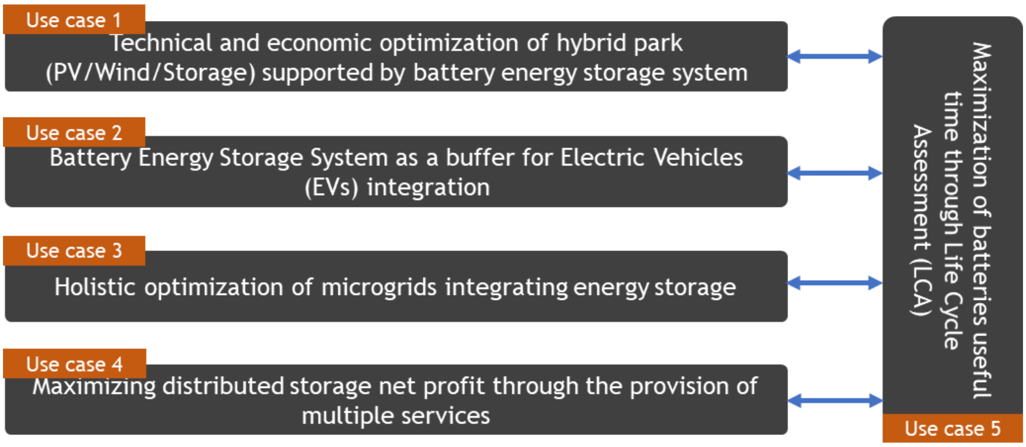


Figure 3 - Interactions between use cases

3.1 Use Case 1

1. Description of the use case

1.1 Name of use case

Use case Identification		
ID	Area/Domain(s)/Zone(s)	Name of use case
UC1	Distributed Energy Resources	Technical and economic optimization of hybrid park (PV/Wind/Storage) supported by battery energy storage

1.2 Version management

Version Management				
Version No.	Date	Name of author(s)	Changes	Approval status
1.01	15/01/2019	Marta Ribeiro	First release	Draft
1.02	29/03/2019	Marta Ribeiro	Corrections and changes	Draft

1.3 Scope and objectives of use case

Scope and objectives of use case	
Scope	This use case refers to a hybrid park where the energy storage system is coupled with a renewable energy source (PV and/or wind), having the same Point of Common Coupling (PCC) with the distribution grid.
Objective(s)	This use case has the following specific objectives: • Optimization of the management of the charge and discharge cycles of the energy storage system in the presence of renewable energy sources • Increase of the predictability and controllability of the energy renewable resource (including the plant power ramp control due to resource unpredictability) • Increase the efficiency in allocating BESS capacity for the participation in different services (grid code compliance) • Maximize the economic performance of the hybrid park • Fast response to grid limitations or constraints
Related business case(s)	• Further integration of renewable energy • Coordinated operation of a hybrid park

1.4 Narrative of the Use Case

Narrative of the use case
Short description
The integration scenario of the energy storage system(s) is its coupling with a renewable energy source(s) (e.g. PV and/or wind plant). The ES Manager, as the management entity of the energy storage system(s) and of the combined system, needs to be able to optimize the management of the charge and discharge cycles of the energy storage system(s) considering the forecasted and actual behavior of the renewable plants and possible TSO or DSO constrains. The optimization of the energy storage cycles with an intelligent management of the SOC allows a better integration of the renewable energy source to the renewable owners, both in technical and economic terms.
Complete description
The integration of renewable energy sources in the grid is the main reason to the integration of energy storage and, particularly, of battery-based systems since this type of technologic solution is seen as complementary to the larger integration of renewable sources with variable and intermittent character, such as wind and photovoltaics. This use case intends to demonstrate the possibility of a larger integration of renewable sources when they are coupled with Battery Energy Storage Systems (BESS), i.e. a hybrid park where energy storage systems and renewable energy sources have the same Point of Common Coupling (PCC). In this use case, the ES Manager will plan the operation of the BESS connected to the hybrid park for the next hours/day in order to maximize the overall revenue of the system, based on the PV/Wind generation forecasts and the forecasted electricity prices/feed-in-tariffs applicable for the respective time horizon and other PCC constrains.

When the BESS control is not able to meet the optimization objective, namely when it lacks the capacity to maintain a given power in the point of common coupling (PCC), the ES Manager will consider the limitation of the maximum power injection of the PV/Wind generators. This can occur for example in hours of higher grid congestion, where the park is requested to reduce its power injection at the PCC and the BESS unit(s) are fully charged. The operation of the BESS unit(s) will also be planned to “smooth” the power generation profile, by ensuring admissible ramp rates (up and down). The ES Manager shall decide when perform the active power smoothing function, using the energy storage system as a buffer to absorb or inject ΔP to counteract local variations of generation and/or demand. For this purpose, when activated, the ES Manager shall determine the minimum capacity allocated to each storage node according to its operational profile/limit and according as well to the load and generation forecast. The optimization tool incorporated in the ES Manager will provide the BESS operation plan for the next hours/day, with a configurable time resolution, consisting in active and reactive power setpoints. It also provides the active power limits for the PV/Wind generators. The operation plan will be updated in real-time considering new forecast information or any relevant changes to the system state (e.g. activation of local control functions, unit(s) outages, amongst others exception scenarios). In addition, the optimization tool will also provide secondary information such as expected SOC throughout the operational day/hour, revenue, available BESS capacity and other important information, that can be relevant for the local monitoring of the park and also for the participation in energy and ancillary markets through an aggregator/VPP.

1.5 Key performance indicators (KPI)

Key Performance Indicators			
ID	Name	Description	Reference to mentioned use case objectives
1	Smoothing performance	Assessment of the impact of the BESS in the power fluctuations at the PCC	Increase of the predictability and controllability of the energy renewable resource(s) (including the plant power ramp control due to resource unpredictability)
2	Power profile predictability increase	Comparison between the combined forecast error with and without the BESS	Increase of the predictability and controllability of the energy renewable resource in terms of predicted power profile
3	Maximize the overall revenue of the hybrid park	Determine the benefits of the hybrid park: increase the revenue of the park	Maximize the economic performance of the hybrid park
4	Energy surplus management	Assessment of the impact of energy excess when a limitation is imposed by the grid (e.g. TSO or DSO)	Fast response to grid limitations or constraints including the optimization of future injection profile for the energy in excess.
5	Reduced energy curtailment of RES	The difference between the energy curtailments before and after the integration of all the proposed solutions	Increase of the predictability and controllability of the energy renewable resource

1.6 Use case conditions

Use case conditions
Assumptions
Availability of the assets/components to carry out this use case
Prerequisites for:
ES Manager
The ES Manager shall have access to electricity prices/feed-in tariffs, updated every 2-4 hours
The ES Manager shall have access to weather and solar radiation forecasts from a weather information provider
The ES Manager shall have access to generation forecast for the next 24 to 48 hours
The ES Manager shall have access or ability to produce renewables forecast, namely PV and Wind forecasts for the facilities with adjustable time resolutions and forecast horizons
The ES Manager shall be capable of programming the BESS power exchange according to the renewable generation forecasts and feed-in tariffs applicable for the respective time horizon
The ES Manager optimization modules shall be capable of updating the BESS and RES operation profiles every 15 minutes (normal operating conditions)

The ES Manager optimization modules execution time shall allow to respond to exceptions within the time period well below 15 minutes periods (response to trigger exceptions events)
The ES Manager shall decide when to apply the active power limit function of the ES Controllers which consists on limiting the active power that is delivered to the grid by the energy storage system aggregated to any type of renewable energy resources and/or loads, considering the batteries' SoC, the renewables' forecast and the constraints at the PCC to the grid
The ES Manager shall be capable of sending the functions inputs to the Controllers
The ES Manager shall decide when to start and adapt the function to improve the smoothing performance of PV or/and wind, considering the batteries SoC and the renewables forecast. It should also be able to determine the necessary storage capacity for power smoothing according to the renewables forecast.
The ES Manager shall be capable of interfacing/providing a Graphical User Interface (GUI) for the solution
The ES Manager shall be capable of storing historical operation profile data for each controlled asset in the platform database, making it available for future analysis.
The ES Manager shall have capability to adjust the planned operation in real time
The ES Manager shall be capable of performing a post-analysis, based on several identified KPIs
The dashboard displays a general overview over the available assets in the grid
The dashboard shows graphical information about the forecasted generation, load and forecasted and actual operation
The ES Manager shall be capable of exchanging information with the ES Controllers regarding relevant data for operational limits and capabilities of each energy storage system.
ES Controllers or other controllers
The ES Controller shall be capable of measuring power related values at different Electrical Coupling Points (ECP)
The ES Controller shall be capable of sending active or reactive power, current and voltage setpoints to the power conversion system
The ES Controller shall be capable of a fast response (order of magnitude – second) to PV generation and/or electric demand fluctuations
The ES controller shall be capable of receiving commands and profile setpoints from the ES Manager
The ES Controller shall be capable of providing the status and availability of the energy storage system to the ES Manager
Inverter
The inverter shall be capable of receiving and implementing active and reactive power, current and voltage setpoints received from the ES Controller

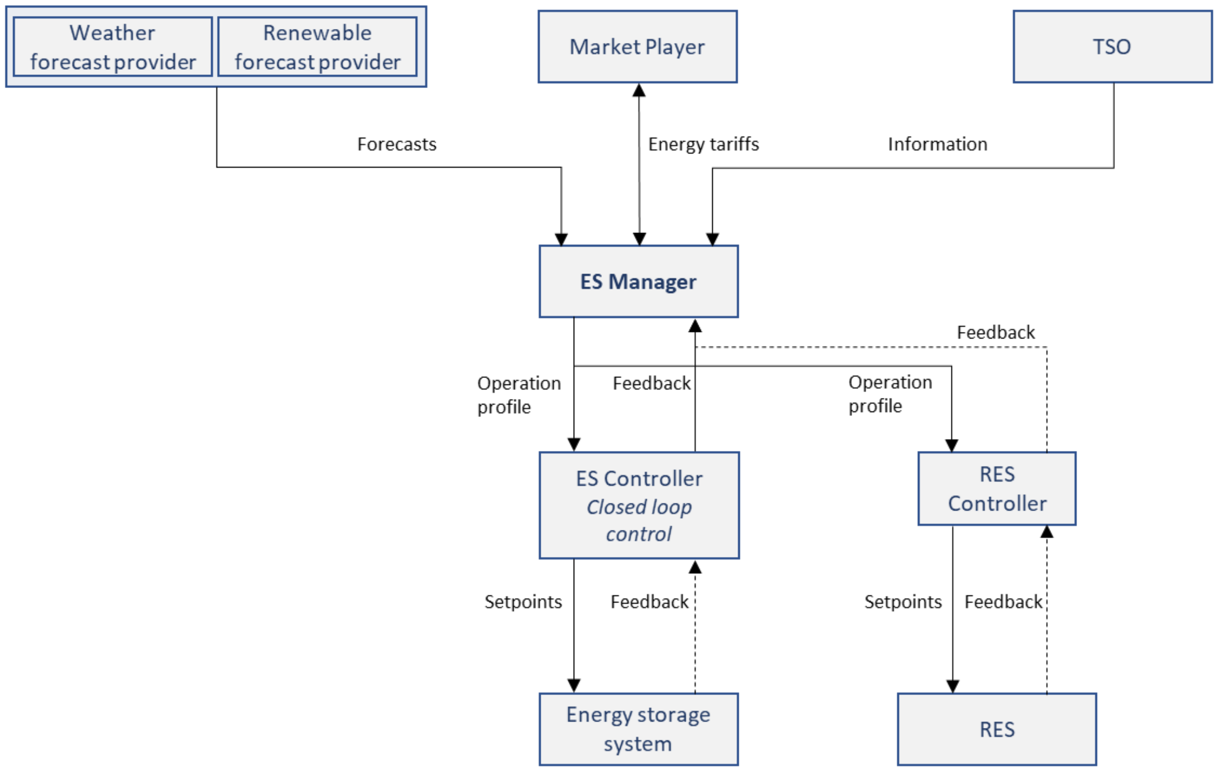
1.7 Further information to the use for classification/mapping

Classification information
Relation to other use cases
Relation with Use Case 5 - will consider typical impact of the charge/discharge schedule and provide feedback for a cycle life optimized schedule.
Level of depth
Primary use case
Prioritization
Must have
Generic, regional or national relation
Generic, but related to national pricing rules and dynamics
Nature of the use case
System use case
Further keywords for classification
BESS scheduling, renewables integration

1.8 General remarks

General remarks

2. Diagrams of use case

Diagram(s) of use case


3. Technical details

3.1 Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case
TSO/DSO or other hierarchical system	System	External power profiles constraints/limitations at the PCC level.	
Weather forecast provider	Software	Software module with access to general weather services that provides information about local weather conditions such as temperatures, cloud cover, radiation, humidity, etc. (up to 48 hours).	
Renewable forecast provider	Software	Software module that takes the data from the previous module and provides calculated information about renewables forecast, namely PV and /or wind forecasts for the facilities with adjustable time resolutions and forecast horizons.	
Market player/ energy prices forecast provider	Software	Software module that establishes the interface with the market player services, providing ahead information about the energy prices/feed-in-tariffs, updated every 2-4 hours.	
ES Manager	Software/ Hardware	The ES Manager represents the main platform responsible for all the tasks that involve the treatment and processing of all the data available from the renewables forecast provider and from the electricity prices/feed-in-tariffs provider. ES Manager provides advanced optimization algorithms to perform an operation plan throughout time for DER systems and for	

		the charge and discharge of the BESS, considering not only, but most importantly, the variability of the renewable energy sources. The ES Manager is able to resolve multi-objective problems: increase of the predictability and controllability of the energy renewable resources and maximize the revenue of the hybrid park.	
Dashboard	Software interface	The dashboard represents the ES Manager interface. It is used as a mean of presenting to the user all the information related with the consumptions and operation of the assets. For example, the dashboard can present all the available information related with the weather conditions and generation forecasts. Can also show the diagram of the electric grid and the electric measurements on the key points. Moreover, it is in the dashboard that the technical and performance evaluation of the BESS over time will be presented.	
ES Controllers	Software/ Hardware	Controller that realizes continuous monitoring of the AC and DC magnitudes of the electric grid and battery system. The ES Controller is responsible to impose the received ES Manager setpoints profile (active or reactive power setpoints) to the power conversion system, in a closed-loop control topology, in order to perform different services. This controller reports directly to the ES Manager and sends all the relevant information and alarms, which are displayed on the dashboard.	The ES Controller performs functions of monitoring, active power smoothing, fixed power factor and active power limit.
Energy Storage System	Hardware/ Software	Flexible asset that can be used to charge and discharge power within a certain range. The energy storage system comprises the power converter system, the batteries and the ancillary equipment such as the fire suppression system, the HVAC, the intrusion detection and the UPS. Operation information (SOC, power, voltage, current) and technical data such as temperature measurements are shared from the battery's controller to the ES Controller.	

3.2 References

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

4. Information exchanged

Information exchanged			
Information exchanged, ID	Name of information	Description of information exchanged	Requirement, R-IDs
INF_WeatherInfo_01	Weather forecast information	Information provided by the weather provider regarding: • Temperatures • Cloud cover • Radiation • Humidity • Etc.	
INF_Prices_02	Market prices forecasting information	Information provided by market player regarding variable electricity prices, such as: • Prices for off-peak periods • Prices for peak periods	
INF_ReneF_03	Renewables forecast	Information provided by ES Manager regarding PV and/or wind forecasts.	

INF_Setpoints_04	Scheduling of BESS	Information provided by ES Manager regarding the active and reactive power setpoints of BESS	
INF_APL_05	Inputs for Active power limit function	Inputs of the active power function of the ESC provided by ES Manager: • ECP • Lower and upper Limit • Mode • Duration Inputs of the active power function of the EPPC provided by ES Manager: • ECP • Upper Limit • Duration	
INF_APS_06	Inputs for the Active power smoothing	Inputs of the active power smoothing function of the ESC provided by ES Manager: • ECP • Filter time • Upper and lower deadband • Active power gradient • Ramptime • Maximum instantaneous difference	
INF_Curtail_07	Curtailment information	Curtailment information received from TSO or DSO	
INF_Dash_08	Dashboard information	Information provided by the ES Manager to be displayed on the dashboard. This information depends on the different scenarios.	

5. Step by step analysis of use case

5.1 Overview of scenarios

Scenarios conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Integration of BESS coupled with a renewable energy source for maximum economic profit.	The ES Manager performs the optimized management of the charge and discharge cycles of BESS considering renewables and prices forecasts for the next hours/day, with an economic perspective. The BESS operation plan can be updated in real time when new forecast information is received.	ES Manager	Periodic event (next hours/day)	The ES Manager needs to access to renewables forecasts and forecasted prices/feed-in-tariffs	Optimized management of charge and discharge cycles of BESS
2	Active Power Smoothing	The ES Manager request to the ESC to perform the active power smoothing function, utilizing the BESS to absorb or produce additional watts to counteract local	ES Controllers + ES Manager	Request from ES Manager	The ES Manager sends the inputs to the ESC. Allocation of capacity for this service in case of multiple	The ESC shall report technical data to ES Manager

		variations of generation and/or demand.			services execution.	
3	Active Power Limit	The ES Manager shall perform a combined control of both the Storage System and renewable resource in order to comply with the grid injection point curtailment. This may lead to direct plant curtailment in case the battery is not able to absorb energy or may lead to storage system negative P setpoints.	ES Manager	Request from TSO	The ES Manager needs to have direct control over the ES Controllers and Renewables Plant Controller.	Both the ESC and EPPC shall report technical data to ES Manager

5.2 Steps - Scenarios

Scenarios conditions								
Scenario name:		**No. 1** - Integration of BESS coupled with a renewable energy source for maximum economic profit.						
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	ES Manager shall have access to weather and renewable forecasts information and forecasted feed-in-tariffs.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining the functionalities of the system, the priorities of each function and the objective function.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The operation plan can be updated in real time or minutes before, considering adjusts in the forecasted information or changes on the system state.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03	
4		Control planning	The operation plan is made for the next day (charge and discharge setpoints) and are sent to the ES Controllers, defining the allocated capacity and minimum allowed capacity for each BESS and each functionality, according to RES forecast and the function priority. The ES Manager can also limit the value in the PCC. The power setpoints shall be transmitted to the ESC for the next hour in a 15 minutes time frame, with the setpoint for each 15-minute interval.		ES Manager	ES Manager	INF_Setpoints_04	

5		Sending inputs	The BESS active and reactive power setpoints calculated by the ES Manager are sent to the ES Controllers. The ES Manager shall be capable of allocating system capacity to this functionality in order to limit it and allow for simultaneous functions.		ES Manager	ES Controllers	INF_Setpoints_04	
6		Report information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard		
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		
Scenario name:		**No. 2** - Active Power Smoothing						
Step No.	Ev ent	Name of process/ activity	Description of process/ activity	Servi ce	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requir ement , R-IDs
1		Information gathering	ES Manager shall have access to weather and renewable forecasts information and forecasted feed-in-tariffs.		ES Manager	ES Manager	INF_WeatherInfo _01 INF_Prices_02 INF_ReneF_03	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining in which time frames to perform this function according to the priorities between multiple functions.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The operation plan can be updated in real time, considering adjusts in the forecasted information or changes on the system state.		ES Manager	ES Manager	INF_WeatherInfo _01 INF_Prices_02 INF_ReneF_03	
4		Control planning	The operation plan is made for the next day (available allocated capacity for service) and are sent to the ES Controllers, defining the allocated capacity and minimum allowed capacity for each BESS and each functionality, according to RES forecast and the functions priority. The ES Manager can also limit the value in the PCC. The power setpoints shall be transmitted to the ESC for the next hour in a 15 minutes time frame, with		ES Manager	ES Controllers	INF_Setpoints_04	

			the setpoint for each 15-minute interval.					
5		Sending Inputs	ES Manager sends the function inputs (ECP, filter time, upper and lower deadband, active power gradient, ramptime). Computation by the ES Controllers of the instantaneous difference in the active power measurement at the ECP and a moving average of the active power level over a rolling time window. When this active power difference exceeds a defined deadband, the ESC needs to respond adequately so that the BESS can contribute to smoothing the active power profile at the Referenced ECP.		ES Manager	ES Controllers	INF_APS_06	
6		Report Information	Report the relevant information to be displayed on the dashboard		ES Controllers	Dashboard	INF_Dash_07	
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		
Scenario name:		**No.3** - Active Power Limit						
Step No.	Ev ent	Name of process/ activity	Description of process/ activity	Servi ce	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requir ement , R-IDs
1		Information gathering	ES Manager shall be capable of receiving information from TSO about requirements and/or setpoints.		TSO	ES Manager	INF_Curtail_07	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining the priority between functions.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The operation plan can be updated in real time or minutes before, considering changes in the TSO information.		ES Manager	ES Manager	INF_Curtail_07	
4		Control planning	The operation plan is made for the next day and are sent to the ES Controllers and to the EPPC, defining the limits of BESS and RES, according to what was imposed by TSO. The ES Manager can also limit the value in the		ES Manager	ES Controllers + EPPCs	INF_Setpoints_04	

			PCC. The power setpoints shall be transmitted to the ES Controllers and to EPPC for the next hour in a 15 minutes time frame, with the setpoint for each 15-minute interval.					
5		Send Inputs	ES Manager sends the function inputs to the ESC and EPPC according to the joint control profile strategy. Both the ESC and EPPC applies at the closed-loop controls to limit(s) and ensure that limit(s) will not be surpassed		ES Manager	ES Controllers + EPPCs	INF_APL_05	
6		Report Information	Report the relevant information to be displayed on the dashboard		ES Manager	Dashboard	INF_Dash_07	
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		

6. Scenarios Validation

Validation of scenarios	
Scenarios to perform	Validation criteria: KPIs
Scenario 1	Power profile predictability increase Maximize the overall revenue of the hybrid park Reduced energy curtailment of RES
Scenario 2	Smoothing performance
Scenario 3	Energy surplus management
Scenarios 1 and 2	Power profile predictability increase Maximize the overall revenue of the hybrid park Reduced energy curtailment of RES Smoothing performance
Scenarios 1, 2 and 3	Power profile predictability increase Maximize the overall revenue of the hybrid park Reduced energy curtailment of RES Smoothing performance Energy surplus management

7. Requirements (Optional)

Requirements (optional)		
Categories ID	Category name for requirements	Category description
Config	Configuration	
Requirement ID	Requirement name	Requirement description
Config_1	Assets information	Configuration of different components into the system, in terms of general information (data models) and I/O information
Config_2	Access configuration	To configure component’s access information (IP address, ports, gateways, …)

8. Common Terms and Definitions

Common Terms and Definitions	
Term	Definition

9. Custom Information (Optional)

Custom information (optional)		
Key	Value	Refers to section

3.2 Use Case 2

1. Description of the use case

1.1 Name of use case

Use case Identification		
ID	Area/Domain(s)/Zone(s)	Name of use case
UC1	Smart charging	BESS as a buffer for Electric Vehicles (EVs) integration

1.2 Version management

Version Management				
Version No.	Date	Name of author(s)	Changes	Approval status
1.01	15/01/2019	Marta Ribeiro	First release	Draft

1.3 Scope and objectives of use case

Scope and objectives of use case	
Scope	Control EV charge operation to minimize its impact on the grid. To ensure the best management of the EV charging stations several factors may be included such as the available energy on the grid, the installed power, the energy storage SOC, the available energy from renewable source (PV) and the electricity energy tariffs.
Objective(s)	This use case has the following specific objectives: • Maximize the economic performance of the system • Reduction of power peaks • Minimize the risks of power outage
Related business case(s)	Smart charging

1.4 Narrative of the Use Case

Narrative of the use case
Short description
The increasing use of EVs brings new challenges on the grid management. It becomes necessary to decrease the EVs impact on the grid to avoid grid reinforcement or contracted power increase. Considering the data coming from the EV charging infrastructure, historical metering data, real-time metering of the EVs, information from the ES Controllers, the ES Manager shall be capable of scheduling the charge operation of BESS and/or the limits of power consumption of EVs.
Complete description
The majority of the EVs charging stations take place on private/semiprivate environment and consequently come up the need of optimizing and managing EV charging. If the EV charging stations are not effectively controlled, a high EV penetration can considerably increase the electricity demand peak as well as cause high voltage deviations, lower power quality and distribution losses. BESS can be widely used for peak power shaving in many scenarios, such as a buffer of EV's to reduce charging loads fluctuations. For a fast charging station, the ability to suppress peak charging power primarily depends on the BESS capacity. The combination of BESS and renewable energy sources can ensure the stabilization and storing of excessive energy during the production in peaks and then use that energy in case of increased load. The security of supply is ensured with BESS as long as BESS can be used to store PV power to use it later, for example when PV is not available or during high tariffs periods. In this use case three main sub use cases (scenarios) shall be considered in which the ES Manager will have an important role: • The ES Manager shall manage the local resources (for example, energy storage and PV) while trying to minimize the use of the network resources for EV charging. This application will consider the limits for each asset, based on production forecasts, maximum operational limits and local network configuration, in order to fully comply with the EV load forecast for the day-ahead strategy and also with the real-time strategy to cope with forecasting errors and/or plant/network contingencies.

- The ES Manager shall manage the local resources (for example, energy storage and PV) present in the grid, assessing the technical and economic benefits. The ES Manager will perform the management functions based on market prices, load and renewable forecasts. In this sense, in terms of control topology, it is similar to case 2.1 having as the main optimization parameter, not the minimization of network resources but instead the optimization of the energy storage system operational profile, while addressing grid's operational constraints (e.g. secondary substation capacity). The point of common coupling (CCP) is seen as a power provider resource (considering the energy prices and CCP limits), and for the storage systems control strategy are also considered the respective constrains, namely: charge/discharge power and energy capacity restrictions, charge/discharge balance requirement, capacity allocation for emergency incidents or other functionalities which may give a higher economical profit and also economical operational aspects related to operational profiles, such as battery degradation according to charge/discharge cycle profile.

- Coordinated charging strategy of EV's and the BESS scheduling with the aim of minimizing charging costs, resulting in constrains/setpoints for charging period and charging pattern for each EV. This shall take into account the EV load forecast, energy prices, resources forecast and a real-time EV SOC snap-shot in order to determine the charging pattern for each EV according to its priority.

The ES Manager sends periodically to the dashboard the detail of the services performed and shows information such as the quantity of EV connected to the grid, the available power from the renewable sources, the batteries SOC, etc. Note that the ES Manager needs to perform the technical and economic performance evaluation of the BESS, performing a post-analysis, based on several identified KPIs

1.5 Key performance indicators (KPI)

Key Performance Indicators			
ID	Name	Description	Reference to mentioned use case objectives
1	Maximize profit	Maximize the profit decreasing the energy costs associated to a certain energy consumption amount	Maximize the economic performance of the system
2	Peak shaving/ flatten load	Reduction of the power peaks	Reduction of power peaks
3	Minimize the risks of power outage	Analysis of the time (hours) that supply will not meet demand.	Continuity of service improvement

1.6 Use case conditions

Use case conditions
Assumptions
Availability of the assets/components to carry out this use case
Prerequisites for:
ES Manager
The ES Manager shall have access to accurate local weather conditions up to 48 hours
The ES Manager shall have access to electricity prices/feed-in-tariffs, updated every 2-4 hours
The ES Manager shall have access or ability to produce renewables and load forecasts for the facilities with adjustable time resolutions and forecast horizons
The ES Manager shall have access to or capability to produce demand forecasts of the facilities based on expected EV charging needs (programed)
The ES Manager optimization modules shall be capable of updating the BESS and RES operation profiles every 15 minutes (normal operating conditions)
The ES Manager optimization modules execution time shall allow to respond to exceptions within the time period well below 15 minutes periods (response to trigger exceptions events)
The ES Manager shall be capable of communicating with the charging stations and send active controls (scenario 3)
The ES Manager shall be capable of gathering measurement data from different locations of the facilities in order to compute the power available for EV charging purposes
The ES Manager shall be capable of optimizing the management of EVs, programming the operation of the charging stations and storage system based on PV generations and charging needs

The ES Manager shall be capable of treating, processing and storing information regarding the EV usage (EVs daily profiles)
The ES Manager shall have the ability of learn over the time the periods of high demand and the periods of decreased activity (EVs) and using machine learning techniques can select the best periods to charge and discharge the batteries
The ES Manager shall be capable of sending the functions inputs to the ES Controllers and other controllers
The ES Manager shall be capable of interfacing/providing a Graphical User Interface (GUI) for the solution
The ES Manager shall be capable of storing historical operation profile data for each controlled asset in the platform database, making it available for future analysis.
The ES Manager shall have the capability to adjust the planned operation in real time
The ES Manager shall be capable of performing a post-analysis, based on several identified KPIs
The dashboard displays a general overview over the available assets in the grid, notifying when an EV is plugged in, displaying as well the actual EV profile. Historical data shall also be possible to consult in the dashboard.
The dashboard shows graphical information about the forecasted and actual operation
ES Controllers or other controllers
The ES Controller shall be capable of measuring power related values at different Electrical Coupling Points (ECP)
The ES Controller shall be capable of sending active or reactive power setpoints to the power conversion system
The ES Controller shall be capable of responding very fast (order of magnitude – second) to PV generation and/or electric demand fluctuations
The ES controller shall be capable of receiving commands from the ES Manager
The ES Controller shall be capable of providing the status and availability of the energy storage system to the ES Manager

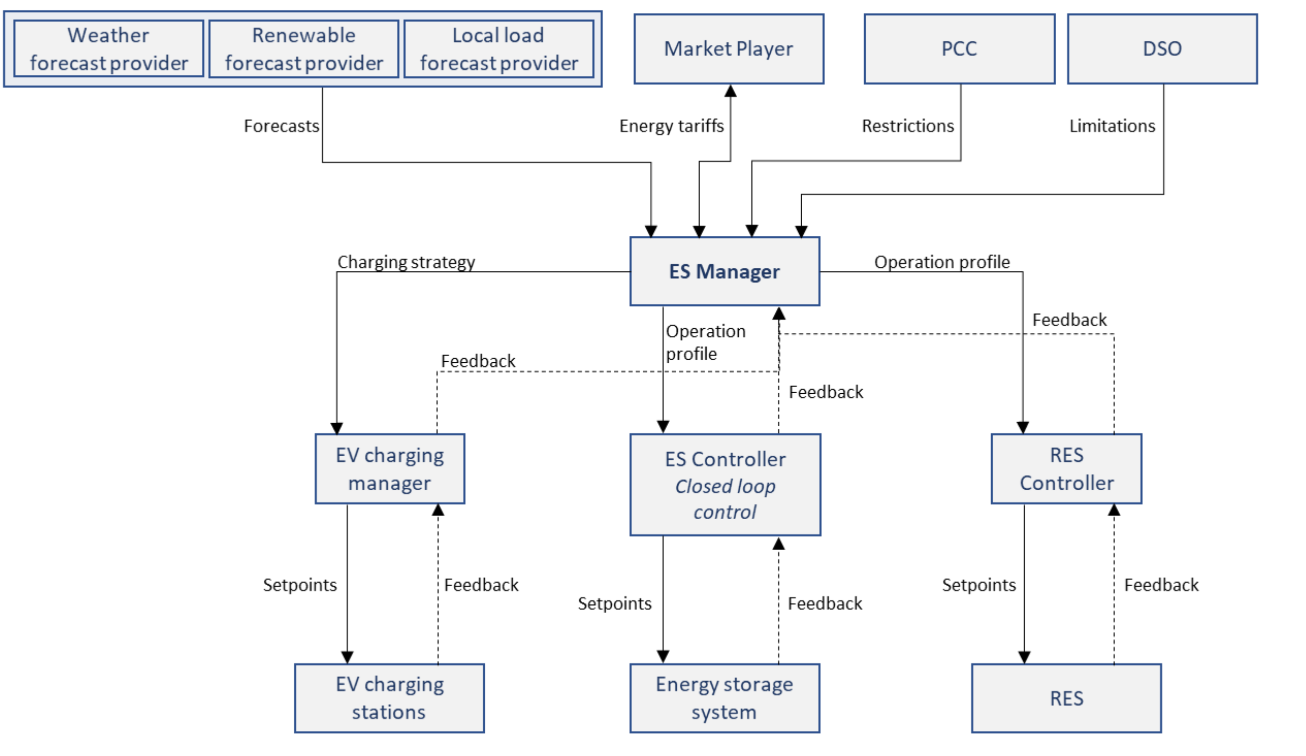
1.7 Further information to the use for classification/mapping

Classification information
Relation to other use cases
Relation with Use Case 5 - will consider typical impact of the charge/discharge schedule and provide feedback for a cycle life optimized schedule.
Level of depth
Primary use case
Prioritization
Mandatory
Generic, regional or national relation
Generic
Nature of the use case
System use case
Further keywords for classification
Electric vehicle, smart grid

1.8 General remarks

General remarks

2. Diagrams of use case

Diagram(s) of use case


3. Technical details

3.1 Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case
Weather forecast provider	Software	Software module with access to general weather services that provides information about local weather conditions such as temperatures, cloud cover, radiation, humidity, etc. (up to 48 hours).	
Renewable energy forecast provider	Software	Software that provides information about renewables forecast, namely PV forecasts for the facilities with adjustable time resolutions and forecast horizons.	
Load forecast provider	Software	Software module to provide ahead information regarding the load schedule, for different type of loads (EVs, general loads) for the day ahead in 15 minutes scheduling.	
Market Player (ESCO's, retailer, aggregator)	Software	Software module that establishes the interface with the market player services, providing ahead information about the energy prices/feed-in-tariffs, updated every 2-4 hours.	
ES Manager	Software/ Hardware	The ES Manager represents the main platform responsible for all the tasks that involve the treatment and processing of all the data available from the renewables forecast provider, from the electricity prices/feed-in-tariffs provider and from the load forecast provider. The ES Manager provides advanced optimization algorithms to realize an operation plan throughout time. The ES Manager is able to resolve multi-objective problems and is capable of responding to different objective functions (minimize charging	

		costs, optimization of the BESS profile, etc.), depending on the scenario.	
Dashboard	Software	The dashboard represents the ES Manager interface. It is used as a mean of presenting to the user all the information related with the consumptions and operation of the assets. The dashboard can show the diagram of the electric grid and the electric measurements on the key points. The dashboard can also comprise other costumer-oriented services. Moreover, it is in the dashboard that the technical and performance evaluation of the BESS over time will be presented.	
ES Controllers	Software/ Hardware	Controller that realizes continuous monitoring of the AC and DC magnitudes of the microgrid resources. The ES Controller is responsible for sending setpoints to the power conversion system, diesel genset and controllable loads. The ES Controller also controls (through open and close setpoints) the circuit breaker responsible for islanding the microgrid. This controller reports directly to the ES Manager and sends all the relevant information and alarms which are displayed on the dashboard.	
Electric Vehicle charging station	System	The charging station is a permanently installed endpoint of the electric grid where an EV is connected to. It incorporates an EV supply equipment and can eventually include an electric energy smart meter.	
Energy storage system	Hardware/ Software	Flexible asset that can be used to charge and discharge power and provide multiple services. The energy storage system comprises the power converter system, the batteries and the ancillary equipment such as the fire suppression system, the HVAC, the intrusion detection and the UPS. Operation information (SOC, power, voltage, current) is shared from the batteries to the ES Controllers and technical data such as temperature measurements are sent from the ancillary equipment to the ES Controllers.	

3.2 References

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

4. Information exchanged

Information exchanged			
Information exchanged, ID	Name of information	Description of information exchanged	Requirement, R-IDs
INF_WeatherInfo_01	Weather forecasts information	Information provided by the weather provider regarding: • Temperatures • Cloud cover • Radiation • Humidity Etc.	
INF_Prices_02	Market prices forecasting information	Information provided by market player regarding variable electricity prices, such as: • Prices for off-peak periods • Prices for peak periods	
INF_ReneF_03	Renewables forecast	Information provided by ES Manager regarding PV and/or wind forecasts.	

INF_LoadF_04	Load forecast	Information provided by Load forecast module provider regarding EV and general load forecasts.	
INF_Setpoints_05	Setpoints	Information provided by the ES Manager regarding: • Active and/ or reactive setpoints For each assets controller.	
INF_Dash_06	Dashboard information	Information provided by the ES Manager to be displayed on the dashboard. This information depends on the different scenarios.	

5. Step by step analysis of use case

5.1 Overview of scenarios

Scenarios conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
	Maximization of the use of local resources	The ES Manager shall be capable of scheduling the BESS operation and limiting the renewable production, according with EV load, weather and renewable forecasts. The main goal of this scenario is the optimization and supply of the EV while trying to avoid the power flow with the main grid and reduce the power peaks.	ES Manager	Periodic event	The ES Manager shall have access to load, weather and renewables forecast.	Reduction of grid congestion
	Efficient exploitation of the energy storage system	The ES Manager shall manage the local resources, such as the BESS and PV, assessing the technical and economic benefits and trying to optimize the energy storage system profile. The ES Manager shall consider in its optimization load, market prices, and renewable forecast as well as constraints related with battery energy storage (charge/discharge power, energy capacity constraints, charge/discharge balance requirements, etc) and PCC constrains. The ES manager shall be capable of deciding when the BESS can be	ES Manager	Periodic event	The ES Manager shall have access to weather, renewable, load and prices forecast.	Reduction of grid congestion Maximization of economic performance

		used to ensure security of supply, for example storing PV power to use it later (when PV is not available or during high tariffs periods).				
	EV's Management capability	The ES Manager shall be capable of coordinate the EV's charging strategy and scheduling the BESS with the aim of minimizing charging costs and, more importantly, avoiding PPC limit violations, resulting in constraints/ setpoints for charging period and charging pattern for each EV. The ES Manager shall be capable of prioritize the EV loads, determining the charging pattern for each EV.	ES Manager	Periodic event	The ES Manager shall have access to EV load forecast, energy prices and real-time EV SOC snap-shot.	Reduction of grid congestion Maximization of economic performance Smart charging

5.2 Steps - Scenarios

Scenarios conditions								
Scenario name:		**No. 1 - Maximization of the use of local resources**						
Step No.	Ev ent	Name of process/ activity	Description of process/ activity	Servi ce	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requiremen t, R-IDs
1		Information gathering	The ES Manager shall have access to weather, renewable (PV) and load forecast.		Load forecast provider Weather forecast provider Renewable forecast provider	ES Manager	INF_WeatherInfo_01 INF_ReneF_03 INF_LoadF_04	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining the functionalities of the system, the priorities of each function and the objective function.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The operation plan can be updated in real time, considering adjusts in the forecasted information or changes on the system state.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_ReneF_03 INF_LoadF_04	
2		Control planning	The ES Manager shall be capable of fully comply with the EV load forecast by scheduling the operation plan of BESS and the PV power plant. The ES Manager realizes the operation plan in the day ahead and tries to		ES Manager	ES Manager		

			avoid the power flow with the main grid.					
5		Sending inputs	The ES Manager shall be capable of sending the operation plan to the ES Controllers and to RES Controllers.		ES Manager	ES Controllers RES Controllers	INF_Setpoints_05	
6		Report information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_Dash_06	
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		
Scenario name:		**No. 2 - Efficient exploitation of the energy storage system**						
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	The ES Manager shall have access to load, weather, renewable and market prices forecast.		ES Manager; Market Player	ES Manager	INF_WeatherInfo_01 INF_ReneF_03 INF_LoadF_04 INF_Prices_02	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining the functionalities of the system, the priorities of each function and the objective function.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The operation plan can be updated in real time or minutes before, considering adjusts in the forecasted information or changes on the system state.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_ReneF_03 INF_LoadF_04 INF_Prices_02	
2		Control planning	The ES Manager shall be capable of performing the operation plan for the next day, considering the load forecast, market prices, weather and renewable forecast and the constraints of BESS. The operation plan is scheduled trying to leverage the economic benefits and the maximization of BESS profile. The ES Manager can use the PCC as a power provider if it is profitable, considering the energy prices and the PCC limits.		ES Manager	ES Manager		

5		Sending inputs	The ES Manager shall be capable of sending the operation plan to the ES Controllers and to RES Controllers.		ES Manager	ES Controllers RES Controllers	INF_Setpoints_05	
6		Report information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_Dash_06	
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	Dashboard ES Manager		
Scenario name:		**No.3 – EV's management capability**						
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	The ES Manager shall have access to EV load forecast, energy prices forecast and a real-time EV SOC snapshot.		ES Manager; Market Player	ES Manager	INF_LoadF_04 INF_Prices_02	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining the functionalities of the system, the priorities of each function and the objective function. The ES Manager shall also be capable of set priorities for the EV charging stations through the information received, giving priority to the EV according to their respective SOC.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The operation plan can be updated in real time or minutes before, considering adjusts in the forecasted information or changes on the system state.		ES Manager	ES Manager	INF_LoadF_04 INF_Prices_02	
2		Control planning	The ES Manager shall be capable of scheduling the operation plan of the BESS and the charging operation strategy of EV's with the aim of minimizing the charging costs and/or avoiding system / grid outages.		ES Manager	ES Manager		
5		Sending inputs	The ES Manager shall be capable of sending the active and reactive setpoints to the ES Controllers and the setpoints to the EV charging manager.		ES Manager	ES Controllers EV charging manager	INF_Setpoints_05	
6		Report information	Report the relevant information to be		ES Manager	Dashboard	INF_Dash_06	

			displayed on the dashboard.					
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	Dashboard ES Manager		

6. Scenarios Validation

Validation of scenarios	
Scenarios to perform	Validation criteria: KPIs
Scenario 1	Peak shaving/ flatten load Minimize the risks of power outage
Scenario 2	Peak shaving/ flatten load Maximize profit Minimize the risks of power outage
Scenario 3	Peak shaving/ flatten load Maximize profit Minimize the risks of power outage

7. Requirements (Optional)

Requirements (optional)		
Categories ID	Category name for requirements	Category description
Config	Configuration	
Requirement ID	Requirement name	Requirement description
Config_1	Assets information	Configuration of different components into the system, in terms of general information (data models) and I/O information
Config_2	Access configuration	To configure component's access information (IP address, ports, gateways, …)

8. Common Terms and Definitions

Common Terms and Definitions	
Term	Definition

9. Custom Information (Optional)

Custom information (optional)		
Key	Value	Refers to section

3.3 Use Case 3

1. Description of the use case

1.1 Name of use case

Use case Identification		
ID	Area/Domain(s)/Zone(s)	Name of use case
UC1	Microgrids/ Distributed Energy Resources	Holistic optimization of microgrid integrating BESS

1.2 Version management

Version Management				
Version No.	Date	Name of author(s)	Changes	Approval status
1.01	15/01/2019	Marta Ribeiro	First release	Draft
1.02	29/03/2019	Marta Ribeiro	Corrections and changes	Draft

1.3 Scope and objectives of use case

Scope and objectives of use case	
Scope	Holistic optimization by the ES Manager of a microgrid integrating energy storage and other distributed energy resources (DER) such as flexible and non-flexible loads, EV chargers, renewable sources (PV or/and wind) and a diesel generator(s).
Objective(s)	This use case has the following specific objectives: • Minimization of the energy costs for the system; • Maximization of self-consumption with maximization of the penetration of Renewable Energy Resources (RES); • Continuity of service improvement • Reduction of power peaks • Reliability of microgrid
Related business case(s)	• Micro-grids integrating BESS; • Further integration of RES.

1.4 Narrative of the Use Case

Narrative of the use case
Short description
Microgrids are an emerging concept for the integration of RES into the power grid by introducing local coordination of distributed energy sources. In a microgrid, an energy management system is essential for optimal use of these distributed energy resources in intelligent, secure, reliable, and coordinated ways. The ES Manager, as the management entity, shall be capable of optimizing and managing the microgrid operation that is connected to the main grid with different focus, depending on the scenarios. The microgrid can be composed by different DER, such as controllable and non-controllable loads, BESS, RES (PV and/or wind) and diesel gensets.
Complete description
The potential added value of BESS is even more clear on microgrids scope with multiple DERs, including several Renewable Energy Sources (RES). The operational flexibility is fundamental to the maximization of reliability, efficiency and resiliency gains which reflect a low environmental impact and high benefits to the final consumer. Particularly, the BESS as a flexible resource is a more obvious solution in microgrids for two main reasons: • First, the main generation system is based on diesel generators with high production and maintenance costs and high levels of gas emissions associated. • Second, the renewable energy sources have a large potential for reducing the operational costs while mitigating the environmental impacts. However, the output power of RES is not as stable as conventional thermal groups. This may induce loss of system overall stability and decrease of system power quality. In order to mitigate the impacts of voltage and power fluctuations and mitigate the constrains associated to the intermittent resources, BESS are commonly used to assist the RES so that they can be used as a buffer to balance the power mismatch between loads and resources and to actively smooth and support the injection profile of such resources into the grid.

This use case will take advantage of an existing infrastructure of a microgrid with BESS developed on the DEMOCRAT scope. The infrastructure is flexible enough to accommodate tests and demonstrations of a storage solution with different application scenarios, being equipped with flexible and non-flexible loads, PV or/and wind generation and a diesel genset. The PCC defines the separation between the grid and the microgrid. The management system shall be capable of limiting the value in the PCC. The ES Manager, as the main management entity, must be capable of balancing the system by meeting the load demand, optimizing overall benefits and efficiency and evaluating the system performance based on the best use of the multiple energy sources.

The following scenarios are about microgrids grid-connected. In the grid-connected mode, the microgrid adjusts power balance of supply and demand by purchasing power from the main grid or selling power to the main grid to maximize operational goals. In this use case fifth types of scenarios can be described:

- In the first scenario: the operation objective of the ES Manager in the microgrid management is to minimize microgrid's operating costs related with battery degradation and purchased cost of electricity from the main grid. In this scenario the microgrids assets are the flexible and non-flexible loads, BESS, PV and/or wind and a diesel genset.

- In the second scenario: the operation objective of the ES Manager is the maximization of the microgrid self-consumption, minimizing the power flow with the upstream network. In this scenario, the power flow with the main grid is allowed, but always from the point of view of resource, adopting a strategy of maximization and controllability of the microgrid resources. Here, the microgrids components are the flexible and non-flexible loads, BESS, PV and/or wind and a diesel genset.

  In the third scenario: the operation objective of the ES Manager is the minimization of the charging costs, considering BESS as a buffer for the EV's integration. The point of common coupling (PCC) is seen as a power provider resource (considering the energy prices and PCC limits), and for the storage systems control strategy are also considered the respective constrains, namely: charge/discharge power and energy capacity restrictions, charge/discharge balance requirement, capacity allocation for emergency incidents or other functionalities which may give a higher economical profit and also economical operational aspects related to operational profiles, such as battery degradation according to charge/discharge cycle profile. For this particular scenario, it must be taken into account possible constrains/limitations on the PCC.

- In the fourth scenario: the operation objective of the ES Manager is the minimization of the costs of energy to the microgrid's owner, performing peak shaving. The ES Manager shall be capable of receiving energy prices forecast (peak and off-peak prices), load forecasts or historical data of the consumption. The BESS operation plan shall be scheduled to discharge in the peak periods of demand, decreasing the load seen by the transformer substation. This also allows the integration of different types of loads with variables characteristics. This functionality also allows to reduce technical losses in the LV grid, as well as reducing power and energy costs, namely through energy arbitrage. In this scenario the microgrid's assets are only the BESS and loads.

- In the fifth scenario: The ES Manager shall optimize and manage the microgrid operation, however in this use case a zero power flow shall be maintained in the point of common coupling. In this application, and based on a load forecast, the ES Manager shall be capable of supplying existing load pattern and to determine the system reserve in order to handle the assets uncertainty and unpredicted contingencies, taking into account the operational profile of each controlled asset (response time, start time, load step, etc.). Moreover, a simplified local network configuration shall also be considered in the analyses in order to determine the asset dispatch for an optimized power flow and respecting the local grid technical parameters. Controllable or dispatchable load shall also be an optimization factor according to a predefined priority level.

To accomplish these goals, the ES Manager shall be capable of dealing with indeterminacy between forecasting data and real-time data (forecasting errors).

1.5 Key performance indicators (KPI)

Key Performance Indicators			
ID	Name	Description	Reference to mentioned use case objectives
1	Levelized Cost of Energy (LCOE)	Determine the benefits of the micro-grid system: reduction the cost of the system	Minimization of the energy costs for the system
2	Renewable curtailment reduction	Assessment of the impact of the BESS in grid flexibility and renewable reduction curtailment	Maximization of the penetration of Renewable Energy Resources (RES)

3	Loss Of Load Expectation (LOLE)	Analysis of the time (hours) that supply will not meet demand.	Continuity of service improvement
4	Peak shaving/ flatten load	Reduction of the power peaks	Reduction of power peaks
5	Microgrid Generation Reliability	Microgrid generation reliability is defined as a percentage of microgrid generation to support connected load	Reliability of microgrid
6	Average Cost Reduction	Determine the microgrid improvement with and without the BESS	Minimization of the energy costs for the system
7	Pollutant Emissions Reduction	Assessment of the reduction of fuel consumption and, consequently, the reduction of pollutant emissions	Maximization of the penetration of Renewable Energy Resources (RES)

1.6 Use case conditions

Use case conditions
Assumptions
Availability of the assets for the demonstration of the use case.
Prerequisites for:
ES Manager
The ES Manager shall have access to accurate local weather conditions, conditions up to 48 hours
The ES Manager shall have access to weather and solar radiation forecasts from a weather information provider
The ES Manager shall have access to electricity prices/ feed-in tariffs, updated every 2-4 hours
The ES Manager shall have access or ability to produce renewables and load forecasts for the facilities (microgrid) with adjustable time resolutions and forecast horizons
The ES Manager shall have the capability to manage different technologies/types of DER: renewable generation (solar and wind), energy storage systems, gensets and controllable and non-controllable loads
The ES Manager shall be capable of gathering data from sensors, meters and other sources, dispersed throughout the microgrid nodes, in order to compute the current state of operation of the microgrid
The ES Manager shall be capable of managing, monitoring and optimizing the microgrid operation considering the energy costs, the integration of renewables and the batteries' SoC with the goal of maximizing the revenue
The ES Manager shall be capable of calculating in advance a variable reserve capacity to respond to frequency events
The ES Manager optimization modules shall be capable of updating the BESS, RES, controllable loads and genset operation profiles every 15 minutes (normal operating conditions)
The ES Manager optimization modules execution time shall allow to respond to exceptions within the time period well below 15 minutes (response to trigger exceptions events)
The ES Manager shall have the capability to send action controls to ES Controller or to other controllers
The ES Manager shall be capable of storing historical operation profile data for each controlled asset in the platform database, making it available for future analysis.
The ES Manager shall be capable of interfacing/providing a GUI for the solution
The ES Manager shall have the capability to adjust the planned operation in real time
The ES Manager shall be capable of performing a post-analysis, based on several identified KPIs
The dashboard displays a general overview over the available assets in the grid and state of the microgrid infrastructure
The dashboard shall be capable of showing graphical information about the forecasted and actual operation
The dashboard shall be capable of allowing the visualization and analysis of real-time data
ES Controllers or other controllers
The ES Controller is capable of receiving active power setpoints from the ES Manager
The ES Controller is capable of managing technical constraints of the battery system
The ES Controller is capable of providing the status and availability of the energy storage system to the ES Manager
The ES Controller is capable of detecting fault in the main grid and follow the adequate procedure to isolate the microgrid fast enough to provide a seamless transition
The inverter is capable of receiving and implementing active and reactive power setpoints received from the ES Controller
Inverter
The inverter is capable of performing the grid forming of the islanded grid, ensuring the frequency and voltage reference

1.7 Further information to the use for classification/mapping

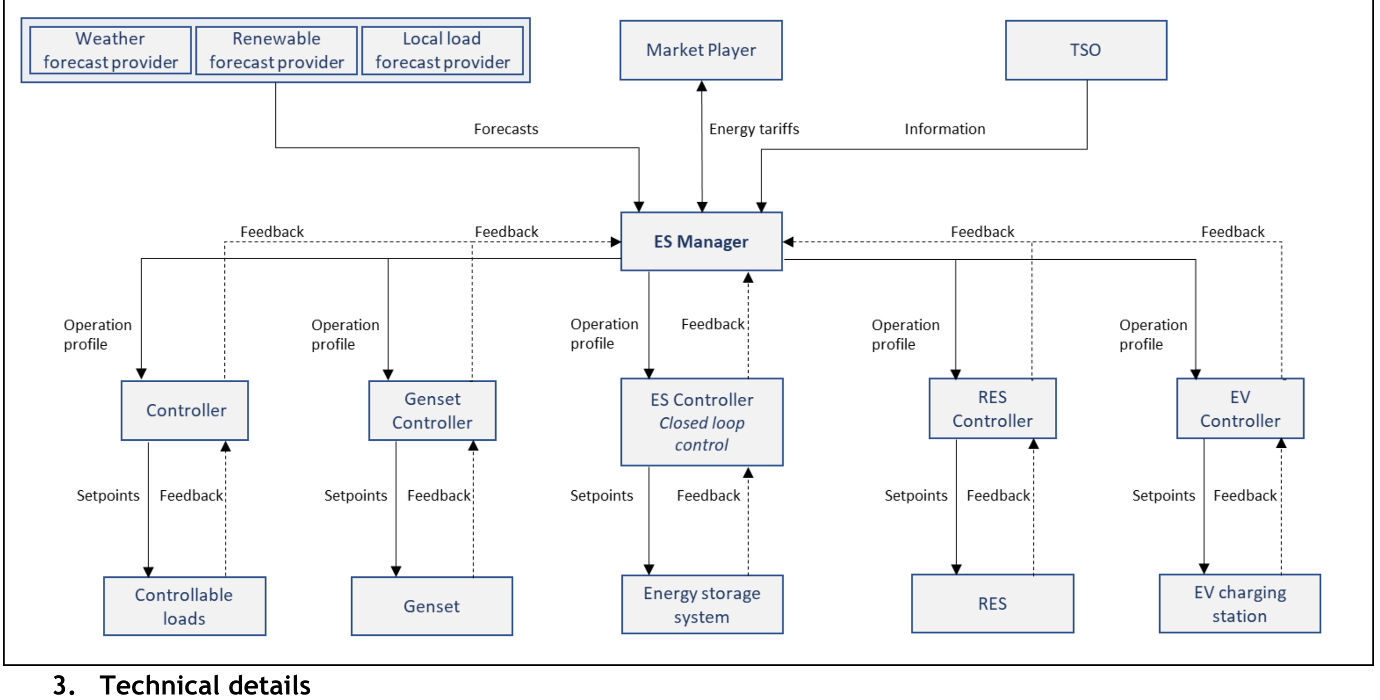
Classification information
Relation to other use cases
Relation with Use Case 5 – will consider typical impact of the microgrid operation and provide feedback for a cycle life optimized schedule.
Level of depth
Primary use case
Prioritization
Must have
Generic, regional or national relation
Generic
Nature of the use case
System use case
Further keywords for classification
Microgrids; on-grid operation; DER

1.8 General remarks

General remarks

2. Diagrams of use case

Diagram(s) of use case



3. Technical details

3.1 Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case
TSO/DSO or other hierarchical system	System	External power profiles constraints/limitations at the PCC level.	

Weather forecast provider	Software	Software module with access to general weather services that provides information about local weather conditions such as temperatures, cloud cover, radiation, humidity, etc. (up to 48 hours).	
Renewable energy forecast provider	Software	Software that provides information about renewables forecast, namely PV forecasts for the facilities with adjustable time resolutions and forecast horizons.	
Load forecast provider	Software	Software module to provide ahead information regarding the load schedule, for different type of loads (EVs, general loads) for the day ahead in 15 minutes scheduling.	
Energy prices forecast provider	Software	Software module that establishes the interface with the market player services, providing ahead information about the energy prices/feed-in-tariffs, updated every 2-4 hours.	
ES Manager	Software/ Hardware	Corresponds to the high-level central management system that is responsible for computing the operation of the microgrid, i.e., controlling and managing the available assets. The ES Manager processes the collected information from the field while tries to accomplish several goals (minimization of costs, integration of RES and decrease the loss of load). It also provides advanced optimization algorithms to realize an operation plan throughout time for the resources in the microgrid, considering the variability of the renewable energy sources, energy renewable forecast, price forecast and local load forecast.	
Dashboard	Software	The dashboard represents the ES Manager interface. It is used as a mean of presenting to the user all the information related with the consumptions and operation of the assets. The dashboard can show the diagram of the electric grid and the electric measurements on the key points. The dashboard can also comprise other costumer-oriented services. Moreover, it is in the dashboard that the technical and performance evaluation of the BESS over time will be presented.	
Distributed Energy Resources (DER)	Hardware/ Software	Assets owned by the microgrid operator, where are comprised energy storage systems and other assets (PV or/and wind, flexible and non-flexible loads, diesel generator). The BESS, flexible loads and diesel genset can be managed by the microgrid management system (ES Manager).	
ES Controllers	Software/ Hardware	Controller that realizes continuous monitoring of the AC and DC magnitudes of the microgrid resources. The ES Controller is responsible for sending setpoints to the power conversion system, diesel genset and controllable loads. The ES Controller also controls (through open and close setpoints) the circuit breaker responsible for islanding the microgrid. This controller reports directly to the ES Manager and sends all the relevant information and alarms which are displayed on the dashboard.	
Electric Vehicle charging station	System	The charging station is a permanently installed endpoint of the electric grid where a EV is connected to. It incorporates an EV supply equipment and can eventually include an electric energy smart meter.	
Other controllers	Software/ Hardware	Identical controllers to the ES Controller that report directly to the ES Manager. These controllers act on RES, diesel gensets, controllable loads and EV's charging stations.	
Controllable loads	Hardware	Controllable loads can be interrupted or shifted, allowing greater flexibility to be scheduled to accommodate grid needs.	

3.2 References

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

4. Information exchanged

Information exchanged			
Information exchanged, ID	Name of information	Description of information exchanged	Requirement, R-IDs
INF_WeatherInfo_01	Weather forecasts information	Information provided by the weather provider regarding: • Temperatures • Cloud cover • Radiation • Humidity • Etc.	
INF_Prices_02	Market prices forecasting information	Information provided by market player regarding variable electricity prices, such as: • Prices for off-peak periods Prices for peak periods	
INF_ReneF_03	Renewables forecast	Information provided by ES Manager regarding PV and/or wind forecasts.	
INF_LoadF_04	Load forecast	Information provided by Load forecast module provider regarding EV and general load forecasts.	
INF_Setpoints_05	Setpoints	Information provided by the ES Manager regarding: • Active and reactive setpoints For each assets controller.	
INF_Dash_06	Dashboard information	Information provided by the ES Manager to be displayed on the dashboard. This information depends on the different scenarios.	

5. Step by step analysis of use case

5.1 Overview of scenarios

Scenarios conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Minimization of microgrid operational costs	In this scenario, the ES Manager shall be capable of managing and controlling the microgrid grid-connected, while trying to leverage the economic benefits. The ES Manager shall be capable of performing the scheduling of the microgrid (sending setpoints to the	ES Manager	Periodic event (day ahead; 15 minutes before; on event)	The ES Manager shall have access to forecasts and assets state of operation.	Minimization of electricity costs of the microgrid Accommodation of renewables

		controllable assets) for the day ahead, after receiving the inputs such as renewables, prices and local loads forecasts. The ES Manager also provides a sliding window scheduling approach (15 minutes) and/or on event approach to adjust forecast errors or any changes in the grid. Changes to assets state shall have immediate response.				
2	Maximization of microgrid self-consumption	The ES Manager shall be capable of managing the microgrid operation and at the same time minimize the power flow with the upstream network. The operation plan of the microgrid is realized in the day-ahead. Near to the real-time operation, an updated scheduling is realized in a sliding window of 15 minutes. The ES Manager shall also be capable of update the setpoints of the controllable loads of the microgrid in real-time.	ES Manager	Periodic event (day ahead; 15 minutes before; on event)	The ES Manager shall have access to data forecasting (renewables and local load) and assets state of operation.	Maximization of the microgrid self-consumption
3	BESS as a buffer for EVs integration	The ES Manager shall be capable of coordinating the charging strategy of EV's and the scheduling of BESS with the aim of minimizing the charging costs, resulting in constraints/setpoints for charging period and charging pattern for each EV.	ES Manager	Periodic event (day ahead; 15 minutes before; on event). Possible constrains on the PCC.	The ES Manager shall take into account the EV load forecast, energy prices forecast and a real-time EV SOC snap-shot	Minimization of charging costs
4	Peak shaving	The ES Manager shall be capable of performing peak shaving on a microgrid grid-connected while trying to leverage the economic benefits. The ES Manager schedules the BESS operation plan (charging and discharging) for the next day, according to energy prices and load forecast.	ES Manager	Periodic event (day ahead; 15 minutes before; on event).	The ES Manager shall have access to energy prices, load forecast or historical consumption data.	Minimization of energy costs for the microgrid owner

5	Zero power flow	The ES Manager shall be capable of optimizing and managing a microgrid operation maintaining a zero power flow in the point of common coupling.	ES Manager	Triggered by ES Manager or requested by system operator	The ES Manager shall have access to load, weather and renewable forecast.	Keeping a zero power flow in the PCC

5.2 Steps - Scenarios

Scenarios conditions								
Scenario name:	**No. 1** - Minimization of microgrid operational costs							
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	The ES Manager shall gather information of renewables forecast, prices forecast, local load forecast and programmed interventions on the microgrid assets.		ES Manager and general controllers for each asset. Additional maintenance table.	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03 INF_LoadF_04	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining the functionalities of the system, the priorities of each function and the objective function.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The operation plan can be updated in real time considering adjusts in the forecasted information or changes on the system state.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03 INF_LoadF_04	
4		Control planning	The ES Manager shall manage and optimize the microgrid operation while trying to leverage the economic benefits. The ES Manager shall be capable of calculating the active and reactive setpoints of BESS, the active setpoints of the controllable loads, diesel gensets and RES. The ES Manager shall also be capable of limiting the active power on the PCC (allowing the curtailment of RES). Every 15 minutes, the ES Manager updates the operation plan of the microgrid due to the errors in the forecasting process. The ES Manager shall also be capable of performing updates in real-time operation due to exceptions on the generation assets or		ES Manager	ES Manager		

			unexpected changes on the load side.					
5		Sending inputs	The ES Manager sends to the ES Controllers and other controllers the setpoints and inputs in accordance with the scheduled. The respective controllers of genset(s), RES and flexible load(s) also ensure the compliance of received setpoints.		ES Manager	ES Controllers Other controllers	INF_Setpoints_04	
6		Report information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_Dash_06	
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		
Scenario name:		**No. 2** - Maximization of microgrid self-consumption						
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	The ES Manager shall gather information of renewables forecast, prices forecast and local load forecast. Should also gather information about programmed interventions on the microgrid assets and real-time assets state of operation.		Forecast providers and general controllers for each asset. Additional maintenance table.	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining the functionalities of the system, the priorities of each function and the objective function. The ES Manager shall be capable of calculating and ensuring a reserve power, with or without the diesel generators, in order to cope with demand variability responses in real-time.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The operation plan can be updated in real time, considering adjusts in the forecasted information or changes on the system state.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03	
4		Control planning	The ES Manager shall be capable of managing the microgrid, supplying the existing load pattern with the local resources available, while trying to minimize the use of the main grid. ES Manager schedules the operation		ES Manager	ES Manager		

			plan of the controllable assets for the day-ahead. Every 15 minutes, the ES Manager updates the operation plan of the microgrid due to the errors in the forecasting process The ES Manager shall be capable of performing updates in real-time operation due to exceptions on the generation assets or unexpected changes on the load side.					
5		Sending inputs	The ES Manager sends to ES Controllers and other controllers the inputs in accordance with the operation plan. The respective controllers of genset(s), RES and flexible load(s) also ensure compliance of received setpoints.		ES Manager; ES Controllers; Other controllers	ES Controllers Other controllers		
6		Report information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_Dash_06	
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		
Scenario name:		**No.3** - BESS as a buffer for EVs integration						
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	The ES Manager shall have access to EV load forecast, energy prices forecast and EV SOC forecast and RES forecast.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining loads priority factor in order to define load shedding.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The operation plan can be updated in real time or minutes before, considering adjusts in the forecasted information or changes on the system state.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03	
4		Control planning	The ES manager shall be capable of coordinate the charging strategy of EV's and the BESS scheduling with the aim of minimizing charging costs and, more importantly, avoiding PPC limit violations. This shall be considered also for the day taking into account		ES Manager	ES Manager		

Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
			existing constrains on the PCC. The ES Manager shall be capable of performing updates in real-time operation due to exceptions on the generation assets or unexpected changes on the EV side, allowing for BESS and/or RES profile changes or EV shedding.					
5		Sending inputs	The ES Manager sends to the ES Controllers the optimized operation of BESS and to the respective controllers of the EVs, genset(s) and RES the controls.		ES Manager	ES Controllers; Other controllers	INF_Setpoints_04	
6		Report information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_Dash_06	
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		
Scenario name:		**No. 4** - Peak shaving						
Step No.	Ev ent	Name of process/ activity	Description of process/ activity	Servic e	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requir ement , R-IDs
1		Information gathering	The ES Manager shall have access to electricity prices, such as peak and off-peak prices and to load forecast or historical consumption data.		ES Manager; Market Player	ES Manager	INF_Prices_02 INF_LoadF_04	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining the functionalities of the system, the priorities of each function and the objective function.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The operation plan can be updated in real time or minutes before, considering adjusts in the forecasted information or changes on the system state.		ES Manager	ES Manager	INF_Prices_02 INF_LoadF_04	
4		Control planning	The ES Manager shall be capable of scheduling the BESS operation plan to perform peak shaving, according to energy prices and load forecast. The objective function of ES Manager is the reduction of energy cost originated from the high load peak power. Consequently, the ES Manager schedules the BESS to charge in periods of low		ES Manager	ES Manager		

			prices and discharge when the prices are higher.					
5		Sending inputs	The ES Manager sends to the ES Controllers the optimized operation of BESS.		ES Manager	ES Controllers	INF_Setpoints_04	
6		Report information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_Dash_06	
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		
Scenario name:		**No. 5 - Zero power flow**						
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	The ES Manager shall have access to load forecast and to weather and renewable forecast if the microgrid comprises renewable generation sources.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_ReneF_03 INF_LoadF_04	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining the functionalities of the system, the priorities of each function and the objective function. The ES Manager shall also be capable of determine the system reserve in order to handle the assets uncertainty and unpredicted contingencies, taking into account the operational profile of each controlled asset.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The operation plan can be updated in real time or minutes before, considering adjusts in the forecasted information or changes on the system state.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_ReneF_03 INF_LoadF_04	
4		Control planning	The ES Manager shall be capable of scheduling the BESS operation and the operation of the controllable assets present in the microgrid with the aim of supplying the existing loads and maintaining a zero power		ES Manager	ES Manager		

			flow in the PCC. This management is based on load, weather and renewable forecast. Controllable or dispatchable loads shall also be an optimization factor according to a predefined priority level, defined in step 2.					
5		Sending inputs	The ES Manager sends to the ES Controllers and other controllers the optimized operation strategy, through setpoints.		ES Manager	ES Controller; Other controllers	INF_Setpoints_04	
6		Report information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_Dash_06	
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		

6. Scenarios Validation

Validation of scenarios	
Scenarios to perform	Validation criteria: KPIs
Scenario 1	Levelized cost of energy Renewable curtailment reduction Microgrid Generation Reliability
Scenario 2	Renewable curtailment reduction Loss of load expectation
Scenarios 1 and 3	Levelized cost of energy
Scenarios 2 and 3	Renewable curtailment reduction Loss of load expectation
Scenario 4	Peak shaving/ flatten load Levelized cost of energy Microgrid Generation Reliability
Scenario 5	Loss of load expectation or excess in production Internal microgrid asset dispatch (generation vs consumption)

7. Requirements (Optional)

Requirements (optional)		
Categories ID	Category name for requirements	Category description
Config	Configuration	
Requirement ID	Requirement name	Requirement description
Config_1	Assets information	Configuration of different components into the system, in terms of general information (data models) and I/O information
Config_2	Access configuration	To configure component’s access information (IP address, ports, gateways, …)

8. Common Terms and Definitions

Common Terms and Definitions	
Term	Definition

9. Custom Information (Optional)

Custom information (optional)		
Key	Value	Refers to section

3.4 Use Case 4

1. Description of the use case

1.1 Name of use case

Use case Identification		
ID	Area/Domain(s)/Zone(s)	Name of use case
UC1		Maximizing distributed storage net profit through the provision of multiple services

1.2 Version management

Version Management				
Version No.	Date	Name of author(s)	Changes	Approval status
1.01	15/01/2019	Marta Ribeiro	First release	Draft
1.02	29/03/2019	Marta Ribeiro	Minor Changes	Draft

1.3 Scope and objectives of use case

Scope and objectives of use case	
Scope	This use case is about the efficient exploitation of the BESS through the provision of multiple services, while leverage the economic benefits. The ES Manager can integrate machine learning techniques that allows intelligent allocation of battery capacity over the time, for multiple operation goals.
Objective(s)	This use case has the following specific objectives: • Maximization of the revenue of the system; • Provision of multiple services; • Higher accommodation of RES; • Reduction of grid congestion;
Related business case(s)	Multiple services;

1.4 Narrative of the Use Case

Narrative of the use case
Short description
Operation strategy optimization for the performance of multiple services, implementing an optimized allocation of battery capacity for different purposes of the electric sector. The ES Manager will be provided of advanced algorithms able to optimize to different time horizons the charge and discharge cycles management, responding to multiple operation goals and integrating renewable generation and load forecast algorithms. The ES Manager will be able to learn over the time the most appropriated way to accomplish multiple services, integrating machine learn techniques. The ES Manager shall be capable of decide which is the strategy that brings higher value to the system, allocating different battery capacities. This allocation will be dynamic to have time-varying allocation capacity, compliant with the grid conditions, with renewable generation fluctuation and with the own BESS conditions.
Complete description
In order to overcome the barriers of the BESS such as the high investment costs and the low useful lifetime is necessary the exploitation of one of the most notable qualities that is its capacity of provide multiple services. Its multifunctional character will allow the aggregation of multiple sources of revenue, leveraging its added value and leading to overcome the associated costs during its useful lifetime. The multifunctional need is also a fundamental factor for the proper integration of renewable energy sources on market electricity environment. The main objective of this use case is to maximize the revenue of the system integrating BESS, such as hybrid parks and microgrids, by considering the provision of multiple services. BESS has the potential to provide ancillary (e.g. frequency regulation and reserve) and other transmission and distribution network support services, e.g. The ES Manager will incorporate an optimization tool which coordinates the system main operation objectives (e.g. maximize revenue, minimize cost, maximize self-consumption) with the provision of the following services, considering a given capacity allocation:

- Balancing Services – is the last market opportunity to balance production and consumption. The gate closure of this market is typically in the range between 30 minutes and 1 hour before the actual energy delivery. This market is organized in a series of 24 balancing markets, each one cleared half an hour prior to the energy delivery. The ES Manager needs to ensure a given upward and downward power reserve and the expected price for a 30 min/hour period. The initial physical notification from the ES Manger shall be submitted at the day-ahead stage and shall be continually updated until gate closure. The system needs to ensure the requested reserve capacity in a period comprised from 30 s to 15 minutes.
- Capacity Management – capacity markets focus on whether the grid will have sufficient energy capacity to meet the predicted peak energy demand on any day of the year, which usually occurs during the hot summer months. The BESS helps reduce the variability associated to the RES and allow its participation in capacity markets. This usually involves a longer-term auction (year/months ahead).
- Congestion Management - BESS can help reduce maximum currents flowing though constrained grid assets, namely lines, cables, transformers and other network equipment. This can be achieved through a combined control of both active and reactive power control of the system. For this a medium (seasonal) to short term (daily) auction can be considered, remunerating the participation of BESS in avoiding/solving congestion in distribution feeders.
- Reactive power support – The system can provide reactive power control to help manage distribution networks in addition to the already existing regulatory requirements. The BESS will be remunerated by the provision of this control (€/kVar) considering the daily needs of the DSO.

The optimization tool incorporated in the ES Manager will provide the BESS operation plan for the next hours/day, with a configurable time resolution, consisting in active and reactive power setpoints. The ES Manager also provides the active power limits for the PV/Wind generators. The operation plan will be updated in real-time considering new forecast information or any relevant changes to the system state (e.g. activation of local control functions, unit(s) outages, amongst others).

In addition, the optimization tool will also provide secondary information such as expected SOC, revenue, available BES capacity, that can be relevant for the local monitoring of the park and also for the participation in energy and ancillary markets through an aggregator/VPP.

1.5 Key performance indicators (KPI)

Key Performance Indicators			
ID	Name	Description	Reference to mentioned use case objectives
1	Maximize the economic performance	Assessment of the impact of allocation of battery capacity on the economic performance of the system	Maximization of the revenue of the system
2	Renewable curtailment reduction	Assessment of the impact of the BESS in grid flexibility and renewable reduction curtailment	Higher accommodation of RES
3	Security of supply	Capacity providers will receive payment for capacity in the delivery year. In return, providers will be obligated to deliver energy in periods of system stress and will be financially penalized if they do not deliver in stress periods.	Maximization of the revenue of the system
4	Grid congestion	Grid sustainability to peaks	Reduction of grid congestion
5	Effectiveness on BESS capacity allocation management for multiple services	Assessment of the impact of BESS capacity allocation	Increase the efficiency in allocating BESS capacity for the participation in different services (grid code compliance)
6	Frequency control	Calculates the percentage of time that the average value of the fundamental frequency measured over periods are outside of the boundaries of the control	Increase the efficiency in allocating BESS capacity for the participation in different services (grid code compliance)

1.6 Use case conditions

Use case conditions
Assumptions
Availability of the assets for the demonstration of the use case

Prerequisites for:
ES Manager
The ES Manager shall have access to weather and solar radiation forecasts from a weather information provider
The ES Manager shall have access to electricity and ancillary services prices from the market player
The ES Manager shall have access to information about the established transactions at the capacity market
The ES Manager shall have access or ability to produce renewables forecast and load forecast for the facilities with adjustable time resolutions and forecast horizons and schedule BESS operation for market participation
The ES Manager shall be capable of calculating in advance a variable reserve capacity for the participation in electricity markets
The ES Manager shall be capable of defining the conflict of interests (technical and economic) between services and calculating rewards and penalties from each service. The ES Manager shall be capable of decide which is the strategy that brings higher value to the system
The ES Manager shall be capable of informing which tasks were chosen to be performed by the BESS
The ES Manager shall be capable of implementing an optimized allocation of battery capacity for different purposes, selecting the optimal priority order of tasks. This allocation will be dynamic to have time-varying allocation capacity, compliant with grid conditions, with renewable generation fluctuation and with the own BESS conditions
The ES Manager shall be capable of learning over the time the most appropriated way to accomplish multiple services, integrating machine learning techniques
The ES Manager shall send the updated BESS profile to the ES Controllers
The ES Manager shall be capable of updating in real-time the operation plan, considering new forecast information or any relevant changes to the system state.
The ES Manager shall have the capability to send action controls to ES Controllers or to other controllers
The ES Manager shall be capable of interfacing/providing a Graphical User Interface (GUI) for the solution
The ES Manager shall be capable of storing historical operation profile data for each controlled asset in the platform database, making it available for future analysis.
The ES Manager shall be capable of performing a post-analysis, based on several identified KPIs
The dashboard displays a general overview over the available assets in the grid
The dashboard shows graphical information about the forecasted and actual operation
ES Controllers or other controllers
The ES Controller shall be capable of measuring power related values at different Electrical Coupling Points (ECP)
The ES Controller shall be capable of sending active or reactive power setpoints to the power conversion system
The ES Controller shall be capable of responding very fast (order of magnitude – second) to PV generation and/or electric demand fluctuations
The ES controller shall be capable of receiving commands from the ES Manager
The ES Controller shall be capable of providing the status and availability of the energy storage system to the ES Manager

1.7 Further information to the use for classification/mapping

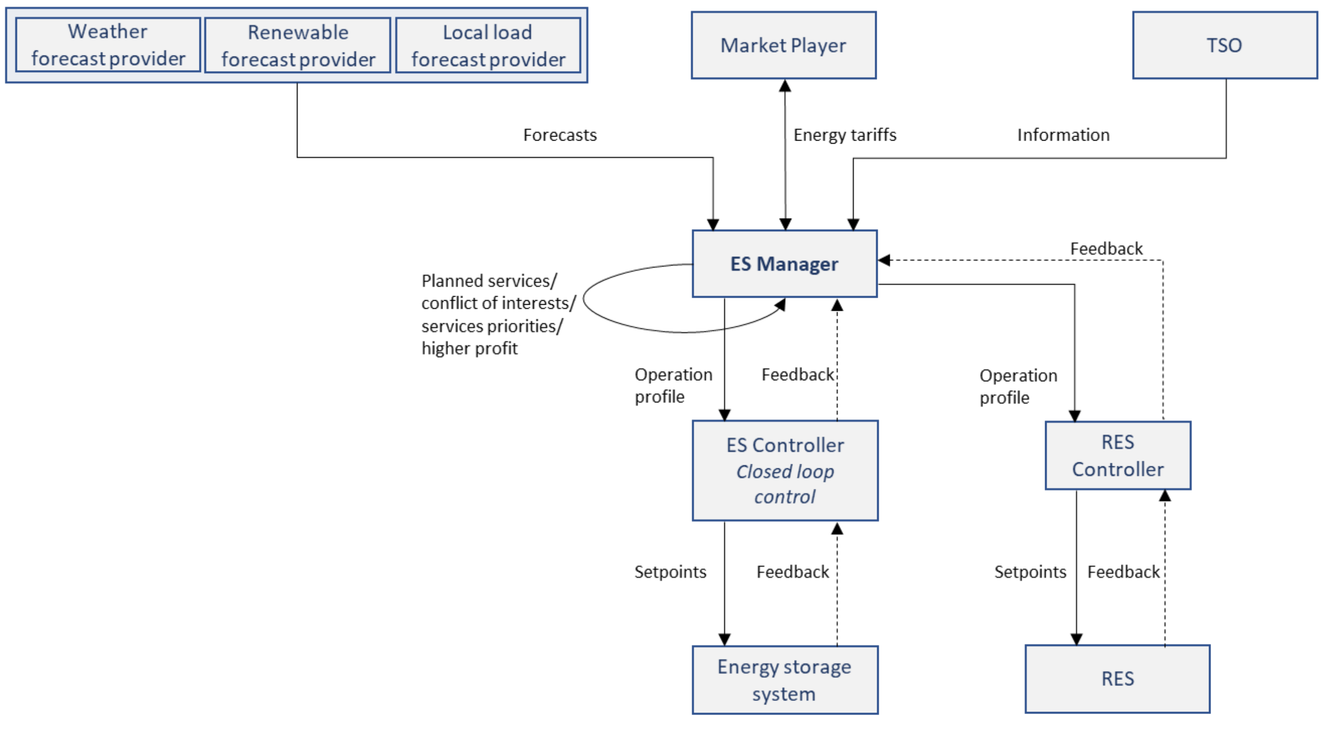
Classification information
Relation to other use cases
Relation with Use Case 5 - will consider typical impact of the charge/discharge schedule and provide feedback for a cycle life optimized schedule
Level of depth
Primary use case
Prioritization
Must have
Generic, regional or national relation
Generic
Nature of the use case
System Use Case
Further keywords for classification
Multiple services; Machine learning

1.8 General remarks

General remarks

2. Diagrams of use case

Diagram(s) of use case



3. Technical details

3.1 Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case
Market player	Software	Software module that establishes the interface with the market player services, providing ahead information about the energy prices/feed-in-tariffs, updated every 2-4 hours.	
Weather forecast provider	Software	Software module with access to general weather services that provides information about local weather conditions such as temperatures, cloud cover, radiation, humidity, etc. (up to 48 hours).	
Renewable energy forecast provider	Software	Software that provides information about renewables forecast, namely PV forecasts for the facilities with adjustable time resolutions and forecast horizons.	
Load forecast provider	Software	Software module to provide ahead information regarding the load schedule, for different type of loads (EVs, general loads) for the day ahead in 15 minutes scheduling.	

ES Manager	Software	Corresponds to the high-level central management system that is responsible for computing the operation of the system. The main responsibility is the allocation of battery capacity for the provision of multiple services. Consequently, the ES Manager shall define the conflict of interests between multiple tasks and calculate rewards and penalties from each task. After that, it has the conditions to define the BESS operation strategy, defining the priority order of tasks. The ES Manager in its algorithms shall comprise machine learning techniques to learn with the experience the most appropriated way to accomplish multiple services.	
Dashboard	Software	The dashboard represents the ES Manager interface. It is used as a mean of presenting to the user all the information related with the consumptions and operation of the assets. The dashboard can also comprise other costumer-oriented services. Moreover, it is in the dashboard that the technical and performance evaluation of the BESS over time will be presented.	
Energy storage system	Hardware/ Software	Flexible asset that can be used to charge and discharge power and provide multiple services. The energy storage system comprises the power converter system, the batteries and the ancillary equipment such as the fire suppression system, the HVAC, the intrusion detection and the UPS. Operation information (SOC, power, voltage, current) is shared from the batteries to the ES Controllers and technical data such as temperature measurements are sent from the ancillary equipment to the ES Controller.	
Distributed Energy Resources (DER)	Hardware/ Software	Assets owned by the microgrid operator, where are comprised energy storage systems and other assets (PV or/and wind, flexible and non-flexible loads, diesel generator). The BESS, flexible loads and diesel genset can be managed by the microgrid management system (ES Manager).	

3.2 References

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

4. Information exchanged

Information exchanged			
Information exchanged, ID	Name of information	Description of information exchanged	Requirement, R-IDs
INF_WeatherInfo_01	Weather forecasts information	Information provided by the weather provider regarding: • Temperatures • Cloud cover • Radiation • Humidity Etc.	
INF_Prices_02	Market prices forecasting information	Information provided by market player regarding variable electricity prices, such as: • Prices for off-peak periods Prices for peak periods	

INF_ReneF_03	Renewables forecast	Information provided by ES Manager regarding PV and/or wind forecasts.	
INF_LoadF_04	Load forecast	Information provided by Load forecast module provider regarding EV and general load forecasts.	
INF_Capacity_05	Capacity needed	Information provided by system operator regarding the capacity needed in future years to maintain security of supply.	
INF_Reactive_06	Reactive Power	Information provided by the system operator regarding: • Reactive power; OR • Power factor	
INF_Setpoints_07	Setpoints	Information provided by the ES Manager regarding: • Active and/or reactive setpoints For each assets controller.	
INF_Dash_08	Dashboard information	Information provided by the ES Manager to be displayed on the dashboard. This information depends on the different scenarios.	

5. Step by step analysis of use case

5.1 Overview of scenarios

Scenarios conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Balancing services	The ES Manager shall be capable of participating in balancing services by providing a given upward or downward power reserve to market participation. The ES Manager shall be capable of provide the reserve capacity in a period comprised between 15 seconds to 15 minutes.	ES Manager	Periodic event - series of 24 balancing markets during the day	The ES Manager shall have access to weather, renewable, load and prices forecast and to grid state	Remuneration for market participation Maximizing the revenue of the system
2	Capacity Management	The ES Manager shall be capable of participating in capacity market in an auction conducted by the system operator (TSO or DSO). Energy storage system can fill the gaps in variable energy production with their fast-acting ramping and cycling abilities.	ES Manager	Periodic event - longer term auction (year/months ahead)	The ES Manager shall have access to weather, renewable, load and prices forecast and to grid state	Remuneration for market participation Maximizing the revenue of the system
3	Congestion Management	The ES Manager can participate in a medium to short auction to alleviate currents flowing though	ES Manager	Periodic event - medium to short term auction	The ES Manager shall have access to weather, renewable, load and	Remuneration for market participation

		constrained grid assets, being remunerated.			prices forecast and to grid state	Maximizing the revenue of the system
4	Reactive power support	In addition to the already existing regulatory requirements, the ES Manager can be requested to manage its assets (BESS and/or PV) for the provision of additional reactive power support.	ES Manager	Periodic event - requested by system operator	The ES Manager shall have access to weather, renewable, load and prices forecast and to grid state	Remuneration for the provision of this control Maximizing the revenue of the system
5	Frequency control	The ES Manager optimization tool shall consider and define the necessary capacity for frequency control allocated to each BESS (ES Controllers). The general requirements shall be configured in the ES Manager according to local grid codes.	ES Manager	Requested from TSO	The ES manager shall have access to grid measurements at PCC. Allocation of capacity for this service in case of multiple services execution.	Both the ESC and EPPC shall report technical data to ES Manager
6	Revenue maximization by providing multiple services	The ES Manager shall be capable of ensuring higher profit to the system through the provision of multiple services. The services that shall be considered by the ES Manager are the services represented by the scenarios above (balancing services, capacity management, congestion management and reactive power support).	ES Manager	Periodic event	The ES Manager shall have access to prices forecasts. The ES Manager shall be capable of knowing the BESS capacity allocated to each service.	Maximizing the revenue of the system

5.2 Steps – Scenarios

Scenarios conditions								
Scenario name:	**No. 1 - Balancing services**							
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	The ES Manager shall have access to weather. The ES Manager shall also have access to grid state. The ES Manager shall be able to produce renewable, load and prices forecast.		Weather information provider; ES Manager; System Operator	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03 INF_LoadF_04	
2		ES Manager optimization parameters	The ES Manager shall be capable of knowing the availability of the generation sources present in its system (hybrid park		ES Manager	ES Manager		

			or microgrid) for market participation.					
3		Exception updates to optimization parameters	The ES Manager shall be capable of identifying the generation sources with problems/errors and the programmed interventions on the assets. With this type of information, the ES Manager can identify the generation sources available for market participation.		ES Manager Additional maintenance table.	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03 INF_LoadF_04	
4		Market biding	The ES Manager shall be capable of calculating the power reserve available for balancing services and the respective price for the submission of bids to the market player. The ES Manager is also required to indicate the current maximum capacity of their units in the auction periods. The system operator (TSO, DSO or other entity) is obligated to accept the bids and offers in an economic an efficient manner and the compensation of the participants is paid according to the proposal.		ES Manager	Market player		
5		Control planning	The ES Manager after being informed that its proposal has been accepted in the market shall be capable of calculating the setpoints to ES Controllers and other controllers, according with the submitted offer.		ES Manager	ES Manager		
6		Sending inputs	The ES Manager sends to ES Controllers and other controllers the inputs in accordance with the operation plan.		ES Manager	ES Controllers Other controllers	INF_Setpoints_07	
7		Report information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_Dash_08	
8		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		
Scenario name:		**No. 2 - Capacity management**						
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs

1		Information gathering	The ES Manager shall have access to weather. The ES Manager shall be able to produce renewable, load and prices forecast. The ES Manager shall also have access to grid state. The ES Manager shall be informed of how much capacity is needed in future years to maintain security of supply.		Weather information provider; Market Player; ES Manager; System Operator	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03 INF_LoadF_04 INF_Capacity_05	
2		ES Manager optimization parameters	The ES Manager shall be capable of knowing the availability of the generation sources present in its system (hybrid park or microgrid) for capacity market participation.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The ES Manager shall be capable of identifying the generation sources with problems/errors and the programmed interventions on the assets. With this type of information, the ES Manager can identify the generation sources available for market participation.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03 INF_LoadF_04 INF_Capacity_05	
5		Market biding	The ES Manager presents its proposal on the auction of the capacity markets. Between auction and delivery time and in the delivery year, the ES Manager will be able to hedge its position though secondary trading.		ES Manager	Market player		
4		Control planning	The ES Manager after being informed that its proposal has been accepted in the market shall be capable of calculating the setpoints to ES Controllers and other controllers, according with the submitted offer.		ES Manager	ES Manager		
5		Sending inputs	The ES Manager sends to ES Controllers and other controllers the inputs in accordance with the operation plan.		ES Manager	ES Controllers Other controllers	INF_Setpoints_07	
6		Report information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_Dash_08	
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis,		ES Manager	ES Manager Dashboard		

			based on several identified KPIs.					
Scenario name:		**No.3 - Congestion management**						
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	The ES Manager shall have access to weather. The ES Manager shall be able to produce renewable, load and prices forecast. The ES Manager shall also have access to grid state.		Weather information provider; ES Manager; Market player; System Operator	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03 INF_LoadF_04	
2		ES Manager optimization parameters	The ES Manager shall be capable of knowing the availability of the generation sources present in its system (hybrid park or microgrid) for the reduction of maximum currents flowing.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The ES Manager shall be capable of identifying the generation sources with problems/errors and the programmed interventions on the assets. With these type of information, the ES Manager can identify the generation sources available for market participation.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03	
4		Market bidding	The ES Manager proposes a scheduling operation of BESS or other assets to be presented to a medium (seasonal) or short term (daily) auction. With this auction the ES Manager is remunerated by avoiding congestion in distribution feeders. The ES Manager shall be capable of deciding if this service brings higher profit to the system, participating on it or not.		ES Manager	Market player		
5		Control planning	The ES Manager after being informed that its proposal has been accepted in the market shall be capable of calculating the setpoints to ES Controllers and other controllers, according with the submitted offer.		ES Manager	ES Manager		
6		Sending inputs	The ES Manager sends to ES Controllers and other controllers the inputs in accordance with the operation plan sent to the auction.		ES Manager	ES Controllers Other controllers	INF_Setpoints_07	

7		Report information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_Dash_08	
8		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		
Scenario name:		**No. 4 - Reactive power support**						
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	The ES Manager shall have access to weather; The ES Manager shall be able to produce renewable, load and prices forecast. The ES Manager shall also have access to grid state. The ES Manager shall be informed by the system operator about the power reactive that is needed or the power factor that shall be maintained.		Weather information provider; ES Manager Market player; System operator;	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03 INF_LoadF_04 INF_Reactive_06	
2		ES Manager optimization parameters	The ES Manager shall be capable of knowing the availability of the generation sources (BESS and/or PV) that can provide reactive power support.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The ES Manager shall be capable of identifying the generation sources with problems/errors and the programmed interventions on the assets.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03 INF_LoadF_04 INF_Reactive_06	
4		Control planning	The ES Manager shall be capable of calculating the reactive setpoints of the BESS and PV, according to system operator requirement.		ES Manager	ES Manager		
5		Sending inputs	The ES Manager sends to ES Controllers and other controllers the inputs in accordance with operation plan.		ES Manager	ES Manager	INF_Setpoints_07	
6		Report information	Report the relevant information to be		ES Manager	Dashboard	INF_Dash_08	

			displayed on the dashboard.					
7		KPI evaluation	The ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		
Scenario name:		**No. 5** - Frequency control						
Step No.	Ev ent	Name of process/ activity	Description of process/ activity	Servi ce	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requiremen t, R-IDs
1		Information gathering	The ES Manager shall have access to P(f) curves, provided by the TSO and to renewables forecast. It shall also include the possibility to choose from different P(f) characteristic curves. The ES Manager shall also be capable of measuring the frequency in the PCC.		TSO; ES Manager	ES Manager	INF_ReneF_ 03	
2		ES Manager optimizatio n parameters	The ES Manager shall be capable of the prioritizing this function and calculating the battery capacity allocated to this specific scenario.		ES Manager	ES Manager		
3		Exception updates to optimizatio n parameters	The operation plan can be updated in real time or minutes before, considering adjusts in the forecasted information or changes on the system state.		ES Manager	ES Manager	INF_ReneF_ 03	
4		Control planning	The operation plan is made for the next day (in 15 minutes time frame) and are sent to the ES Controllers or EPPCs, defining the necessary capacity for frequency control allocated to each BESS.		ES Manager	ES Controllers or EPPCs	INF_Setpoi nts_04	
5		Sending inputs	ES Manager sends the function inputs to the ES Controllers or EPPCs according to control profile strategy.		ES Manager	ES Controllers or EPPCs		
6		Report Information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_Dash_0 7	
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		

Scenario name:	No. 6 Revenue maximization by providing multiple services							
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	The ES Manager shall have access to the services/ tasks that BESS or other assets need to perform. The ES Manager shall have access to weather, renewable, load and prices forecasts.		Weather information provider; Renewable information provider; Market player; Load forecast provider.	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03 INF_LoadF_04	
2		ES Manager optimization parameters	The ES Manager shall be capable of calculating the combination of services that deliver the highest profit. The ES Manager shall be capable of prioritizing the services and defining the conflict of interests between them. The conflict of interest may be either technical or economic. The technical conflict means that the BESS capacity is limited because of the capacity allocation to higher prioritized task. The economic conflict means that there is a limitation on providing the service because of insufficient reward obtained from it. Each service may request the BESS to provide an active and/or reactive power and/or energy in either charging and discharging quadrants. In a case of BESS resource is required in opposite directions during the same period, a conflict of objectives occurs. Contrarily, when BESS resource is required in the same direction, there is a question of how fairly reward the services.		ES Manager	ES Manager		
3		Exception updates to optimization parameters	The operation plan can be updated in real time or minutes before, considering adjusts in the forecasted information or changes on the system state.		ES Manager	ES Manager	INF_WeatherInfo_01 INF_Prices_02 INF_ReneF_03 INF_LoadF_04	
4		Control planning	At this time, the ES Manager shall be capable		ES Manager	ES Manager		

			of knowing the priorities and the services that will provide higher benefit and starts to schedule the operation plan of the system, defining the allocated capacity for each asset reserved to each service.					
5		Sending inputs	The ES Manager sends the inputs to the ES Controllers or to other controllers, according with the operation plan.		ES Manager	ES Controllers Other controllers	INF_Setpoints_07	
6		Report information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_Dash_08	
7		KPI evaluation	ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager Dashboard		

6. Scenarios Validation

Validation of scenarios	
Scenarios to perform	Validation criteria: KPIs
Scenario 1	Maximize the economic performance
Scenario 2	Maximize the economic performance Renewable curtailment reduction Security of supply
Scenario 3	Maximize the economic performance Grid congestion
Scenario 4	Maximize the economic performance
Scenario 5	Maximize the economic performance Frequency Control
Scenario 6 (scenarios 1, 2, 3, 4 and 5)	Maximize the economic performance

7. Requirements (Optional)

Requirements (optional)		
Categories ID	Category name for requirements	Category description
Config	Configuration	
Requirement ID	Requirement name	Requirement description
Config_1	Assets information	Configuration of different components into the system, in terms of general information (data models) and I/O information
Config_2	Access configuration	To configure component's access information (IP address, ports, gateways, …)

8. Common Terms and Definitions

Common Terms and Definitions	
Term	Definition

9. Custom Information (Optional)

Custom information (optional)		
Key	Value	Refers to section

3.5 Use Case 5

1. Description of the use case

1.1 Name of use case

Use case Identification		
ID	Area/Domain(s)/Zone(s)	Name of use case
UC1		Maximization of batteries useful time through Life Cycle Assessment (LCA)

1.2 Version management

Version Management				
Version No.	Date	Name of author(s)	Changes	Approval status
1.01	15/01/2019	Marta Ribeiro	First release	Draft
1.02	29/03/2019	José Fonseca	Correction and changes	Draft

1.3 Scope and objectives of use case

Scope and objectives of use case	
Scope	The ES Manager must have a holistic vision of the factors that play a decisive role in the useful lifetime of the batteries for the optimization of the operational strategy. This use case will be applied to other existing use cases as a final step by adjusting controllable parameters of the batteries.
Objective(s)	This use case has the following specific objectives: • Maximization of the useful lifetime of the batteries considering controllable variables, such as the adjustment of the DoD and the C-rate • Dynamic charge and discharge control for real-time estimation of battery system degradation and allowing monitoring and regulation • Increase the global efficiency of the system
Related business case(s)	• Improve the batteries useful lifetime

1.4 Narrative of the Use Case

Narrative of the use case
Short description
The optimization process of the BESS coordinated with the optimization of the useful lifetime of the batteries contemplates not only the system operation, but also some adjustments on controllable parameters associated to the batteries state of health (SoH). Depending on the BESS functionality, the system can operate cycles of charge and discharge that comprise the batteries SoH, accelerating its degradation – for example, excessive numbers of cycles or state of charge (SoC) during operation or standby periods outside of acceptable limits. The ES Manager through advanced functionalities could balance these handicaps ensuring the most favorable circumstances that addresses parallel goals and the BESS exploitation conditions – establishing boundaries to the power or depth of charge and discharge/charge cycles profiles.
Complete description
The high investment costs of the most BESS are presented as the major obstacle to the dissemination of this type of systems. This problem is worsened by the fact that the useful life of the batteries used in a BESS is lower in comparison to other active assets of the distribution grids such as transformers and lines. The batteries present in the BESS, depending on its potential use, can achieve the end of life in 10 years, contrarily to a transformer that can adequately operate for 40+ years and with lower maintenance cost as well. The useful life of the batteries is the time during which the system is able to operate until the degradation of their battery devices affects the performance of the system in such a way that the BESS can no longer fulfil its purpose. Typically, manufacturers and owners define that the end of the useful life of the battery device is reached when its storage capacity falls below 70% to 80% of its initial storage capacity. The useful life of the batteries is limited by both their calendar life and their cycle life. The calendar life results from the fact that the battery presents degradation whether it is cycled or not. This degradation through time can have several causes, although it is recognized that temperature and the SoC in

which the battery is kept the majority of time are the main factors for calendar ageing. The cycle life is defined as the number of charge and discharge frequency cycles that a battery can perform at a certain depth of discharge (DoD) and at a certain C-rate. The cycle ageing occurs as a direct consequence of the level, the utilization, the temperature and the current requests of the battery, i.e., the cycle life is limited by the number and depth of the cycles as well as the conditions in which they occur.

The main objective of this use case is to create a Life Cycle Assessment (LCA) model based on past operating data to estimate the remaining useful life of the batteries and to provide a weighted factor on future operations on the BESS.

The output of this model will be a set of indicators that enable the classification of the BESS usage and degradation for a given period of time (e.g. indicating for example a slow, average or fast degradation). The main objective of the LCA model is to quantify the impact of the BESS operation strategies, using the following information as input:

- Number of charge/discharge occurrences
- Energy charged/discharged per occurrence
- Charge/discharge rate per occurrence
- Daily SOC at full charge
- Battery degradation curves/information
- Other relevant data that can be collected

Based on the classification performed, the control parameters for the BESS operation can then be adjusted, for example, the admissible charge/discharge rate, the maximum number of charging/discharging cycles per day, the maximum DoD per occurrence, the target SoC level at the beginning of a resting period, etc. The updated control parameters can then be used as input in the tools for operational planning and real-time operation to maximize the BESS useful time for the service being provided.

This use case is transversal to all use cases previously detailed and shall be understood as one of the optimization parameters that should be considered for the overall optimization algorithm/problem. In this sense, it is a weighted factor reflected in a set of constrains, meaning that in some particular applications it may not assume a preponderant factor or, in worst case scenario, may not be considered at all.

Note that the ES Manager needs to perform the technical and economic performance evaluation of the BESS, performing a post-analysis, based on several identified KPIs. The performance management platform processes all the historic information about the behavior of the storage system on the realization of the different functionalities. This platform shall be capable of providing to the management system the ability to detect and avoid technical problems, foresee the batteries useful lifetime and adjusting the parametrizations of the algorithms of charge and discharge in real time.

1.5 Key performance indicators (KPI)

Key Performance Indicators			
ID	Name	Description	Reference to mentioned use case objectives
1	State of Health	Assessment of the impact of ageing mechanisms of the battery	Maximization of the useful lifetime of the batteries considering their internal variables
2	Cycle Benefits	Determines the benefits of operating a BESS.	Maximization of the useful lifetime of the batteries considering their internal variables
3	System global efficiency	Analysis of each equipment/stage efficiency and the overall system efficiency	Increase the global efficiency of the system
4	Number of cycles to failure (Rainflow method)	Estimation of material fatigue damage	Maximization of the useful lifetime of the batteries considering their internal variables
5	BESS availability index	Impact of the optimization in the overall operation of the BESS	Maximization of the useful lifetime of the batteries considering their internal variables Increase the global efficiency of the system

6	Useful available energy	Available energy after electrical and thermal losses intended to the selected BESS application	Maximization of the useful lifetime of the batteries considering their internal variables Increase the global efficiency of the system

1.6 Use case conditions

Use case conditions
Assumptions
This use case will be applied to the other existing use cases as a final step of optimization
Prerequisites for:
ES Manager:
The ES Manager shall have access to accurate local weather conditions, up to 48 hours
The ES Manager shall have access to weather and solar radiation forecasts from weather information provider
The ES Manager shall have access to electricity prices/feed-in tariffs, updated every 2-4 hours
The ES Manager shall be capable of managing different technologies/types of DER: renewable generation, energy storage systems, gensets and controllable and non-controllable loads
The ES Manager shall be capable of programing the BESS power exchange according to the renewable generation forecasts and feed-in tariffs applicable for the respective time horizon
The ES Manager shall have access to electricity and ancillary services prices from the market player
The ES Manager optimization modules shall be capable of updating the BESS, RES, controllable loads and genset operation profiles every 15 minutes (normal operating conditions)
The ES Manager shall be capable of managing, monitoring and optimizing the microgrid operation considering energy costs, the integration of renewables and the batteries' SoC with the goal of minimizing the energy needs from the upstream network and minimizing the costs
The ES Manager shall be able of saving in an historical database the parameters associated to the BESS operation (for example: charging and discharging power, SOC, operation modes, battery and ambient temperatures, etc.).
The ES Manager module for the LCA will provide inputs for the dashboard related with the current degradation of the BESS and to the operation strategy of the BESS.
The ES Manager shall be able to predict evolution of the batteries' temperature according to the parameters associated to the BESS operation
The ES Manager shall be capable of optimizing the BESS operation according to the use cases while trying to adjust the batteries parameters for minimizing battery degradation
The ES Manager shall be capable of defining conflict of interests (technical and economic) between services and calculating rewards and penalties from each service. The ES Manager shall be capable of decide which is the strategy that brings higher value to the system
The ES Manager shall be capable of informing which tasks were chosen to be performed by the BESS
The ES Manager shall be capable of implementing an optimized allocation of battery capacity for different purposes, selecting the optimal priority order of tasks. This allocation will be dynamic to have time-varying allocation capacity, compliant with grid conditions, with renewable generation fluctuation and with the own BESS conditions
The ES Manager shall be able to send action controls to the ES Controllers or to other controllers
The ES Manager shall be capable of interfacing/providing a GUI for the solution
The ES Manager shall be capable of storing historical generation/consumption data in the platform database, making it available for future analysis
The ES Manager shall have capability to adjust the planned operation in real time
The ES Manager shall be capable of optimizing the total system efficiency
The ES Manager shall be capable of performing a post-analysis, based on several identified KPIs
The ES Manager shall be capable of learning over the time the most appropriated way to accomplish multiple services, integrating machine learning techniques
The dashboard shall display a general overview over the available assets in the grid
The dashboard shall show graphical information about the forecasted and actual operation
The dashboard shall be capable of allowing the visualization and analysis of real-time data
The dashboard
The ES Manager shall be capable of exchanging information with the ES Controllers.
ES Controller
The ES Controllers shall be capable of reading power related values at different ECPs

The ES Controllers shall be capable of maintaining the optimum range of temperatures of the batteries by controlling the HVACs.
The ES Controllers shall be capable of sending setpoints to the power conversion system
The ES Controllers shall be capable of responding fast (order of magnitude – minute) to temperature changes in the batteries
The ES controllers shall be capable of receiving commands from the ES Manager
The ES Controllers shall be capable of managing technical constraints of the battery system
The ES Controllers shall be capable of providing the status and availability of the energy storage system to the ES Manager
The ES Controllers shall be able to send action controls to the ancillary equipments (HVACs, etc.) controllers

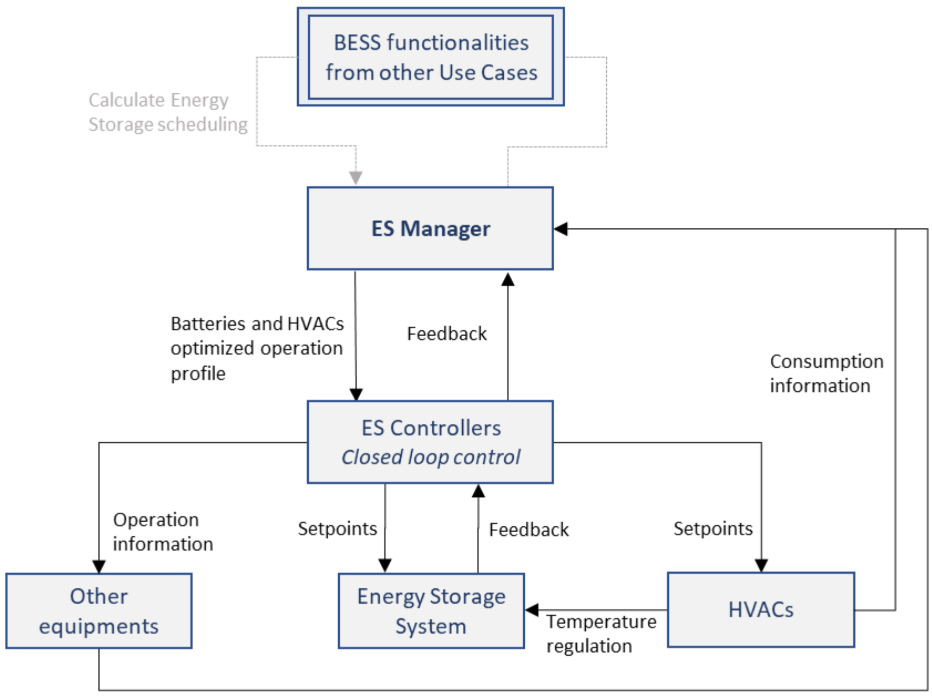
1.7 Further information to the use for classification/mapping

Classification information
Relation to other use cases
Use Case 1, Use Case 2, Use Case 3, Use Case 4 – will optimize the batteries useful lifetime for the different functionalities present in each use case
Level of depth
Primary use case
Prioritization
Nice to have
Generic, regional or national relation
Generic
Nature of the use case
System use case
Further keywords for classification
Energy efficiency, battery useful life, state of health

1.8 General remarks

General remarks

2. Diagrams of use case

Diagram(s) of use case


3. Technical details

3.1 Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case
ES Manager	Software	The ES Manager is responsible for the maximization of the useful lifetime of the batteries in each use case. The ES Manager will apply an optimization strategy for all the scenarios of each use case, trying to maximize the battery useful lifetime by changing some controllable parameters such as the C-rate, DoD.	
Dashboard	Software	The dashboard represents the ES Manager interface. It is used as a mean of presenting to the user all the information related with the consumptions and operation of the assets. The dashboard can show the diagram of the electric grid and the electric measurements on the key points. The dashboard can also comprise other costumer-oriented services. Moreover, it is in the dashboard that the technical and performance evaluation of the BESS over time will be presented.	

Energy storage system	Hardware/ Software	Flexible asset that can be used to charge and discharge power within a certain range. The energy storage system comprises the power converter system, the batteries and the ancillary equipment such as the ES Controllers and the HVAC. Operation information (SOC, power, voltage, current, temperature) is shared from the batteries to the ES Controllers and technical data is sent from the ancillary equipment to the ES Controllers.	
ES Controller	Software/ Hardware	Controller that realizes continuous monitoring of the AC and DC magnitudes of the electric grid and battery system and monitors all the other ancillary equipment in respect to the energy storage, such as the fire suppression system, HVAC and intrusion system. The ES Controller is responsible to impose the received ES Manager setpoints profile (active or reactive power setpoints) to the power conversion system, in a closed-loop control topology, in order to perform different services. The ancillary equipments, such as the HVACs will also receive setpoints from the respective ES Controller. This controller reports directly to the ES Manager and sends all the relevant information, status and alarms, which are displayed on the dashboard.	

3.2 References

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

4. Information exchanged

Information exchanged			
Information exchanged, ID	Name of information	Description of information exchanged	Requirement, R-IDs
INF_PowerSP_01	Calculated power setpoints	Power setpoints calculated by the ES Manager according to the in-use Use Case.	
INF_BatteryData_02	Datasheet information from the batteries	Information provided by the battery's manufacturer regarding electrical, mechanical and thermal data.	
INF_SetpointsBESS_03	Scheduling of BESS	Information provided by the ES Manager regarding: • Active and reactive setpoints For each asset's controller.	
INF_BatteryStatus_04	Status from the batteries	Information provided by the MBMS concerning the continuous status of the batteries such as: • Temperature • SoC, SoH	
INF_AncillaryConsumption_05	Consumption of ancillary equipment	Information provided by some readers which allow an overview about the equipment's consumption.	
INF_Dash_06	Dashboard information	Information provided by the ES Manager to be displayed on the dashboard. This information depends on the different scenarios.	

5. Step by step analysis of use case

5.1 Overview of scenarios

Scenarios conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Maximization of the global efficiency of the BESS	In this scenario the ES Manager will try to optimize the BESS in terms of global efficiency. This optimization will be applied to the functionalities of the other use cases (UC1, UC2, UC3 and UC4) by changing some controllable parameters of the batteries.	ES Manager	Simultaneous event		Increase the global efficiency of the system
2	Maximization of the battery's useful lifetime	In this scenario the ES Manager will try to optimize the BESS in terms of battery useful life. This optimization will be applied to the functionalities of the other use cases (UC1, UC2, UC3 and UC4) by changing some controllable parameters of the batteries.	ES Manager	Simultaneous event	Availability of information from the batteries and from the actual functionality of the BESS	Maximization of the useful lifetime of batteries

5.2 Steps - Scenarios

Scenarios conditions								
Scenario name:	No. 1 - Maximization of the global efficiency of the BESS							
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	The ES Manager shall calculate the usage profile required to the BESS according to the use case running		ES Manager	ES Manager	INF_PowerSP_01 INF_BatteryData_02 INF_BatteryStatus_04	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining the functionalities of the system, the priorities of each function.		ES Manager; MBMS	ES Manager	INF_BatteryData_02 INF_BatteryStatus_04	
3		Exception updates to optimization parameters	The operation plan can be updated in real time or minutes before, considering adjusts in the forecasted information or changes on the system state.		ES Manager; ES Controller	ES Controller; Energy Storage System	INF_PowerSP_01 INF_BatteryStatus_04	
4		Control planning	The operation plan is made for the next day		ES Manager	ES Controller	INF_PowerSP_01	

			and is sent to the ES Controllers, defining the allocated capacity and minimum allowed capacity for each BESS and each functionality, according to the forecast and the functions priorities. The setpoints shall be transmitted to the ES Controllers for the next hour in a 15 minutes time frame, with the setpoint for each 15-minute interval. The ES manager shall be capable of managing the operation plan while trying to leverage the economic benefits, considering existing constrains on the battery's efficiency. The ES Manager shall be capable of performing updates in real-time operation allowing BESS profile changes.				INF_BatteryStatus_04	
5		Sending inputs	The BESS setpoints calculated by the ES Manager are sent to the ES Controllers in accordance with the scheduled. The ES Manager shall be capable of allocating system capacity to this functionality in order to limit it and allow for simultaneous functions.		ES Manager; ES Controller	ES Controller; Energy Storage System	INF_SetpointsBESS_03	
6		Report Information	Report the relevant information to be displayed on the dashboard		ES Manager	Dashboard	INF_BatteryStatus_04 INF_Dash_06	
7		KPI evaluation	The ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager; Dashboard	INF_Dash_06	
Scenario name:		**No.2 -** Maximization of the batteries' useful lifetime						
Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirement, R-IDs
1		Information gathering	The ES Manager shall calculate the usage profile required to the BESS according to the use case running.		ES Manager	ES Manager	INF_PowerSP_01INF_BatteryData_02 INF_BatteryStatus_04	
2		ES Manager optimization parameters	The ES Manager shall be capable of defining the functionalities of the system, the priorities of each function and the		ES Manager	ES Manager		

			weight of the maximization of the useful lifetime on the scheduling.					
3		Exception updates to optimization parameters	The operation plan can be updated in real time or minutes before, considering adjusts in the forecasted information or changes on the system state.		ES Manager; MBMS	Energy Storage System	INF_PowerSP_01INF_BatteryStatus_04	
4		Control planning	The operation plan is made for the next day (charge and discharge setpoints) and is sent to the ES Controllers, defining the allocated capacity and minimum allowed capacity for each BESS and each functionality, according to the forecast and the functions priorities. The power setpoints shall be transmitted to the ES Controllers for the next hour in a 15 minutes time frame, with the setpoint for each 15-minute interval. The ES manager shall be capable of managing the operation plan while trying to leverage the economic benefits, considering existing constrains on the PCC, on the batteries and in other equipments functioning. The ES Manager shall be capable of performing updates in real-time operation due to exceptions on the generation assets or unexpected changes on the load side, allowing for BESS and/or RES profile changes or EV sheading, etc. Moreover, the ES Manager shall be capable to determine and adapt global BESS operation profile taking into account and predicting necessary maintenance charge/discharge cycles for each BESS asset in order to ensure maximization of this resource.		ES Manager	ES Manager; ES Controller	INF_PowerSP_01 INF_BatteryStatus_04	
5		Sending inputs	The BESS active and reactive optimized power setpoints calculated by the ES Manager are sent		ES Manager; ES Controller	ES Controller;	INF_SetpointsBESS_03	

			to the ES Controllers and to the respective controllers of the EVs, genset(s) and RES, in accordance with the scheduled profile. The ES Manager shall be capable of determine system capacity for the use case in use considering the boundaries that result from this particular use case.			Energy Storage System		
6		Report Information	Report the relevant information to be displayed on the dashboard.		ES Manager	Dashboard	INF_BatteryStatus_04 INF_Dash_06	
7		KPI evaluation	The ES Manager needs to perform the technical and economic performance evaluation of the system, performing a post-analysis, based on several identified KPIs.		ES Manager	ES Manager; Dashboard	INF_Dash_06	

6. Scenarios Validation

Validation of scenarios	
Scenarios to perform	Validation criteria: KPIs
Scenario 1	System Global Efficiency
Scenario 2	SoH LCOE Number of cycles to failure BESS availability index
Scenario 1 and 2	System Global Efficiency SoH LCOE Number of cycles to failure BESS availability index

7. Requirements (Optional)

Requirements (optional)		
Categories ID	Category name for requirements	Category description
Config	Configuration	
Requirement ID	Requirement name	Requirement description
Config_1	Assets information	Configuration of different components into the system, in terms of general information (data models) and I/O information
Config_2	Access configuration	To configure components, access information (IP address, ports, gateways, …)

8. Common Terms and Definitions

Common Terms and Definitions	
Term	Definition

9. Custom Information (Optional)

Custom information (optional)		
Key	Value	Refers to section