European Research Infrastructure supporting Smart Grid Systems Technology Development, Validation and Roll Out

Work Package 07

JRA1 - Use Case/Scenario Identification, Analysis and Selection

Deliverable D7.2

D-JRA1.2 Focal use case collection

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Table of contents

Abbreviations

aFRR	Automatic Frequency Restoration Reserve
DER	Distribution Energy Resource
DMS	Distribution Management System
DSO	Distribution System Operator
EPRI	Electric Power Research Institute
EV	Electric Vehicle
FCC	Frequency Containment Control
HVDC	High Voltage Direct Current
ICT	Information and Communication Technology
JRA	Joint Research Activity
LV	Low Voltage
MMS	Microgrid Management System
MV	Medium Voltage
NA	Networking Activity
OLTC	On Load Tap Changer
RI	Research Infrastructure
SC	System Configuration
SCADA	Supervisory Control and Data Acquisition
SGCG	Smart Grid Coordination Group
SS	System Service
TER	Transmission Energy Resources
TSO	Transmission System Operator
UC	Use Case
UCMR	Use Case Management Repository
UML	Unified Modelling Language
VSC	Voltage Source Converter
VPP	Virtual Power Plant

Executive Summary

Research infrastructures are continuously evolving in order to develop new testing procedures aimed at validating and providing solutions to the growing number of challenges that modern or future energy systems will be called to face. For this reason, ERIGrid has previously defined three system configurations that represent possible evolutions of the electric power system, involving also other domains that will be supposed to have relevant roles in the operation of the latter.

This document reports the procedure followed in ERIGrid for the selection of the use cases that will be taken as references and will be further developed during the progress of the project. The proposed focal use cases have been selected by merging the ones available in open access repositories, research projects reports and existing procedures in ERIGrid research infrastructures. During the selection, particular attention has been paid to the most fundamental services that smart grid equipment and devices are likely required to provide in the ERIGrid system configurations.

The report list and briefly describes the 16 ERIGrid focal use cases, highlighting the main functions, involved domains having considered the system configurations and services in which they can contribute and can be operated.

1 Introduction

1.1 Purpose of the Document

Different smart grid Use Cases (UC) and scenarios require different validation and testing methods, infrastructures, deployment approaches as well as procedures. The development is also rapid on this area and new solutions require more cross-cutting methodology. ERIGrid work package JRA1 “Use Case/Scenario Identification, Analysis and Selection” addresses these needs. The main objectives of this work package include:

- Identifying relevant scenarios and use cases
- Analysing them in the context of ERIGrid capabilities
- Defining needs of extending RI services or developing new ones

The work in JRA1 progresses from high-level generic system configurations towards more practical use cases. After defining the use cases, their implementation in corresponding partner laboratories will be planned. Following the general alignments of ERIGrid, the work is emphasized on:

- Needs for high-level Research Infrastructures (RI)
- Needs for supporting technology validation and roll-out phases
- Potential of integration of infrastructures

JRA1 work is closely linked with other ERIGrid work packages. Especially, the concepts of system configuration, use case, test cases, the actual terminology as well as structures of the description templates have been defined in co-operation with work package NA5.

Additionally JRA1 provides input for JRA2 in terms of simulation environment development as well as JRA3 and JRA4 in terms of development of research infrastructures and their mutual integration.

The work within JRA1 is conducted as three tasks, each focusing a specific area of development of scenarios and use cases for project use:

- JRA1.1: Identification of high-level scenarios
  - Identifying and specifying generic system configurations
  - Providing basis for use case development
  - Gathering generic views and needs among research infrastructures
- JRA1.2: Analysis and selection of use cases
  - Defining the detailed use cases based on system configuration development
  - Considering ERIGrid capabilities
- JRA1.3: Detailed implementation plan
  - Practical plans for taking the cases in ERIGrid infrastructures
  - Mapping use case requirements with infrastructure facilities

1.2 Scope and Structure of the Document

This report summarizes the activities taken for the selection of the ERIGrid focal use cases. On the basis of the high level scenarios defined in JRA1.1, JRA1.2 has analysed different sources of information in order to identify the most relevant functions that simultaneously:

- Support the operation of one or more of the JRA1.1 system configurations
- Are applicable and testable in the ERIGrid research infrastructures

In order to describe the activities, the report is outlined as follows:

- Section 2 explains the approach used during the task progress, highlighting the different significant steps in the focal use cases selection process.
- Section 3 reports and describes the selected focal use cases. One use case has been proposed for each high level system service (power/energy balance, power quality, power system stability and infrastructure integrity, protection and restoration) and for each system configuration.

2 Approach

The selection of focal use cases has been performed by taking into account different aspects which have been considered relevant according to the objectives of ERIGrid. In particular, the activity has been carried out by following four main steps:

1. Investigation of the high level scenarios described by the ERIGrid system configurations [1]
2. Identification of the main services required by the considered system configurations
3. Collection of use cases that describes functions aimed at supporting the required services
4. Selection of the most relevant UCs for each service and system configuration.

In the next sub-sections, few details of each step are going to be presented. Each paragraph provides a brief description of the carried out activity and highlight its relevance for ERIGrid.

2.1 ERIGrid System Configurations

Thanks to the analysis of the energy system projections performed by e-Highway 2050, [1] has proposed a series of different scenarios in which the electricity network is expected to evolve. These scenarios have been detailed by means of three System Configurations (SCs) which describes an assembly of sub-systems, components and domains (Table 1)

Table 1: ERIGrid System Configurations [1]

No	***System Configuration***	***Brief Description***
SC1	Distribution Grid	This SC considers the electricity distribution system at Medium Voltage (MV) and Low Voltage (LV) levels. The configuration includes the electricity area operated by the Distribution System Operator (DSO) but it also extends to other domains beyond the distribution network connection point (Distribution Energy Resources – DERs)
SC2	Transmission Grid and Offshore Wind	The increasing presence of off-shore wind power plants is one of the main characteristics for which the transmission system is expected to evolve. Even for this SC, a combination of traditional and innovative resources (Transmission Energy Resources – TERs) is expected to participate in system services: in particular, the most challenging tasks are expected to be the ones related to the exploitation of the most innovative resources (High Voltage Direct Current – HVDCs, offshore wind power plants, Voltage Source Converter – VSCs) for the provision of ancillary services.
SC3	Vertical Integration	This SC provides a possible background for the development/testing of functions related to the coordination between transmission and distribution systems. It is an extension of other two SCs and includes the same actors, stakeholders and domains. Due to its nature, vertical integration use cases will be focused on the services exchange between SC1 and SC2.

It can be immediately recognized that the predominant nature of these three SCs is represented by the electric domain. However, in order to provide specific functions, more domains can be called to contribute in the system regulation. According to the detailed descriptions of the ERIGrid SCs [1], these domains are the ones listed in Table 2.

Table 2: Domains of ERIGrid System Configurations

Domain	***Brief Description/Functionality***
Electric	The electrical domain includes the distribution and transmission network together with the HVDC links and the pure-electrical/electronic devices. It is the predominant area of interests in the ERIGrid system configuration and it represents the main way of energy transport.

Heat	Because of the large variety of systems in which electricity is converted into heat (and vice versa), this domain has a strong significance for the development of use cases. In fact, most of the traditional equipment is based on thermodynamic cycles (particularly interesting for SC2) but also new devices (such as Distributed Energy Resources – DERs) exploit electric/heat interfaces in order to provide relevant services to the system.
Mechanic	This domain is particularly relevant in systems where rotating electrical machines are used. For instance, mechanic domain plays a fundamental role for the provision of inertia to the electricity system, which is very relevant for stability purposes.
Transport	According to the envisaged scenarios, transport domain (Electric Vehicles – EVs) is expected to be a consistent energy player in the future electricity system. In particular, significant contribution can be also expected in terms of ancillary service provision, taking advantage of the capillary diffusion of EVs charging stations/supply equippment.
Primary source	For all the generation units, the primary source represents a fundamental domain and, in many cases, it can be managed in order to control the generation profile and provide ancillary services to the electricity grid.
Control	The coordination of all the components of a device or of a system is necessary task in the operation of a SC. This coordination is generally performed by one or more controllers that operate on each single component in order to exploit its functionalities in the conversion of the energy or the provision of a system service.
Communication	In smart grid infrastructures, the information exchange represents one of the most important domains. In fact, communication is fundamental for the wide-area coordination of the SC assets, devices and resources and an efficient exploitation of the required functions. The communication also involves the operators of the different areas of the SCs, especially in SC3.
Sensors and monitoring	This domain is fundamental for the exploitation of all the system regulating functions and it has to be accurately considered in many applications. It includes all the sensing components aimed at providing measurement for the systems under investigation or, in some circumstances, the estimated internal state of systems and networks.
Market	According to the projections in terms of evolution of the energetic system, the market will be subjected to deep transformations involving new actors and energy players. In particular, new ancillary services are expected to be remunerated and, thanks to the growing importance of distribution in energy balancing, markets will soon include a significant participation of DERs.
Legal/business	In spite the ERIGird RIs are not specifically designed to simulate/reproduce this domain, business use cases and legal implications can be modelled and investigated together with their impact on the other domains. New roles of network operators, incentives schemes for the operation of low carbon resources, failures in providing system critical functions, are just some of the issues that can be addressed in this domain.

2.2 Services Provided to the System Configurations by Means of their Components

The combination of all the SCs components (listed in [1]) and the domains reported in Table 2 allow the study of a large variety of UCs. In order to select functions which are relevant for the considered SCs, some of the most relevant System Services (SS) have been taken as reference:

- **SS1 – Energy balance**
- **SS2 – Energy efficiency**
- **SS3 – Power quality**
- **SS4 – Power system stability**
- **SS5 – Infrastructure integrity, protection and restoration**

In addition to their relevance, the selection of these four services has been carried out having considered the impacts that the innovation process of the electric power system can have on them. In fact, most of their aspects are expected to significantly change in the next future because of the growing presence of renewable-based generators, load/generation flexibility (even at distribution level), and stronger interdependencies between domains (especially the electric and communication ones).

According to this, UCs aimed at supporting one (or more) of these services in one (or more) SCs are of great interest to ERIGrid RIs since they would cover innovative functions for which laboratories and simulation infrastructures will be likely called to provide dedicated and standardized tests.

2.3 Collection of Potential Focal Use Cases

According to the agreed definitions of ERIGrid, 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 system*. Nowadays the UCs concepts are widely adopted in many initiatives and standardized description methodologies [2] are commonly adopted.

Thanks to existence of these standard description methods (the state of the art is investigated by NA5.2) numerous UCs and related descriptions can be extracted/deduced from the experience reported by several research projects and initiatives. The main source of information for the selection of the ERIGrid focal UCs is shown in Table 3.

Table 3: Source of Potential ERIGrid Focal UCs

Use Cases Source	***Description***
EPRI Use Case Repository [3]	The Electric Power Research Institute (EPRI) Use Case Repository is a collection of use cases and requirements developed within the industry as well as through EPRI's smart grid demonstration initiatives.
SGCG Use Case Management Repository [4]	The Use Case Management Repository (UCMR) from the Smart Grid Coordination Group (SGCG) is designed as collaborative platform for standardization committees, inter alia equipped with export functionalities as Unified Modelling Language (UML) model or text template. The UCMR is also aimed at the editing, maintenance and administration of use cases which are based on the template defined by [2]. The UCMR repository is not active/accessible anymore.
Research and development projects	Numerous research and innovation projects have adopted the UC methodology in order to describe the investigated functionality by using a standard model. Taking into account the matching between the ERIGrid goals and objectives of the other research projects, the level of details in UCs available descriptions, the following initiatives have been found to be particularly interesting: *(i)* ELECTRA project [5], *(ii)* DISCERN project [6], *(iii)* IDE4L project [7], and *(iv)* FENIX project [8].
Official reports released by Smart Grid studies initiatives	Due to the peculiarities of some SCs, the availability of significant UCs sometimes is not immediate. Especially for SC2, very few detailed UCs description have been found. However, potential Focal UCs have been deduced from documents [9]-[12] reporting the results of smart grid studies on off-shore wind power plants and transmission grid evolution.
Experience and tests procedures from ERIGrid RIs	The ERIGrid RIs are equipped for the development of numerous tests aimed at measuring the performance of different UCs. Taking into account what is currently available in ERIGrid RIs, a series of UCs have been proposed by the partners.

From this source, the UCs listed in Section 1.1 have been collected and categorized in order to identify the ERIGrid system configurations (as described in Section 2.1) in which they can be applied and the supported services (reported in Section 2.2). Once the possibility of developing test cases in the ERIGrid RIs have been verified for each of them and, from their combination, 16 comprehensive focal use cases have been proposed by and briefly described in the next section.

3 Focal Use Cases for the ERIGrid System Configurations

The previous section reports the steps of the methodology adopted for the collection of the focal UC candidates which are listed and briefly described in Section 1.1. By scrolling their detailed descriptions (available in the references reported within the table), it can be noticed that most of them refer to very particular situations which are investigated for the scenarios/projects from which they have been developed.

Taking into account that RIs should be able to test models, concepts and equipment in several scenarios, the selection of very specific UCs has not been considered beneficial for ERIGrid. In fact, in order to provide the highest flexibility in terms of test cases development, more comprehensive UCs have been proposed as focal UCs.

The following sub-sections report four of the most important services that can be provided at system level (see Section 2.2) and, for each ERIGrid system configuration, one focal UC is proposed. Each described focal UC is an adaptation (and merging) of more UCs (the ones reported in Section 1.1) and it is designed in order to cover a high number of actors, stakeholders, and components.

3.1 Energy Balance

The energy balance of a network is a fundamental requirement for its operation; in fact the generation has to constantly follow the demand curve in order to maintain the system stable. Taking into account the time horizon for which the ERIGrid SCs have been developed, scenarios in which also the demand is controlled in order to match the generation availability are included.

Depending on the considered SC, the energy balancing functions can be supported in different ways. In particular, having also considered that energy balancing is fundamental for the stability of the system, functions related to this service can be often confused with the ones related to system stability (described in Section 3.4). In order to make a more clear distinction:

- Functions aimed at guaranteeing fast and prompt support in the restoration of the power balancing have been categorized as Focal UC in SS4 (Power system stability);
- Functions aimed at guaranteeing the long-term energy balancing and in the restoration of the planned power exchanges with external systems have been categorized in SS1 (Energy balance).

The focal UCs described in the following sub-sections describes the selected functions for the support of system energy balance.

3.1.1 Focal Use Case SS1.SC1 – Management of Flexible DERs for the Long-term Balancing (Frequency/Voltage Restoration Reserve) of Microgrids in Island-Mode

Microgrids are discrete energy systems which are located at distribution level. There are several reasons for which a microgrid is operated in island-mode (physically separated by the rest of the electricity system) and, in this situation, the microgrid operator has to guarantee the maintenance of power balancing by managing the flexible DERs (which include demand side management, storage devices and distributed generation).

If the considered microgrid consists of a distribution grid, the frequency and voltage regulation can be obtained with a management that may differ from the one traditionally adopted at transmission level. In fact, since distribution lines are normally characterized by high R/X ratios, often frequency and voltage are not regulated by means of active and reactive power respectively, but from a combination of them. This means that the power balancing is operated by acting on both frequency and voltage magnitude.

This use case will be developed in order to describe how the distribution assets and energy players interact in order to maintain the energy balance of the considered distribution system (microgrid) while it is operated in island-mode. Under the coordination of the microgrid operator, and eventually through the interaction with aggregators, the flexible resources are orchestrated. Each involved DER uses its own flexibilities which may involve the other domains (see Table 4).

Table 4: Domains Involvement in SS1.SC1

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of distribution grid asset • Controllable DER interface converters (electrical side)
Heat	• Controllable thermoelectric DERs (thermostatically controlled loads, electrical heating systems, cogeneration, waste heat recovery systems, etc.)
Mechanic	None
Transport	• EV charging stations (charging current modulation, charging scheduling, etc.)
Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, biogas/fuel storage, etc.)
Control	• Controllers of DERs electrical interfaces (electric domain control) • Internal controllers of DERs (control of non-electric domains) • Distribution grid asset controllers (protection devices, lines switches, On Load Tap Changer – OLTC transformers, static compensators, etc.) • Microgrid Management System (MMS)
Communication	• Delivery of active/reactive power set points from MMS to DERs • Collection of DERs and asset status
Sensors and monitoring	• Local and remote sensors for network state estimation • Estimation of the system imbalance • DERs sensors for internal control purposes
Market	• Potentiality of having a dedicated market for microgrid flexible resources.
Legal/business	• Interactions between DSO and DERs owners • Aggregator-DERs and Microgrid System Operator-Aggregators interactions

3.1.2 Focal Use Case SS1.SC2 – Automatic Frequency Restoration Reserve from VSCs of Large Wind Farms

Future scenarios, in which renewable energy resources are expected to represent a large portion of the generation mix, will require that the functions (such as Automatic Frequency Restoration Reserve – aFRR) traditionally operated by conventional power plants will be carried out also by other resources. One of the devices that feature flexibilities able to perform these functions is represented by the VSC which is the most common interface between the transmission network, HVDC sections and on/offshore wind power plants.

This use case will be developed in order to describe how the components of a transmission network (with particular reference to SC2) and energy players (traditional TERs and wind power plants) interact in order to maintain the energy balance. The domains with the highest potential in contributing in this focal use case are reported in Table 5.

Table 5: Domains Involvement in SS1.SC2

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of transmission grid asset • Controllable TER interface converters (electrical side) • External electricity networks (electricity system of border countries, connected distribution systems)

Heat	None
Mechanic	None
Transport	None
Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, fuel storage, etc.)
Control	• Controllers of TERs electrical interfaces (electric domain control) • Internal controllers of TERs (control of non-electric domains) • Transmission grid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Transmission System Supervisory Control and Data Acquisition (SCADA)
Communication	• Delivery of aFRR participation parameters to TERs • Collection of TERs bid for the participation in aFRR • Collection of TERs and asset status
Sensors and monitoring	• Remote sensors for network state estimation • Estimation of the system imbalance • TERs sensors for internal control purposes
Market	• Capacity market including on/offshore wind power plants participation • Capacity market including international exchanges of aFRR service
Legal/business	• Interactions between Transmission System Operator (TSO) and TERs owners • Interactions between different countries for the exchange of aFRR capacity

3.1.3 Focal Use Case SS1.SC3 – Automatic Frequency Restoration Reserve from DERs

As described above, renewable energy resources will probably represent a large portion of the generation mix and their participation in critical services will be very likely required. In particular, since the highest contribution of renewable energy resources is expected from distribution networks, the vertical integration system configuration (SC3) is the most appropriate scenario in which to test the provision of system functions (such as aFRR) from the distribution levels.

This use case will be developed in order to describe how the energy resources of a distribution networks interact with network operators (DSO and TSO) in order to maintain the energy balance at system level (transmission). The domains with the highest potential in contributing to this focal UC are reported in Table 6.

Table 6: Domains Involvement in SS1.SC3

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of distribution and transmission grid asset • Controllable DER and TER interface converters (electrical side)
Heat	• Controllable thermoelectric DERs (thermostatically controlled loads, electrical heating systems, cogeneration, waste heat recovery systems, etc.)
Mechanic	None
Transport	• EV charging stations (charging current modulation, charging scheduling, etc.)
Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, biogas/fuel storage, etc.)

Control	• Controllers of TERs and DERs electrical interfaces (electric domain control) • Internal controllers of TERs and DERs (control of non-electric domains) • Transmission and distribution grid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Transmission System SCADA and Distribution Management System (DMS)
Communication	• Delivery of aFRR participation parameters to TERs and DERs • Collection of TERs and DERs bid for the participation in aFRR • Collection of TERs and DERs and asset status
Sensors and monitoring	• Remote sensors for network state estimation • Estimation of the system imbalance • TERs/DERs sensors for internal control purposes
Market	• Capacity market including TERs and (single/aggregated) DERs participation
Legal/business	• Interactions between TSO and DSO, TSO and TERs owners, DSO and TER owners, network operators and aggregators, aggregators and DERs. • Competition between TERs and DERs for the participation in aFRR • DSO responsibilities in terms of market facilitator for DERs

3.2 Energy Efficiency

The containment of the losses in energy conversion, transportation and storage has always been one of the main objectives in the design and operation of power systems. In fact, several UCs can be found or deduced from literature specifically aimed at enhancing the energy efficiency of systems, particularly considering that specific targets of improvement are fixed by climate-change committees and governments.

According to this, energy efficiency related UCs have high potential to be considered focal in ERIGrid. As happens for other services, the energy efficiency functions strongly depend on the considered SC, and the UCs can be implemented in different ways by taking advantage of the available domains and components.

3.2.1 Focal Use Case SS2.SC1 – Optimal Distribution Network Control for the Reduction of System Energy Losses

Distribution networks (SC1) and the energy conversions located at this level (DERs) have a high potential in terms of energy efficiency improvement. Thanks to the exploitation of advanced controllers, in fact, network flexibilities can be exploited and managed in order to reduce the losses due to energy transport when they are not involved in the provision of other services (i.e. congestion management). Simultaneously, DERs internal processes can integrate functionalities that allow a better utilization and conversion of the energy, as well as the recovery of waste energy and storage functions.

This use case will be developed in order to describe how the distribution assets and energy players are operated in order to enhance the energy efficiency at the distribution level. Stand-alone functions of DERs internal controllers, coordinated control of multiple DERs and network assets for distribution energy efficiency will be described by this focal UC taking advantage of the available domains (listed in Table 7).

Table 7: Domains Involvement in SS2.SC1

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of distribution grid asset • Controllable DER interface converters (electrical side)

Heat	• Controllable thermoelectric DERs (thermostatically controlled loads, electrical heating systems, cogeneration, waste heat recovery systems, etc.)
Mechanic	• Controllable electromechanical DERs (e.g. mechanical cogeneration, regenerative braking of industrial machines)
Transport	• EV charging stations (charging current modulation, charging scheduling, etc.) • Public transportation (e.g. regenerative braking)
Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, biogas/fuel storage, etc.)
Control	• Controllers of DERs electrical interfaces (electric domain control) • Internal controllers of DERs (control of non-electric domains) • Distribution grid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Distribution Management System
Communication	• Delivery of active/reactive power set points from DMS to DERs • Controlling signals of remote areas of DERs • Collection of DERs and asset status
Sensors and monitoring	• Local and remote sensors for network state estimation • Estimation of the system imbalance • DERs sensors for internal control purposes
Market	None
Legal/business	• Interactions between DSO and DERs owners • Identification, localization and penalization of non-technical losses • Incentives for DERs contribution in system energy efficiency

3.2.2 Focal Use Case SS2.SC2 – Optimal Transmission Network Management Level for System Energy Losses Reduction

Transmission network are generally featuring higher performances with respect to distribution systems in terms of energy efficiency. However, several solutions can be exploited and implemented in order to further increase the energy transport performance. In fact, taking advantage of the meshed nature of transmission grids, energy flows can be driven through preferential paths, or large generation units can be operated in order to convert energy in a more efficient way.

This use case will be developed in order to describe how the components of a transmission network (with particular reference to SC2) and energy players (traditional TERs and wind power plants) can be operated singularly and/or in a coordinated way in order to enhance the energy efficiency of the system. The domains with the highest potential in contributing to this focal UC are reported in Table 8.

Table 8: Domains Involvement in SS2.SC2

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of transmission grid asset • Controllable TER interface converters (electrical side) • External electricity networks (electricity system of border countries, connected distribution systems)
Heat	None
Mechanic	• Controllable electromechanical TERs (e.g., mechanical cogeneration, regenerative braking of industrial machines, large generation units machines)
Transport	None

Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, fuel storage, etc.)
Control	• Controllers of TERs electrical interfaces (electric domain control) • Internal controllers of TERs (control of non-electric domains) • Transmission grid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Transmission System SCADA
Communication	• Delivery of active/reactive power set points from transmission SCADA to TERs • Controlling signals of remote areas of TERs • Collection of TERs and transmission asset status
Sensors and monitoring	• Remote sensors for network state estimation • Estimation of the overall transmission system efficiency • TERs sensors for internal control purposes
Market	None
Legal/business	• Interactions between TSO and TERs owners • Incentives for TERs contribution in system energy efficiency

3.2.3 Focal Use Case SS2.SC3 – Incentivising Distribution Network Local Balancing to Minimize Transmission Network Loading

One of the functions that can be featured by distribution networks consists in the optimization of the local available flexible resources in order to manage the exchange profile in correspondence of the primary substation (point of common coupling between distribution and transmission system). Thanks to this functionality it is possible to incentivise the local consumption of the energy injected by distribution generators. This allows the reduction of the energy transport, especially at transmission level where a well-balanced distribution grid requires marginal provision/taking of electricity.

This use case will be developed in order to describe how the energy resources and the assets of a distribution network interact with the DSO in order to reduce the energy flows from/to transmission network. The domains with the highest potential in contributing to this focal UC are reported in Table 9.

Table 9: Domains Involvement in SS2.SC3

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of distribution and transmission grid assets • Controllable DER and TER interface converters (electrical side)
Heat	• Controllable thermoelectric DERs (thermostatically controlled loads, electrical heating systems, cogeneration, waste heat recovery systems, etc.)
Mechanic	None
Transport	• EV charging stations (charging current modulation, charging scheduling, etc.)
Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, biogas/fuel storage, etc.)
Control	• Controllers of DERs electrical interfaces (electric domain control) • Internal controllers of DERs (control of non-electric domains) • Transmission and distribution grid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Transmission System SCADA and DMS

Communication	• Delivery of active/reactive power set points from DMS to DERs • Controlling signals of remote areas of DERs • Collection of DERs and asset status
Sensors and monitoring	• Remote sensors for network state estimation • DERs sensors for internal control purposes
Market	None
Legal/business	• Interactions between TSO and DSO • Interactions between DSO and DERs owners • Incentives for DERs contribution in system energy efficiency

3.3 Power Quality

The increasing penetration of distributed generation is particularly challenging from the power quality point of view and, currently, one of the most relevant limitations in terms of renewable integration is the voltage issues caused by generation at distribution level. In order to mitigate these effects, potential solutions have to be developed and most of them require the coordination of more resources in order to manage the voltage congestions. Usually, power quality issues can spread to the transmission system and, in this case, even the resources at this electricity level can actively participate in the mitigation of voltage issues.

According to this, all the ERIGrid system configurations can be considered as proper scenarios in which power quality functions can be tested and, for each of them, specific focal use cases have been proposed and reported in the following sub-sections.

3.3.1 Focal Use Case SS3.SC1 – Advanced Voltage Control of Distribution Grids Supported by DERs Power Interfaces

As mentioned above, distribution networks are mostly subject to power quality issues, especially when high penetration of distributed generation is present. Currently, many research initiatives are oriented to the investigation of potential solutions and this is confirmed also by the large amount of UCs related to the topic (see Section 1.1).

One of the most promising solutions is represented by a coordinated control of the DERs aimed at solving network congestions due to power quality issues. This can be performed by means of a central controller (DMS) which, on the basis of the estimated state of the network, sends active/reactive power set points to the flexible resource. In addition, single DERs can exploit control algorithms aimed at compensating eventual harmonic content and voltage unbalancing present on the distribution grid.

This use case will be developed in order to describe this DERs control function for which the involvement of most of the system domains is required (see Table 10).

Table 10: Domains Involvement in SS3.SC1

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of distribution grid asset • Controllable DER interface converters (electrical side)
Heat	• Controllable thermoelectric DERs (thermostatically controlled loads, electrical heating systems, cogeneration, waste heat recovery systems, etc.)
Mechanic	None
Transport	• EV charging stations (charging current modulation, charging scheduling, etc.)

Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, biogas/fuel storage, etc.)
Control	• Controllers of DERs electrical interfaces (electric domain control) • Internal controllers of DERs (control of non-electric domains) • Distribution grid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Distribution Management System
Communication	• Delivery of active/reactive power set points from DMS to DERs • Controlling signals of remote areas of DERs • Collection of DERs and asset status • Technology able of communicating also in case of contingency
Sensors and monitoring	• Local and remote sensors for network state estimation • Sensors capable of providing alarms in case of power quality issues • DERs sensors for internal control purposes
Market	• Potential market for DERs participation in power quality services
Legal/business	• Interactions between DSO and DERs owners • Identification, localization and penalization of devices causing power quality issues • Incentives for DERs contribution in power quality services

3.3.2 Focal Use Case SS3.SC2 – Voltage Quality Support by Onshore and Offshore (VSC-HVDC connected) Wind Power Plants

Even though the transmission network is less subject to power quality issues (they are generally experienced in proximity of electric arc furnaces and locally compensated), the growing energetic importance of distribution networks may soon increase the levels of distortion and voltage unbalance even at transmission level. Taking advantage of highly flexible resources (such as the VSCs), power quality supporting functions can be implemented in order to mitigate voltage fluctuations, voltage waveform distortions, unbalances and severe voltage dips.

This use case will be developed in order to describe how onshore and offshore (VSC-HVDC connected) wind power plants can be operated in order to provide power quality services. The domains with the highest potential in contributing in this focal UC are reported in Table 11.

Table 11: Domains Involvement in SS3.SC2

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of transmission grid asset • Controllable TER interface converters (electrical side) • External electricity networks (electricity system of border countries, connected distribution systems)
Heat	None
Mechanic	None
Transport	None
Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, fuel storage, etc.)
Control	• Controllers of TERs electrical interfaces (electric domain control) • Internal controllers of TERs (control of non-electric domains) • Transmission grid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Transmission System SCADA

Communication	• Delivery of active/reactive power set points from SCADA to TERs • Controlling signals of remote areas of TERs • Collection of TERs and asset status • Technology able of communicating also in case of contingency
Sensors and monitoring	• Local and remote sensors for network state estimation • Sensors capable of providing alarms in case of power quality issues • TERs sensors for internal control purposes
Market	• Participation of VSC-based wind power plant in the voltage control market
Legal/business	• Interactions between TSO and TERs owners • Identification, localization and penalization of devices causing power quality issues • Grid connection requirements • Incentives for TERs contribution in power quality services

3.3.3 Focal Use Case SS3.SC3 – Transmission Network Voltage Quality Support by the Distribution Network (VPP)

Thanks to the coordinated control of DERs, part of an active distribution network can be operated as a Virtual Power Plant (VPP) and provide similar services to the ones that can be featured by a traditional generation plant. According to this, the aggregation of the DERs can provide arbitrary control of the reactive power in correspondence of the point of common coupling between distribution and transmission network and perform voltage control. In addition, taking advantage of the high flexibility of some distribution resources, other services such as the suppression of harmonic content and voltage unbalance (not attributable to distribution network issues) can be exploited.

This use case will be developed in order to describe how the DERs interact with the DSO in order to support the voltage regulation at transmission level and the domains with the highest potential in contributing in this focal UC are reported in Table 12.

Table 12: Domains Involvement in SS3.SC3

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of distribution grid asset • Controllable DER interface converters (electrical side) • Transmission network components
Heat	• Controllable thermoelectric DERs (thermostatically controlled loads, electrical heating systems, cogeneration, waste heat recovery systems, etc.)
Mechanic	None
Transport	• EV charging stations (charging current modulation, charging scheduling, etc.)
Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, biogas/fuel storage, etc.)
Control	• Controllers of DERs electrical interfaces (electric domain control) • Internal controllers of DERs (control of non-electric domains) • Distribution grid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Distribution Management System
Communication	• Delivery of active/reactive power set points from DMS to DERs • Controlling signals of remote areas of DERs • Collection of DERs and asset status • Technology able of communicating also in case of contingency

Sensors and monitoring	• Local and remote sensors for network state estimation • Sensors capable of providing alarms in case of power quality issues in correspondence of the primary substation • Monitoring system capable of identify the source of power quality disturbances • DERs sensors for internal control purposes
Market	• Potential market for DERs participation in power quality services
Legal/business	• Interactions between DSO and DERs owners • Interactions between TSO and DSO • Identification, localization and penalization of devices causing power quality issues • Incentives for DERs contribution in power quality services • Competition between TERs and DERs for the provision of power quality services

3.4 Power System Stability

Another aspect particularly challenging in future power systems is represented by the stability. Most of the functions aimed at supporting the system robustness are currently performed by traditional generators and, for scenarios in which their presence is expected to be less predominant, other solutions have to be exploited.

In order to support the power system stability, many actors can be involved as well as all the domains considered within ERIGrid. Also in this case, on the basis of ERIGrid SCs, different focal UCs have been proposed and described in the following sub-sections.

3.4.1 Focal Use Case SS4.SC1 – Management of Flexible DERs for the Instantaneous Active/Reactive Power Balancing of Microgrids in Island-Mode

As mentioned in Section 3.1.1, there are possible scenarios in which an electricity gird can be operated in island mode (microgrid). In these cases, the stability of the microgrid is depending on the ability of the flexible DERs in regulating active and reactive power exchanges according to the actual availability/demand of energy. The DERs participating in voltage and frequency regulation, in addition to be able of receiving and imposing power exchange set points, should be also able to promptly react to system perturbations by opportunely modifying their consumption/generation according to predefined voltage/frequency droop curves (normally implemented on DERs interface controllers).

Another important contribution that DERs participating in microgrid stability functions should provide is represented by the inertial response: this function, intrinsically available on DERs based on rotating machines interfaces, have to be simulated on VSC-based energy resources.

This use case will be developed in order to describe this DERs control functions and their impact on the stability of the microgrid. The domains with a potential role for the provision of these services in SC1 are reported in Table 13.

Table 13: Domains Involvement in SS4.SC1

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of microgrid asset • Controllable DER interface converters (electrical side)
Heat	• Controllable thermoelectric DERs (thermostatically controlled loads, electrical heating systems, cogeneration, waste heat recovery systems, etc.)

Mechanic	• Controllable electromechanical DERs (e.g. mechanical cogeneration, regenerative braking of industrial machines) • Mechanical components of the conversion system of DERs based on rotating machines (wind/water turbines, additional flywheels)
Transport	• EV charging stations (charging current modulation, charging scheduling, etc.)
Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, biogas/fuel storage, etc.)
Control	• Controllers of DERs electrical interfaces (electric domain control) • Internal controllers of DERs (control of non-electric domains) • Microgrid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Microgrid Management System
Communication	• Delivery of DERs participation factors/droop curves from MMS • Controlling signals of remote areas of DERs • Collection of DERs and asset status
Sensors and monitoring	• Local and remote sensors for network state estimation • Sensors capable of providing a fast measurement of electrical quantities for supporting the DERs controllers • DERs sensors for internal control purposes
Market	• Potential market for DERs participation in stabilization functions
Legal/business	• Interactions between microgrid operator and DERs owners • Incentives for DERs contribution in stabilization functions

3.4.2 Focal Use Case SS4.SC2 – Large-scale Wind Power Plant (Onshore and Offshore VSC-HVDC Connected) Support in Frequency Containment Control and Power System Inertia

Frequency Containment Control (FCC) and inertial response are services normally provided by traditional generation units for which dedicated markets (at least for FCC) are currently operated. VSC-based TERs normally do not provide these services but, still considering a future system configuration in which wind farms constitutes a large portion of the energy mix, their contribution in FCC and power inertia could represent a mandatory requirement for the system stability. In spite large wind generation units are composed by large rotating turbines, the VSC-based interface does not allow a simple implementation of frequency control functions and dedicated algorithms have to be implemented.

This use case will be developed in order to describe how the VSC located at transmission level and interfacing large wind power plants can be operated in order to provide fast frequency control (FCC and inertial response). The domains with the highest potential in contributing in this focal UC are reported in Table 14.

Table 14: Domains Involvement in SS4.SC2

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of transmission grid asset • Controllable TER interface converters (electrical side) • External electricity networks (electricity system of border countries, connected distribution systems)
Heat	None
Mechanic	• Mechanical components of the conversion system of TERs based on rotating machines (wind/water turbines, additional flywheels)

Transport	None
Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, fuel storage, etc.)
Control	• Controllers of TERs electrical interfaces (electric domain control) • Internal controllers of TERs (control of non-electric domains) • Transmission grid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Transmission System SCADA controllers
Communication	• Delivery of participation factors/droop curves from SCADA to TERs • Controlling signals of remote areas of TERs • Collection of TERs and asset status
Sensors and monitoring	• Local and remote sensors for network state estimation • Sensors capable of providing a fast measurement of electrical quantities for supporting the TERs frequency controllers • TERs sensors for internal control purposes
Market	• Integration of VSC-based wind power plant in the frequency control market
Legal/business	• Interactions between TSO and TERs owners • Grid connection requirements

3.4.3 Focal Use Case SS4.SC3 – DERs Support in Frequency Containment Control and Power System Inertia

As it happens for SS4.SC2, the lacking of conventional generation units due to the growing amount of renewables (according to the ERIGrid SCs) defines scenarios in which also generators characterized by static interfaces (VSCs) will be called to provide the fundamental system services (such as the ones aimed at maintaining the power stability). In SC3 a large amount of generation is connected at distribution level and DERs (generators and loads) are likely expected to provide frequency control functions such as FCC and inertia support. Even in this case, since most of the DERs units are based on static interfaces, dedicated algorithms have to be implemented in order to make their power exchange responsive to system frequency variations.

This use case will be developed in order to describe how the DERs respond to frequency variations due to perturbation in the overall system energy balancing. The domains with the highest potential in contributing in this focal UC are reported in Table 15.

Table 15: Domains involvement in SS4.SC3

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of distribution and transmission grid asset • Controllable DER and TERs interface converters (electrical side)
Heat	• Controllable thermoelectric DERs (thermostatically controlled loads, electrical heating systems, cogeneration, waste heat recovery systems, etc.)
Mechanic	• Controllable electromechanical DERs (e.g. mechanical cogeneration, regenerative braking of industrial machines) • Mechanical components of the conversion system of DERs and TERs based on rotating machines (wind/water turbines, additional flywheels)
Transport	• EV charging stations (charging current modulation, charging scheduling, etc.)
Primary source	• Controllable/storable primary sources (e.g. wind turbine pitch control, water basin, biogas/fuel storage, etc.)

Control	• Controllers of DERs and TERs electrical interfaces (electric domain control) • Internal controllers of DERs and TERs (control of non-electric domains) • Transmission and distribution grid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Distribution DMS and Transmission SCADA
Communication	• Delivery of participation factors/droop curves from SCADA/DMS to TERs/DERs • Controlling signals of remote areas of TERs and DERs • Collection of TERs and DERs and asset status
Sensors and monitoring	• Local and remote sensors for network state estimation • Sensors capable of providing a fast measurement of electrical quantities for supporting the TERs and DERs frequency controllers • TERs and DERs sensors for internal control purposes
Market	• Inclusion of DERs in the frequency control market
Legal/business	• Interactions between DSO and DERs owners • Interactions between TSO and DSO • Competition between TERs and DERs for the provision of frequency control functions

3.5 Infrastructure Integrity, Protection, and Restoration

Other functions that are expected to evolve in the ERIGrid system configurations (with respect to the current power system operation) are represented by the ones supporting the integrity, protection and restoration of the SCs infrastructures. In fact, taking into account the high flexibility that energy players are able to provide in all the power system levels, significant benefits can be provided by the operation of dedicated UCs.

As it has been done for the other services, the next sub-sections report a description of the proposed focal UCs which have been defined for each ERIgrid SC (Section 3.5.1 – 3.5.3). In addition, having considered the importance of the communication domain in the overall system management, a focal UC describing functions aimed at guaranteeing Information and Communication Technology (ICT) integrity, protection and restoration has been proposed (Section 3.5.4)

3.5.1 Focal Use Case SS5.SC1 – Fault Detection and Corrective Management of Distribution Grid Assets and Energy Resources

The power supply continuity plays an important role in the energy systems and thanks to the exploitation of distribution network flexibilities (remotely controllable assets and DERs) as well as wide-area monitoring it is possible to increase the performance of the electricity networks in terms of faults localization, isolation and service restoration.

According to this, the proposed focal UC describes the functions aimed at analysing the network state in order to locate the faults, reconfigure the network assets and topology in order to minimize the area subjected to power interruption, and eventually supply isolated portion of the network by means of distributed generation flexibility. The domains with a potential role for the provision of these services in SC1 are reported in Table 16.

Table 16: Domains Involvement in SS5.SC1

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of distribution grid asset • Controllable DER interface converters (electrical side) • Protection and trip units located at distribution level

Heat	• Controllable thermoelectric DERs (thermostatically controlled loads, electrical heating systems, cogeneration, waste heat recovery systems, etc.)
Mechanic	• Controllable electromechanical DERs (e.g. mechanical cogeneration, regenerative braking of industrial machines) • Mechanical components of the conversion system of DERs based on rotating machines (wind/water turbines, additional flywheels)
Transport	• EV charging stations (charging current modulation, charging scheduling, etc.)
Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, biogas/fuel storage, etc.)
Control	• Controllers of DERs electrical interfaces (electric domain control) • Internal controllers of DERs (control of non-electric domains) • Distribution grid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Distribution Management System
Communication	• Delivery of DERs participation factors/droop curves from DMS • Controlling signals of remote areas of DERs • Collection of DERs and asset status • Communication infrastructure able to send/receive commands even in case of contingencies
Sensors and monitoring	• Local and remote sensors for network state estimation • Monitoring system capable of recognizing network faults and supporting their localization • DERs sensors for internal control purposes
Market	None
Legal/business	• Interactions between DSO and DERs owners • Incentives for DERs contribution during emergency situations

3.5.2 Focal Use Case SS5.SC2 – VSCs (of HVDC and Large Wind farms) support during transmission network restoration

During the restoration of a portion of the network that was subject to blackout, only few components have specific roles and these are generally represented by conventional generation units. It is clear that in SC2, the support of restoration functions can be provided also by the VSCs interfacing (offshore) wind power plants and HVDC links. In this case, dedicated control algorithms and communication interfaces for the coordination of the system restoration has to be implemented on VSCs controller as well as on the wind power plant supervisory controller.

This use case will be developed in order to describe how the VSCs located at transmission level can be operated in order to support the system during the restoration and the reconnection with the rest of the (healthy) electricity system. The domains with the highest potential in contributing to this focal Use Case are reported in Table 17.

Table 17: Domains Involvement in SS5.SC2

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of transmission grid asset • Controllable TERs interface converters (electrical side) • External electricity networks (electricity system of border countries, connected distribution systems)
Heat	None

Mechanic	• Mechanical components of the conversion system of TERs based on rotating machines (wind/water turbines, additional flywheels)
Transport	None
Primary source	• Controllable/storable primary sources (wind turbine pitch control, water basin, fuel storage, etc.)
Control	• Controllers of TERs electrical interfaces (electric domain control) • Internal controllers of TERs (control of non-electric domains) • Transmission grid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Transmission System SCADA
Communication	• Delivery of participation factors/droop curves from SCADA to TERs • Controlling signals of remote areas of TERs • Collection of TERs and asset status • Communication infrastructure able to send/receive commands even in case of contingencies
Sensors and monitoring	• Local and remote sensors for network state estimation • TERs sensors for internal control purposes
Market	None
Legal/business	• Interactions between TSO and TERs owners

3.5.3 Focal Use Case SS5.SC3 – Intentional Islanding of Microgrids During Widespread Disturbances and Restoration of the Transmission System

One of the reasons for which a microgrid is operated in island-mode is for guaranteeing the power supply continuity to DERs in case of transmission system contingencies or critical situations. In addition, the physical disconnection of a microgrid capable of being operated in island-mode can simplify the management of the transmission system restoration.

The proposed focal UC includes functions that describe how the network operators identify transmission criticalities and the emergency management of the distribution resources (assets and DERs) in order to promptly create an independent and robust islanded system. The same UC also describes the functions aimed at reconnecting the microgrid once the transmission system stability margin has been restored. The domains with the highest potential in contributing in this focal UC are reported in Table 18.

Table 18: Domains Involvement in SS5.SC3

Domain	***Potential Contributors in Focal UC Functions***
Electric	• Controllable components of microgrid and transmission grid asset • Controllable DER interface converters (electrical side)
Heat	• Controllable thermoelectric DERs (thermostatically controlled loads, electrical heating systems, cogeneration, waste heat recovery systems, etc.)
Mechanic	• Controllable electromechanical DERs (e.g. mechanical cogeneration, regenerative braking of industrial machines) • Mechanical components of the conversion system of DERs based on rotating machines (wind/water turbines, additional flywheels)
Transport	• EV charging stations (charging current modulation, charging scheduling, etc.)
Primary source	• Controllable/storable primary sources (e.g. wind turbine pitch control, water basin, biogas/fuel storage, etc.)

Control	• Controllers of DERs electrical interfaces (electric domain control) • Internal controllers of DERs (control of non-electric domains) • Microgrid asset controllers (protection devices, lines switches, OLTC transformers, static compensators, etc.) • Microgrid Management System (MMS) and Transmission SCADA
Communication	• Delivery of participation factors/droop curves from MMS to DERs • Controlling signals of remote areas of DERs • Collection of DERs and asset status • SCADA-MMS communication for the management of microgrid disconnection/reconnection
Sensors and monitoring	• Local and remote sensors for network state estimation • Sensors capable of proving reference measurements aimed at resynchronizing microgrid and transmission network before reconnection • TERs and DERs sensors for internal control purposes
Market	None
Legal/business	• Interactions between microgrid operator and DERs owners • Interactions between TSO and microgrid operator • Incentives to DERs for the support in transmission energy restoration

3.5.4 Focal Use Case SS5.SC4 – Identification of ICT Anomalies and Restoration of the Communication Links

In order to implement all the proposed focal UCs and to effectively operate all the ERIGrid SCs, the communication layer has to be fully operative and robust to the potential disturbances that may occur in the real world. In particular, real ICT is subjected to failures, cyber-attacks and often influenced by external and uncontrollable factors (such as weather conditions). For this reason, specific functions for its protection and restoration have to be implemented.

This focal UC groups all the functions aimed at increasing the reliability, availability and safety of the communication infrastructure and it is, in principle, applicable to all the ERIGrid SCs. Due to its peculiar nature only few domains are involved (as reported in Table 19).

Table 19: Domains involvement in SS5.SC4

Domain	***Potential Contributors in Focal UC Functions***
Electric	None
Heat	None
Mechanic	None
Transport	None
Primary source	None
Control	None
Communication	• Communication interface of controllable/monitored DERs and TERs • DMS, Transmission SCADA, and aggregator communication interface • Communication links between actors • Redundant communication links for emergency service
Sensors and monitoring	• Local and remote sensors for network state estimation
Market	None
Legal/business	• Responsibilities in terms of operation and maintenance of ICT network • Corrective and restoration actions in case of communication failures

4 Discussion and Conclusions

ERIGrid counts several RIs and, having considered the continuous innovation of the electricity networks, they have to be constantly updated and adapted for the provision of testing procedures more and more in line with the new concepts that are gradually becoming common in network practices. For this reason, the adequacy (and eventual update) of RIs has to be carefully considered by investigating the expectations in terms of power system evolution.

According to this, JRA1.2 has investigated some of the most critical services that smart grid equipment and devices are expected to provide in future scenarios (represented by the ERIGrid system configurations). Starting from these services, the potential network/resources functions have been investigated by analysing several related use cases extracted and/or deduced from open access repositories, smart grid studies and other research projects.

From the collected information sixteen focal UCs have been proposed and considered representative of some of the most relevant functions that can be reasonably expected to be operative in the ERIGrid system configurations. Focal UCs have been designed in order to cover a large spectrum of system domains and actors, and to comprehend several more specific functions (such as the ones described by the literature use cases). Thanks to this extensiveness, several test cases can be designed, taking advantage of the different domains which can be easily reproduced and/or simulated by the ERIGrid RIs.

The proposed focal UCs will be further developed during the project and readapted according to the test cases that will be found to be of high interest (JRA1.3) for the potential experimentations in simulation environment (JRA2) and laboratory infrastructures (JRA3). In addition, the detailed descriptions will be carried out by means of the procedure (currently under definition in NA5.2) based on the existing standard IEC PAS 62559 [2], which has been modified and aligned with the description methods of system configurations and test cases. Simultaneously the advisory board will be consulted in order to collect feedbacks and recommendations on the proposed focal UCs.

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6 Annex

6.1 List of Tables

6.2 Collected Use Cases for Being Considered in the Selection of the ERIGrid Focal Ones

Use Case	*Short Description*	*Source Information*	*System Service*	*System Conf.*	*Related Focal UC*
1. Frequency Restoration Reserve from large wind power plants	The EU-project REserviceS assessed the technical and operational state-of-art possibilities of wind farms taking into account existing specifications in grid codes, standards, technical literature, validated by practical experience in case studies, and found that in general for the investigated voltage and frequency services the necessary capabilities are already incorporated in existing wind turbine technology or can be installed if required.	TKI Wind op Zee-Ancillary services from offshore windfarms in the Netherlands	SS1	SC2	SS1.SC2
2. Peak Shift Contribution by Battery Aggregation	Many batteries are being deployed in the smart grid. These batteries are small scale and distributed. These batteries can be aggregated and controlled as Virtual Energy Storage which can be used for peak shifting or load leveling. The control technology comprises a Grid EMS, Grid Operator, and communications via Battery SCADA. A scenario that describes control functions for Peak Shift Contribution by Battery Aggregation is introduced in this use case.	*http://smartgrid.epri.com/UseCases/NEDO%20Peak%20Shift%20Contribution.pdf*	SS1, SS2	SC1, SC3	SS1.SC1, SS1.SC3, SS3.SC1, SS3.SC3
3. Energy management of grid-connected microgrid that makes optimum use of city gas as the fuel and mitigates negative effects of intermittent generators on distribution grid	This use case describes energy management of a grid-connected microgrid system that optimizes the use of city gas while making optimum use of renewable energy and mitigates negative effects on the distribution grid with respect to demand-supply balance and power quality. The microgrid system is connected to the distribution grid at a single point and is controlled by the energy management system (EMS) which maintains the amount of power purchased from the distribution grid (power flow at PCC (point of common coupling)) to contribute to frequency control of the distribution grid and develops a generation schedule in accordance with the load within the microgrid.	*http://smartgrid.epri.com/UseCases/System%20Use%20Case%20_A1%20Aichi%20Microgrid%20rev4.pdf*	SS1, SS3	SC1	SS1.SC1, SS3.SC1

4. Advanced control of distribution grid	Aggregation of more functions: implementation of intelligent voltage control (OLTC, VVC), dynamic reconfiguration of the grids, faults management, grid protection plans, etc.	GINP Research Infrastructure	SS1, SS2, SS3, SS4, SS5	SC1	SS1.SC3, SS2.SC1, SS2.SC3, SS3.SC1, SS3.SC3, SS4.SC3, SS5.SC1, SS5.SC3, SS5.SCx
5. Aggregate DER as commercial VPP	The CVPP collects the price curve and generation schedule of each DER. The CVPP prepares the bids (risk mitigation strategy), after market process, the CVPP gets the global schedule back from the market. After technical validation by DSO & TSO, the CVPP sends a specific schedule to each DER The CVPP must be able to modify its production in real time.	FENIX project	SS1	SC3	SS1.SC3
6. Automated energy trading platform for microgrids participation in the energy market	The objective of the specific microgrid central controller is the automated and cost effective participation of a microgrid in the energy market. The market model assumed in the process is the ENTSO-E role model. In the context of this model, the microgrid represents a cluster of prosumers which belong in a Balance Group and submit flexibility offers to a Balance Responsible Party. The goal of the process is to successfully submit the offers, to receive the accepted ones, to assess the short-term future state base on forecasting and to optimally dispatch the flexibility, in order to reduce the energy cost, minimize the requirements of the system in peak power and steer the power flows to the desired values.	CRES Research Infrastructure	SS1	SC3	SS1.SC3
7. Allocation and activation of highly-distributed reserves for balance restoration	The use case involves restoration of system balance following any significant event or disturbance which results in a frequency deviation. It is assumed that reserves are available from a wide variety of highly-distributed resources, and the grid is based on the "web-of-cells" architecture. The use case requires that these resources are allocated efficiently and cost-effectively to prepare for a possible event, and are correctly activated when an event occurs. Due to the nature of web-of-cells architecture, the monitoring and control for implementing this use case must use a distributed approach.	Strathclyde Research Infrastructure	SS1	SC3	SS1.SC3

8. Multi energy ancillary services	Ancillary services typically for TSO; therefore is interested in verification; unclear if TSO is actually verification responsible. Metering responsible. DSO as resources provided from distributions grid and may affect DSO operation; alternatively, also service provided to DSO. Aggregator delivers the service, controls the DER. DER performs physical serivce. Also metering is close to / at DER.	DTU Research Infrastructure	SS1	SC3	SS1.SC1, SS1.SC2, SS1.SC3
9. Aggregator Service delivery monitoring and verification	The aggregation of DERs for the provision of ancillary services is a process that requires a frequent coordination and the service has to be constantly monitored in order to verify its proper operation.	DTU Research Infrastructure	SS1	SC3	SS1.SC3
10. Hours Ahead Load Optimization	Contingency analysis determines that there is likelihood that there is congestion that can be reduced through load and/or distribution networks management when a new weather forecast is published.	*http://smartgrid.epri.com/UseCases/HoursAheadLoadOptimization.pdf*	SS1	SC3	SS1.SC3
11. Cross-border exchange of automatic Frequency Restoration Reserve	Automatic FRR represent the main product for real-time balancing in many countries. Cross-borders cooperation may be very beneficial for TSOs of confinant countries in spite several challenges can limit the exploitation of its full potential: treatment and harmonization of current product specifications, design and implementation of a proper IT system, adaptation of existing regulatory framework, etc.	DNV KEMA Energy & Sustainability - Cross-border balancing study	SS1	SC2	SS1.SC2, SS1.SC3
12. Power Quality Event Notifications	The purpose of the power quality event notifications enterprise activity is to enable a mechanism whereby stakeholders are alerted as soon as possible to the location, time and severity of power quality events that occur.	*http://smartgrid.epri.com/UseCases/PowerQualityEventNotifications.pdf*	SS3	SC1	SS3.SC1, SS3.SC2, SS3.SC3
13. Coordinated voltage control in power distribution grids with a high penetration of renewables	In this scenario a centralized coordinated voltage control algorithm is implemented in a distribution network, as a solution to the voltage rise problem due to DG production. The algorithm will be receiving real-time measurements from selected nodes of the network, solving an optimization problem and transmitting the resulting set-points to all the devices with voltage control capabilities (e.g., DG and storage inverters, tap-changer etc.) in the network.	D-JRA1.1	SS3	SC1	SS3.SC1, SS3.SC3

14. Coordination of Volt/VAr control in Connected Mode under Normal Operating Conditions	The objective of the function is to provide the DSO with the aggregated at the PCC near-real-time and short term look-ahead reactive power of the microgrid under current volt/var control conditions in the microgrid within the given ranges of the PCC voltage for the use by the microgrid operator for the coordination of the system elements, and provide the microgrid operator with system requirements/requests for the aggregated at the PCC volt/var capabilities.	*http://smartgrid.epri.com/UseCases/Use%20Case%20IA-2.pdf*	SS3	SC3	SS3.SC1
15. Steady-state reactive power/voltage control	Controlling voltage node profile to a target value or within a target range. This control is commonly achieved by injecting or absorbing reactive power at a voltage controlled node by means of synchronous sources, static compensation, tap changing transformers in the substations, transmission lines' switching, virtual power plants including demand facilities and if necessary load shedding. The system operator dispatches the reactive power using the active and passive reactive power sources that belong to different levels: generation, transmission and distribution, using Optimal Power Flow methods. This type of services has a similarity with the active power economic dispatch related to the implementation of the hourly pool-based energy market.	*http://orbit.dtu.dk/files/118349095/Technical_Feasibility.pdf*	SS3	SC2	SS3.SC1, SS3.SC3
16. Real time optimal voltage regulation for distribution networks incorporating high penetration of Plugged-in-vehicles and high photovoltaic generation	Coordinated voltage control primarily aiming on using all available local resources such as flexible loads, storage systems, distributed generation inverters aiming to relieve the stresses on OLTCs.	SINTEF Research Infrastructure	SS3	SC1	SS3.SC1, SS3.SC3
17. Fast reactive current injection	Oriented toward system dynamic security and voltage quality, it can be provided by spinning generators and synchronous compensators, reactors and capacitors, Static VAR Compensators (SVCs), HVDC (implemented with technology VSC) substations and other FACTS devices, or other equipment capable of fast regulation. This type of service can be considered analogous to active power reserve and frequency-control services (primary and secondary AGC frequency regulation).	*http://orbit.dtu.dk/files/118349095/Technical_Feasibility.pdf*	SS3	SC2	SS3.SC2, SS3.SC3

18. Wide-Area Monitoring and Control - Automated Control Functions	Describes a set of functions that are typically automated within a substation, but are not directly associated with protection, fault handling, or equipment maintenance. In general, they serve to optimize the operation of the power system and ensure its safe operation by preventing manually generated faults. These functions include: changing transformer taps to regulate system voltage; switching capacitor banks or shunts in and out of the system to control voltage and reactive load; interlocking of controls to prevent unsafe operation; sequencing controls to ensure safe operation; load balancing of feeders and transmission lines to reduce system wear and resistive losses; restoring service quickly in the event of a fault, with or without operator confirmation; etc.	*http://smartgrid.epri.com/UseCases/Wide-AreaMonitoringandControl-AutomatedControlFunctions.pdf*	SS1, SS2, SS3	SC1, SC3	SS1.SC2, SS1.SC3, SS2.SC1, SS2.SC2, SS2.SC3, SS3.SC1, SS3.SC2, SS3.SC3
19. Multi energy congestion management	The use case describes the resolution of a congestion problem in the distribution grid due to high PV production. As a start condition, congestion is detected in an electrical distribution substation. A control algorithm activates local electrical booster heaters in the district heating system which allows electrical energy to be dissipated into a local heat storage tank. The end condition is the removal of the congestion condition.	---	SS3	SC1	SS3.SC1, SS3.SC3
20. Multi objective control strategy for coordinated tertiary voltage control in distribution grid	The MOB Controller is a central controller that takes multiple set points from the user and, primarily tries to match both the voltage and power set points as specified by the user. To this end, the MOB Controller continuously monitors and steers the assets under its control through a communication interface. The controller is also equipped with a learning algorithm based on which, it learns the droop of each asset according to previous behaviour.	CRES Research Infrastructure	SS3	SC1	SS3.SC1, SS3.SC3
21. Real-time network reconfiguration algorithms for loss reduction and to increase hosting capacity	Algorithm for the reconfiguration of network topology aimed at reduce the energy losses and to increase the hosting capacity	SINTEF Research Infrastructure	SS2, SS3	SC1	SS2.SC1, SS2.SC2, SS2.SC3, SS3.SC1, SS3.SC3

22. Equipment control with smart house by Home Energy Management System (HEMS)	Efficient management of residential customer energy demand and usage can be achieved through load management and the control of installed energy resources. This use case describes the process to control the energy resources such as PV/ES (Photovoltaic/Energy Storage), HP (Heat Pump Hot water storage) and Smart Appliances, in a Smart House.	*http://smartgrid.epri.com/UseCases/NEDO%20L4%20SmartHouse%20UseCase%20Ver5.1.pdf*	SS2	SC1	SS2.SC1, SS2.SC3
23. Direct load control	Demand Response is a temporary change in electricity consumption by demand control devices in response to market or reliability conditions. Demand control devices control loads capable of measurably and verifiably providing temporary changes in demand. Demand Response may be used to support electricity demand or supply management opportunities for reliability or economic reasons. By managing loads through Demand Response the opportunity exists to: Engage the consumer by allowing market participation and consumption/billing choices; Introduce new markets for aggregators, micro-grid operators, distributed generation; Control peak power conditions and limit or remove brownout/blackout instances; Flatten consumption curves or peaks and shift consumption times; Respond to temporary grid anomalies; Maximize use of available power and increase system efficiencies through Time-of-Use (TOU) and dynamic pricing models.	*http://smartgrid.epri.com/UseCases/Direct%20Load%20Control%20V3.2.pdf*	SS1, SS2, SS3	SC1, SC3	SS1.SC1, SS1.SC3, SS2.SC1, SS2.SC3, SS3.SC1, SS3.SC3
24. Information Support for Coordination of Electric Power System and Microgrid Load Shedding Schemes	The objective of the function is a) to provide information to the EPS operator on the states and performance of the microgrid load and DER in cases of emergency situations of EPS and b) to provide information to the operators of Advanced1 Microgrids (μGrid) on the possible emergency operating conditions of the EPS related to the emergency performance of the microgrid's load and DER.	*http://smartgrid.epri.com/UseCases/Use%20Case%20IA-1.pdf*	SS3, SS4, SS5	SC1	SS3.SC1, SS4.SC1, SS4.SC3, SS5.SC1, SS5.SC3, SS5.SCx
25. Inter-Area Oscillation Damping	Low frequency Inter-area oscillations are detrimental to the goals of maximum power transfer and optimal power flow. An available solution to this problem is the addition of power system stabilizers to the automatic voltage regulators on the generators. The damping provided by this technique provides a means to minimize the effects of the oscillations.	*http://smartgrid.epri.com/UseCases/Inter-AreaOscillationDamping.pdf*	SS4, SS5	SC2	SS4.SC3

26. Cyberphysical Intrusion detection	DSO monitoring and responsibility for the distributions grid physical & cyber-infrastructure; in some variants also responsible for issueing control signals (e.g. PV curtailment). In some variants, DER is controlled by an aggregator; remote communication. DER is physically being controlled and is also scope of the monitor.	DTU Research Infrastructure	SS4	SC1	SS5.SCx
27. Microgrid intentional islanding	This use case describes the function when a microgrid disconnects from the area power system (AEPS) in a planned manner when the AEPS is grid-connected and in a normal operating mode. The process by which the microgrid transitions from grid-connected operation to islanded operation is described.	*http://smartgrid.epri.com/UseCases/F3%20Intentional%20Islanding.pdf*	SS4	SC3	SS5.SC3
28. Microgrid Protection - blackstart	During a blackstart procedure, a microgrid is restored to islanded operation mode after a complete shutdown. The restoration process involves the microgrid central controller (microgrid EMS and microgrid SCADA), multiple resources, loads, and switchgear. Based on the system topology, capacities and sizes of the resources and loads, and the controllability of the devices, the blackstart procedure can be pre-determined and implemented in the microgrid central controller and other devices. The execution of the blackstart can be automatic with minimal operator involvement.	*http://smartgrid.epri.com/UseCases/F9%20Microgrid%20Blackstart.pdf*	SS4	SC3	SS5.SC3
29. Black start service provision by wind power plants	A relevant service, black-start, is used in the power system restoration phase, defined as “a set of actions implemented after a disturbance with large-scale consequences to bring the system from emergency or blackout system state back to normal state”. Presently, wind farms are not providing this service, as TSOs have even higher demands for reliability than during normal operation and will avoid any components adding uncertainty. This means that for wind, uncertainty and variability during this time should be fully mitigated (for example by adding local storage) in order to be suitable/ eligible for this service provision.	TKI Wind op Zee-Ancillary services from offshore windfarms in the Netherlands	SS4	SC2	SS5.SC2
30. Fault ride-through of offshore wind power plants connected through HVDC	TSOs typically regard VSC-HVDC connected WPPs as one single plant entity, which must be compatible with the grid code specifications enforced at the point(s) of common coupling. Fault ride-through (FRT) is among the hardest to implement: the plant must stay connected during onshore faults according to a time-voltage profile. High-bandwidth VSC-HVDC and WPP controllers and protection equipment have to achieve this. The FRT implementation can be local (at the onshore VSC) or system-wide (onshore/offshore VSCs + WPP controls).	TUD Research Infrastructure	SS4, SS5	SC2	SS4.SC2

31. Utilizing smart meters in outage management	Utilizing smart meters in outage management. It includes several functions: - Outage Management System Poll (uni/multi cast) - Outage notification - Outage Restoration Notification	http://smartgrid.epri.com/UseCases/Outage%20Management%20System%20Poll%20Multi_ph2add.pdf - http://smartgrid.epri.com/UseCases/Outage%20Management%20System%20Poll%20Uni_ph2add.pdf - http://smartgrid.epri.com/UseCases/Outage%20Notification_ph2add.pdf - http://smartgrid.epri.com/UseCases/Outage%20Restoration%20Notification_ph2add.pdf	SS4	SC1	SS5.SC1, SS5.SCx
32. Adaptive Transmission Line Protection	The requirements for improvement in the performance of protection relays under different system conditions lead to the implementation of adaptive protection that adjusts to changes in the configuration of the electric power system. This is especially important in the cases of double circuit transmission lines or lines that have one or more segments in parallel with one or more transmission lines on the same or on different voltage levels. Changes in the state of any of the parallel lines or the system around them may affect differently the operation of the line protection relays for faults on the protected line or even on some of the parallel lines. The protection system needs to be able to adapt to changes in the system configuration.	http://smartgrid.epri.com/UseCases/AdaptiveTransmissionLineProtection.pdf	SS4	SC2	SS5.SC1
33. Fault anticipation and corrective control in distribution grid	The aim is to devise intelligent fault anticipation algorithms to predict an upcoming fault and perform corrective switching/control actions to prevent the fault from occurring. The sensors placed at the distribution grid should be able to study certain parameter (like current, voltage) patterns and if any instability is detected, the control mechanism should take over and protect the power system.	TUD Research Infrastructure	SS4	SC1	SS5.SC1

34. Tracking of distribution grid topology	The use case describes a distributed topology tracking system, specifically designed for the tracking of the feeder transfer from one substation busbar to another. The start condition of the use case assumes the distributed tracking system, consisting of multiple tracking nodes which form an overlay network, to be in equilibrium, i.e. all nodes agree on and have the same view of the overall system topology. A change to the system topology is detected by one tracking node in whose monitoring area the changing breaker is located. That tracking node then initiates data exchange with its neighbours in the overlay network to exchange topology information. The end condition is met when all topology nodes agree on the same topology information.	DTU Research Infrastructure	SS4	SC1	SS5.SC1
35. Aggregator rescheduling after communication loss	This use case focuses on portfolio reconfiguration when an aggregator loses communication to a set of units. The aggregator is providing an ancillary service to the grid by controlling a portfolio of DER units. As a start condition, communication to a subset of units is lost. The aggregator detects the loss of communication and reconfigures its control pool, activating reserve units in order to continue providing the service.	DTU Research Infrastructure	SS5	SC1, SC3	SS4.SC3
36. Anti-islanding protection scheme on PV inverters	The purpose of the protection scheme is to detect unintentional or intentional islanding states of the local distribution grid with a view to disconnecting the PV inverter so as to prevent potential hazards for the personnel and equipment. The control itself may be based on various algorithms (e.g. frequency perturbation) and the overall goal is to disconnect the inverter once a discrepancy of a value or parameter is detected.	CRES Research Infrastructure	SS4	SC1	SS5.SC1
37. Leakage current protection scheme of PV inverters	The purpose of the protection scheme is to detect unintentional leakage currents which exceed a specific threshold in terms of absolute value and rate of change.	CRES Research Infrastructure	SS4	SC1	SS5.SC1
38. Frequency containment control using offshore wind parks connected with (multiterminal) HVDC grids	In modern integrated DC/AC systems offshore wind farms can modulate their active power only in case of over-frequencies (so called “Limited Frequency Sensitive Mode”, LFSM) or they can react to both under- and over-frequencies with a linear (droop) control (so called “Frequency Sensitive Mode”, FSM): in case of under-frequencies, offshore wind turbines can take part in FSM control only if they are operated in a deloaded way.	*http://orca.cf.ac.uk/90288/1/2016AdeuyiODPhD.pdf*	SS5	SC2	SS4.SC2

39. Special Protection Schemes (SPS) applied to VSCs	SPSs can be used to modify the setpoints of VSCs in order to improve the security of the integrated AC/DC system. as an example, in case of an overloading on an AC line, one can deploy an SPS which recognizes the overload and sends a modifications of power setpoints to local controllers of the onshore VSCs of a HVDC grid for offshore wind power integration so that the power is rerouted through the HVDC grid, thus relieving the AC line overload.	https://www.eeh.ee.ethz.ch/uploads/tx_ethpublications/zima_survey.pdf	SS4	SC2	SS5.SC2
40. Provision of synthetic inertia from HVDC VSCs endowed with adequate control schemes	Inertia support can be provided by the VSC in combination with the mechanical inertia of wind turbines/blades.	RSE Research Infrastructure	SS5	SC2	SS4.SC2
41. Use of HVDC VSC as black start units for restoration	A VSC link connecting two active strong AC systems can be used to launch the restoration path providing the voltage control and the active power to cover the ballast loads of the path. The fast control of VSC allows to keep frequency and voltage within a small operational range.	http://ieeexplore.ieee.org/document/4517039/?reload=true&section=abstract	SS4	SC2	SS5.SC2
42. Use of VSC as STATCOM during restoration	In case that a HVDC link (also connecting offshore wind farms) is out of service, one can run the VSC in a stand-alone mode so that it can provide voltage support during the restoration path (i.e. VSC would operate in STATCOM mode)	http://upcommons.upc.edu/bitstream/handle/2117/20684/Optimal+control+of+VSC+for+STATCOM+applications.pdf;jsessionid=A4C8171E6109C3174CD14A1ACAFA4E8C?sequence=1	SS4	SC2	SS5.SC2
43. Adaptive protection schemes to compensate the impact of VSC controllers on distance protections	The voltage support provided by VSC controllers of HVDC connections of offshore wind farms may alter the “impedance” seen by distance relays, leading to slower clearance of the faults. This calls for adaptive protection relays.	RSE Research Infrastructure	SS4	SC2	SS5.SC2
44. Enhanced monitoring and control of MV/LV network	This use case deals with MV network supervision. The MV supervision is performed using voltage and current sensors, as well as fault passage indicators. Grid supervisors (IED’s), also called MV supervisors have the capability to identify faults. The IED’s will generate signals and alarms that are sent to the SCADA system where an operator can act on it.	http://discern.eu/datas/DISCERN_WP4_D4.3_160229.pdf	SS4	SC1	SS5.SC1

45. Advanced monitoring of LV grid	This Use Case deals with the advanced monitoring of LV networks in SS collecting and calculating magnitudes at both phase line and LV panel busbar levels	*http://discern.eu/datas/DISCERN_WP4_D4.3_160229.pdf*	SS2, SS3, SS4	SC1	SS2.SC1, SS2.SC3, SS3.SC1, SS5.SC1
46. Optimized AMR data collection and analysis using virtualized as well as physical concentrators	This Use Case deals with the collection of data reports generated in smart meters located at customer premises. Data collection is performed by Meter Data Concentrators. The use case presents two main alternative solutions for data concentration that can be used depending on the number of customers that are fed through the secondary substations: Conventional Meter Data Concentration and Virtual Meter Data Concentration.	*http://discern.eu/datas/DISCERN_WP4_D4.3_160229.pdf*	SS2	SC1	SS3.SC1
47. Calculation and separation of non-technical losses	This Use Case deals with the development of algorithms to compute power balances and identify technical and non-technical losses as well as methods to identify energy thefts. The main inputs used by the algorithms will be the energy data collected from smart meters located at customer premises and from LV supervisors located at secondary substations. Events reports and alarms collected at Meter Data Management System indicating suspicious behaviours in smart meters will also help to identify energy thefts.	*http://discern.eu/datas/DISCERN_WP4_D4.3_160229.pdf*	SS2	SC1	SS2.SC1, SS2.SC3
48. Energy Scheduling, Billing and Settlement	This Use Case presents the activities involved in the creation of an energy trading transaction. It shows the integration of the deregulated energy market with regulated transmission operations through the Transaction Information System (TIS). TIS produced tags, which link up the commercial transaction (Purchase/Sale) with the operational energy interchange transaction (Received/Delivered), also provide the link to the Billing and Settlement process. This Use Case is focused on the management and tagging of information involved in energy transactions and Billing and Settlement. The supporting functions, such as interface capacity calculation, etc. are not directly addressed.	*http://smartgrid.epri.com/UseCases/EnergySchedulingBillingandSettlement.pdf*	SS1	SC2	SS1.SC1, SS1.SC3

49. Power Quality Contracts	The purpose of the power quality contracts enterprise activity is to enable a mechanism whereby energy service providers could lock in long term contracts with large industrial customers by providing service guarantees based on the quality of electric power supplied over a period of time. In return for signing a long term contract, the customer receives favourable long term rates as well as power quality performance guarantees from the energy service provider. This assures the industrial customer that the energy service provider will be responsive to their problems over the duration of the contract.	*http://smartgrid.epri.com/UseCases/PowerQualityContracts.pdf*	SS3	SC1, SC2, SC3	SS3.SC1, SS3.SC3
50. Medium/Low Voltage Network Real Time Monitoring (MVRTM/LVRTM)	The data collection for the MV/LV grid is performed storing real-time measurements (mean values and PQ indexes), states and alarms in a unique repository – located in the Primary/Secondary Substation – after managing some implementation issues, such as protocol conversion and writing of data into the PSAU.RDBMS/SSAU.RDBMS. "Real-time" in this context means something in between 1 second and some minutes.	IDE4L project	SS2, SS3, SS4	SC1	SS2.SC1, SS2.SC3, SS3.SC1, SS3.SC3, SS5.SC1
51. Distribution grid dynamic monitoring for providing dynamic information to TSOs	Utilizing time-stamped PMU data and discrete traditional measurements for providing "dynamics" information on distribution grid operation to TSOs.	IDE4L project	SS1, SS2, SS3, SS4	SC3	SS1.SC3, SS2.SC1, SS2.SC3, SS3.SC3, SS5.SC1
52. Real-Time Medium/Low Voltage Network State Estimation (MVSE/LVSE)	The medium/low voltage state estimator (PSAU.SE/SSAU.SE) combines all the available measurement information and calculates the most likely state of the network. State estimates are calculated for present time (t=0) using the newest available input data. PSAU.SE/SSAU.SE calculation will run an intelligent device located either on a primary substation or in a control center. Real-time PSAU.SE/SSAU.SE is a secondary function serving primary functions (e.g. medium/low voltage network power control, PSAU.PC/SSAU.PC) and will be run based on primary function needs (on-demand or periodically). The input data includes the real-time measurements for the load, production and line flows, load estimates for unmeasured loads, and the network topology. Output will be the network state described with node voltages, line current flows, and node power injection values.	IDE4L project	SS2, SS3, SS4	SC1	SS2.SC1, SS2.SC3, SS3.SC1, SS3.SC3, SS5.SC1

53. Medium/Low Voltage load-production Forecaster (MVF/LVF)	The medium/low voltage load forecasting algorithms provide estimated future load demands and micro-generation production for the medium/low voltage network. The input data are the historical measurements of smart meters, the flexible demand schedule and meteorological forecasts.	IDE4L project	SS2, SS3, SS4	SC1	SS2.SC1, SS2.SC3, SS3.SC1, SS3.SC3, SS5.SC1
54. Medium/Low Voltage Network State Forecasting (MVSF/LVSF)	The PSAU.SF/SSAU.SF provides forecasts for the states that are related to a specific MV/LV network. The PSAU.SF/SSAU.SF will run once every 10 minutes after the PSAU.FC/SSAU.FC and deliver distributional properties for the pre-requested prediction horizon. The PSAU.SF/SSAU.SF algorithm utilizes the available secondary substation, MV/LV customer, and distributed generation forecasts to provide distributional forecasts for the electric quantities of the MV/LV network.	IDE4L project	SS2, SS3, SS4	SC1	SS2.SC1, SS2.SC3, SS3.SC1, SS3.SC3, SS5.SC1
55. Network Description Update (NDU)	This update process maintains aligned the description of the network topology, the list of assets and their parameters, the list of customers and some relevant information among the main database of the DMS – located in the utility Control Center – and the distributed database of RDBMS in the Primary and Secondary Substations every time a network change is performed in the DMS or a customer change is performed in the CIS.	IDE4L project	SS2, SS3, SS4	SC1	SS2.SC1, SS2.SC2, SS2.SC3, SS3.SC1, SS3.SC3, SS5.SC1
56. Protection Configuration Update (PCU)	The use case consists in updating the configuration file of protection devices when a change is done in the network configuration (status of breakers and disconnectors). The changes has to be reflected in the setting of protection functions and in the coordination between protection devices used by the FLISR use case.	IDE4L project	SS4	SC1	SS5.SC1, SS5.SC2, SS5.SCx
57. Control Centre Power Control (CCPC)	The primary objective of the CCPC during offline operation is to define and develop functions for the congestion management of MV distribution network for the next hours (day-ahead market or intraday market timeframe). These functions are implemented on control centre level to manage MV networks by means of: Network related measures, in particular through network circuit reconfiguration and changes of the setting values of voltage controllers in the MV network and reactive power units; Market related measures to propose changes of scheduled generation/consumption values of DER units, through flexibility products to provide a feasible combination of schedules.	IDE4L project	SS1, SS2	SC1, SC3	SS1.SC1, SS1.SC2, SS1.SC3, SS3.SC1, SS3.SC3

58. Medium Voltage Network Reconfiguration	MVNR update network switches status in order to alleviate congestion problems that are related to a specific MV network. The MVNR runs on demand and also run on fixed intervals such as once a day or scheduled hours to find the optimal configuration of the network. The MVNR algorithm utilizes switches state information (open/close), and the load and production forecast that are saved at the DXP.	IDE4L project	SS3, SS4	SC1	SS3.SC1, SS3.SC3, SS5.SC1
59. Real-time/off-line Medium/low Voltage Network Power Control (MVPC/LVPC)	The main functionality of the MVPC is to mitigate congestion in the MV/LV networks. The MVPC/LVPC tries to reach and balance the following goals: reduction of the MV network losses, reduction of production curtailment, minimizing the load control actions and tap changer operations, reducing the cost of reactive power flow supplied by the transmission network, reducing the cost of active power flow supplied by the transmission network, reducing the voltage violation at each node.	IDE4L project	SS1, SS2, SS3	SC1	SS1.SC1, SS1.SC3, SS2.SC1, SS2.SC3, SS3.SC1, SS3.SC3
60. Power Quality Control by means of Storage Systems	With the aim of power quality improvement, the UC explores the use of fast energy storage systems with high ramp power rates and short time responses, to rapidly exchange active and reactive power, thus smoothing power flows in LV networks and improving quality of current and voltage waveforms.	IDE4L project	SS3	SC1	SS3.SC1, SS3.SC3
61. Commercial aggregator asset planning	This UC describes the operation of the commercial aggregator in order to evaluate the capacity of the DERs within its load area to perform scheduled Re-profiling (SRP) and conditional Re-profiling (CRP) actions (later described), then to match this availability with the requirements of the TSOs and technical aggregator contained in the flexibility tables and finally to send the bids of SRPs and CRPs to the market.	IDE4L project	SS1	SC3	SS1.SC3
62. Decentralized FLISR	The use case contemplates the detection process using relevant information for different types of faults. A distributed control functions is proposed in order to locate and isolate the part of the network that has been affected by acting on circuit breakers, switches and microgrid interconnection switches located along the feeder under test. Once the fault is located and isolated, the service restoration process will start.	IDE4L project	SS4	SC1	SS5.SC1

63. Microgrid FLISR	This use case explains the disconnection of a microgrid from the MV or LV distribution grid responding to a status change and analyzes the reconnection to the distribution grid after fault restoration. The isolation of microgrids will allow the continuity of the service in case of contingencies in the distribution network.	IDE4L project	SS4	SC1	SS5.SC3
64. Load Areas Configuration	The function of the load area is to group prosumers in terms of: consumption pattern, impedance value, prosumer connectivity, and other parameters to be considered by the DSO.technical aggregator.	IDE4L project	SS1	SC1, SC3	SS1.SC3, SS2.SC1, SS3.SC1, SS3.SC3, SS5.SC1
65. SRP Day-ahead and intra-day market procurement	The MO will send a bidding process creation message to flexibility providers/buyers before the gate opens for the day-ahead or intra-day market (SRP). In between gate opening and gate closure of the market, flexibility bids will be taken into consideration during the clearing phase. Flexibility buyers/providers will submit flexibility bids to be considered during the market clearing phase. These bids should be sent during the gate opening period. One message will be sent for each load area for which the service is required/offered. Finally the market will clear itself to work out the set of accepted bids and the market clearing price. This information will be published by the MO to inform the flexibility buyers/providers about the market clearing price and the bidding acceptance. For those accepted bids, the possible modifications on the accepted volume will be also communicated.	IDE4L project	SS1	SC2, SC3	SS1.SC2, SS1.SC3
66. Day-Ahead Dynamic Tariff for Medium Voltage Grid Congestion Management	The day-ahead dynamic tariff algorithm based on the predicted demand and local production is to determine a day-ahead tariff for the distribution network to alleviate potential congestion induced by the demand or local production. The congestion in this context is the component overloading. The input data are the customer day-ahead energy plan and local production forecast, the grid topology and the grid model.	IDE4L project	SS3	SC1	SS3.SC1, SS3.SC3

67. EV integration in the smart grid	A smart grid with a massive penetration of electric vehicles where a granular control of EVs load management is performed. This allows the optimisation of hosting capacity, and additionally can consider the local connection of distributed energy resources (DER) that can benefit from the EV penetration via a positive feedback loop. No grid reinforcement is carried out to cope with the massive presence of EVs in the network. Bidirectional energy flow from grid to vehicle (G2V) and vehicle to grid (V2G) is available.	D-JRA1.1	SS3	SC1	SS3.SC1, SS3.SC3
68. Grid support by DG and storage	In this scenario various methods for providing grid support by distributed generation and storage systems will be developed and tested. These functions could include voltage control (e.g., Q(U) and cosφ(P) control), frequency control (P(f) droop, virtual inertia etc.), among other work.	D-JRA1.1	SS3, SS4, SS5	SC1, SC3	SS3.SC1, SS3.SC3, SS4.SC2, SS4.SC3, SS5.SC1, SS5.SC2
69. Management of low-power-factor exchanges in primary/secondary substations	TSO agreements and protection devices often impose restrictions in terms of reactive power flows. The introduction of local DG controllers based on reactive power injection may significantly impact on the power factor of the power exchanged with the upper stream network: loads balance active power production and in case of DG=load, only reactive power is exchanged with the upper stream network; DG is participating to voltage control even for under voltage mitigation (production of reactive power). Positive reactive power cannot be balanced with capacitors.	D-JRA1.1	SS5	SC1, SC2	SS4.SC3
70. Use of flexibility in active power networks	This scenario studies the use of flexible resources to maintain power quality in a distribution network characterized by volatile and intermittent distributed production, along with demanding loads such as electric vehicles and modern household appliances. Specific challenges include smart EV charging, microgrid operation, and network flexibility, e.g. in terms of thermal and chemical storage (possibly including V2G/V2H).	D-JRA1.1	SS3	SC1	SS3.SC1, SS3.SC3
71. Network reconfiguration for post-fault restoration and demand response	With enhanced remote control and automation capabilities, DSOs can implement new methods for post-fault restoration: remote control of network switching elements and transformers.	D-JRA1.1	SS4	SC1	SS5.SC1

72. Protection of networks with high levels of converter-connected generation	The presence of DG can present additional challenges in protecting distribution systems: bi-directional power flows, protection “blinding”, and sympathetic tripping. Protection is especially challenging for scenarios with high-levels of converter-interfaced generation because of the typically small converter fault current contribution and the fact that and converter responses during faults may not be well known. Therefore, improved methods of protecting future distribution systems – involving real-time coordination – are required.	D-JRA1.1	SS4	SC1	SS5.SC1, SS5.SC2
73. Smart metering for smart grids	Smart metering brings intelligence to the last mile of the grid and it is seen as a key enabler for many smart grid applications, with interfaces with many smart grid areas such as building/home automation and demand side management. The Advanced Metering Infrastructure (AMI) provide services for the customer, the supplier and network operator and is used for automated meter reading and billing and a range of other functionalities (network monitoring and control, demand response, etc.). The AMI system will enable and encourage stronger and direct involvement of consumers in their energy usage and management (including also management and market participation of variable and non-programmable generation).	D-JRA1.1	SS1, SS3	SC1, SC3	SS1.SC1, SS1.SC3, SS3.SC1, SS3.SC3
74. Monitoring, control and automation in Smart Grids	Ever more operational data from the network is available in the control centres. Alongside the improved opportunity to, directly or indirectly, control network components, load and generation, this provides new opportunities for functionality in future control centres. Among such features are: congestion and over-load prediction and mitigation, on-line risk assessment and fault mitigation, automated fault response, improved monitoring, event detection, and protection by utilization of PMUs	D-JRA1.1	SS2, SS4, SS5	SC1	SS3.SC1, SS3.SC3, SS4.SC3, SS5.SC1
75. Unintentional islanding protection	Similar power levels of DG and loads, as well as DG participating in frequency control, may results in situations in which some portions of a non-supplied network (due to a failure) remain operating as an island and are thereby still energized by local DG. This can easily lead to concerns with safety and power quality.	D-JRA1.1	SS4	SC1	SS5.SC1

76. Optimal operation of microgrids	This use case refers to optimisation of the operation of microgrids by means of a central controller. The objective of the implementation was the maximisation of profits and reduction of CO2 emissions in a microgrid via alternative solutions of optimal control such as model-predictive and stochastic-optimal-predictive control.	D-JRA1.1	SS1	SC1	SS1.SC1, SS2.SC1, SS2.SC3, SS3.SC1, SS4.SC1, SS5.SC3
77. Restoration Reserves Procurement using Distributed Control	Generic, distributed algorithm for allocating reserves for frequency control during loss of generation (or major tie-line) events. The scenario assumes that future the grid is logically organized into multiple interconnected areas (i.e. cells in a web-of-cells architecture). The areas collaboratively allocate reserves for inertia, frequency containment, and restoration in a fully-distributed manner - i.e. without vertical control.	D-JRA1.1	SS1	SC3	SS1.SC3