Hybrid Provision of Energy based on Reliability and Resiliency by Integration of Dc Equipment

Work Package WP2

Requirements on Grid Infrastructure

Deliverable D2.2

Use case description, specification and implementation roadmap report

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Co-author(s):	Thomas Strasser (AIT), Paul Smith (AIT), Johannes Stöckl (AIT), Gerhard Jambrich (AIT), Alberto Dognini (RWTH), Massimo Cresta (ASM), Drazen Dujic (EPFL), Hamid Aghaie (AIT)
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List of Abbreviations

AC	Alternating Current
ACDC	Alternating Current and Direct Current
DC	Direct Current
DER	Decentralized Energy Resources
DMS	Distribution Management System
DSO	Distribution System Operator
EC	European Commission
EMS	Energy Management System
EV	Electric Vehicle
ICT	Information and Communications Technology
IEC	Interntional Electrotechnical Commission
LV	Low Voltage
LVDC	Low Voltage Direct Current
MV	Medium Voltage
MVDC	Medium Voltage Direct Current
NIST	National Institute of Standards and Technology
PMU	Phasor Measurement Unit
PV	Photovoltaics
RES	Renewable Energy Sources
SCADA	Supervisory Control and Data Acquisition
SGAM	Smart Grid Architecture Model
SG	Smart Grid
TSO	Transmission System Operator
VPP	Virtual Power Plant

Executive Summary

The role of distributed energy resources is increasing significantly in electrical power systems due to many environmental, economical, and political drivers. This transition has also put the electrical distribution grid in a central role. The challenges arising from this transition are largely being addressed under Smart Grid (SG) initiatives. Although there is no standard definition, in general, a smart grid refers to a method of incorporating intelligence into the operation of distribution grids to increase flexibility and performance. For electrical power systems, Alternating Current (AC) distribution grids are a well-known infrastructure that has been in use for a long time. This infrastructure can be assisted by Direct Current (DC) technologies as a possible backbone to increase, for example, Renewable Energy Sources (RES) hosting capability; however, they must be designed on a solid basis to allow for rapid roll-out and integration. It is critical to provide and test suitable methodologies and resources to lower entry barriers for early adoption processes to maximise the implementation capability of new DC technologies.

The HYPERRIDE project aims to support this transition toward the transformation in the electrical grid infrastructure by laying the groundwork for widespread adoption of DC technology. The future distribution grid both at the Low Voltage Direct Current (LVDC) component to Medium Voltage Direct Current (MVDC) backbone is planned to be demonstrated at three pilot sites (Germany, Italy, and Switzerland) implementing relevant use cases. These pilots will provide valuable insights as well as help in identifying the gaps in knowledge and possible solutions for the various focus areas. The use cases to be used for the implementation are documented in this deliverable along with the standards and background, the methodology and the analysis.

To perform a systematic analysis to discover the use cases that would be interesting to implement and cover the goals of the project, a well-thought-over methodology is needed. This methodology should be based on the well-known standard and reference architectures to make the communication and dissemination among the consortium and beyond be made easy and effective. A methodology is derived based on National Institute of Standards and Technology (NIST) and SGAM to identify first the context and boundaries and defining the use cases.

With the help of partners, several workshops are conducted to collect the inputs. These inputs provided the basis for the analysis that later resulted in the form of the summary use cases. These summary use cases are then debated in the workshops and, based on the aim of the pilot, are adopted for the development of the detailed use uses. The detailed use cases are then documented using Interntional Electrotechnical Commission (IEC) “Use Case Methodology” method using IEC 62559-2 templates. The background, methodology and analysis, and the summary use cases are described in detail in this report while the adopted and detailed use cases for individual pilot sites implementations are included in the three appendices of the document.

1 Introduction

1.1 Purpose and Scope of the Document

The purpose of this document is to analyse the goals and objectives, as well as the pilot demonstrators, in order to define use cases that can be used for future development and implementations.

The use case is a powerful method for capturing the interaction between a system and its stakeholders. It documents the system behaviour under various conditions and in response to a primary actor interaction. As a result, use cases have been regarded as an important method for determining the system features and stakeholders' goals. The use case view of the system also helps in connecting and linking various other requirements as adapted and summarised in the Figure 1 below from (Kruchten, 1995).

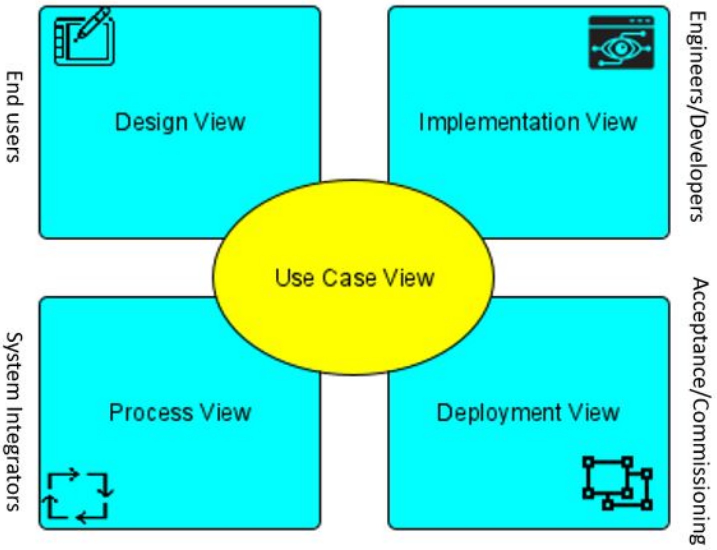


Figure 1: The 4+1 architectural view (Kruchten, 1995)

The identification of the context, selection of the actors and their goals are guided by the mission statement of the project:

> *Providing technical solutions/methods for accessing feasibility, for helping in planning, implementing, operating, and business proposals designing toward a resilient, high local generation and consumption DC/hybrid ACDC LV distribution grids.*

The focus is on achieving high-level goals such as:

- Provide technical solutions for grid planning, operation strategies and its implementation via automation technologies and algorithms of DC and hybrid Alternating Current and Direct Current (ACDC) grids,
- Provision of technical solutions for components, test and validation methods,
- Development of a layer based control architecture for future hybrid ACDC grids that enables a stable grid operation even under failure situations or cyber attack scenarios,

- Development of effective business models ready to facilitate additional investments in the sector, and
- Reducing cost of integration of local generation.

1.2 Structure of the Document

The reminder of this report is organised as follows: Section 2 presents briefly, the relevant standard that are considered and consulted during the course of this activity. The standards discussed include SGAM, NIST, and IEC 62559, etc. Section 3 presents the methodology for the requirement elicitation and context and boundary identification along with the analysis. The three steps of the methodology are explained individually. Later the analysis of the inputs is documented and the context and boundary are shown graphically. Section 4 presents the nine summary use cases as the main outcome of the analysis. For each of the summary use case, the primary actor, the goals along with possible other actors are identified and a brief description of the interaction and behaviour is also documented. Additionally, a summary of each of the three pilot sites is provided that is used to select and map the summary use cases for implementation. Section 5 presents the conclusion from the study and analysis along with the identified next steps. Four appendices are also provided at the end of this report. Appendix A – NIST Smart Grid Actors presents a summary of the SG actors. While the remaining three presents the detailed use cases documented with IEC 62559-2 use case template for German, Italian and Swiss pilot implementation, respectively.

2 Background

There are numerous European and international guidelines and reference models for SGs that provide a systematic approach to analysing the criteria for identifying a SG solution. Using such methods has the benefit of simplifying and formalising communication among the stakeholders. Among the standards used in this activity's research and review are NIST Framework and Roadmap for Smart Grid Interoperability Standards 4.0 (Gopstein et al., 2021) and NISTIR 7628 (*Guidelines for smart grid cybersecurity*, 2014), SGAM and the Use Case Methodology (IEC 62559-2).

Some of these standards and reference architectures, as well as their function and implementation in this task, are briefly listed in the sections below.

2.1 NIST Framework and Roadmap for Smart Grid Interoperability Standards 4.0 and NISTIR 7628

The NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 4.0 (Gopstein et al., 2021), is a comprehensive standard that includes recommendations for providing interoperability as well as a cybersecurity solution for mitigating threats thus enabling communication. This standard also included a number of models. The NIST Smart Grid Conceptual Model is one of them. This model depicts the general structure and implementations of electric grid networks. This concept is constructed in such a way that it offers a high degree of abstraction, allowing for a holistic vision of the SG. A high-level perspective like this is generally beneficial in terms of having a shared interpretation that can be understood by a large number of stakeholders. Such models are therefore helpful in aiding understanding of interoperability and other smart grid concerns, and facilitate common language and communication across stakeholders.

The SG conceptual model is a seven-domain model that defines and characterises the major operations/roles and resources in a SG environment. Figure 2 illustrates the model. As can be seen in the model, both Information and Communications Technology (ICT) (blue solid-lines) and electrical (yellow dot-lines) flows between individual domains are possible and normally occur. Figure 3 gives a high-level description of each domain, which is followed by a short discussion of each one.

2.1.1 NIST Smart Grid Conceptual Model Domains

The SG conceptual model has seven domains covering roles and services in customers, markets, service providers, operations, generation including DER, transmission and distribution. Below, a short description of each domain is presented summarised from (Gopstein et al., 2021).

Customer Domain This domain represents the energy customers/consumers.These consumers can produce, store, and manage energy. Customers are historically divided into three categories: residential, commercial, and industrial, each with its own sub-domains. An overview of this domain is presented in Figure 3a.

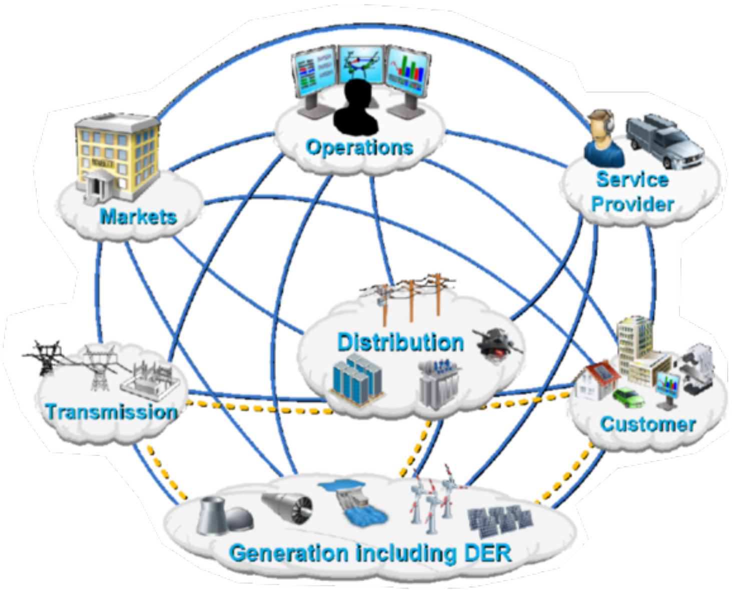


Figure 2: NIST Framework and Roadmap for Smart Grid Interoperability Standards 4.0 Smart Grid Conceptual model (Gopstein et al., 2021).

Markets Domain The facilitators and participants in electricity markets and other economic processes that drive behaviour and optimise system outcomes are represented in this domain. An overview of this domain is presented in Figure 3b.

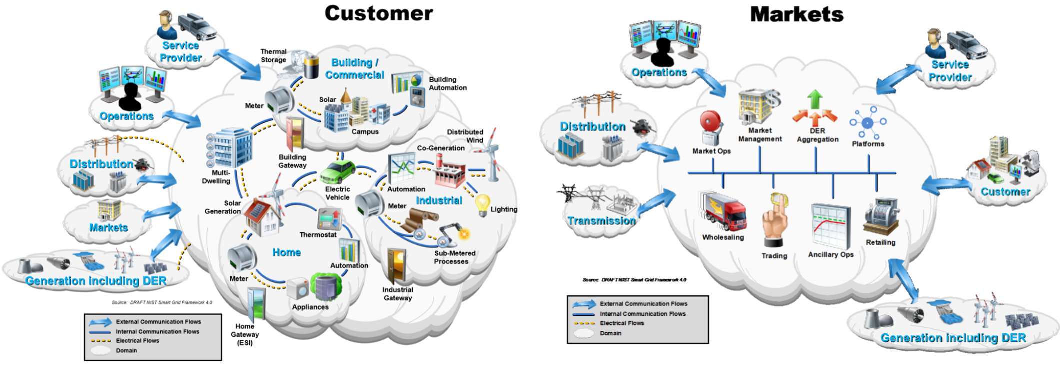
Service Provider Domain The organisations that provide services to electrical customers and utilities are represented in this domain. An overview of this domain is presented in Figure 3c.

Operations Domain The operators of electricity movement are represented by this domain. An overview of this domain is presented in Figure 3d.

Generation including DER Domain This domain includes traditional generation sources as well as Decentralized Energy Resources (DER). In general, this domain denotes electricity producers who may also store energy for later delivery. On a logical level, “generation” refers to conventional larger-scale technologies such as traditional thermal generation, large-scale hydro generation, and utility-scale renewable installations that are usually connected to the transmission grid. DER is associated with generation, storage, and demand response in the customer and distribution domains. An overview of this domain is presented in Figure 3e.

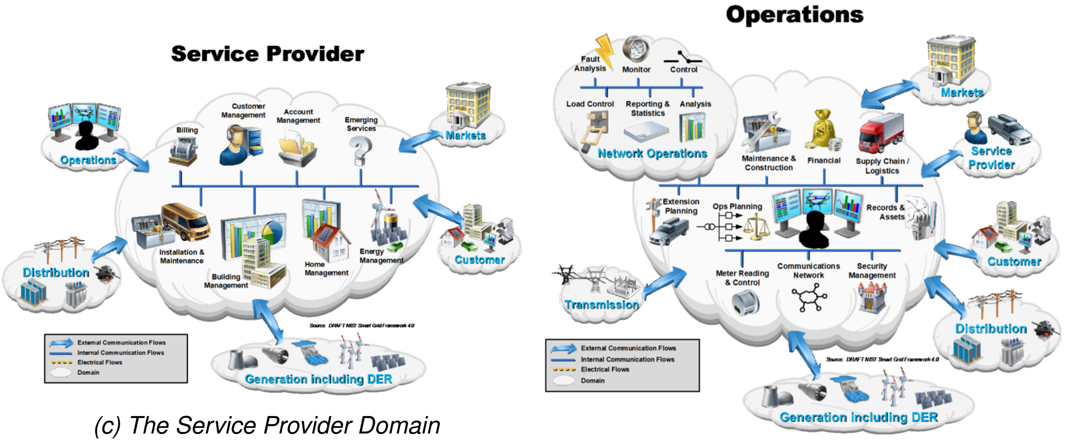
Transmission Domain Long-distance high-voltage electricity carriers are represented in this domain. These carriers can store and generate energy as well. An overview of this domain is presented in Figure 3f.

Distribution Domain The entities that supply electricity to and from consumers are represented by this domain. These entities may have the ability to store and/or produce electricity. An overview of this domain is presented in Figure 3g.



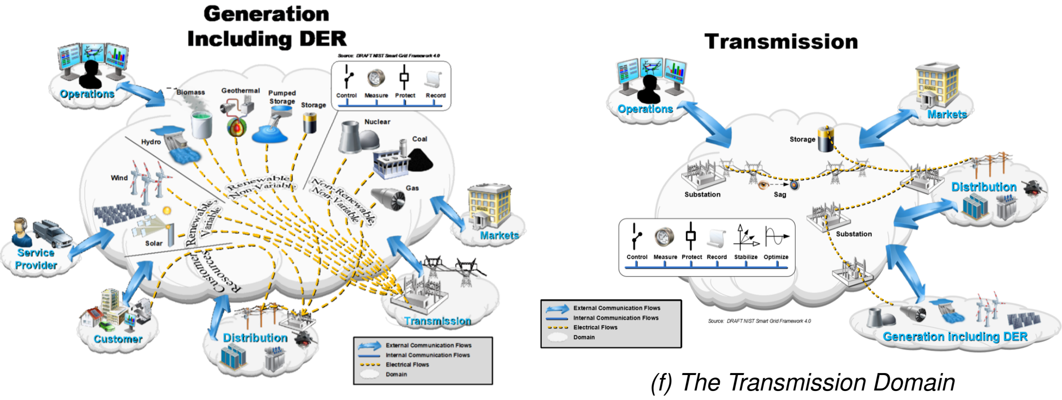
(a) The Customer Domain

(b) The Markets Domain



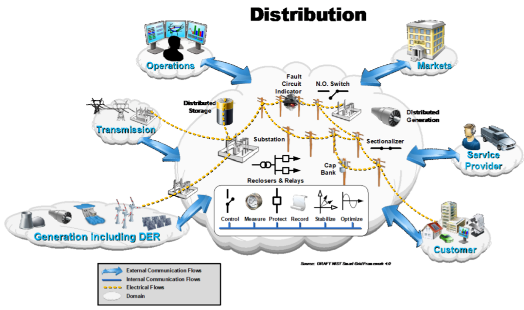
(c) The Service Provider Domain

(d) The Operations Domain



(e) The Generation including DER Domain

(f) The Transmission Domain



(g) The Distribution Domain

Figure 3: An graphical overview of the seven smart grid domains (Gopstein et al., 2021).

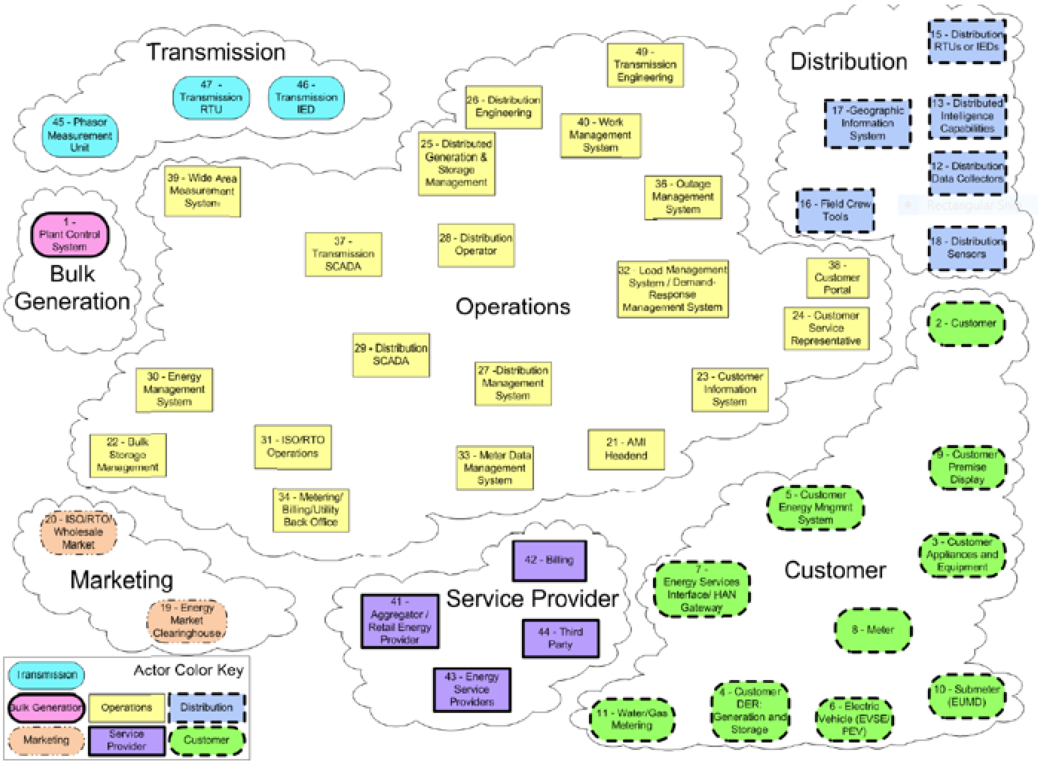


*Figure 4: NISTIR 7628 Actors categorised in domains (*Guidelines for smart grid cybersecurity*, 2014)*

2.1.2 NISTIR 7628 Smart Grid Actors

NISTIR 7628 is a companion guide to the NIST Framework and Roadmap for Smart Grid Interoperability Standards. This report includes a list of smart grid actors as well as the most frequently occurring logical interfaces between them in different scenarios. These interfaces were classified into 22 groups based on mutual or related security characteristics. The report identifies 46 actors, as depicted in Figure 4, distributed in the seven domains of the Smart Grid Conceptual model (see Figure 2). It further includes the security specifications for the 130 defined logical interfaces.

For each of the 22 categories of SG interfaces The three security characteristics are identified for SG performance, information and information system. These are:

Confidentiality: the level of system ability to prevent any unauthorised disclosure of information.

Integrity: the level of system's ability to prevent any unauthorised modification or destruction of information; and

Availability: the level of system's ability to prevent any disruption of access to or use of information or an information system.

2.2 Smart Grid Architecture Model (SGAM)

The SGAM was created by the Smart Grid Coordination Group/Reference Architecture Working Group in response to the European Commissions (ECs) Standardisation Mandate M/490[1] as a holistic view of an overall SG architecture. It is a technology-independent reference model used to analyse and visualise SG use cases. It also enables the comparison of various approaches to SG solutions, allowing for the identification of differences and similarities among various paradigms, roadmaps, and points of view. It also provides a systematic approach to dealing with the complexities of smart grids by considering the principles of universality, localisation, consistency, reliability, and interoperability, allowing for a reflection of current state of implementation in the electrical grid as well as the evolution to potential smart grid scenarios. Below, an overview of the SGAM, it domains, zones and its interoperability layers is presented, mainly summarised from (CENELEC-ETSI, 2014).

The SGAM incorporates validated approaches from power systems as well as interdisciplinary fields such as systems engineering into a clear yet detailed model. The SGAM work is based on significant existing material such as the NIST Conceptual Model (see Figure 2) and GridWise Architecture Council Stack interoperability categories (see Figure 7).

The SGAM can be used in standardisation and more generally, according to the CENELEC-ETSI SGAM User Manual:

- To enable a structured analysis of SG use cases,
- To visualise and compare different approaches to SG architectures, paradigms, roadmaps and viewpoints
- To provide a guide to analyse potential implementation scenarios,
- To ensure a common understanding between different stakeholders,
- To identify standards and standardisation gaps,
- To visualise the scope of SG projects, and in summary, to cope with the complexity of SG.

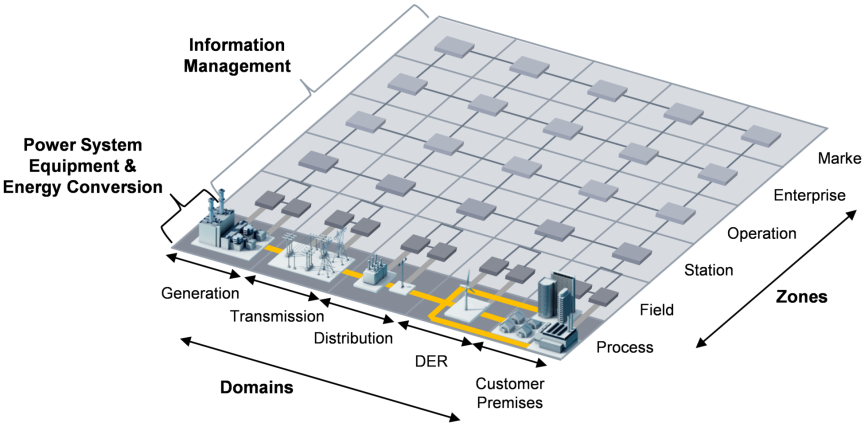


Figure 5: Overview of the Smart Grid Architecture Model Plane.

Using the SGAM, SG use cases can be visualised, detailed, and mapped to the model's layers to see if they are covered by current standards or if there are gaps in them. Based

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[1] https://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=475

on the use case specification, the SGAM conducts a use case analysis. The various fields in the IEC 62559-2 use case template provide data for this analysis; for example, the field domain(s)/zone(s) determines how the use case maps directly onto the SG plane (see Figure 5).

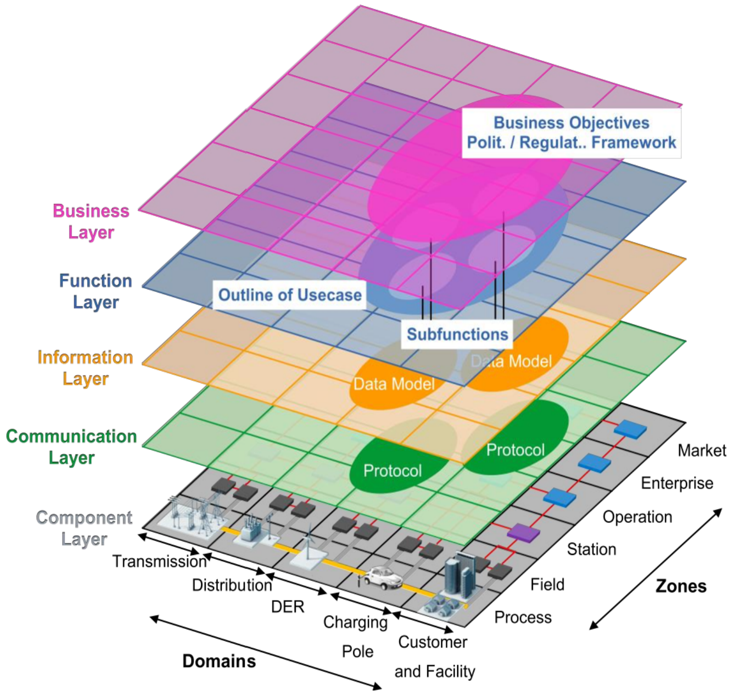


Figure 6: Overview of the Smart Grid Architecture Model (CENELEC-ETSI, 2014).

Figure 6 depicts the hierarchical three-dimensional representation of SGAM representation. The model consists of three dimensions; domains, zones and layers. A brief description of each of these three dimensions is presented below.

2.2.1 SGAM Domains

The SGAM is divided into five domains, each of which represents a physical region of the electrical grid. Generation, transmission, DER, and consumer premises are among them. A brief overview of each is given below.

Generation Representing generation of electrical energy in bulk quantities typically connected to the transmission system, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale Photovoltaics (PV).

Transmission This domain represents the infrastructure that allows energy to be transported over long distances.

Distribution The infrastructure that distributes electricity to customers is represented by this domain.

DER This domain represents small-scale power generation and consumption technologies that are directly related to the public distribution grid (typically in the range of 3 kW to 10,000 kW). A Transmission System Operator (TSO), Distribution System Operator (DSO), aggregator, or Balance Responsible Party may have direct control over these distributed electrical resources.

Customer Premises This domain serves both end consumers of electricity as well as local electricity producers. There are manufacturing, commercial, and residential facilities on the property (e.g. chemical plants, airports, harbours, shopping centres, homes). Photovoltaic generation, electric vehicle storage, batteries, and micro turbines are all examples of such generation.

2.2.2 SGAM Zones

The hierarchical levels of power system management are represented by the SGAM zones that takes into account the concepts of aggregation and functional separation. The six SGAM zones are surmised below.

Process The electrical, chemical, and spatial transformations of energy (electricity, solar, heat, water, and wind) as well as the physical equipment directly involved in the process are included in this zone.

Field This zone includes equipment that protects, controls, and monitors the power system's processes, such as security relays, bay controllers, and any other intelligent electronic devices that acquire and use power system process data.

Station This zone contains the field-level areal aggregation level, such as data concentration, functional aggregation, substation automation, local Supervisory Control and Data Acquisition (SCADA) systems, and plant supervision.

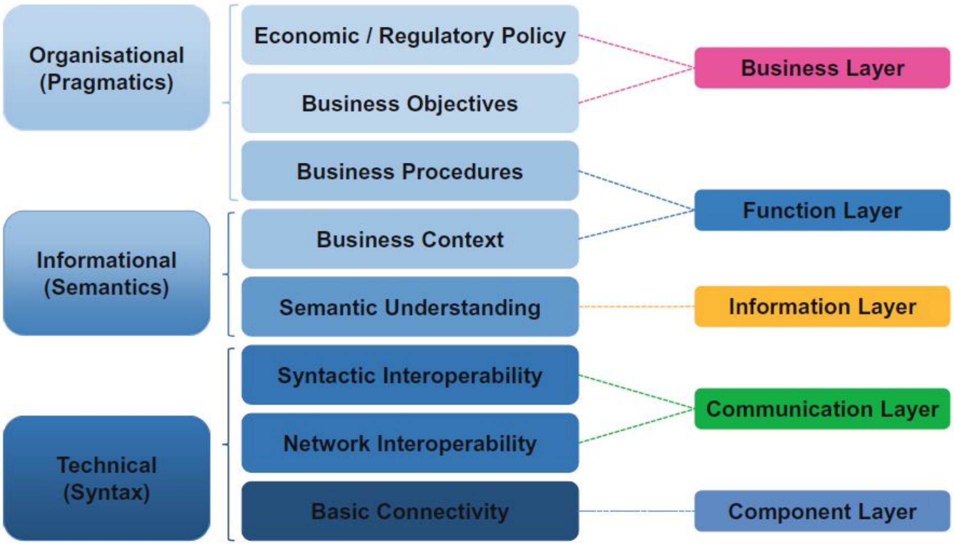


Figure 7: Grid Wise Stack in SGAM context (CENELEC-ETSI, 2014).

Operation The Distribution Management System (DMS), Energy Management System (EMS) in generation and transmission systems, microgrid management systems, Virtual Power Plant (VPP) management systems (aggregating multiple DER), and Electric Vehicle (EV) fleet charging management systems are all included in this zone.

Enterprise This zone includes commercial and organisational processes, services and infrastructures for enterprises, e.g. asset management, logistics, work force management, staff training, customer relation management, billing and procurement.

Market Reflecting the market operations possible along the energy conversion chain, e.g. energy trading, retail market.

2.2.3 SGAM Interoperability Layers

The SGAM has five layers that represent the business and its functions, the communication that is necessary and the components that are necessary for the interoperability between systems or components. These five interoperability layers are a simplified and streamlined version of the GridWise Architecture Council's interoperability stack. This mapping of the GridWise stack in the context of SGAM is show in the Figure 7. The interoperability layers provide various levels of abstractions at each layer. An overview of this concept is presented in Figure 8.

Business The business layer represents a business perspective on smart grid knowledge sharing. SGAM may be used to identify regulatory and economic frameworks and policies, business models and use cases, and market participants' business portfolios.

Function From an architectural standpoint, the function layer defines device use cases, functions, and utilities, as well as their relationships. Functions are expressed in applications, structures, and materials independently of actors and physical implementations. The functions are extracted by removing actor-independent use case features.

Information The information layer defines the data that is used and shared between functions, programs, and modules. It includes knowledge objects as well as the canonical data models that underpin them. This knowledge objects and canonical data models reflect the common semantics for functions and services, allowing for interoperable information sharing through communication channels.

Communication The communication layer's focus is on describing protocols and frameworks for the interoperable sharing of information between components in the sense of the underlying use case, function, or service, as well as related information objects or data models.

Component The component layer focuses on the physical delivery of all participating components in the smart grid context. This involves system and device actors, power system equipment (typically located at the process and field levels), security and telecontrol devices, network infrastructure (wired / wireless networking links, routers, switches, servers), and computers of any kind.

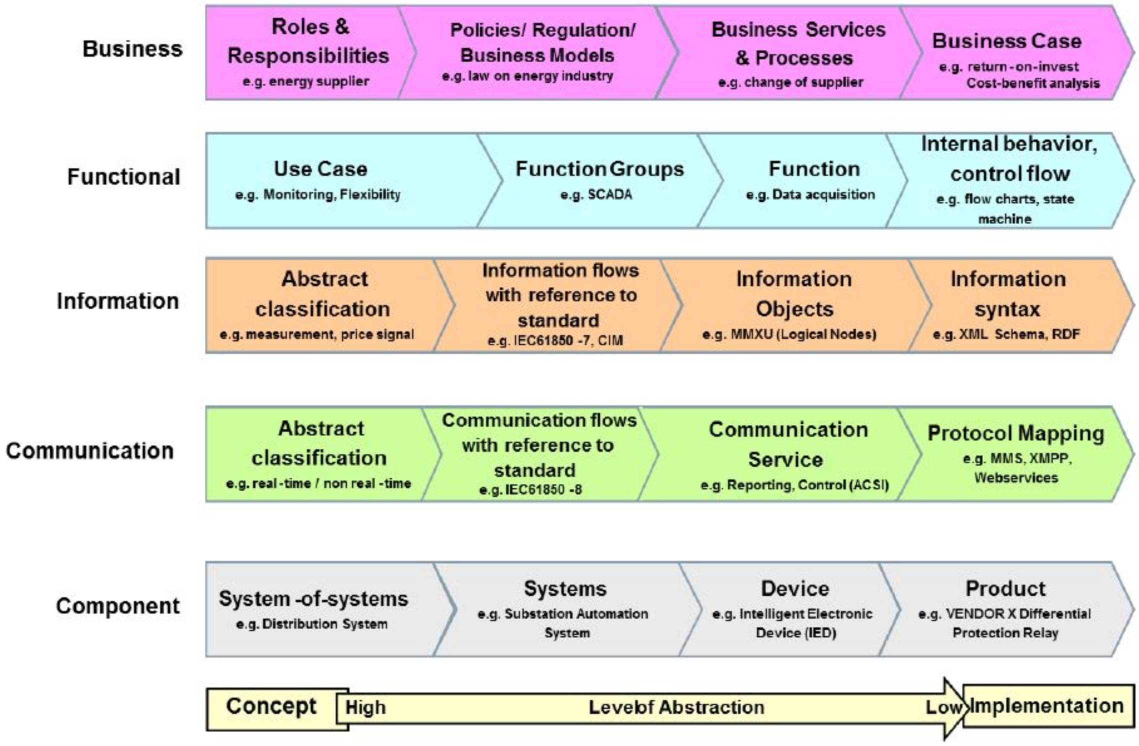


Figure 8: SGAM abstraction levels per layer (CENELEC-ETSI, 2014).

2.3 The IEC 62559-2 Use Case Methodology

It is important for to document the use cases for defining the functionalities of the system-under-development in a standardised and organised manner. IEC TC8 has specified this procedure as a guide in the form of a multi-part standard called IEC 62559. In this family of standards, part 2 that is frequently reference as the IEC 62559-2 defines and presents the “Use Case Methodology” along with a template that can be used for documenting a Smart Grid use case with SGAM domains and zones.

The standard template is defined with eight sections where some of the sections are optional. The eight sections are:

- Description of the use case,
- Diagrams of use case,
- Technical details,
- Step by step analysis of use case,
- Information exchanged,
- Requirements,
- Common terms and definitions,
- Custom information

Due to its structured approach and strong support for SGAM, the use cases in HYPERRIDE are documented using this template.

2.4 Mapping NIST Smart Gird actors on to the SGAM plane

The two primary conceptual models and reference architecture model presented in this section are highly important and widely utilised for use case-level Smart Grid application planning and analysis. Due to their importance, there are some mappings available for representing actors. One such mapping from (Uslar et al., 2014) is presented in Figure 9. The figure is redrawn from (Uslar et al., 2014) and shows how the NIST Smart Grid actors can be mapped and presented onto an SGAM plan. Such mapping is useful for translation between the standards. As can be seen, the figure only shows the actor ids as assigned in the NISTIR7628 Smart Grid actors. These ids can be found in the list of actors along with some short description in Appendix A – NIST Smart Grid Actors.

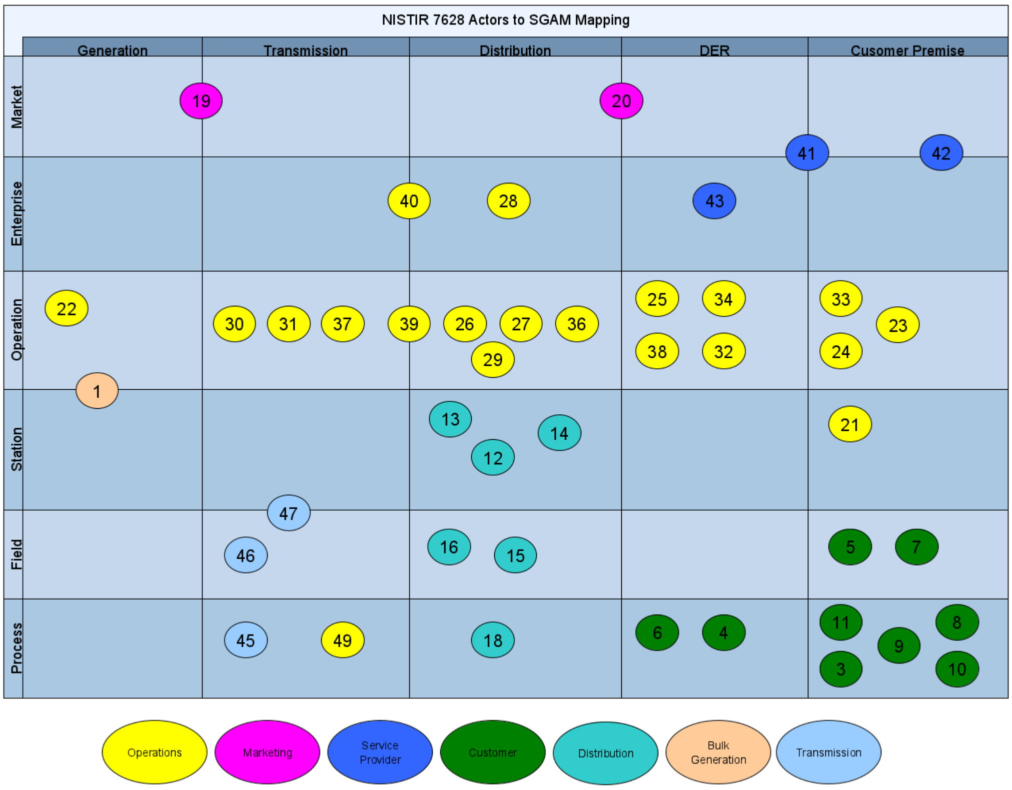


Figure 9: The mapping of NIST Smart Grid Actors to the SGAM plane (Uslar et al., 2014).

3 Methodology and Analysis

Designing and building a complex system such as HYPERRIDE is a challenging task that requires defining and using a carefully crafted methodology to achieve the system objectives. However, it should be noted that building any system requires a reasonably good understanding of the requirements of the system-to-be-developed. This understanding further requires that sufficient effort has to be employed in the clear identification of the context of such a system. A methodology is therefore defined having six main steps towards developing the use cases that can then be used as the basis for implementation in three pilot sites in HYPERRIDE. An overview of the methodology is presented in Figure 10.

Figure 10: Overview of the methodology.

3.1 Context

This is the first and most critical step in the methodology. In this step, the focus is on attempting to determine the context of the HYPERRIDE solution. No system can function in a vacuum, and it will always be deployed and operate in an environment. The context describes the environment, which includes the individuals, systems, sub-systems, processes, and so on that can exist and interact with HYPERRIDE. Knowing the context is critical because it provides a wealth of knowledge about the surroundings and potential solutions, as well as aids in deciding the solution boundaries.

This first step consists of various sub-steps including:

- the identification of the Smart Grid domains and the possible flows (electrical and ICT) between them and HYPERRIDE
- from the identified domains above, identifications of the actors that could be relevant in HYPERRIDE.

A detailed study is conducted to find the relevant information needed for determining the context including Smart Grid domains and actors. For this study, the NIST Smart Grid conceptual (see Section 2.1.1) model is used. The outcome is summarised in the Table 1. As can be seen, five out of seven domains were considered constituting the context for the HYPERRIDE solution. Relevance and intention of each pilot site with respect to the identified domains are also documented. As can be seen, each of the pilot is expected to implement as part of the project.

In addition to the table, the context is also represented graphically in Figure 11. As shown in the figure, the five identified domains; customers (see Section 2.1.1), distribution (see Section 2.1.1), operation (see Section 2.1.1, market (see Section 2.1.1) and service providers (see Section 2.1.1) domains. Both the electrical and ICT flows are identified and represented with blue and yellow lines.

The actors identification is addressed in next section.

Table 1: The summarised representation of the identified HYPERRIDE Smart Grid domains context.

Domain	Relevance			Flow Type		Addressed in pilots		
	Direct	Indirect	N/A	Electrical	ICT	German	Swiss	Italian
Customer	X			**X**	**X**	X	X	X
Distribution	X			X	X	X	X	X
Operations	X				X	X	X	X
Service Provider	X				X	X	X	X
Market	X				X	X	X	X
Transmission			X					
Generation			X					

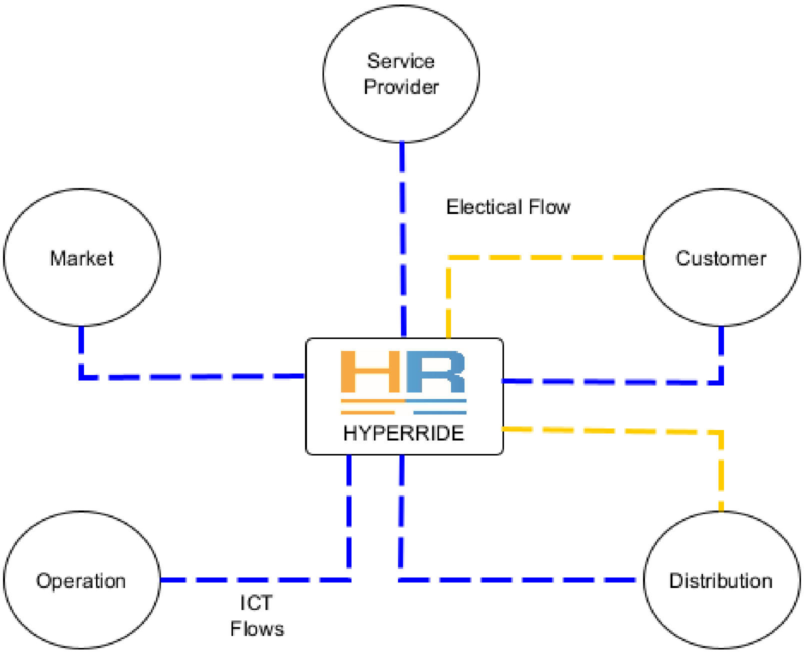


Figure 11: The graphical representation of the identified HYPERRIDE Smart Grid domains context.

3.2 Characterisation and goals

This is the second logical step in the methodology and concerns with identifying and classifying the Smart Grid actors that could have a behaviour relevant to HYPERRIDE. Since the domain context has already been identified, this step focuses on analysing the actors in each of the relevant domain. Once they are identified, they need to be characterised based on their roles. The three main roles considered for such characterisation are:

A primary actor: the target-system directly serves this actor's objectives. The use cases address the functionality and behaviour needs of this actor, which serve as the foundation for the system's operation. This actor also derives some business value from the target-system as a stakeholder.

A secondary actor: this actor serves as a support actor for a primary actor and can be used to initiate interaction with the target-system on its behalf. As a proxy actor, this actor cannot exist without a primary actor.

A supporting actor: this actor is a helper to the target-system in achieving the goals of a primary actor.

In addition to the classification, the other important factors addressed in this step are:

- finding the relevance of each actor to each of the HYPERRIDE pilot implementation
- finding the goals of all the identified primary actors
- realising the HYPERRIDE responsibilities for fulfilling the primary actors' goals

The finding of this step are summarised in Table 2. As can be seen, the table shows various aspects of each of 46 Smart Grid actors. Each actor is described with its original ID, the domain it belongs to and its name. Then there are various aspects that address the relevance, flow types and pilots where the actor is addressed in HYPERRIDE.

The classification helps to identify the three main types of actors including the primary actors. The primary actors are defined as the stakeholder that the system is expected to server directly. It is therefore important to know them as well as their goals so that appropriate functionalities can be provided fulling these goals. Identification of such functionalities put various responsibilities on system that form the core of the functional requirements.

3.3 Use cases

This step focuses on defining the use case on the basis of the inputs and finding collected from the previous two steps. More specifically, the input more relevant here is the primary actors' goals and HYPERRIDE responsibilities. The detailed discussions and finds are described in the next chapter.

doi:10.5281/zenodo.4772166

Table 2: The list of identified actors during analysis phase.

Actor							Flow Type			
							Electrical		ICT	
ID	Domain	Name	Relevant	Classification			Consumer	Producer	Source	Sink
				Primary	Secondary	Supporting				
1	Generation with DER	Plant Control System – Distributed Control System	No							
2	Customer	Customer	Yes	X			X	X	X	X
3	Customer	Customer Appliances and Equipment	No							
4	Customer	Customer Distributed Energy Resources: Generation and Storage	Yes			X	X	X	X	X
5	Customer	Customer Energy Management System	No							
6	Customer	Electric Vehicle Service Element/Plug-in Electric Vehicle	Yes			X	X	X	X	X
7	Customer	Home Area Network Gateway	No							
8	Customer	Meter	Yes			X	X		X	
9	Customer	Customer Premise Display	No							
10	Customer	Sub-Meter – Energy Usage Metering Device	Yes			X	X		x	
11	Customer	Water/Gas Metering	No							
12	Distribution	Distribution Data Collector	No							
13	Distribution	Distributed Intelligence Capabilities	Yes			X	X		X	X
14	Distribution	Distribution Automation Field Devices	No							

(continued)

Actor							Flow Type			
							Electrical		ICT	
ID	Domain	Name	Relevant	Classification			Consumer	Producer	Source	Sink
				Primary	Secondary	Supporting				
15	Distribution	Distribution Remote Terminal Unit/Intelligent Electronic Device	Yes			X	X	X	X	X
16	Distribution	Field Crew Tools	Yes			X			X	X
17	Distribution	Geographic Information System	No							
18	Distribution	Distribution Sensor	Yes			X			X	X
19	Marketing	Energy Market Clearinghouse	No							
20	Marketing	Independent System Operator/Regional Transmission Organization Wholesale Market	No							
21	Operations	Advanced Metering Infrastructure Headend	Yes			X	X	X	X	
22	Operations	Bulk Storage Management	No							
23	Operations	Customer Information System	No							
24	Operations	Customer Service Representative	No							
25	Operations	Distributed Generation and Storage Management	Yes		X			X	X	X
26	Operations	Distribution Engineering	Yes			X			X	X
27	Operations	Distribution Management Systems	Yes		X		X	X	X	X
28	Operations	Distribution Operator	Yes	X			X	X	X	X

doi:10.5281/zenodo.4772166

(continued)

Actor							Flow Type			
				Classification			Electrical		ICT	
ID	Domain	Name	Relevant	Primary	Secondary	Supporting	Consumer	Producer	Source	Sink
29	Operations	Distribution Supervisory Control and Data Acquisition	Yes		X		X	X	X	
30	Operations	Energy Management System	Yes			X	X	X	X	
31	Operations	ISO/RTO Operations	No							
32	Operations	Load Management Systems/Demand Response Management System	No							
33	Operations	Meter Data Management System	No							
34	Operations	Metering/Billing/Utility Back Office	No							
36	Operations	Outage Management System	Yes		X		X	X	X	
37	Operations	Transmission SCADA	No							
38	Operations	Customer Portal	No							
39	Operations	Wide Area Measurement System	Yes			X	X		X	
40	Operations	Work Management System	No							
41	Service Provider	Aggregator/Retail Energy Provider	No							
42	Service Provider	Billing	No							
43	Service Provider	Energy Service Provider	Yes	X				X	X	X
44	Service Provider	Third Party	No							

(continued)

Actor							Flow Type			
							Electrical		ICT	
ID	Domain	Name	Relevant	Classification			Consumer	Producer	Source	Sink
				Primary	Secondary	Supporting				
45	Transmission	Phasor Measurement Unit	No							
46	Transmission	Transmission IED	No							
47	Transmission	Transmission RTU	No							
49	Transmission	Transmission Engineering	No							
49	Transmission	Transmission Engineering	No							

doi:10.5281/zenodo.4772166

4 Use Cases Definition

The findings after applying the step 3 (see Section 3.3) of the methodology are presented in this section. It begins with the derived listing the “Summary Use Cases” and moves on to the pilot implementation and developed use cases.

4.1 Summary Use cases

Based on the discussions and collected input for partners, the following summary use case were developed as the basis for identifying the use cases that would be developed further for implementation into pilots. An overview of them is presented below in Table 3.

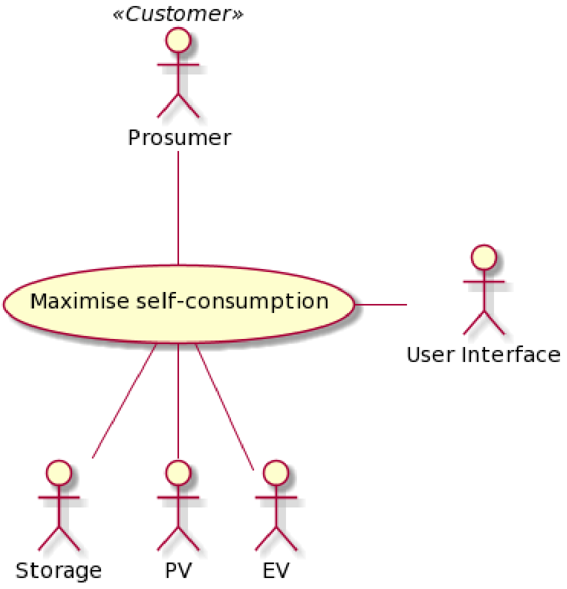
Table 3: Developed Summery Use Cases.

ID	Title
1	Maximisation of self-consumption
2	Forming an energy community
3	Optimisation of day-ahead & intraday market costs
4	Reduce grid connection costs by optimising peak load
5	Provide flexibility to the grid operator (DSO) to earn money
6	Efficient Low Voltage (LV) distribution grid monitoring and control by using flexibilities (on the customer side)
7	Efficient fault management in grid operation
8	Business models development for energy markets engagements and investments
9	Reducing cost of integration of local generation

4.1.1 Maximisation of self-consumption

This summary use case address a goal of achieving self-sustainability by maximising the self consumption for the primary actor “Customer”. The actor has both the local generation and storage capabilities. Table 4 presents an overview of this summery use case.

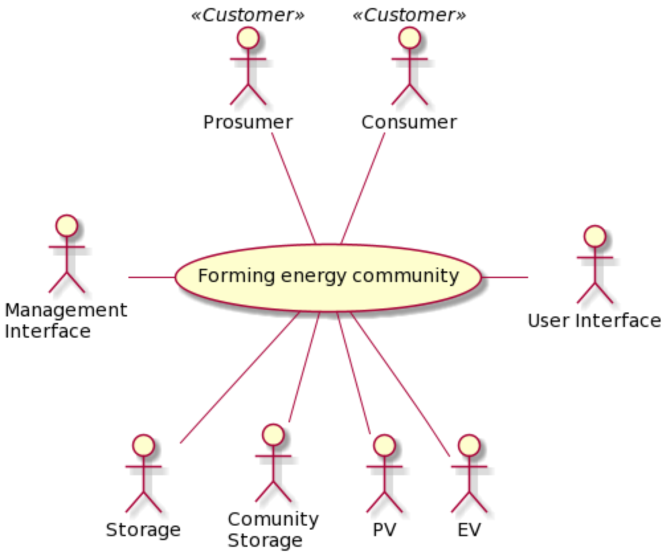
Table 4: Summery Use Case 1.

Title	**Maximisation of self-consumption**
Primary Actor:	**CUSTOMER**
Goal(s):	Achieving self-sustainability by maximising self consumption
Scope:	HYPERRIDE
Level:	Summary
Description	The prosumer has a goal to minimise its energy consumption cost and achieve self-sustainability. It, therefore, wishes to use the energy produced by its local sources (PV, EV, storage, etc.) as much as possible.
Secondary Actors:	User interface
Supporting Actors:	Prosumer PV, Prosumer EV, local storage
Overview Diagram	

4.1.2 Forming an energy community

This use case address a goal for a group of primary actors “Customer” that are wishing enable local sharing of the excess energy. The the group of actors could own both the local generation and storage capabilities as well a community storage. Table 5 presents an overview of this summary use case.

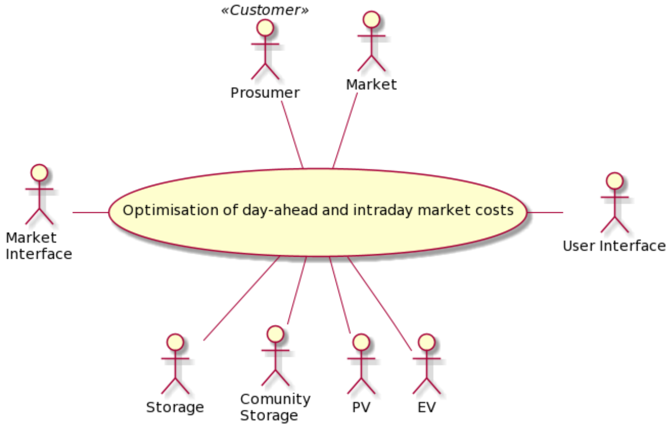
Table 5: Summery Use Case 2.

Title	**Forming an energy community**
Primary Actor:	**CUSTOMER**
Goal(s):	Forming a local energy community, increase self consumption, etc.
Scope:	HYPERRIDE
Level:	Summary
Description	A group of prosumers wants to minimise its energy consumption cost and achieve self-sustainability. They together agree to use and share/sell the excess energy produced by either their locally-owned sources (PV, EV, storage, etc.) or from some community-owned sources as much as possible.
Secondary Actors:	User interface, Management Interface
Supporting Actors:	Prosumer PV, Prosumer EV, local storage, community storage
Overview Diagram	

4.1.3 Optimisation of day-ahead and intraday market costs

This use case address a goal for the primary actor “Customer” that is wishing to optimise the day-ahead and intraday market costs. Table 6 presents an overview of this summery use case.

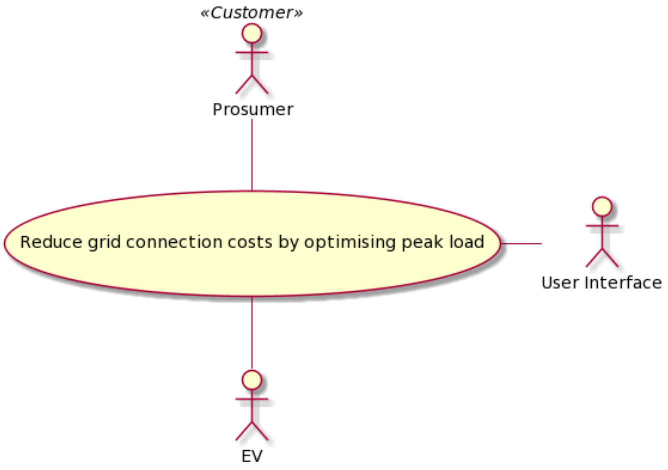
Table 6: *Summery Use Case 3.*

Title	**Optimisation of day-ahead and intraday market costs**
Primary Actor:	**CUSTOMER**
Goal(s):	Efficient fault management
Scope:	HYPERRIDE
Level:	Summary
Description	The prosumer wants to minimise its energy consumption cost. The customer is interested to buy electricity from the market when the prices are low or shifting its load from a high-priced to a low-priced period. On the other hand, during the high-priced, the customer wishes to sell its excess generation in the market for profit.
Secondary Actors:	User interface and/or energy market participation interface
Supporting Actors:	Prosumer PV, Prosumer EV, local storage, market, aggregator
Overview Diagram	

4.1.4 Reduce Grid Connection Costs by optimising peak load

This summary use case addresses a goal for the primary actor "Customer," who wishes to minimise grid link costs by optimising peak load and opts to schedule/delay charging of its EV until there is a low cost for its electrical consumption. Table 7 presents an overview of this summary use case with an overview picture.

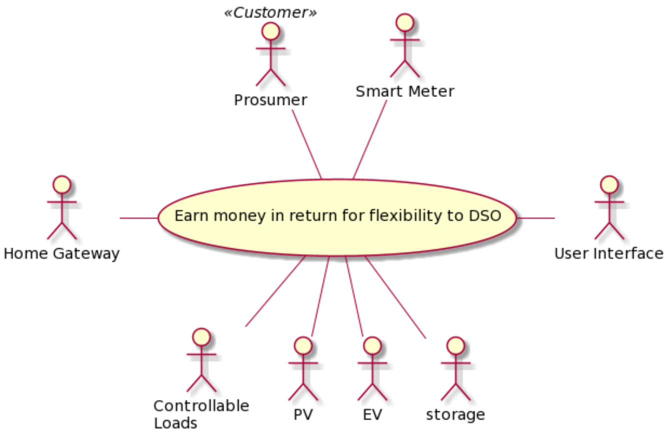
Table 7: Summery Use Case 4.

Title	**Reduce grid connection costs by optimising peak load**
Primary Actor:	**CUSTOMER**
Goal(s):	Reduce grid connection costs by optimising peak load
Scope:	HYPERRIDE
Level:	Summary
Description	The customer is interested in reducing its EV charging costs and wishes to schedule/delay the charging until there is a low cost of consumption. This way, the service providers can optimise their charging station's utilisation with a better quality of service (QoS).
Secondary Actors:	User interface
Supporting Actors:	Prosumer PV
Overview Diagram	

4.1.5 Provide flexibility to the grid operator for monetary benefits

This summery use case address the goal for the primary actor "Customer" who is interested in provide flexibility to the grid operator in exchange for monetary benefits. Table 8 presents an overview of this summery use case.

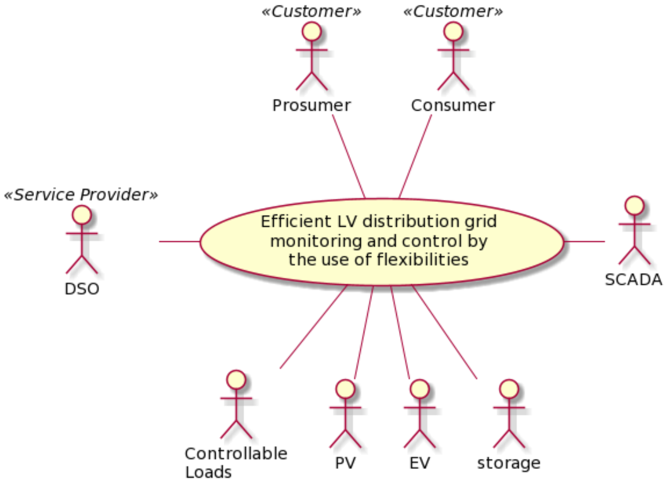
Table 8: Summery Use Case 5.

Title	**Provide flexibility to the grid operator for monetary benefits**
Primary Actor:	**CUSTOMER**
Goal(s):	Earn money in return for flexibility to DSO
Scope:	HYPERRIDE
Level:	Summary
Description	The customers provide flexibility to the grid operator to support stable grid operation. In return, the customer receives reduced grid tariffs (and reduced electricity price) in his electricity bill.
Secondary Actors:	Home gateway/Smart meter
Supporting Actors:	Prosumer PV, Prosumer EV, local storage, controllable loads
Overview Diagram	

4.1.6 Efficient LV distribution grid monitoring and control by using flexibilities (customer side)

The DSO’s target of effective LV distribution grid monitoring and regulation through the use of flexibilities is addressed in this summary use case. It is focused on the primary actor “DSO/Service Provider” and as the primary beneficiary. Table 9 presents an overview of this summery use case.

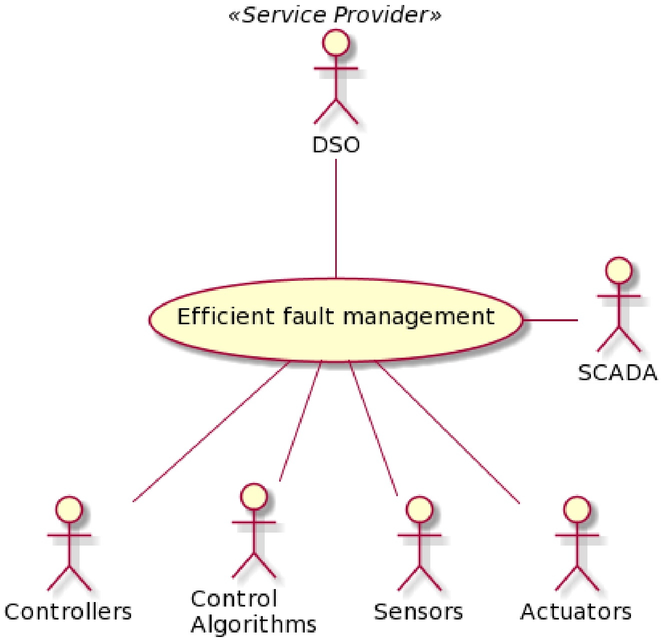
Table 9: Summery Use Case 6.

Title	**Efficient LV distribution grid monitoring and control by using flexibilities**
Primary Actor:	**DSO/Service Provider**
Goal(s):	Efficient LV distribution grid monitoring and control by the use of flexibilities
Scope:	HYPERRIDE
Level:	Summary
Description	The DSO is interested in better monitoring and control of the distribution network by using flexible services from the market and prosumers to avoid technical violations that may occur in LV networks such as under-voltages and over-voltages or branch overload.
Secondary Actors:	SCADA
Supporting Actors:	Prosumer PV, Prosumer EV, storage, sensors
Overview Diagram	

4.1.7 Efficient fault management in grid operation

This summary use case addresses the primary actor DSO/Service Provider's goal of achieving an efficient fault management. Table 10 presents an overview of this use case.

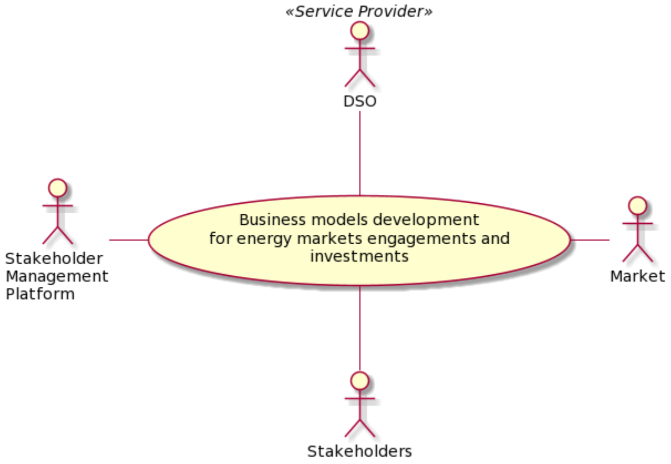
Table 10: Summery Use Case 7.

Title	**Efficient fault management in grid operation**
Primary Actor:	**DSO/Service Provider**
Goal(s):	Efficient fault management
Scope:	HYPERRIDE
Level:	Summary
Description	Development of a layer-based control architecture for future hybrid AC/DC grids that enables a stable grid operation even under failure situations or cyber-attack scenarios.
Secondary Actors:	SCADA
Supporting Actors:	Sensors, actuators, control algorithm
Overview Diagram	

4.1.8 Business models development for energy markets engagements and investments

This summary use case addresses a goal for the primary actor, the DSO/Service Provider, who is attempting to create an effective business model that can help involve stakeholders and draw further investment. Table 11 presents an overview of this summery use case.

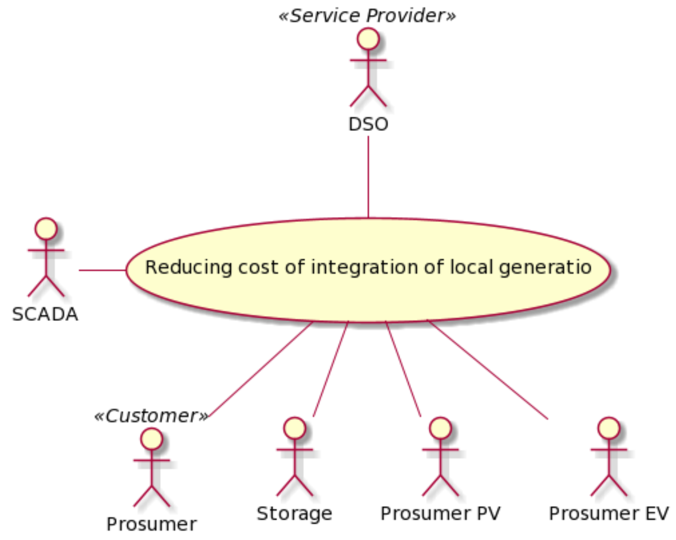
Table 11: Summery Use Case 8.

Title	**Business models development for energy markets engagements and investments**
Primary Actor:	**DSO/Service Provider**
Goal(s):	Efficient business models development
Scope:	HYPERRIDE
Level:	Summary
Description	A DSO is interested in implementing better business models to not only achieve efficient stakeholder engagement but also improve participation in energy markets and attract more investments. The DSO , therefore, would need to develop efficient strategies to engage various stakeholders for enhanced participation and development of the energy market with fit-for-all business models utilising innovative data and stakeholder management and consumer involvement approach.
Secondary Actors:	Stakeholder management platform
Supporting Actors:	Stakeholders, Market
Overview Diagram	

4.1.9 Reducing cost of integration of local generation

The primary actor, the DSO /Service Provider, wanted to lower the cost of integrating local generation from prosumers so that it could be used as a versatile resource, and this use case addresses that goal. Table 12 provides an overview of this summary use case.

Table 12: Summery Use Case 9.

Title	**Reducing cost of integration of local generation**
Primary Actor:	**DSO/Service Provider**
Goal(s):	Efficient fault management
Scope:	HYPERRIDE
Level:	Summary
Description	Enabling self/local consumption to reduce the in-feed peak power into grid and eventually the grid connection and monitoring costs.
Secondary Actors:	SCADA
Supporting Actors:	Prosumer PV, Prosumer EV, local storage
Overview Diagram	

4.2 Pilot implementations and selected Use Cases

This section presents first an overview of the three HYPERRIDE pilot sites and then summarises the use cases that are being developed, based on the summary use cases presented in the previous section, for implementation. A more detailed description of the pilot site can be found in other HYPERRIDE deliverable e.g. D2.3.

4.2.1 The German pilot and its use cases

The German pilot is a 5 km long Medium-Voltage Direct Current (MVDC) cable that connects three separate locations at the RWTH-Aachen Campus Melaten. The Institute for Power Generation and Storage Systems (RWTH-PGS)[2], in collaboration with Flexible Electrical Networks Research Campus[3] manages the grid. RWTH-PGS also has a diverse range of high-power

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[2] https://www.pgs.eonerc.rwth-aachen.de/go/id/dnjx/

[3] https://www.forschungscampus.bmbf.de/research_campuses/flexible-electrical-networks

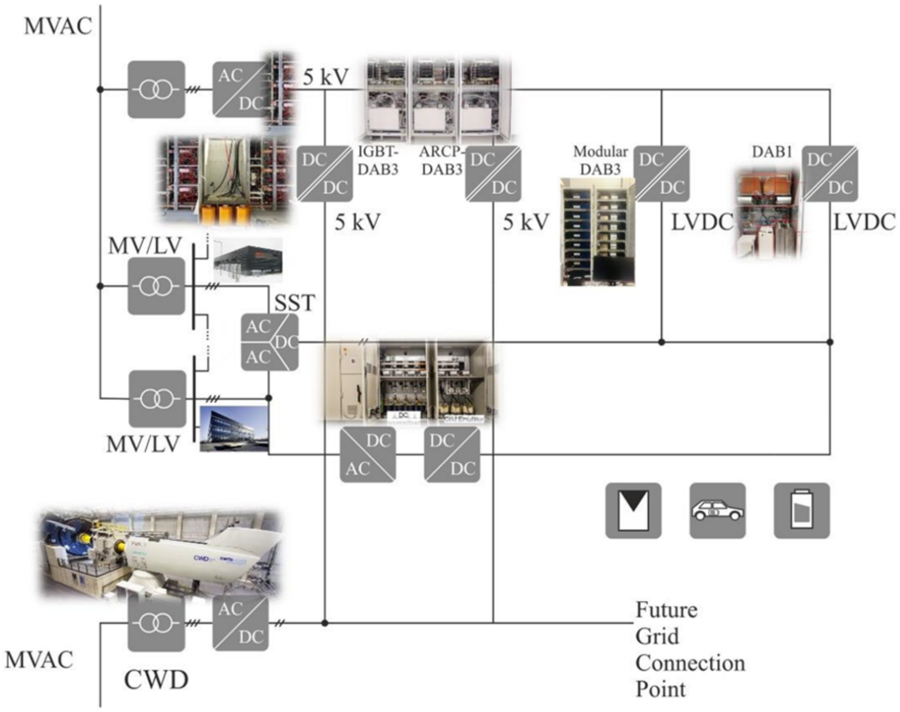

Figure 12: Overview of the German Pilot.

DC/DC and DC/AC converters that can be used to build hybrid AC/DC grid structures. An overview of the pilot is depicted in Figure 12 below.

Two use cases are defined for implementation in the German pilot. The use cases are based on UC summery 4 and 7. The use cases are documented using the IEC62559-2 template and included with this deliverable in Appendix B.

Table 13: Overview of German Pilot's Use Cases.

ID	Name	Short Description	Based on
HYPERRIDE-UC-GERMAN-001	Reduce grid connection costs by optimizing peak load	The OPF algorithm, implemented as middleware software component in the HYPERRIDE platform, allow to determine setpoints of AC/DC converters and operating positions of switching devices (network reconfiguration) to optimize the power flow in the AC/DC grid and improve energy management.	Section 4.1.4
HYPERRIDE-UC-GERMAN-002	Efficient fault management in grid operation	The service restoration algorithm starts when the fault area has been cleared and the action of reclosers failed: it aims to reconnect disconnected loads by changing the grid topology and, in the AC/DC grids, exploiting the AC/DC converters controllability.	Section 4.1.7

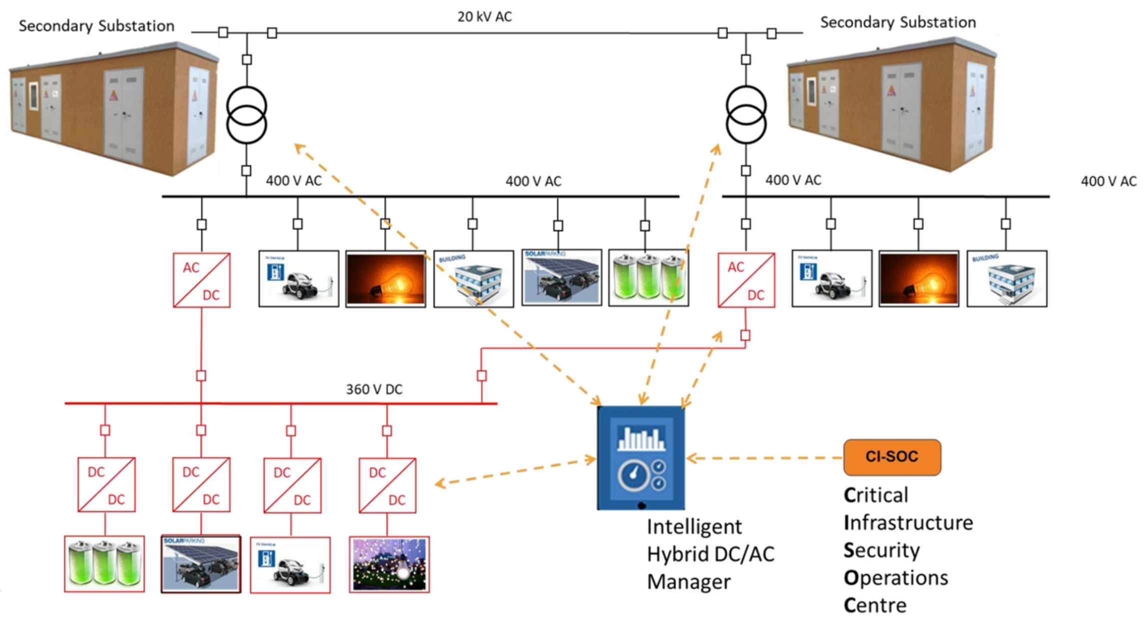

Figure 13: Overview of the Italian Pilot Site.

4.2.2 The Italian Pilot and its Use Cases

ASM Terni S.p.A. [4] operates the Italian pilot, which is based in Terni, Italy. The distributed renewable energy sources embedded in the medium and low voltage distribution networks characterise the ASM electric grid. Currently, 41 units are connected to Medium Voltage (MV) networks, while 1325 units are connected to LV networks. Two secondary substations attached to the same MV feeder make up the portion of the network used for the trials. The former connects the building to the smaller PV plant and serves approximately 15 LV users. The latter links the larger PV plant and one EV charging station, as well as hosting the ASM headquarters as its load. An overview of the pilot is depicted in Figure 13 below.

Two use cases are defined for implementation in the German pilot. The use cases are based on summery use cases 4 and 7. The use cases are documented using the IEC62559-2 template and included with this deliverable in Appendix B.

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[4] https://www.asmterni.it/

Table 14: Overview of Italian Pilot's Use Cases.

ID	**Name**	**Short Description**	**Based on**
HYPERRIDE-UC-ITALIAN-001	FORMING AN ENERGY COMMUNITY	Energy Communities are promoted by the Renewable Energy Directive (EU Directive 2018/2001), in which the definitions of collective self-consumption among members of an apartment block or building and Renewable Energy Community (REC) are given. This European Directive stipulates that members must produce energy for their own consumption and that the energy produced can be shared among users using existing distribution networks. In Italy, Energy Communities can install systems powered by renewable sources with a total power not exceeding 200 kW.	Section 4.1.2
HYPERRIDE-UC-ITALIAN-002	PROVIDE FLEXIBILITY TO THE GRID OPERATOR (DSO)	The prosumers, producers and users provide ancillary services or balancing services to the grid by exploiting their flexibility to support stable grid operation. All these actors assume an active role in local energy capacity market in a power grid where are present DERs and distributed storage. In return, the customer plugged to the distribution grid receives economic benefits for the services provided.	Section 4.1.5
HYPERRIDE-UC-ITALIAN-003	EFFICIENT FAULT MANAGEMENT IN GRID OPERATION	The implementation of the hybrid AC/DC grid in a LV distribution grid make it possible the pluralisation of LV feeder from different sources. Double power supply increase the reliability of the system.	Section 4.1.7

4.2.3 The Swiss Pilot and its Use Cases

The Swiss pilot is operated by the Ecole Polytechnique Fédérale de Lausanne (EPFL)[5], which is based near the Léman lake in Switzerland. The pilot site combines two lab infrastructures: the DESL AC microgrid and the PEL's DC microgrid. A step-down transformer connects the 0.4kV AC microgrid to the 20kV MV network. As a result of this configuration, an AC-DC microgrid was developed, with most of the elements rated at less than 50kW. The AC microgrid is built on top of the CIGRE benchmark network, with four DC links created using bidirectional AC-DC converters. An overview of the pilot configuration is depicted in Figure 13 below.

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[5] https://www.epfl.ch/en/

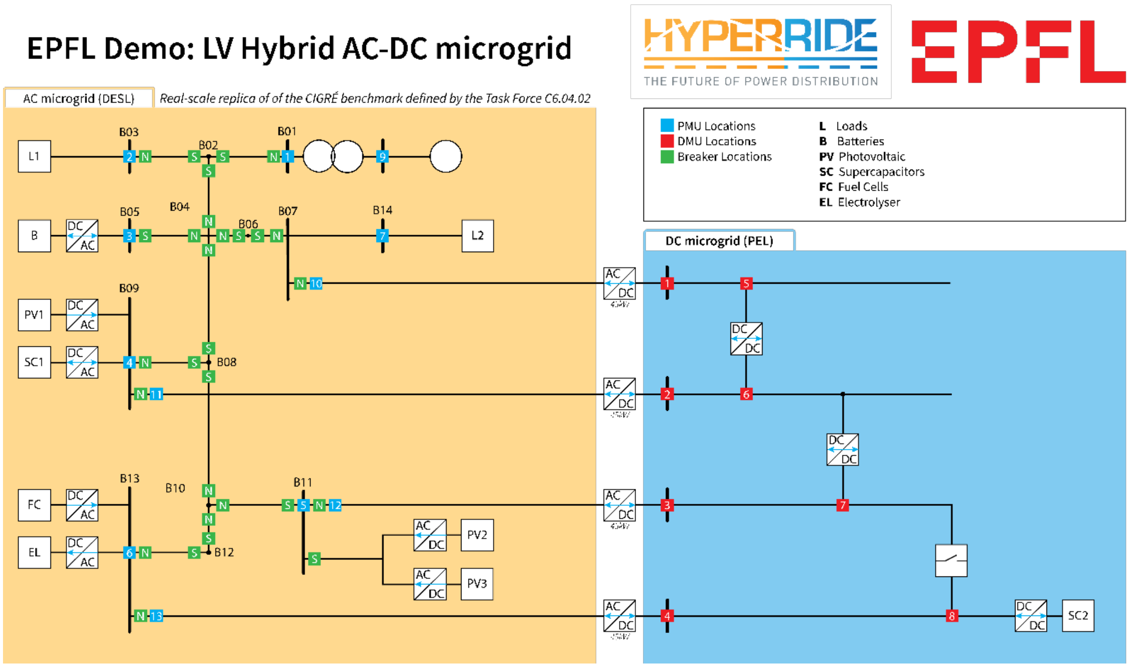

Figure 14: Overview of the Swiss Pilot.

Two use cases are defined for implementation in the German pilot. The use cases are based on UC summery 4 and 7. The use cases are documented using the IEC62559-2 template and included with this deliverable in Appendix B.

Table 15: Overview of Swiss Pilot's Use Cases

ID	Name	Short Description	Based on
HYPERRIDE-UC-SWISS-001	Efficient LV distribution grid monitoring and control by using flexibilities (on the customer side)	Using a National Instrument CRio real time controller to implement a direct measurement unit that output time synchronised DC measurements. The DMU will be based on the already existing PMU. However, the difference with the PMU is that it relies on the interpolated discrete Fourier transform to extract the phasor and magnitude, while the DMU can extract the magnitudes by simply making use of a filter. The time synchronised PMU and DMU measurements are used in a linear hybrid state estimation to estimate the most likelihood state. The computed states are required for the monitoring of the system, performing the hybrid OPF.	Section 4.1.6

ID	**Name**	**Short Description**	**Based on**
HYPERRIDE-UC-SWISS-002	Efficient fault management in grid operation	Different types of faults can occur during grid operations: line-to-line, line-to-ground in the AC and DC system, faulty converter, etc. Faults needs to be suppressed in order to provide safe operations for loads and users. In a first step, AC circuit breakers, DC solid state circuit breakers, and/or DC-DC controllers will detect the fault and disconnect the line or go in safe mode. After the suppression of the fault, a procedure is started to re-energies the grid. By removing the faulty lines and/or converters and using the updated grid topology, the OPF is computed in order to recompute the new optimal setpoints after the fault.	Section 4.1.7

4.3 Implementation Roadmap

Table 16 provides a summary of defined use case along with the implementing pilot. Each use case is assigned a simple serial number so that it can be referred to later.

Table 16: Summary of use case along with the implementing pilots

Serial Number	Use Case ID	Implementing Pilot
UC1	HYPERRIDE-UC-GERMAN-001	German
UC2	HYPERRIDE-UC-GERMAN-002	German
UC3	HYPERRIDE-UC-ITALIAN-001	Italian
UC4	HYPERRIDE-UC-ITALIAN-002	Italian
UC5	HYPERRIDE-UC-ITALIAN-003	Italian
UC6	HYPERRIDE-UC-SWISS-001	Swiss
UC7	HYPERRIDE-UC-SWISS-002	Swiss

Figure 15 presents a tentative roadmap for the implementation of the developed use case whereas each use case's implementation is divided into four major phases that include:

- Design & Development
- Simulation & Validation
- Pilot implementation
- Analysis & Findings

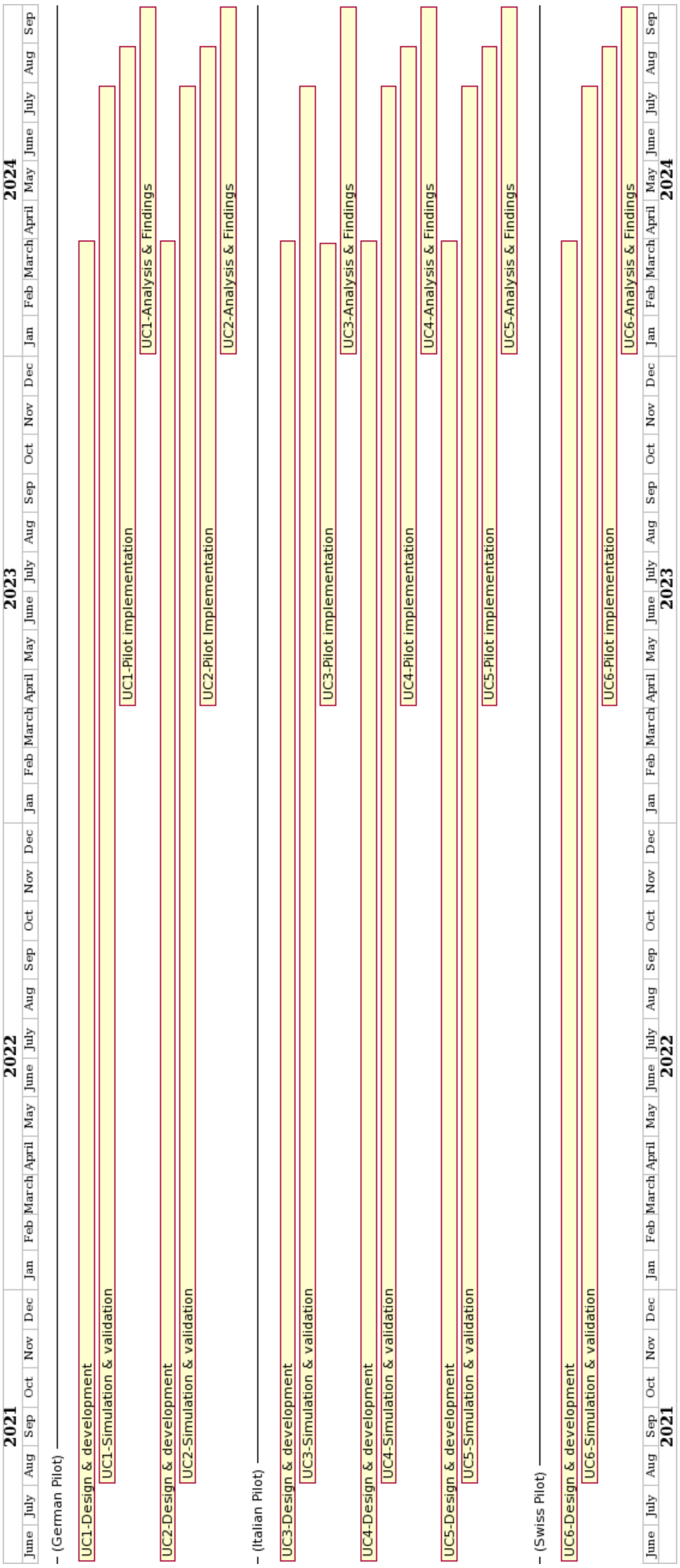

Figure 15: Use cases implementation roadmap.

4.4 Use cases as living documents

The HYPERRIDE use cases will be available in the form of "*living documents*"[6] on project website[7]. This way, updates can be made available to partners as well as the interested EU or international research community. This is also in line with the H2020 BRIDGE initiative[8].

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[6] https://en.wikipedia.org/wiki/Living_document

[7] https://hyperride.eu/

[8] https://www.h2020-bridge.eu/

5 Conclusions

The deliverable provides detailed insight on the use cases to be implemented at the three pilot sites within the HYPERRIDE project. In general, the following aspects are covered:

- What are the available and relevant standards and reference architectures?
- What is the context and boundary of the HYPERRIDE solution?
- What are the major actors (primary, secondary and supporting) and smart grid domains?
- What could be the interesting interactions with the identified primary actors and their goals and how fulfilment of these goals can be addressed?
- What are the detailed implementation plan for setting up the selected use cases at the three pilot sites?

This report is to be used in the context of D2.1 (Infrastructure Requirements) and D2.3 (Enabling Technologies) to gain a full picture of the activities in the project in general and WP2 in particular.

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Appendix A – NIST Smart Grid Actors

The list of actors is taken from NISTIR 7628[9].

ID	Domain	Name	Description
1	Generation with DER	Plant Control System – Distributed Control System	A local control system at a bulk generation plant. This is sometimes called a Distributed Control System (DCS).
2	Customer	Customer	An entity that pays for electrical goods or services. A customer of a utility, including customers who provide more power than they consume.
3	Customer	Customer Appliances and Equipment	A device or instrument designed to perform a specific function, especially an electrical device, such as a toaster, for household use. An electric appliance or machinery that may have the ability to be monitored, controlled, and/or displayed.
4	Customer	Customer Distributed Energy Resources: Generation and Storage	Energy generation resources, such as solar or wind, used to generate and store energy (located on a customer site) to interface to the controller (HAN/BAN) to perform an energy-related activity.
5	Customer	Customer Energy Management System	An application service or device that communicates with devices in the home. The application service or device may have interfaces to the meter to read usage data or to the operations domain to get pricing or other information to make automated or manual decisions to control energy consumption more efficiently. The EMS may be a utility subscription service, a third party-offered service, a consumer-specified policy, a consumer-owned device, or a manual control by the utility or consumer.
6	Customer	Electric Vehicle Service Element/Plug-in Electric Vehicle	A vehicle driven primarily by an electric motor powered by a rechargeable battery that may be recharged by plugging into the grid or by recharging from a gasoline-driven alternator.
7	Customer	Home Area Network Gateway	An interface between the distribution, operations, service provider, and customer domains and the devices within the customer domain.
8	Customer	Meter	Point of sale device used for the transfer of product and measuring usage from one domain/system to another.
9	Customer	Customer Premise Display	This device will enable customers to view their usage and cost data within their home or business.

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[9] https://www.nist.gov/publications/release-nist-interagency-report-7628-revision-1-guidelines-smart-grid-cybersecurity

(continued)

ID	Domain	Name	Description
10	Customer	Sub-Meter – Energy Usage Metering Device	A meter connected after the main billing meter. It may or may not be a billing meter and is typically used for information-monitoring purposes.
11	Customer	Water/Gas Metering	Point of sale device used for the transfer of product (water and gas) and measuring usage from one domain/system to another.
12	Distribution	Distribution Data Collector	A data concentrator collecting data from multiple sources and modifying/transforming it into different form factors.
13	Distribution	Distributed Intelligence Capabilities	Advanced automated/intelligence application that operates in a normally autonomous mode from the centralized control system to increase reliability and responsiveness.
14	Distribution	Distribution Automation Field Devices	Multifeatured installations meeting a broad range of control, operations, measurements for planning, and system performance reports for the utility personnel.
15	Distribution	Distribution Remote Terminal Unit/Intelligent Electronic Device	Receive data from sensors and power equipment, and can issue control commands, such as tripping circuit breakers, if they sense voltage, current, or frequency anomalies, or raise/lower voltage levels in order to maintain the desired level.
16	Distribution	Field Crew Tools	A field engineering and maintenance tool set that includes any mobile computing and handheld devices.
17	Distribution	Geographic Information System	A spatial asset management system that provides utilities with asset information and network connectivity for advanced applications.
18	Distribution	Distribution Sensor	A device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.
19	Marketing	Energy Market Clearinghouse	Wide-area energy market operation system providing high-level market signals for distribution companies (ISO/RTO and Utility Operations). The control is a financial system, not in the sense of SCADA.
20	Marketing	Independent System Operator/Regional Transmission Organization Wholesale Market	An ISO/RTO control center that participates in the market and does not operate the market. From the Electric Power Supply Association (EPSA) Web site, “The electric wholesale market is open to anyone who, after securing the necessary approvals, can generate power, connect to the grid and find a counterparty willing to buy their output. These include competitive suppliers and marketers that are affiliated with utilities, independent power producers (IPPs) not affiliated with a utility, as well as some excess generation sold by traditional vertically integrated utilities. All these market participants compete with each other on the wholesale market.

(continued)

ID	Domain	Name	Description
21	Operations	Advanced Metering Infrastructure Headend	This system manages the information exchanges between third-party systems or systems not considered headend, such as the Meter Data Management System (MDMS) and the AMI network.
22	Operations	Bulk Storage Management	Energy storage connected to the bulk power system.
23	Operations	Customer Information System	Enterprise-wide software applications that allow companies to manage aspects of their relationship with a customer.
24	Operations	Customer Service Representative	Customer service provided by a person (e.g., sales and service representative) or by automated means called self-service (e.g., Interactive Voice Response [IVR]).
25	Operations	Distributed Generation and Storage Management	Distributed generation is also referred to as on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy, or distributed energy. This process generates electricity from many small energy sources for use or storage on dispersed, small devices or systems. This approach reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used, perhaps even in the same building.
26	Operations	Distribution Engineering	A technical function of planning or managing the design or upgrade of the distribution system. For example: the addition of new customers, the build out for new load, the configuration and/or capital investments for improving system reliability.
27	Operations	Distribution Management Systems	A suite of application software that supports electric system operations. Example applications include topology processor, online three-phase unbalanced distribution power flow, contingency analysis, study mode analysis, switch order management, short-circuit analysis, volt/VAR management, and loss analysis. These applications provide operations staff and engineering personnel additional information and tools to help accomplish their objectives.
28	Operations	Distribution Operator	Person operating the distribution system.
29	Operations	Distribution Supervisory Control and Data Acquisition	A type of control system that transmits individual device status, manages energy consumption by controlling compliant devices, and allows operators to directly control power system equipment.

(continued)

ID	Domain	Name	Description
30	Operations	Energy Management System	A system of computer-aided tools used by operators of electric utility grids to monitor, controls, and optimize the performance of the generation and/or transmission system. The monitor and control functions are known as SCADA; the optimization packages are often referred to as "advanced applications." (Note: Gas and water could be separate from or integrated within the EMS.)
31	Operations	ISO/RTO Operations	Wide-area power system control center providing high-level load management and security analysis for the transmission grid, typically using an EMS with generation applications and network analysis applications.
32	Operations	Load Management Systems/Demand Response Management System	An LMS issues load management commands to appliances or equipment at customer locations in order to decrease load during peak or emergency situations. The DRMS issues pricing or other signals to appliances and equipment at customer locations in order to request customers (or their preprogrammed systems) to decrease or increase their loads in response to the signals.
33	Operations	Meter Data Management System	System that stores meter data (e.g., energy usage, energy generation, meter logs, meter test results) and makes data available to authorized systems. This system is a component of the customer communication system. This may also be referred to as a 'billing meter.'
34	Operations	Metering/Billing/Utility Back Office	Back office utility systems for metering and billing.
36	Operations	Outage Management System	An OMS is a computer system used by operators of electric distribution systems to assist in outage identification and restoration of power.
37	Operations	Transmission SCADA	Transmits individual device status, manages energy consumption by controlling compliant devices, and allowing operators to directly control power system equipment.
38	Operations	Customer Portal	A computer or service that makes available Web pages. Typical services may include customer viewing of their energy and cost information online, enrollment in prepayment electric services, and enablement of third-party monitoring and control of customer equipment.
39	Operations	Wide Area Measurement System	Communication system that monitors all phase measurements and substation equipment over a large geographical base that can use visual modeling and other techniques to provide system information to power system operators.

doi:10.5281/zenodo.4772166

(continued)

ID	Domain	Name	Description
40	Operations	Work Management System	A system that provides project details and schedules for work crews to construct and maintain the power system infrastructure.
41	Service Provider	Aggregator/Retail Energy Provider	Any marketer, broker, public agency, city, county, or special district that combines the loads of multiple end-use customers in facilitating the sale and purchase of electric energy, transmission, and other services on behalf of these customers.
42	Service Provider	Billing	Process of generating an invoice to obtain reimbursement from the customer.
43	Service Provider	Energy Service Provider	Provides retail electricity, natural gas, and clean energy options, along with energy efficiency products and services.
44	Service Provider	Third Party	A third party providing a business function outside of the utility.
45	Transmission	Phasor Measurement Unit	Measures the electrical parameters of an electricity grid with respect to universal time (UTC) such as phase angle, amplitude, and frequency to determine the state of the system.
46	Transmission	Transmission IED	IEDs receive data from sensors and power equipment and can issue control commands, such as tripping circuit breakers if they sense voltage, current, or frequency anomalies, or raise/lower voltage levels in order to maintain the desired level. A device that sends data to a data concentrator for potential reformatting.
47	Transmission	Transmission RTU	RTUs pass status and measurement information from a substation or feeder equipment to a SCADA system and transmit control commands from the SCADA system to the field equipment.
49	Transmission	Transmission Engineering	Equipment designed for more than 345,000 volts between conductors.

Table 17: NIST Smart Grid Actors

Appendix B – German Pilot's Use Cases

For the German pilot, two use cases were described, which are summarised in the table below. The full documentation, of the use cases, using the IEC62559-2 template can be found at the end of this appendix.

Summary of German Pilot's Use Cases

ID	Name	Short Description
4	Reduce grid connection costs by optimizing peak load	The OPF algorithm, implemented as middleware software component in the HYPERRIDE platform, allow to determine setpoints of AC/DC converters and operating positions of switching devices (network reconfiguration) to optimize the power flow in the AC/DC grid and improve energy management.
7	Efficient fault management in grid operation	The service restoration algorithm starts when the fault area has been cleared and the action of reclosers failed: it aims to reconnect disconnected loads by changing the grid topology and, in the AC/DC grids, exploiting the AC/DC converters controllability.

1 Description of the use case

1.1 Name of use case

Use case identification		
ID	***Area Domain(s)/ Zone(s)***	***Name of use case***
4		Reduce grid connection costs by optimizing peak load

1.2 Version management

Version management				
Version No.	***Date***	***Name of author(s)***	***Changes***	***Approval status***
1	26.04.2021	Dognini, Alberto		

1.3 Scope and objectives of use case

Scope and objectives of use case	
Scope	Deploy Optimal Power Flow (OPF) algorithm
Objective(s)	(1) Reduce power flow losses, (2) exploit line utilization, (3) exploit production of DGs and RES
Related business case(s)	

1.4 Narrative of use case

Narrative of use case
Short description
The OPF algorithm, implemented as middleware software component in the HYPERRIDE platform, allow to determine setpoints of AC/DC converters and operating positions of switching devices (network reconfiguration) to optimize the power flow in the AC/DC grid and improve energy management.
Complete description
Optimal power flow is a grid management technique that consists of determining the most optimal set of variables in an electrical network, in order that the related power flow results fulfil pre-determined criteria. The variables considered in the adjustment can be, for example, the power set points of Distributed Generators (DG) or power converters, the position of transformers tap-changers or the position (open - close) of tie-switches. Among the objective criteria, the minimization of power losses, together with the exploitation of renewable energy sources, can be considered. Network reconfiguration, in general, is defined as altering the topological structure of feeders by changing the state of switches. In other words, thanks to the switches we have the possibility of configuring the grid, depending on the number of switches in the network. Having N number of

switches, there are 2^N possible combinations considering every on/off combination regarding the state of each switch, by which the network can be reconfigured. Said that, having immense number of possible combinations pose a difficulty in finding the optimal solution, i.e. optimal configuration. Generally, distribution networks operate in radial configurations to increase effectiveness and coordination among protection devices. Open tie units allow to overcome fault or overload conditions. The target is the real power loss reduction by changing the network topology while keeping the radiality, and keeping every node connected and energize the loads connected to it. Considering the particular configuration of AC/DC grids, an important aspect is the system control, necessary to regulate the power flow among the AC/DC converters and guarantee the stability of the network.

1.5 Key performance indicators (KPI)

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
1	Reduced power losses	Reduction of power losses in the network (on a daily, weekly, yearly basis) by applying the algorithm, with respect to the unchanged network parameters (switching devices and converter setpoints)	(1)
2	Reduced constraints violations	Considering the considered production/consumption scenario, the avoidance of load curtailment of production curtailment by re-arranging network topology and converter control	(2) and (3)

1.6 Use case conditions

Use case conditions
Assumptions
Remotely controlled switching devices, presence and suitability of monitoring components to provide measurements for state estimation
Prerequisites
Presence of remotely controllable switching devices, presence of AC/DC converters with Voltage Source Controlled (VSC) capability

1.7 Further information to the use case for classification / mapping

Classification Information
Relation to other use cases
Maximization of self-consumption, Optimization of day-ahead & intraday market costs
Level of depth
Detailed use case
Prioritisation
mandatory

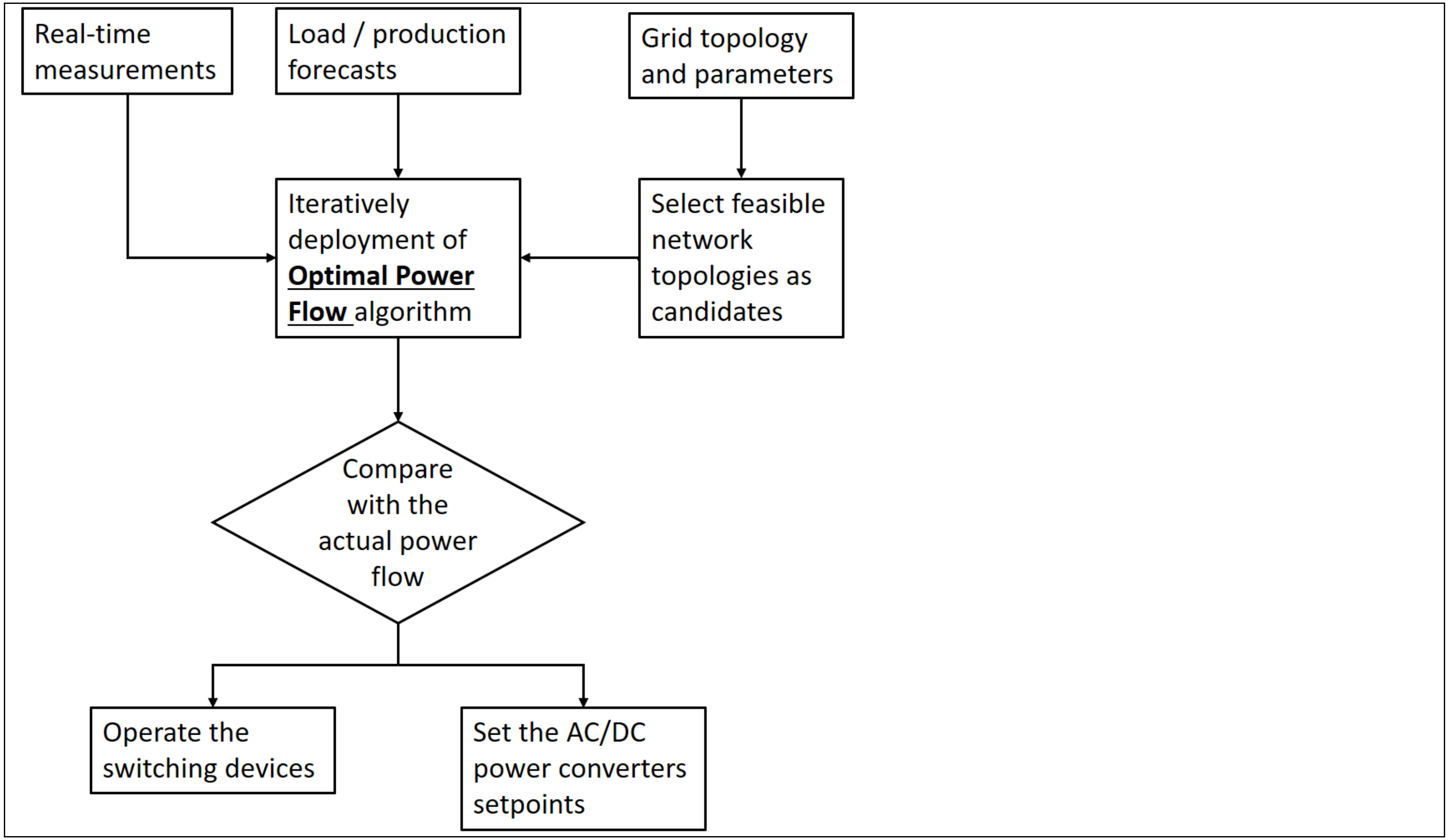
Generic, regional or national relation
Generic/DSO level
Nature of the use case
Dispatch management
Further keywords for classification
Energy management, system monitoring

1.8 General remarks

General remarks

2 Diagrams of use case

Diagram(s) of use case


Real-time measurements
Load / production forecasts
Grid topology and parameters
Iteratively deployment of **Optimal Power Flow** algorithm
Select feasible network topologies as candidates
Compare with the actual power flow
Operate the switching devices
Set the AC/DC power converters setpoints

3 Technical details

3.1 Actors

Actors			
Grouping		***Group description***	
Sensors		Measurement devices and transducers to collect relevant data from the grid	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
Current Transformer	Device	To measure the current value on the distribution line or in the loads/generations premises	It can be associated to PMU device or provide data about AC/DC power converters
Voltage Transformer	Device	To measure the voltage value on the distribution nodes of the grids or at the Point of Common Coupling (PCC) with loads/generations premises	It can be associated to PMU device or provide data about AC/DC power converters

Actors			
Grouping		***Group description***	
Actuators		Entities related to the grid management and operations	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
Switching device	Grid component	Switching device can correspond to the circuit breaker, disconnector or switch-disconnector: it is a device capable of modifying the topology of the electrical grid.	
AC/DC converter	Grid component	Device used to transfer controllable power among the AC and the DC portions of the grid.	

Actors			
Grouping		***Group description***	
Electrical grid company		Entities related to the grid management and operations	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
Distribution grid operator	Electrical grid company	Owner of the facilities operated by the OPF solution: switching devices and AC/DC power converters. Interested in reducing power losses	

		in the system and improving the energy management.	
Energy provider	Electrical grid company	Providing data regarding real time measurements and forecasts about the loads/distributed generations.	

3.2 References

References						
No.	***References type***	***Reference***	***Status***	***Impact on use case***	***Originator / organisation***	***Link***
1	Scientific Publication	Algorithm implementation		High	IEEE	https://ieeexplore.ieee.org/document/7964724

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1	Network Reconfiguration	Due to power losses reduction that overcomes the specified threshold in the defined time, the operation of switching devices is carried out.	DSO and its assets	Change of load/production levels in the nodes	Excessive power losses or violation of network constraints	Reconfigured grid
2	Converter setpoints adjustment	Due to power losses reduction that overcomes the specified	DSO and its assets	Change of load/production levels in the nodes	Excessive power losses or violation of network constraints	Modified power flow in the DC lines

		threshold in the defined time, the converter setpoints are modified to improve the energy management through the DC lines				

4.2 Steps – Scenarios

Scenario								
Scenario name :								
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information exchanged (IDs)***	***Requirements R-ID***
1	Load/Production variation	Grid variation	Consider the power injection/production in the time frames		DSO measurement devices	HYPERRIDE platform	Active and Reactive Power in the defined time frame, number of switching operations	
2	State estimation	Measurements collected	Deployment of state estimation in the different grid configurations to find the optimal solution among the candidates	State estimation	AC/DC state estimation middleware	HYPERRIDE platform	New optimal topology configuration and converters setpoints	
3	Switching operations and setpoints implemented	Setpoints and switching operations collected	Implementation of computed commands and collect feedbacks about correctness of implemented actions	Automation and IoT data layer	HYPERRIDE platform (data layer)	Netowork components (switching devices and power converters)	Opening/closing commands and converter regulation setpoints	

5 Information exchanged

Information Exchanged			
Information exchanged ID	***Name of information exchanged***	***Description of information exchanged***	***Requirements IDs***
1	Power consumption/injection measurements	Power measurements carried out at the connection points with secondary substations, Distributed Generations locations, etc. It is provided to the control centre of the Distribution Grid Operator to deploy the Optimal Power Flow algorithm	
2	Voltage and current measurements	Measurements of electrical quantities collected along the grid network. It is provided to the control centre of the Distribution Grid Operator to deploy the Optimal Power Flow algorithm.	
3	Load/Production forecasts	From the databases of forecasting applications, they are provided as input for the Optimal Power Flow algorithm.	
4	Actual network topology	Data provided by switching devices about the operating status (open/close) of the circuit breakers, disconnectors, etc.	
5	Commands for switching devices operations	From the control centre in which the OPF has been deployed, the commands are issue to operate (open/close) the switching devices in the field	
6	Commands for AC/DC converters setpoints	From the control centre in which the OPF has been deployed, the commands are issue to modify the power setpoints of AC/DC converters.	

6 Requirements (optional)

Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Requirement ID	***Requirement name***	***Requirement description***

7 Common Terms and Definitions

Common terms and definitions	
Term	***Definition***
Network Reconfiguration	Altering the topological structure of feeders by changing the state of switches (open / close)
Optimal Power Flow	Determining the most optimal set of variables in an electrical network, in order that the related power flow results fulfil pre-determined criteria.

8 Custom information (optional)

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

1 Description of the use case

1.1 Name of use case

Use case identification		
ID	**Area Domain(s)/ Zone(s)**	**Name of use case**
7		Efficient fault management in grid operation

1.2 Version management

Version management				
Version No.	**Date**	**Name of author(s)**	**Changes**	**Approval status**
1	26.04.2021	Dognini, Alberto		

1.3 Scope and objectives of use case

Scope and objectives of use case	
Scope	Deploy Service Restoration (SR) algorithm
Objective(s)	After the occurrence of faults: (1) Reconfigure as much disconnected loads as possible, (2) Choose configuration with lower power losses, (3) choose long-term configuration considering consumption/production forecasts
Related business case(s)	

1.4 Narrative of use case

Narrative of use case
Short description
The service restoration algorithm starts when the fault area has been cleared and the action of reclosers failed: it aims to reconnect disconnected loads by changing the grid topology and, in the AC/DC grids, exploiting the AC/DC converters controllability.
Complete description
Distribution networks are managed with radial scheme; therefore, the nodes downstream of the faulted zone become de-energized and they have to be re-powered from an alternative source: the main goal of service restoration is to reconnect these healthy portions of the network that are electrically disconnected after the fault clearance. This is pursued by finding an alternative path, from another power source, and closing the normally open tie switches. Considering the AC/DC grid configuration, is necessary to analyse the modelling of power converters, particularly with respect to its power losses, and the implementation of dedicated AC/DC power flow algorithms. In HYPERRIDE, strict relationship will be kept with the implementation of the AC/DC state estimation solution: similarly to the AC service restoration, also in the AC/DC case the state

estimation algorithm will be implemented to verify the electrical constraints and compute the criteria parameters. The specific role of the AC/DC converter station, together with the Distributed Energy Resources (RES), introduce new possibilities in the topology reconfiguration solutions.

1.5 Key performance indicators (KPI)

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
1	Reconnect disconnected loads	Number, or amount of associated active power, of customers de-energized after fault occurrence	(1)
2	Among the different candidate solutions, reduction of power losses	Different topologies and AC/DC converters setpoints can be available to reconfigure the grids. The reduced power losses in the long term scenario (considering load/production forecasts) is measured	(2) and (3)

1.6 Use case conditions

Use case conditions
Assumptions
Remotely controlled switching devices, presence and suitability of monitoring components to provide measurements for state estimation
Prerequisites
Presence of remotely controllable switching devices, presence of AC/DC converters with Voltage Source Controlled (VSC) capability

1.7 Further information to the use case for classification / mapping

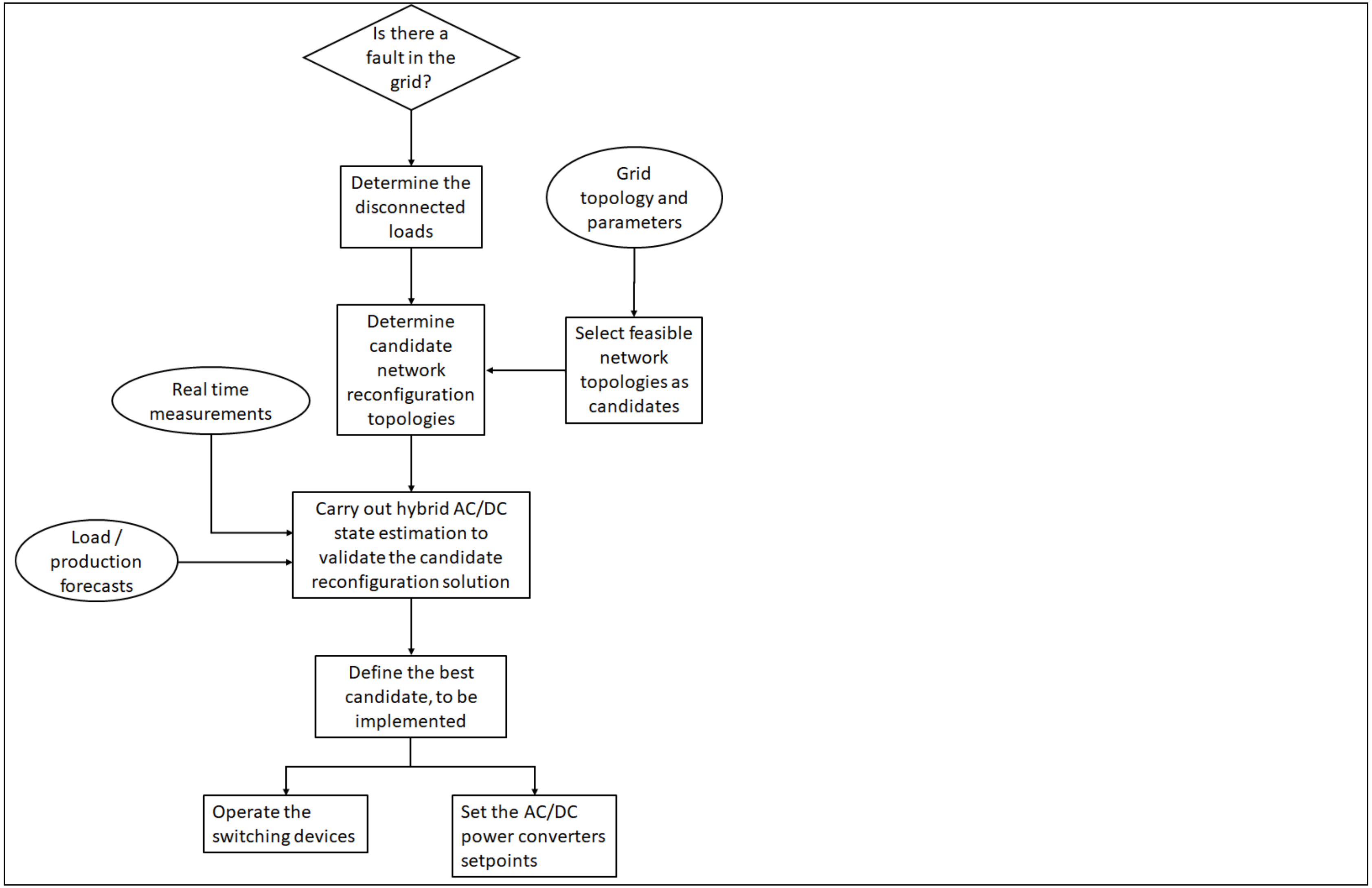
Classification Information
Relation to other use cases
Level of depth
Detailed use case
Prioritisation
Mandatory
Generic, regional or national relation
Generic/DSO level
Nature of the use case
Fault management
Further keywords for classification
Faults, AC/DC converters

1.8 General remarks

General remarks

2 Diagrams of use case

Diagram(s) of use case


Is there a fault in the grid?
Determine the disconnected loads
Grid topology and parameters
Determine candidate network reconfiguration topologies
Select feasible network topologies as candidates
Real time measurements
Load / production forecasts
Carry out hybrid AC/DC state estimation to validate the candidate reconfiguration solution
Define the best candidate, to be implemented
Operate the switching devices
Set the AC/DC power converters setpoints

3 Technical details

3.1 Actors

Actors			
Grouping		***Group description***	
Device		Measurement devices and transducers to collect relevant data from the grid	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
Current Transformer	Sensor	To measure the current value on the distribution line or in the loads/generations premises.	It can be associated to PMU device or provide data about AC/DC power converters
Voltage Transformer	Sensor	To measure the voltage value on the distribution nodes of the grids or at the Point of Common Coupling (PCC) with loads/generations premises.	It can be associated to PMU device or provide data about AC/DC power converters
Protection relay	IED	In case of fault in the network, it operates the tripping of circuit breakers in order to isolate the faulted area and provide information to the control centre of the DSO.	

Actors			
Grouping		***Group description***	
Actuators		Entities related to the grid management and operations	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***
Switching device	Grid component	Switching device can correspond to the circuit breaker, disconnector or switch-disconnector: it is a device capable of modifying the topology of the electrical grid.	Controlled by the Service Restoration algorithm to re-energize the disconnected devices.
AC/DC converter	Grid component	Device used to transfer controllable power among the AC and the DC portions of the grid.	Controlled by the Service Restoration algorithm to improve the energy flow and re-energize more disconnected devices.

Actors			
Grouping		**Group description**	
Electrical grid company		Entities related to the grid management and operations	
Actor name	**Actor type**	**Actor description**	**Further information specific to this use case**
Distribution grid operator	Electrical grid company	Owner of the facilities that involve the service restoration: switching devices and AC/DC power converters.	Interested in recovering from emergency grid operations by re-energizing the disconnected customers.
Energy provider	Electrical grid company	Providing data regarding real time measurements and forecasts about the loads/distributed generations.	Forecasts used by the service restoration to improve the control of AC/DC converters

3.2 References

References						
No.	**References type**	**Reference**	**Status**	**Impact on use case**	**Originator / organisation**	**Link**
1	IEEE Standard	“IEEE Guide for Electric Power Distribution Reliability Indices”		Medium-High	IEEE	https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6329910

4 Step by step analysis of use case

4.1 Overview of scenarios

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

1	Network reconfiguration	The reconnection of loads imply the closing of normally open tie-switches, among two feeders	DSO and its assets	Occurrence of fault	Disconnected customers	Reconfigured grid via operating switching devices
2	Converter setpoints adjustment	To improve the reconnection of de-energized loads, the power flow in the DC lines is adjusted	DSO and its assets	Occurrence of fault	Disconnected customers	Modified power flow in the DC lines

4.2 Steps – Scenarios

Scenario							
Scenario name :							
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information exchanged (IDs)***	***Requirements R-ID***
1	Determination of target nodes to be reconnected	Determine disconnected nodes	Consider the criticality of nodes and the possible alternative reconnection paths		DSO control center	HYPERRIDE platform	Switching devices conditions, active powers flows and consumptions	
2	Evaluation of candidate solutions	State Estimation	Deployment of state estimation in the different grid configurations to find the optimal solution among the candidates	State estimation	AC/DC state estimation middleware	HYPERRIDE platform	New optimal topology configuration and converters setpoints	
3	Switching operations	Setpoints and switching	Implementation of computed commands and	Automation and IoT data layer	HYPERRIDE platform (data layer)	Netowork components (switching	Opening/closing commands and converter	

	and setpoints implemented	operations collected	collect feedbacks about correctness of implemented actions			devices and power converters)	regulation setpoints	

5 Information exchanged

Information Exchanged			
Information exchanged ID	***Name of information exchanged***	***Description of information exchanged***	***Requirements IDs***
1	Power consumption/injection measurements	Power measurements carried out at the connection points with secondary substations, Distributed Generations locations, etc. It is provided to the control centre of the Distribution Grid Operator to deploy the Service Restoration algorithm.	
2	Voltage and current measurements	Measurements of electrical quantities collected along the grid network. It is provided to the control centre of the Distribution Grid Operator to deploy the Service Restoration algorithm.	
3	Load/Production forecasts	From the databases of forecasting applications, they are provided as input for the Service Restoration algorithm.	
4	Fault Occurrence	Data from protection relay about the tripped circuit breakers allow to determine the fault area and the disconnected loads.	
5	Actual network topology	Data provided by switching devices about the operating status (open/close) of the circuit breakers, disconnectors, etc.	
6	Commands for switching devices operations	From the control centre in which the SR has been deployed, the commands are issue to operate (open/close) the switching devices in the field	
7	Commands for AC/DC converters setpoints	From the control centre in which the SR has been deployed, the commands are issue to modify the power setpoints of AC/DC converters.	

6 Requirements (optional)

Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Requirement ID	***Requirement name***	***Requirement description***

7 Common Terms and Definitions

Common terms and definitions	
Term	***Definition***
Service Restoration	After the clearing of a fault and isolation of fault area, the operation on the network to re-energize all possible loads

8 Custom information (optional)

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

Appendix C – Italian Pilot's Use Cases

For the Italian pilot, three use cases were identified for implementation, which are summarised in the table below. The full documentation, of the use cases, using the IEC62559-2 template can be found at the end of this appendix.

Summary of Italian Pilot's Use Cases

ID	**Name**	**Short Description**
HYPERRIDE-UC-ITALIAN-001	FORMING AN ENERGY COMUNITY	Energy Communities are promoted by the Renewable Energy Directive (EU Directive 2018/2001), in which the definitions of collective self-consumption among members of an apartment block or building and Renewable Energy Community (REC) are given. This European Directive stipulates that members must produce energy for their own consumption and that the energy produced can be shared among users using existing distribution networks. In Italy, Energy Communities can install systems powered by renewable sources with a total power not exceeding 200 kW.
HYPERRIDE-UC-ITALIAN-002	PROVIDE FLEXIBILITY TO THE GRID OPERATOR (DSO)	The prosumers, producers and users provide ancillary services or balancing services to the grid by exploiting their flexibility to support stable grid operation. All these actors assume an active role in local energy capacity market in a power grid where are present DERs and distributed storage. In return, the customer plugged to the distribution grid receives economic benefits for the services provided.
HYPERRIDE-UC-ITALIAN-003	EFFICIENT FAULT MANAGEMENT IN GRID OPERATION	The implementation of the hybrid AC/DC grid in a LV distribution grid make it possible the parallelization of LV feeder from different sources. Double power supply icrease the reiliability of the system.

1 Description of the use case

1.1 Name of use case

Use case identification		
ID	***Area Domain(s)/ Zone(s)***	***Name of use case***
HYPERRIDE-UC-ITALIAN-001	DER/OPERATION	FORMING AN ENERGY COMUNITY

1.2 Version management

Version management				
Version No.	***Date***	***Name of author(s)***	***Changes***	***Approval status***
1.0	30.04.2021	Cresta M.	Initial creation	Draft

1.3 Scope and objectives of use case

Scope and objectives of use case	
Scope	A group of prosumers together agree to use and share/sell the excess energy produced by either their locally owned sources (PV, EV, storage, etc.) or from some community owned sources as much as possible
Objective(s)	To minimize its energy consumption cost and achieve self sustainability
Related business case(s)	To maximaze the diffusion of the DER in the Distribution Power Grid

1.4 Narrative of use case

Narrative of use case
Short description
Energy Communities are promoted by the Renewable Energy Directive (EU Directive 2018/2001), in which the definitions of collective self-consumption among members of an apartment block or building and Renewable Energy Community (REC) are given. This European Directive stipulates that members must produce energy for their own consumption and that the energy produced can be shared among users using existing distribution networks. In Italy, Energy Communities can install systems powered by renewable sources with a total power not exceeding 200 kW.
Complete description
In the Italian pilot, an energy community is simulated in a portion of the grid where a hybrid AC/DC grid is installed. In this portion of the low-voltage grid there are AC and DC users, renewable generation plants and storage. The purpose of the energy community is not only profit but

also benefit sharing towards the community by sharing the self-produced energy and managing the energy according to the needs of the DSO to optimise the operation of the distribution grid. The energy community of the Italian pilot cannot disconnect from the grid, i.e. operate in island mode, but must remain connected to it because if the energy needed by the community cannot come from its production facilities, the grid itself will provide the necessary energy.

1.5 Key performance indicators (KPI)

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
Kpi_001_01	Saving costs	The energy costs reduction in a year	Saving costs

1.6 Use case conditions

Use case conditions
Assumptions
All the Prosumers in the Energy Community are connected to the same Secondary Substation
Prerequisites
Incentives for the Energy Community

1.7 Further information to the use case for classification / mapping

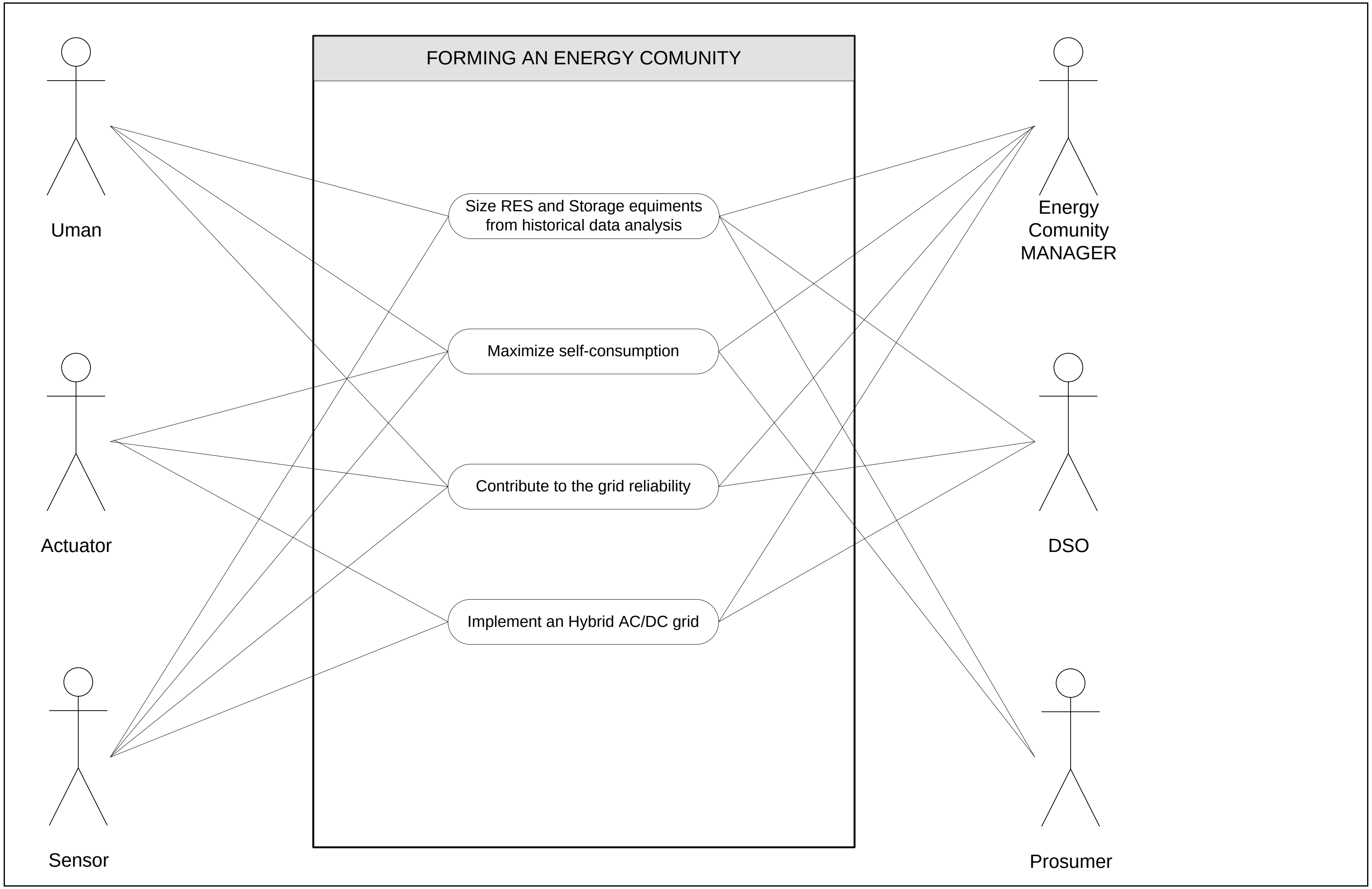
Classification Information
Relation to other use cases
Level of depth
Prioritisation
Generic, regional or national relation
Nature of the use case
Further keywords for classification

1.8 General remarks

General remarks

2 Diagrams of use case

Diagram(s) of use case


FORMING AN ENERGY COMUNITY
Uman
Actuator
Sensor
Energy Comunity MANAGER
DSO
Prosumer
Size RES and Storage equiments from historical data analysis
Maximize self-consumption
Contribute to the grid reliability
Implement an Hybrid AC/DC grid

3 Technical details

3.1 Actors

Actors			
Grouping		Group description	
Actor name	Actor type	Actor description	Further information specific to this use case

3.2 References

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

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	Scenario name	Scenario description	Primary actor	Triggering event	Pre-condition	Post-condition
1	Presence of historical data	All participants at the energy community must have historical data about their consumption/production over the last 5 years. Not availability of historical data make it no possible the correct design of power plant, storage and the drawing up of a business plan to	Prosumers	Availability of Historical data or reliable forecasts of energy consumption	Users and Prosumers know their habits	Flexibility in the prosumers/users habits

		assess the profitability of investments.				

4.2 Steps – Scenarios

Scenario								
Scenario name :								
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information exchanged (IDs)***	***Requirements R-ID***

5 Information exchanged

Information Exchanged			
Information exchanged ID	***Name of information exchanged***	***Description of information exchanged***	***Requirements IDs***
I-01	Historical data	Historical consumption data of the users belonging to the Energy Community are used to size the photovoltaic power plant and the storage	
I-02	Resolution Plan	Weather forecasts for energy production and any special consumption needs must be considered to maximize the use of self-produced energy.	
I-03	Flexibility Plan	Excess energy which is produced by the Energy Community and energy consumption not guaranteed by its self-production are used by the distribution grid to improve its efficiency	

6 Requirements (optional)

Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Requirement ID	***Requirement name***	***Requirement description***

7 Common Terms and Definitions

Common terms and definitions	
Term	***Definition***

8 Custom information (optional)

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

1 Description of the use case

1.1 Name of use case

Use case identification		
ID	***Area Domain(s)/ Zone(s)***	***Name of use case***
HYPERRIDE-UC-ITALIAN-002	DISTRIBUTION/STATION	Provide flexibility to the grid operator (DSO)

1.2 Version management

Version management				
Version No.	***Date***	***Name of author(s)***	***Changes***	***Approval status***
1.0	30.04.2021	Cresta M.	Initial creation	Draft

1.3 Scope and objectives of use case

Scope and objectives of use case	
Scope	The prosumers, producers and users provide ancillary services or balancing services to the grid by exploiting their flexibility to support stable grid operation. All these actors assume an active role in local energy capacity market in a power grid where are present DERs and distributed storage. In return, the customer plugged to the distribution grid receives economic benefits for the services provided.
Objective(s)	To minimize reverse power flow in secondary substations.
Related business case(s)	To reduce losses in the grid and related costs.

1.4 Narrative of use case

Narrative of use case
Short description
Flexibility is the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system. The parameters used to characterize flexibility in electricity include: the amount of power modulation; the duration; the rate of change; the response time; the location etc.
Complete description

The main services related to the flexibility of a customer connected to the hybrid AC/DC grid of the pilot in Terni are: Demand Response; PV Power smoothing; Peak shaving; E-Car flexible charging service. Demand Response is a voluntary changes by consumers or producers of their usual electricity flow patterns in response to market signals such as time variable prices or incentives. PV Power smoothing consisting in store PV extra production (defined as difference between the power produced by PV system and power load of the facility) in order to maximize the consumption of energy produced by local renewable sources and reduce revers power flow in secondary substation; Peak shaving is the flattening of an electricity consumption load curve and is closely linked to Demand Response; E-Car flexible charging service is performed by increasing as much as possible the self consumption share of renewable power or when cheap electricity is available, e. g. from high renewable power production at times when the demand is low and sufficient grid capacity allows for providing the required charging power at the spot.

1.5 Key performance indicators (KPI)

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
Kpi_002_01	To reduce reverse power flow	The renewable energy produced locally is also used locally	Saving losses in the grid and power required from remote power plant

1.6 Use case conditions

Use case conditions
Assumptions
Presence of DER in the pilot.
Prerequisites
Incentives for ancillary services.

1.7 Further information to the use case for classification / mapping

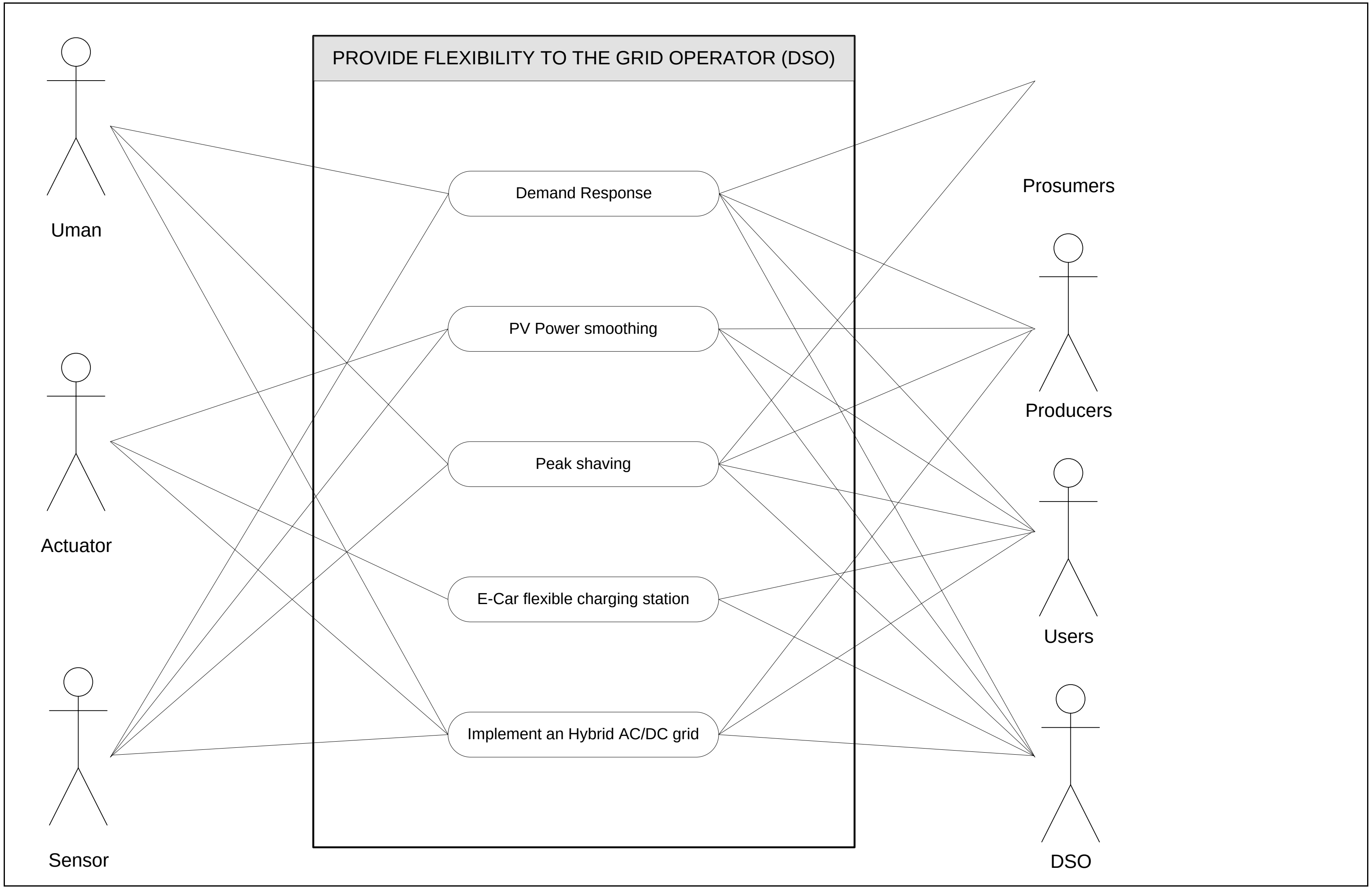
Classification Information
Relation to other use cases
Level of depth
Prioritisation
Generic, regional or national relation
Nature of the use case
Further keywords for classification

1.8 General remarks

General remarks

2 Diagrams of use case

Diagram(s) of use case


PROVIDE FLEXIBILITY TO THE GRID OPERATOR (DSO)
Uman
Actuator
Sensor
Demand Response
PV Power smoothing
Peak shaving
E-Car flexible charging station
Implement an Hybrid AC/DC grid
Prosumers
Producers
Users
DSO

3 Technical details

3.1 Actors

Actors			
Grouping		**Group description**	
Actor name	**Actor type**	**Actor description**	**Further information specific to this use case**

3.2 References

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

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
1	Dynamic SCADA to manage flexibility	Hybrid AC/DC grid has an integrated SCADA with the existing Low Voltage Distribution grid	Users and Prosumers	Renewable energy overproduction	Near real time AC/DC measure	No reverse power flow

4.2 Steps – Scenarios

Scenario	
Scenario name :	

Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirements R-ID

5 Information exchanged

Information Exchanged			
Information exchanged ID	**Name of information exchanged**	**Description of information exchanged**	**Requirements IDs**
I-01	Consumption Plan for DR	Market signals are sent to hybrid AC/DC grid users to adjust their usual electricity consumption patterns to increase the security of the power grid.	
I-02	Power Plan for Power Smoothing	Data from DSO to the prosumers are sent for planning the storage PV extra production in order to maximize the consumption of energy produced by local renewable sources, reduce reverse power flow in secondary substation and increase the power quality.	
I-03	Consumption Plan for Peak Shaving	Data from DSO to Users are sent to flat the electricity consumption load curve; this topic is closely linked to Demand Response;	
I-04	E-Car Flexiblity	Data from the DSO to the Mobility Service Operator (MSO) are sent for flexible charging service performed by increasing renewable energy consumption or when low-cost electricity is available	

6 Requirements (optional)

Requirements (optional)		
Categories ID	**Category name for requirements**	**Category description**
Requirement ID	**Requirement name**	**Requirement description**

7 Common Terms and Definitions

Common terms and definitions	
Term	***Definition***

8 Custom information (optional)

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

1 Description of the use case

1.1 Name of use case

Use case identification		
ID	***Area Domain(s)/ Zone(s)***	***Name of use case***
HYPERRIDE-UC-ITALIAN-003	DER/OPERATION	Efficient Fault Management in Grid Operation

1.2 Version management

Version management				
Version No.	***Date***	***Name of author(s)***	***Changes***	***Approval status***
1.0	30.04.2021	Cresta M.	Initial creation	Draft

1.3 Scope and objectives of use case

Scope and objectives of use case	
Scope	Development of a layer based control architecture for future hybrid AC/DC grids that enables a stable grid operation even under failure situations or cyber attack scenarios.
Objective(s)	To increase the power grid reliability.
Related business case(s)	To reduce penalties due to low quality in energy distribution.

1.4 Narrative of use case

Narrative of use case
Short description
The implementation of the hybrid AC/DC grid in a LV distribution grid make it possible the parallelization of LV feeder from different sources. Double power supply increases the reliability of the system.
Complete description
The hybrid AC/DC grid and in particular the DC busbars feeder by a double power line coming from different Secondary Substations can be classified as preferential loads with a major level of security in terms of uninterrupted power system. For this, each DC bus bars have a great resilience to face physical fault and cyber attack. This feature is ensured by an automatic automation system that can vary operation according

to operating or fault conditions. The architecture of the platform is designed to be in compliance with the Cybersecurity requirements for an IT infrastructure serving an Electrical Power and Energy System (EPES).

1.5 Key performance indicators (KPI)

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
Kpi_003_01	Resilience to face cyber attacks	The AC/DC hybrid grid increase the resilience of an EPES in case of a cyber attack.	To protect a critical infrastructure

1.6 Use case conditions

Use case conditions
Assumptions
The use of IT infrastructure in EPES increase the perimeter of a cyber attack.
Prerequisites
Modern Smart Grid and AC/DC hybrid grid as his components must be based on a widely distributed IT infrastructure

1.7 Further information to the use case for classification / mapping

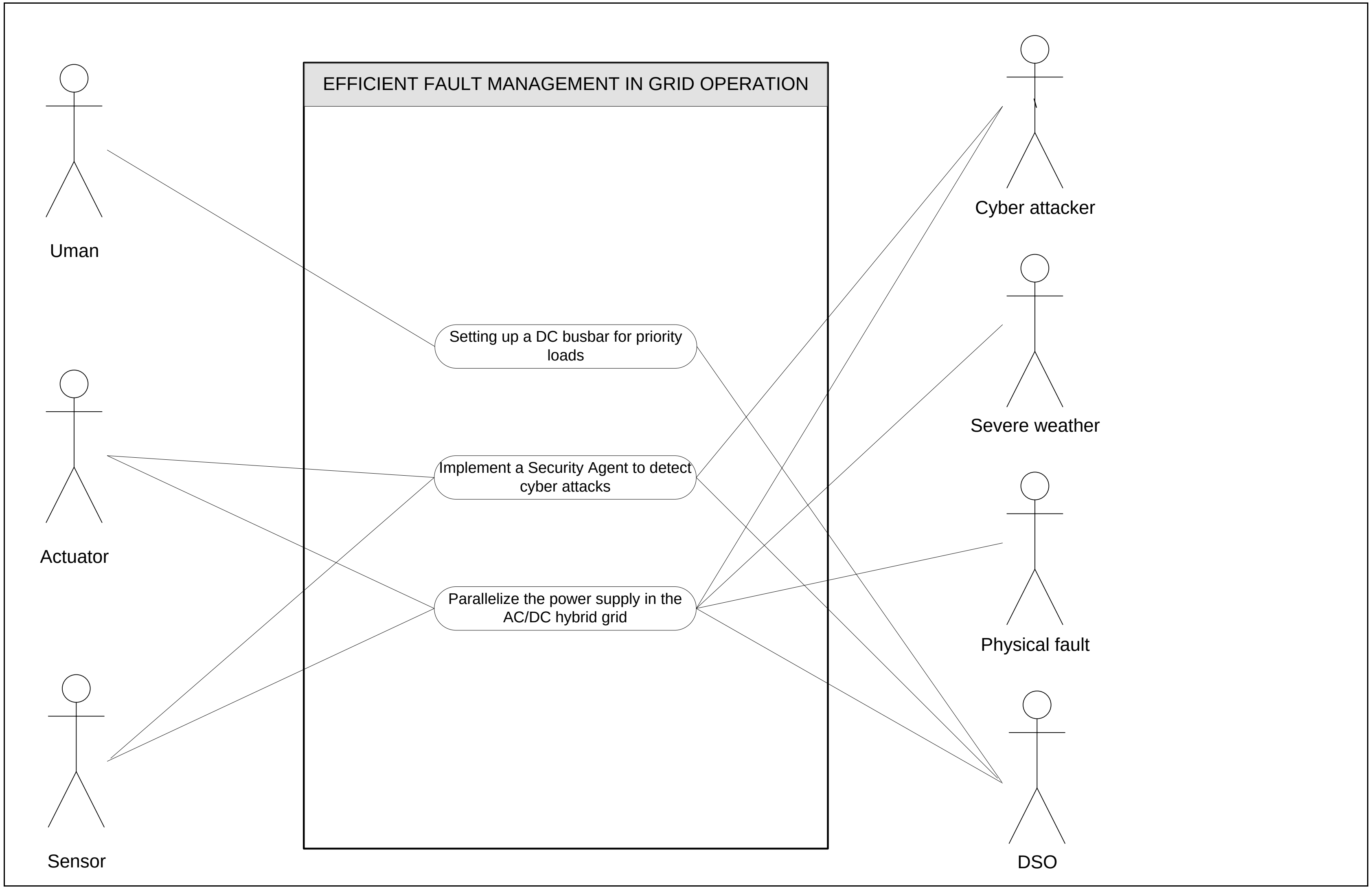
Classification Information
Relation to other use cases
Level of depth
Prioritisation
Generic, regional or national relation
Nature of the use case
Further keywords for classification

1.8 General remarks

General remarks

2 Diagrams of use case

Diagram(s) of use case


EFFICIENT FAULT MANAGEMENT IN GRID OPERATION
Uman
Actuator
Sensor
Setting up a DC busbar for priority loads
Implement a Security Agent to detect cyber attacks
Parallelize the power supply in the AC/DC hybrid grid
Cyber attacker
Severe weather
Physical fault
DSO

3 Technical details

3.1 Actors

Actors			
Grouping		***Group description***	
Actor name	***Actor type***	***Actor description***	***Further information specific to this use case***

3.2 References

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

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	***Scenario name***	***Scenario description***	***Primary actor***	***Triggering event***	***Pre-condition***	***Post-condition***
1	Hybrid AC/DC grid resilience	Hybrid AC/DC grid has a physical infrastructure that increase Cyber security	DSO	Cyber attack	Different DC feeder parallelization	Continuity of service

4.2 Steps – Scenarios

Scenario	
Scenario name :	

Step No.	Event	Name of process/ activity	Description of process/ activity	Service	Information producer (actor)	Information receiver (actor)	Information exchanged (IDs)	Requirements R-ID

5 Information exchanged

Information Exchanged			
Information exchanged ID	**Name of information exchanged**	**Description of information exchanged**	**Requirements IDs**
I-01	Real time data for grid status	Real-time measurements of significant grid status parameters are compared with historical values to detect anomalies resulting from possible cyber attacks. It is necessary to identify the thresholds of physical parameters in significant grid nodes such as voltage, current and frequency beyond which alarms are triggered for possible attacks.	
I-02	Grid securing	Once the physical failure or the cyber attack has been detected, commands from the SCADA system are sent to the actuators of the AC/DC hybrid grid, in order to adapt the grid asset to guarantee the power supply to the priority loads.	

6 Requirements (optional)

Requirements (optional)		
Categories ID	**Category name for requirements**	**Category description**
Requirement ID	**Requirement name**	**Requirement description**

7 Common Terms and Definitions

Common terms and definitions

Term	Definition

8 Custom information (optional)

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

Appendix D – Swiss Pilot's Use Cases

For the Swiss pilot, one use case is identified for implementation. The use case is summarised in the table below. The full documentation, of the use cases, using the IEC62559-2 template can be found at the end of this appendix.

Summary of Swiss Pilot's Use Cases

ID	**Name**	**Short Description**
HYPERRIDE-UC-SWISS-001	Efficient LV distribution grid monitoring and control by using flexibilities (on the customer side)	Using a National Instrument CRio real time controller to implement a direct measurement unit that output time synchronised DC measurements. The DMU will be based on the already existing Phasor Measurement Unit (PMU). However, the difference with the PMU is that it relies on the interpolated discrete Fourier transform to extract the phasor and magnitude, while the DMU can extract the magnitudes by simply making use of a filter. The time synchronised PMU and DMU measurements are used in a linear hybrid state estimation to estimate the most likelihood state. The computed states are required for the monitoring of the system, performing the hybrid OPF.
HYPERRIDE-UC-SWISS-002	Efficient fault management in grid operation	Different types of faults can occur during grid operations: line-to-line, line-to-ground in the AC and DC system, faulty converter, etc. Faults needs to be suppressed in order to provide safe operations for loads and users. In a first step, AC circuit breakers, DC solid state circuit breakers, and/or DC-DC controllers will detect the fault and disconnect the line or go in safe mode. After the suppression of the fault, a procedure is started to re-energies the grid. By removing the faulty lines and/or converters and using the updated grid topology, the OPF is computed in order to recompute the new optimal setpoints of the grid after the fault.

1 Description of the use case

1.1 Name of use case

Use case identification		
ID	***Area Domain(s)/ Zone(s)***	***Name of use case***
		Efficient LV distribution grid monitoring and control by using flexibilities (on the customer side)

1.2 Version management

Version management				
Version No.	***Date***	***Name of author(s)***	***Changes***	***Approval status***
1	05.12.2021	Willem Lambrichts, Jules Mace		

1.3 Scope and objectives of use case

Scope and objectives of use case	
Scope	Deploy a RTSE (Real-Time State Estimator) to for the OPF
Objective(s)	1) implementing DMUs 2) Hybrid Real Time State Estimator (RTSE), 3) hybrid OPF
Related business case(s)	

1.4 Narrative of use case

Narrative of use case
Short description
Using measurements from PMUs and DMUs as input for a RTSE. The state estimator computes the most likelihood state of the hybrid grid. The states are used in an OPF algorithm to determine the optimal setpoints of the AC/DC and the operating point of the switches.
Complete description
Using a National Instrument CRio real time controller to implement a direct measurement unit that output time synchronised DC measurements. The DMU will be based on the already existing PMU. However, the difference with the PMU is that it relies on the interpolated discrete Fourier transform to extract the phasor and magnitude, while the DMU can extract the magnitudes by simply making use of a filter. The time synchronised PMU and DMU measurements are used in a linear hybrid state estimation to estimate the most likelihood state. The computed states are required for the monitoring of the system, performing the hybrid OPF...

1.5 Key performance indicators (KPI)

Key performance indicators			
ID	**Name**	**Description**	**Reference to mentioned use case objectives**
1	DMU	Total Vector Error of the DMU must be below the standard	
2	Computation time of the SE	The CPU time should be significantly small for real time implementation	
3	Validation of the SE	All the assumptions made a priori should be validated	

1.6 Use case conditions

Use case conditions
Assumptions
The grid is observable
Prerequisites
The number of measurements is larger than the number of states and the measurement matrix is full rank.

1.7 Further information to the use case for classification / mapping

Classification Information
Relation to other use cases
RTSE is a key element and a prerequisite for the monitoring and computing the optimal power flow in the grid
Level of depth
Direct relation
Prioritisation
High priority
Generic, regional or national relation
Generic SE, also for MV and HV
Nature of the use case
Algorithm implementation
Further keywords for classification
Grid monitoring, estimation, control

1.8 General remarks

General remarks

2 Diagrams of use case

Diagram(s) of use case

3 Technical details

3.1 Actors

Actors			
Grouping		**Group description**	
Grid operator		Actors operating the grid	
Actor name	**Actor type**	**Actor description**	**Further information specific to this use case**
Distribution System Operator (DSO)	Usually a company (can be state-owned)	Operator that is operating portion or entire grid	

3.2 References

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

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
1	Real-Time State Estimation in an AC-DC microgrid	The grid is only composed of AC nodes. Microgrid because the number of AC nodes is limited	DSO	Every time sample	All units are synchronized with the central unit	The state estimation has been updated

		and all the nodes are accessible and controllable by a central unit				

4.2 Steps – Scenarios

Scenario								
Scenario name :	Real-Time State Estimation in an AC microgrid							
Step No.	***Event***	***Name of process/ activity***	***Description of process/ activity***	***Service***	***Information producer (actor)***	***Information receiver (actor)***	***Information exchanged (IDs)***	***Requirements R-ID***
1	Acquisition of PMU and DMU information	Measurement	acquisition of time synchronised measurements		voltage and current sensors	Data concentrator	PMU: voltage and current phasors, DMU: voltage, current magnitudes	
	Data concentration	Communication of data	Concentration of the time aligned phasors and magnitudes		PMU and DMU	state estimator		
	State estimation	Computation	Estimation of the most likelihood state using a linear AC-DC RTSE algorithm		Data concentrator	OPF	States	

5 Information exchanged

Information Exchanged			
Information exchanged ID	***Name of information exchanged***	***Description of information exchanged***	***Requirements IDs***

6 Requirements (optional)

Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Requirement ID	***Requirement name***	***Requirement description***

7 Common Terms and Definitions

Common terms and definitions	
Term	***Definition***

8 Custom information (optional)

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

1 Description of the use case

1.1 Name of use case

Use case identification		
ID	***Area Domain(s)/ Zone(s)***	***Name of use case***
HYPERRIDE-UC-SWISS-002		Efficient fault management in grid operation

1.2 Version management

Version management				
Version No.	***Date***	***Name of author(s)***	***Changes***	***Approval status***
1	14.06.2021	Jules Macé, Willem Lambrichts		

1.3 Scope and objectives of use case

Scope and objectives of use case	
Scope	Development of a layer-based control architecture for future hybrid AC/DC grids that enables a stable grid operation even under failure situations.
Objective(s)	1) location and identification of the fault, 2) re-energization after faults
Related business case(s)	

1.4 Narrative of use case

Narrative of use case
Short description
Efficient fault management in AC and DC system. Safe disconnection, localisation and identification of the fault and re-energizing of the system after the fault
Complete description
Different types of faults can occur during grid operations: line-to-line, line-to-ground in the AC and DC system, faulty converter. Faults needs to be suppressed in order to provide safe operations for loads and users. In a first step, AC circuit breakers, DC solid state circuit breakers, and/or DC-DC controllers will detect the fault and disconnect the line or go in safe mode. After the suppression of the fault, a procedure is started to

re-energize the grid. By removing the faulty lines and/or converters and using the updated grid topology, the OPF is computed in order to recompute the new optimal setpoints of the grid after the fault. Network reconfiguration, in general, is defined as altering the topological structure of feeders by changing the state of switches. In other words, thanks to the switches we have the possibility of configuring the grid, depending on the number of switches in the network. Having N number of switches, there are 2^N possible combinations considering every on/off combination regarding the state of each switch, by which the network can be reconfigured. Said that, having immense number of possible combinations pose a difficulty in finding the optimal solution, i.e. optimal configuration. Generally, distribution networks operate in radial configurations to increase effectiveness and coordination among protection devices. Open tie units allow to overcome fault or overload conditions. The target is the real power loss reduction by changing the network topology while keeping the radiality, and keeping every node connected and energize the loads connected to it. Considering the configuration of AC/DC grids, an important aspect is the system control, necessary to regulate the power flow among the AC/DC converters and guarantee the stability of the network.

1.5 Key performance indicators (KPI)

Key performance indicators			
ID	***Name***	***Description***	***Reference to mentioned use case objectives***
1	Re-energizing	Fault detection and identification	
2	Re-energize the grid after a fault	Fast and reliable detection and identification of the fault	

1.6 Use case conditions

Use case conditions
Assumptions
A centralized controller
Prerequisites
none

1.7 Further information to the use case for classification / mapping

Classification Information
Relation to other use cases
Important element for a safe and reliable grid operation
Level of depth
Detailed use case
Prioritisation
medium/high priority
Generic, regional or national relation
Generic, for AC and DC grid, both MV and HV

Nature of the use case
Algorithm implementation
Further keywords for classification
fault management, re-energizing after fault

1.8 General remarks

General remarks

2 Diagrams of use case

Diagram(s) of use case

3 Technical details

3.1 Actors

Actors			
Grouping		**Group description**	
Grid operator		Measurement devices and transducers to collect relevant data from the grid	
Actor name	**Actor type**	**Actor description**	**Further information specific to this use case**
DSO		Distributional Grid Operator	

3.2 References

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

4 Step by step analysis of use case

4.1 Overview of scenarios

Scenario conditions						
No.	**Scenario name**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-condition**
1	Temporary DC line fault detection, protection and power restoration	A line-to-ground fault occurs at DC line and the scenario describes the behaviour of the line isolation and restoration	DSO and its assets	Line-to-ground fault	Grid is fully operational	Fault rectified

4.2 Steps – Scenarios

Scenario								
Scenario name:	Temporary DC line fault detection, protection and power restoration							
Step No.	**Event**	**Name of process/ activity**	**Description of process/ activity**	**Service**	**Information producer (actor)**	**Information receiver (actor)**	**Information exchanged (IDs)**	**Requirements R-ID**
1	Fault occurs in a DC line (line-to-ground, temporary)	Fault	An event puts the line in a fault situation (for instance, line touches a tree)					
2	Current inrush in the converters and the circuit breakers	Fault	The fault occurs: current inrushes in the line, high energy release					
3	Fault identified at the local level: 3.a. Fault	Local (device level: converter or circuit breaker)	Computation by the local controllers, using fault					

	identified by one DC-DC converter (DAB), blocks the current by putting the active bridges in safe mode (all switches open) 3.b. Fault identified by one DC-DC converter (LLC), blocks the current by putting the active bridges in safe mode (all switches open) when at ZCS 3.c. SSCB detects inrush current, triggers the turn-off of the CB 3.d. the faulty DC line is isolated	voltage and current measurements and local controller analysis of the measurements to identify fault	identification algorithm					
4	Fault information sent to the higher level (to the SCADA then to the microgrid controller)	local to central level communication of converter status [fault]	Communication through ethernet of the converter status		Converter, PMU, DMU, CB	Central Controller	Converter status	

5	Microgrid controller algorithm defines rerouting of the power flow and sends the new power flow set points to the grid elements. In the meantime, the DC energy sources (capacitor banks) are providing the power for the DC/AC loads	Central decisions for local controller's power flow set points	Computation of OPF with the new grid topology and new grid state					
6	In the meantime, the recording during fault of the voltage and current at each measurement unit is sent to the database and the microgrid controller processes those data to identify the fault nature: it is a temporary fault!	Local-to-central level communication and Fault nature identification	Communication through ethernet of the fault event "video"		Converter, PMU, DMU, CB	Database	fault event data communicated	

7	The microgrid controller gives order to the converters to start one by one to test the reenergizing of the DC line	central-to-local communication of power flow set points	Communication through ethernet of the grid elements power flow set points		Central Controller	Converter, PMU, DMU, CB	Grid converter set points	
8	During energizing, no fault has been detected, the DC line is fully energized, and the information is sent to the microgrid controller. Microgrid controller acknowledges it, computes the new power flow and set points and gives order to the reactivate the other converters providing the new power flow set points.	Local-to-central communication of converter status [NO FAULT]	Communication through ethernet of the converter status		Converter, PMU, DMU, CB	Central Controller	Converter status	
9	Controllers are all online again, send the	Local-to-central communication	Communication through ethernet of the grid status		Central Controller	Converter, PMU, DMU, CB	grid status	

	information to the microgrid controller, acknowledges it and the power is completely restored	of grid status [HEALTHY]							

5 Information exchanged

Information Exchanged			
Information exchanged ID	***Name of information exchanged***	***Description of information exchanged***	***Requirements IDs***

6 Requirements (optional)

Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Requirement ID	***Requirement name***	***Requirement description***

7 Common Terms and Definitions

Common terms and definitions	
Term	***Definition***

8 Custom information (optional)

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

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