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SHIFT to Direct Current

Deliverable D 1.3
Use Case Repository

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Disclaimer

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Executive Summary

This deliverable (D1.3) was prepared as part of the SHIFT2DC project. It yields a database of use cases published in an online repository (GitHub). The database was prepared by project partners working on the Task 1.3, "DC applications Use Cases," in Work Package 1 (WP1) “DC Solutions: Use Cases, Policies, Barriers, Opportunities and Social Adoption.” The purpose of this document is to provide an overview of the methodology used to create the specifications of use cases and what use cases are included in the first version of the database published in the online repository. The majority of the derived use cases have direct relations to the four pilots that will be built within the Work Package 4 (WP4) “DC Solutions: Demonstration and Field-tests,” while some of them can be used in nearly any practical DC installation.

Chapter 1 provides a short introduction. Chapter 2 provides a brief description of the methodology used to create the Use Case Repository. Chapter 3 describer types of use cases and actors involved in them. Chapter 4 provides an overview of use cases included in the database. It is assumed that the repository is a “live” deliverable that will be updated along the project development and extended with new use cases becoming apparent to project partners.

The deliverable forms the foundation for the next stages of the SHIFT2DC project, with its specifications guiding the development of the tools and solutions in WP2 and WP3. It marks a significant milestone in the project’s progress and sets the stage for future evaluations and implementations of DC systems.

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Keywords, Acronym

AC	Alternating Current
API	Application Programming Interface
BESS	Battery Energy Storage System
BUC	Business Use Case
DC	Direct Current
DER	Distributed Energy Resource
DSO	Distribution System Operator
EA	Sparx Systems Enterprise Architect
EMS	Energy Management System
IEC	International Electrotechnical Commission
ILC	Interlinking converter
G2V	Grid-to-vehicle
GIS	Geographic Information System
LVAC	Low-voltage Alternating Current
LVDC	Low-Voltage Direct Current
MS	Microsoft
PLC	Programmable Logic Controller
PGO	Prot Grid Operator
SCADA	Supervisory Control and Data Acquisition
SGAM	Smart Grid Architecture Model
SO	System Operator
SOC	State of Charge
SSCB	Solid-state Circuit Breaker
SSO	Ship System Operator
SUC	System Use Case
V2G	Vehicle-to-grid
WP	Work Package
UML	Unified Modeling Language

1 Introduction

1.1 Scope and Objectives

Microgrids represent a pivotal advancement towards a sustainable, resilient, and digitally integrated distribution and consumption of renewable energy. This paradigm shift signifies the evolution of electrical distribution through the incorporation of distributed energy resources in commercial and industrial settings. Many microgrid projects are exploring the application of direct current (DC) technology. Research and demonstration of technologies in the SHIFT2DC project are instrumental in elucidating this market trend, encompassing various activities from designing and simulating DC systems to technology development and field applications.

This document is an explanatory note for the database of use cases published in an online repository (GitHub). The database was prepared by project partners working on the Task 1.3, "DC applications Use Cases," in Work Package 1 (WP1) “DC Solutions: Use Cases, Policies, Barriers, Opportunities and Social Adoption.” The purpose of this document is to provide an overview of the methodology used to create the specifications of use cases and what use cases are included in the first version of the database published in the online repository.

The main objective of this deliverable is to create an openly shared database that can be used by interested researchers and practitioners and extended by the consortia members at the request of external stakeholders. The provided use cases create a framework allowing anyone to learn how DC-based systems can be operated and what functionality they can implement.

1.2 Structure

This deliverable is structured around four chapters, as depicted in Figure 1.1.
Chapter 1 provides a short introduction. Chapter 2 provides a brief description of the methodology used to create the Use Case Repository. Chapter 3 describes the types of use cases and the actors involved in them. Chapter 4 provides an overview of the use cases included in the database.

It is assumed that the repository is a “live” deliverable that will be updated along the project development and extended with new use cases becoming apparent to project partners.

Chapter 1: Introduction and definitions

Chapter 2: Methodology of use case description

Chapter 3: Definition of use case types and actors.

Chapter 4: List of use cases and corresponding scenarios included in the database.

Figure 1.1 – Chapter structure of the deliverable D1.3.

1.3 Relationship with other deliverables

The database of use cases directly relates to the task T1.4 as an input in terms of application scenarios and requirements. Also, the use cases describe information exchange and envisioned communication protocols, providing background information for the task T1.5. Moreover, it provides a guide to further development of tools in devices that can meet the requirements of the envisioned use cases in WP2 and WP3, respectively. The majority of the derived use cases have direct relations to the four pilots that will be built within the Work Package 4 (WP4) "DC Solutions: Demonstration and Field-tests," while many of them can be used in nearly any practical DC installation (Figure 1.2).

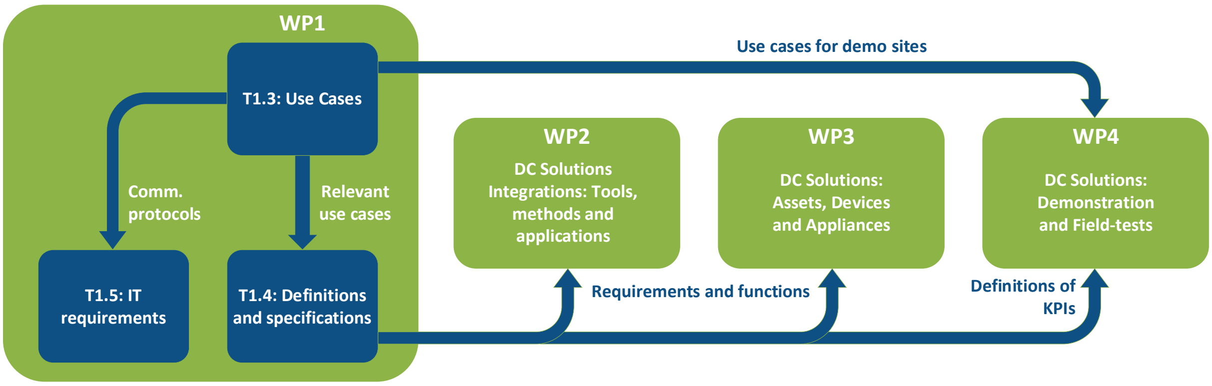

Figure 1.2 – Relation between T1.3 and other tasks and WPs within the project.

2 Use Case Definition using IEC 62559 Standards Series

This chapter explains how to define use cases and their functionalities in a structured and organized manner. This process employs the use case methodology based on the International Electrotechnical Commission (IEC) 62559-2 standard by IEC TC8. The associated parts of the IEC 62559 series — parts 1, 3, and 4 — further classify the Use Case Methodology and explore potential tool support.

2.1 Basics of Smart Grid Architecture Module and IEC 62559 Standards Series

The Smart Grid Architecture Model (SGAM) was developed by the Smart Grid Coordination Group/Reference Architecture Working Group under the auspices of the European Commission's Standardisation Mandate M/490. SGAM presents a comprehensive framework for understanding the overall architecture within the smart grid domain. It integrates various perspectives and methodologies pertinent to the conceptualization and development of the smart grid. Thereby, it facilitates the visualization of use cases.

The SGAM is based on five layers:

- **Business Layer** provides an overview of the information exchange within the Smart Grid from a business perspective. This layer encompasses regulatory and economic frameworks, policies, business models, portfolios, and the capabilities necessary for effective business operations. Additionally, it outlines business processes that illustrate various business models and specific projects aimed at recognizing and potentially developing new initiatives, such as corporate objectives like reducing energy consumption.
- **Function Layer** delineates functions and services, highlighting their interrelationships from an architectural standpoint. These functions and services are derived from the business perspective. They are designed to be independent of the actors involved and the physical implementations within applications, systems, and components.
- **Information Layer** focuses on the information utilized and exchanged among actors—specifically, systems and components. This layer includes information objects and their canonical data models, which embody the common semantics necessary for functions and services to facilitate interoperable exchanges.
- **Communication Layer** illustrates the protocols and mechanisms that enable interoperable data exchange among components concerning functions or services and their corresponding information objects or data models. Examples include ModBus and power line communication protocols.
- **Component Layer** details the physical distribution of all components within the Smart Grid. This encompasses systems and components, applications, power system equipment, protection and control devices, network infrastructure, and various intelligent devices, such as smart meters, voltage sensors, etc.

Each layer of the SGAM can be conceptualized as a two-dimensional plane that encompasses, on the one hand, the **domains** representing the electrical energy conversion chain from generation to consumption and, on the other hand, the hierarchical **zones** involved in managing electrical processes from market to operational levels. Notably, the SGAM distinguishes between the viewpoints of electrical processes and information management.

In this framework, **domains** characterize capacities physically associated with the electric grid as Generation, Distribution, Distributed Energy Resources (low to medium power), and Customer Premises (facilities). The **zones** within the SGAM provide a hierarchical framework for information management in the smart grid, emphasizing data aggregation and functional separation in power system management. Data aggregation involves consolidating field data within the station zone, while functional separation assigns distinct functions to specific zones based on the unique nature of those functions and the differing philosophies of users. The foundational concept of zones is derived from the Purdue Reference Model for computer-integrated manufacturing, which has been incorporated into the IEC 62264-1 standard for enterprise-control system integration. This standard has been further applied to power system management and is elaborated in the IEC 62357 standard as a reference architecture for object model services.

2.2 Methodology of Use Case Definition

One of the main shortcomings of the SGAM is that it provides a high level of abstraction from particular technologies used to implement a particular use case. As a result, certain functionalities at the business level will not depend on whether they are implemented using alternating current or DC. Hence, the repository of use cases mostly concentrates on how to operate DC-based installations. Such use cases could be referred to as system use cases as they do not involve any actors from outside a DC-based system. However, several business use cases are also defined with clear definitions of their implementation using the aforementioned system use cases to preserve the relevance of DC technologies.

IEC 62559-2 standard defines a template of the use case description. The template provides a structured approach to defining use cases in the context of smart grids and other applications. The use case template defined by this standard typically includes several key components:

1. **Use Case Identifier**: A unique identifier for the use case, often including a reference number or code.
2. **Use Case Title**: A brief title that summarizes the purpose of the use case.
3. **Narrative**: A detailed narrative that outlines what the use case entails, including its objectives and context.
4. **Actors**: Identification of the various stakeholders involved in the use case, such as users, systems, devices, or external entities. Each actor may have specific roles and responsibilities.
5. **Conditions:** Preconditions and requirements must be met before the use case can be executed. This might include specific states of the system or prerequisites that need to be fulfilled. Postconditions could also be added to define expected outcomes or the system state after the use case has been executed to indicate what changes have occurred after a use case execution.
6. **Scenarios**: A step-by-step description of the primary interactions and processes that occur during the execution of the use case. This includes the sequence of actions taken by the actors, as well as information exchange between them, if any. There could be more than one scenario of use case execution if it depends on the presence of particular assets.
7. **Requirements**: Any specific functional or non-functional requirements that the use case addresses, which may include performance, security, or usability criteria.
8. **Traceability**: Links to related use cases, requirements, or standards that provide context or additional information about the use case.

This structured approach helps ensure that use cases are comprehensive, clear, and aligned with the overall goals of the project being developed. The stakeholders or interested third parties have to decide first whether they can use EA software environment for the best compatibility with the repository created in the task T1.3, or use a text processor (for example, MS Word or an alternative open-source solution) along with a technical drawing software (such as draw.io) that supports Unified Modeling Language (UML) defined by the IEC 62559-3 standard. The simplified workflow is defined in Figure 2.1.

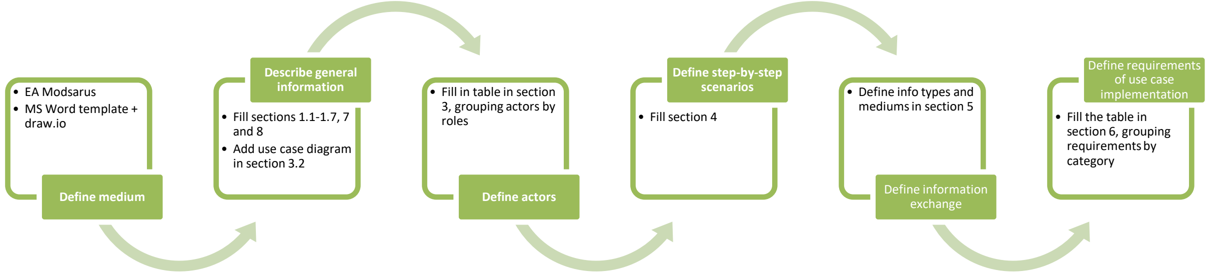

Figure 2.1 – Use case definition methodology

The proposed methodology was executed in the Task 1.3 to produce a repository of the use cases. The repository was homogenized in the EA MODSARUS® software environment, which is the free add-on for EA software package provided by EDF[1], one of the project beneficiaries. It is commonly used for the development of use cases according to the IEC 62559-2 standard. Moreover, printouts of use cases in PDF format (according to the template defined by the IEC 62559-2 standard) will be provided for interested parties without access to EA software.

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[1] Électricité de France

3 Description of Roles of the Actors Involved in Use Cases

As mentioned above, the use cases could be logically split into business and system. It is logical to split use case actors accordingly, as in the two subsections below.

3.1 Actors in System Use Cases

In the domain of the system use cases (SUC), the actors involved are grouped and listed in Table 3.1. It is important to mention that there is a big variety of different Energy Management System (EMS) as their implementation depends on a particular installation. In general, an EMS is a global controller for an electrical installation. Its role is to optimize energy flow in order to ensure system efficiency and stability. It interacts with all grid components to manage energy in real-time.

All this actos are categorized as "System" in the Enterprize Architect. However, this document detail their type.

Table 3.1: Actors Involved in System Use Cases

Actor	Actor Type	Actor Description	Notes
EMS (day-ahead)	System	An energy management system that can predict energy generation and consumption one day ahead.	Important for business use cases, especially for the markets with day-ahead electricity pricing.
Energy Management System	System	The Energy Management System (EMS) is the core controller of a DC grid, optimizing energy flow and ensuring system efficiency and stability. It integrates with all grid components to manage and balance energy in real time.	Used in all four domains where use cases were considered.
Building EMS	System	Optimize energy flow to ensure system efficiency and stability in a building, as well as comfortable living conditions in terms of temperature and humidity.	Related to DC building use cases.
DSO/TSO EMS	System	System scheduling power dispatch in the distribution grid based on information about the predicted consumption of large consumers, like ports.	Related to DC ports specifically.
Ship EMS	System	On-board software assets that manage and oversee the vessel's power supply while coordinating energy distribution from various available power sources.	Related to DC port use cases only.
Port EMS	System	SCADA-like system that manages the operation of engineering systems in the port, both those connected to DC and to AC.	
Ship tracking system	System	Typically, a GIS-based system that can define and exchange ship position with other systems.	

AC grid	System	The utility Low-voltage AC (LVAC) grid, which delivers power to the input of the Interlinking converter (ILC)	
Operator	System	Either a digital higher-level supervisory control device or a human operator on-site	It is not considered as a business entity as no business interactions happen.
Weather data system	Software	Typically an API or other software means of receiving information about current and forecasted weather.	
Market data system	Software	Typically, an API or other software means of receiving information on electricity market prices.	
Energy consumption monitoring system	Software	Software that continuously analyzes real-time and historical power consumption data from various components in the data center, such as servers, cooling systems, and power distribution units, in order to make future forecasts.	
Interlink converter	Device	AC/DC converter responsible for the interface/separation between the LVAC utility grid and the Low-Voltage DC (LVDC) grid. It has a crucial role since it is the main responsible for ensuring grid stability and is often the most powerful asset in the grid. It is often the equipment responsible for the grounding system as well. It acts as the main connection of the DC grid to the public AC grid. Current/power and, in some cases, even direction of power flow can actively be controlled.	This asset is commonly used in the vast majority of DC installations.
DC loads	Device	Plurality of loads connected to a DC grid.	Aggregated type for devices.
Droop controlled load(s)	Device	Loads that regulate their power consumption based on a linear droop control curve dependent on the DC grid voltage.	
Controllable loads	Device	Generalized definition of DC devices that have the possibility of changing their DC droop control characteristic or disabling when needed.	Generalized term for a multitude of controllable assets to generalize description of some system use cases.
Power meter	Device	Measurement units that can measure active power, reactive power, grid frequency, voltage/current, consumption, etc. as the point of connection to an AC grid. However, DC	Mostly involved in business use cases where information about the power exchange and conditions at the point of

		meters are also feasible and needed in DC installations.	connection to AC grid is needed.
DC measurement device(s)	Device	Continuously monitors DC bus and reports parameters such as voltage, current, and power consumption.	
Data logger	Device	A passive monitoring and recording device essential for gathering real-time or historical data on energy consumption, voltage levels, and other critical metrics within the grid infrastructure.	In the data center demonstrator, the Power Distribution Unit (PDU) is a data logger for monitoring power usage and environmental conditions.
Energy storage system	Device	Set of devices which are responsible for storing the excess of energy generated locally by Distributed Energy Resource (DER) and also for supplying energy to the LVDC grid when needed. Typically, this is a modular battery energy storage. Also, it can implement energy arbitrage owing to EMS control.	
Energy generation sources	Device	Local assets responsible for generating energy and connected to the DC grid. A typical example is photovoltaic energy.	
EV Charger (Bidirectional)	Device	Depending on the device as well as the connected electric vehicle (EV) (if any), the EV charger can act as a bidirectional system (G2V/V2G), similar to an ESS but with a more volatile availability or like a standard controllable load.	It could also act as an energy storage to stabilize DC grid operation.
Power distribution unit converter	Device	DC/DC converter responsible for adapting the internal distribution DC voltage level. For example, interfacing 700 VDC and 350 VDC buses. It may have a galvanic isolation or not, and depending on the topology, it may also have current limitation capabilities.	
Central converter	Device	LVAC/LVDC, LVDC/LVDC, or MVDC/LVDC power electronic converter system connected to the LVDC grid. It is an aggregated class used in industrial DC use cases. These converters manage voltage transformation within the grid, ensuring stable DC power supply. Converters operate based on pre-set parameters and are monitored for fault detection by local sensors and Solid-state Circuit Breakers (SSCBs).	

DC Circuit Breaker(s)	Device	Overcurrent protection device, typically very fast semiconductor-based.	A typical device for most of the DC installations.
DC Switch	Device	Electronically supported relay used to connect DC devices even under load conditions with implemented pre-charging functionality.	Relevant in many industrial DC installations.
Pre-cahrger(s)	Device	DC pre-charging device(s) used to passively pre-charge converters' DC-link capacitors before startup.	
Office area heat exchanger fans	Device	Devices that blow air. Sector coupling requires two types of fans: one group for the office area heat exchanger and one group for the exhaust heat exchanger.	Relevant for sector coupling use case.
Exhaust heat exchanger fans	Device		
Fan speed controller	Device	A device to control the speed of fans.	Relevant for sector coupling use case.
Programmable logic controller	Device	A device having a programmable memory with inputs and outputs to monitor and control equipment or processes.	Relevant for sector coupling use case.
Thermocouple	Device	A sensor made of two different metals joined together at one end and that produces a temperature dependent voltage.	Relevant for sector coupling use case.
Server(s) - Uncontrollable	Device	IT equipment and servers can usually not be controlled by an overarching EMS and even less so by droop control. Their power intake is defined by their current computation task.	IT devices and servers cannot usually be controlled by a higher-level EMS and certainly not by a droop controller.
Server(s) - Controllable	Device	IT devices and servers cannot usually be controlled by a higher-level EMS and certainly not by a droop controller. The “controllable server” is a key player in this use case as it is equipped with advanced capabilities to dynamically control its power consumption and operating parameters based on real-time inputs and instructions.	
Solid-state circuit breakers	Device	SSCBs are responsible for detecting overcurrent or other fault conditions locally and isolating the faulted section of the DC grid.	SSCBs operate autonomously to detect faults and interrupt the current flow in the event of a fault.
Power Converters	Device	Represents generalized power electronic converters connected to an industrial DC grid, i.e., without DC switches. Used as an	Typically, converters operate based on pre-set parameters and are

		aggregated class to simplify use case description.	monitored for fault detection by local sensors and SSCBs
DC relay(s)/ contactor(s)	Device	Relay(s)/contactor(s) used to connect the converter to the LVDC grid under no-load conditions.	
Modular MVDC-LVDC	Device	AC/DC or DC/DC power electronics converter system connected to the LVDC grid.	
Pre-charge circuit	Device	Device used to passively pre-charge the converter's DC-link capacitors before startup	

3.2 Business Actors

In the domain of the business use cases (BUCs), the actors involved are listed in Table 3.2.

Table 3.2: Actors Involved in Business Use Cases

Actor	Actor Type	Actor Description	Notes
Ship	Business	Supervises transactions.	This actor is involved only in use cases related to DC ports.
Port Grid Operator	Business	Buys energy services	This actor is involved only in use cases related to DC ports.
H_2 Retailer	Business	An entity buying/selling hydrogen in bulk	Hydrogen use is considered in the port use cases.
Building consumer	Business	A physical person or business entity occupying the totality or a part of the building to carry out a certain activity.	This actor is mainly related to DC building use cases. The main user of the building's electricity and assets.
Building manager	Business	An entity responsible for the building's electrical installation, and operation of different assets (energy storage system, energy sources, control features, etc.)	This actor is mainly related to DC building use cases.
Distribution System Operator (DSO)	Business	An entity responsible for delivering power to the building in the form of an LVAC distribution system. Its perimeter finishes at the Point of Connection defined by the installation's electrical meter.	Common actor that could be involved in numerous business use cases.

4 Use Cases Included in the Initial Repository

This section provides a concise list of use cases included in the EA MODSARUS® file modeling use cases based on UML. They are listed below.

The repository could be located in GitHub by the following link:
https://github.com/SHIFT2DC/UseCases

Table 4.1: Use Cases Included in the Initial Version of the Repository

Use case title	**Ahead Scheduling**
Use case domain	DC ports, system use case
Short narrative	
This SUC aims to describe the information exchange needed to perform the operational planning process by the Prot Grid Operator (PGO). This process should be executed daily or whenever requested by supervisory algorithms (in cases of significant deviations between measurements and forecasts).	
Step-by-step scenarios	
1	One scenario is included.
Use case title	**Asset Control**
Use case domain	DC ports, system use case
Short narrative	
This SUC intends to describe the systems exchanges allowing the control of devices installed in a DC Port. The devices are described in a generic way but, in all cases, should allow distributed droop control. The Ship represents a load that can have flexibility in its operation. In that case, the PGO should define the operation set point in the limits previously defined by the Ship.	
Step-by-step scenarios	
1	One scenario is included.
Use case title	**Connection Preparation**
Use case domain	DC ports, system use case
Short narrative	
This SUC aims to describe the connection request process. This process may vary depending on the ship type but primarily on whether the ship is a regular visitor to the port. Different procedures may apply if the ship has never connected to the port or has not done so for over a year.	
Step-by-step scenarios	
1	One scenario is included.
Use case title	**Microgrid Operation**
Use case domain	DC ports, business use case
Short narrative	
This BUC intends to descrive the activation of Microgrid Operation. Microgrid operation can be activated in different cases.	

First, can be the Ship System Operator (SSO) activating the operation of the Port as a microgrid. In most of the cases, the operation as a Microgrid is activated during extreme weather conditions where the risks of grid failures increase. A second case can occour as a Demand Response service. In that case, the System Operator (SO) will activate the service paying an incentive. The participation is voluntary and the SSO can coordinate the service with the SO avoiding degradation of the service of the Port (Operation of the Port as a Microgrid limited on time). A third case can occur when an extreme and unexpected event happens. In that case, Under Frequency Load Shedding can be activated by the SO. Some degradation in service can be expected due to the lack of a defined operation time in microgrid mode.	
Step-by-step scenarios	
1	One scenario is included.

Use case title	**Hydrogen production**
Use case domain	DC ports, business use case
Short narrative	
This use case describe DC port operation with on-site hydrogen generation and storage. In the present case, it is assumed that: • The Port can produce H2 (Electrolysis), consume hydrogen to prouce electricity (Fuel Cell) and store hydrogen. • The SSO manages the process and storage • The Hydrogen can be sold and bought to "Hydrogen Stakeholders". • It is assumed that the price of H_2 (buy and sell) is established daily in markets, and the SSO can sell/buy based on this price.	
Step-by-step scenarios	
1	One scenario is included.

Use case title	**Provision of Grid Services**
Use case domain	DC ports, business use case
Short narrative	
This BUC intends to descrive the activation of different services by the system operator. The services can be used to solve systema and/or grid services. The main aim is not to understand why the services are activated but mainly how the SSO can participate in these services.	
Step-by-step scenarios	
1	One scenario is included.

Use case title	**Secondary droop control**
Use case domain	DC buildings, system use case
Short narrative	
EMS is able to adjust droop curves for sources/loads in order to match an operation point and to guarantee system stability while optimizing the use of different energy sources. It requests internal communication between the EMS and different assets. Different scenarios are described for the operation of the secondary droop control, such as AC grid outage or faults in other assets. Regarding the different droop curves possible, two technical scenarios are feasible: either a set of	

droop curves are already defined in the EMS and are sent to the assets depending on the state of the grid, or the droop curves are calculated and updated periodically. A trade-off between simplicity and accuracy exists.	
Step-by-step scenarios	
1	AC grid or inter-linking converter failure
2	Energy storage system fault or low State of Charge (SOC) in islanded mode
3	Energy storage system fault under high photovoltaic energy generation

Use case title	**Voltage droop control**
Use case domain	DC buildings, system use case
Short narrative	
This SUC represents the capacity of different assets, sources and loads connected to the DC building to adapt their energy production/consumption in function of the state of the grid, represented by the DC grid voltage. It happens through different droop control curves and dead-bands, which associate a power setpoint in function of the DC grid voltage. The droop control is implemented at a system level in the different converters associated with each source/load as an external control loop to the internal current loops.	
Step-by-step scenarios	
1	Emergency band
2	Overvoltage band
3	Voltage in nominal band - oversupply
4	Voltage in nominal band - undersupply

Use case title	**Power setpoint at AC connection point**
Use case domain	DC buildings, system use case
Short narrative	
This SUC represents the capacity of the ILC to receive, process and execute the order from the EMS to update the active and reactive power setpoints. The most used technique to control current loops, and power loops as a consequence, in ILCs is the vector approach. With a decoupled vector system, it is simple to impose a certain level of active and reactive power in the AC port of the ILC.	
Step-by-step scenarios	
1	Provide active power for the distribution grid
2	Provide reactive power supply for the distribution grid

Use case title	**DC Grid Resilience in case of AC Grid outage or faulty asset**
Use case domain	DC buildings, business use case
Short narrative	
BUC describes how the DC Building grid is able to maintain operation autonomously in case of AC main grid outage or a faulty asset. Various scenarios depending on local resources instantaneous power are possible. Critical loads have to be able to operate in downgraded mode in case of supply-demand balance issues. In addition, for droop stability, it is important to consider if the capacitance	

of the AC/DC converter will be decoupled from the DC bus or not, since it represents an instantaneous voltage inertia factor.	
Step-by-step scenarios	
1	None, interconnection with SUCs is given.

Use case title	**Maximize local energy consumption**
Use case domain	DC buildings, business use case
Short narrative	
This BUC represents the operation of the DC building regarding the management of different assets connected to the DC building grid with the objective of maximizing the use of locally generated energy through DER (PV). The overall goal is to reduce the power flow from the LVAC grid, which will reduce the potential overload of the utility grid and allow the building consumer/operator to reduce energy costs.	
Step-by-step scenarios	
1	None, interconnection with SUCs is given.

Use case title	**Provide grid services**
Use case domain	DC buildings, business use case
Short narrative	
This BUC represents the capacity of the DC-powered building to provide grid services, which are mainly related to power flow. Depending on the state of operation of different building assets (PV generation, Battery Energy Storage System (BESS) state of charge, etc.) and on the state of the distribution grid, the DC building can provide active power, and provide/consume reactive power to/from the AC grid. It represents an additional flexibility lever to the DSO.	
Step-by-step scenarios	
1	None, interconnection with SUCs is given.

Use case title	**DC Grid Resilience**
Use case domain	DC data centers, system use case
Short narrative	
This set of SUCs provides a comprehensive framework demonstrating how a DC data center can be operated resiliently in various conditions.	
Step-by-step scenarios	
1	AC grid failure
2	Interlinking converter failure
3	Battery management in the event of a fault - Insufficient energy production
4	Battery management in the event of a fault - Sufficient energy production
5	Battery management in the event of a fault - Energy overproduction
6	Controlled shutdown
7	Power restoration

Use case title	**Operation of an Industrial LVDC Grid**
Use case domain	DC industry, system use case
Short narrative	
Operators of industrial production facilities and process plants require a high availability of power and reliable supply. Outages, which pause or stop production processes, can result in significant costs. Nowadays, energy prices and sustainability goals such as decarbonization are very much the focus of facility management and energy managers. For electricity, peak power management and prevention have become a business case on its own. All these goals can be achieved at the same time by optimizing the grid operation and managing the connected assets by an appropriate EMS, though still giving the production the highest priority. Flexibility of the connected assets is key. Where immanent system flexibility is insufficient, additional BESS can add the flexibility required to achieve the goals. Since a BESS is a very valuable actor within DC systems anyway, a nice synergy in combination with further BESS-related use cases can be found.	
Step-by-step scenarios	
1	Switching ON DC grid
2	Device pre-charging
3	Intrinsic voltage support
4	BESS Balancing
5	Outage prevention
6	Shutdown

Use case title	**Sector coupling**
Use case domain	General with focus on DC data centers, system use case
Short narrative	
In the DC data center demonstrator, a high-power density edge data center is located close to an office area. The cooling system of this edge data center, coupled with a water loop, ensures that the dissipated heat is reused when heating the office area is needed.	
Step-by-step scenarios	
1	DC Data Center – Heating services needed
2	DC Data Center – No heating services needed

Use case title	**Data Center Scalability**
Use case domain	DC data centers, system use case
Short narrative	
When using edge data centers, one can often assume a semi-modular structure in which a finished system is transferred to a new environment. The power supply from the AC grid on site is not always guaranteed to a sufficient extent, and the computing requirements can exceed the available power. If regularly recurring peak demands can be assumed, the power of the AC grid can be buffered by using battery technology.	
Step-by-step scenarios	
1	Updating the energy consumption model
2	Computational load negotiation

3	Disabling overload compensation

Use case title	**Fault detection and isolation in a meshed LVDC grid using Solid State Circuit Breakers**
Use case domain	General with focus on DC industries, system use case
Short narrative	
In an industrial meshed LVDC grid, electrical faults are detected using sensors, and isolated using SSCBs to prevent system-wide disruptions and maintain operational continuity. • The meshed LVDC industrial grid includes multiple power sources, loads, power electronics converters for interconnection with mediam voltage DC (MVDC) as well as LVAC, and communication network. • SSCBs are integrated into the system for fast and reliable fault isolation. • Sensors and monitoring devices are used to detect faults. • Upon fault detection, SSCBs isolate the faulted section.	
Step-by-step scenarios	
1	Pre-charging of converters’ DC link capacitors
2	Normal operation
3	Detection of a fault condition
4	Isolation of the faulted section

Use case title	**Interfacing LVDC and MVDC grids**
Use case domain	General with focus on DC industries, system use case
Short narrative	
This use case essentially describes operation of a modular MVDC/LVDC interface converter. Operators of large industrial process plants or data centres require a high availability of power supply. The operation of industrial process plants and data centers on direct current offers advantages in terms of efficiency, operation and potentially low investment costs. Large plants and data centers as well as charging parks for truck fleets require a high power connection in the multi MW range. Thus high-cumulated power can only be provided economically by medium-voltage grids. Future distribution grids may have MVDC sections. MVDC grids are also suitable as larger collector grids for wind and PV parks. Heavy-duty machines such as drives in the multi-megawatt range can also be operated efficiently on MVDC grids. The integration of MVDC grids into local and possibly meshed LVDC grids therefore offers great advantages for the direct use of locally generated energy or recuperated energy from large electric drives.	
Step-by-step scenarios	
1	Operation
2	Shutdown
3	Start up

Use case title	**Operation of meshed LVDC grids**

Use case domain	General with focus on DC industries, system use case
Short narrative	
A meshed LVDC system increases the system reliability to ensure that critical processes/systems are supplied with electrical energy. Furthermore, systems with fluctuating power consumption and withdrawal can be better integrated into existing grids if several grid connection points are used. There is also a path for providing balancing energy between two grid areas. If the target loads and renewable generation units operate internally on DC, it is worth coupling them directly using a powerful direct current grid to eliminate conversion stages and minimize material consumption and transmission losses. A meshed or ring bus DC grid with several feed-in points from higher-level power grids can achieve high availability and distribute the required peak power to several grid connections. Superimposed grids for integration can be classic AC grids as well as medium-voltage DC grids.	
Step-by-step scenarios	
1	Converter pre-charging
2	Grid pre-charging
3	Normal operation – AC grid coupling (throughput)
4	Normal operation – Peak power
5	Normal operation – Self consumption