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Microgrid Scenario Building Blocks

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Abstract:
Microgrids will have a massive impact on the future electricity smart grid architecture and the associated control network. This deliverable identifies the essential use cases of the microgrid scenario. A series of relevant and ICT-prone use cases have been evaluated up to a level where the potential impact on prominent ICT requirements is recognizable. This report is the basis for further work on ICT requirements and a functional ICT architecture for microgrids.

Keyword list:

Microgrid, Demand-side Management, Supply-side Management, Balancing, Distributed Energy Resources, Aggregator, Virtual Power Plant, Smart Grid, Smart Energy

Disclaimer:

Not applicable.

Executive Summary

The Microgrid scenario has been chosen as an important and visionary electricity grid scenario to analyze ICT requirements. Microgrids are essentially a substructure of the global grid and comprise local low-voltage and even medium-voltage distribution systems with distributed energy resources and storage devices in order to satisfy the demands of energy consumers. Such systems can be operated in a semi-autonomous way, if interconnected to the grid, or in an autonomous way (islanding mode), if disconnected from the main grid.

With the help of ICT a Microgrid could improve the technical performance of a local distribution grid. For example, by reduction of line losses due to generation closer to the loads, by mitigation of voltage variations through coordinated reactive power control or islanding mode in case of connection loss to the main grid.

This deliverable defines the Microgrid scenario and outlines the methodology used for evaluating this scenario. The main part describes the identified use cases for the Microgrid. We classified between "Business Use Cases" and "Control and Management Use Cases". The first ones are use cases addressing the interactions with other market roles to negotiate and to contract energy or ancillary services, whereas the control and management use cases describe the actions taken to run a function of the system. Four major business use cases as well as nine control and management use cases have been identified with a number of sub use cases.

Business use cases include the participation on wholesale or retail markets, providing balancing or ancillary services as well as the islanding mode of the Microgrid as a service and an open trading platform where prosumers in the Microgrid can interact with internal and external market players.

Control and management use cases comprise demand-side and supply-side management. A major control task handles the balancing of supply and demand on different time scales. Furthermore, black start in islanding mode and planning for upgrading the Microgrid infrastructure are described in detail as well as the auto-configuration of new devices or sub-systems in the Microgrid. To draw a complete picture of the Microgrid scenario smart metering, protection & restoration and storage management are also listed as Microgrid control and management use cases.

Because of the clear scope on Future Internet requirements of a Microgrid the use cases are chosen according to their potential ICT relevance beyond the state-of-the-art and have been evaluated up to a level where the potential impact on a series of first ICT requirements is recognizable.

The Microgrid is an aggregation platform which reduces the complexity for management and operation for the overall electricity network. In this role it comprises and extends the essential features of Virtual Power Plants. Hence, a subset of the derived results in this report applies also for aggregators and Virtual Power Plants (VPPs).

Based on the use case descriptions outlined in this report the ICT requirements will be fully identified and a functional ICT architecture will be derived in subsequent work. Additionally, possible trial candidates will be identified and evaluated.

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1. Introduction

The Microgrid scenario has been selected by the project since Microgrids are smart, small-scale versions of future electricity systems and therefore will be an integral part of a future smart grid landscape. A smart Microgrid generates, distributes and balances the flow of electricity to consumers, but does so locally. It aggregates and controls largely autonomously its own supply- and demand-side resources in low-voltage and even medium-voltage distribution grids. Well designed Microgrids produce enough electric energy to meet the power needs of the users within the Microgrid. They achieve specific local goals, such as reliability, carbon emission reduction, diversification of energy sources and cost reduction for the community being served.

Microgrids will have a massive impact on the future electricity smart grid architecture and the associated control network. They provide an efficient and economic way to manage and deliver electricity to a local user base. Economic and environmental benefits to smart grid users are maximized while minimizing energy loss through transmission over long distances. Other savings are achieved through smart use of power and higher efficiency of distributed generation, e.g. through combined heat and power. Furthermore, Microgrids will be able to flexibly offer services to their overlay grid, thus enhancing the possibility to establish new markets and improving the overall efficiency in electricity supply.

Smart Microgrids are an ideal way to integrate renewable resources on the community level and allow for customer participation in the electricity enterprise. Controlling the infrastructure on the local level allows for private investment in the system and makes Microgrids hotbeds for entrepreneurial innovation.

Microgrid technology could also help to drive down the cost of adoption for the emerging markets where the potential to bring cheap reliable electricity will provide a huge improvement in the living standards of so many people in the world.

To make Microgrids a success story it is necessary to standardize their design and establish the regulatory framework for a bunch of new business models.

The idea of a decentralized model for generating and delivering electricity was what Thomas Edison had originally envisioned. However, the lack of appropriate technologies to allow such a model to scale reliably on a national basis led to the development of today's centralized power system. With the improvements on all relevant technology fields, e.g. small scale distributed generation, improved electronic switches and inverters, computerized control and advanced networking and IC techniques, the time has come to rebuild the models of generation, transmission and distribution.

The FINSENY project goals are to shape the next wave of Internet Technologies to allow that vision to become reality.

We expect major benefits from advanced ICT solutions for the development of future Microgrids, e.g.

- 'Smarter' grid equipment
- A reliable distributed control architecture
- An improved system flexibility for all involved stakeholders
- The introduction of new services
- A 'future-proof' design

The project follows a well-defined approach to identify the prominent ICT requirements. Starting from a set of ICT relevant use cases these can be broken down to a level where the major ICT requirements can be defined.

This deliverable describes the selected use cases and deducts high-level ICT requirements using a first coarse-grained ICT metric.

2. Methodology

FINSENY will use scenario techniques to identify the prominent ICT challenges. The term ‘scenario’ refers to an application domain in the evolving Smart Energy landscape, expected to be of significant importance, and requiring advanced ICT technologies.

This deliverable is part of WP3, which addresses the Microgrid scenario. For every considered scenario four main tasks have been identified:

- Task 1: Scenario Evaluation
- Task 2: ICT Requirements
- Task 3: Functional ICT Architecture
- Task 4: Trial Candidates

This document summarizes the results of the scenario evaluation of Task 3.1. The Microgrid scenario is evaluated in detail by describing the most relevant use cases, the interrelations between these use cases and the actors involved in this use cases. There are many other activities (e.g. other related EU and national R&D projects, task forces like Smart Grid Task force of the European Commission [1] and standardization activities and roadmaps) ongoing in this field of interest, which will be reviewed and taken into account. This will avoid repeating work and allows for making use of it. The relevance of the use cases will be evaluated according to their potential to induce remarkable ICT requirements. Finally, selected use cases will be described according to a common template. Based on the use case descriptions the ICT requirements will be identified in Task 3.2 and a functional ICT architecture will be derived in Task 3.3. Finally, Task 3.4 will evaluate and propose trial candidates and work out a potential field trial design in detail.

WP3 separates the evaluation of the scenario from the technical specifications and concentrates in Task 3.1 on describing the use cases for the Microgrid scenario. This approach is well known from systems engineering. In IEC/PAS 62559 [2] the system engineering methodology is described briefly:

“Systems engineering methodology separates the concepts of “user requirements” from “technical specifications”: user requirements define “what” is needed without reference to any specific designs or technologies, while technical specifications define “how” to implement the automation systems in order to meet the user requirements.”

Furthermore, this publicly available specification describes a methodology for developing requirements for energy systems which was initially used in the IntelliGrid project [3]. Also other related research projects use a use case approach, e.g. OpenNode [4], ADDRESS [5] and FENIX [6]. And, also in the Smart Grid Mandate M/490 issued by the European Commission deliverables on use cases are planned [7].

The scenario evaluation of Task 3.1 is approached as depicted in Figure 1. The work starts in parallel by identifying and collecting use cases relevant for the scenario from other projects. These high-level use cases are described shortly. To draw a complete picture the interrelations of the high-level use cases are identified and visualised in a structured use case diagram. Furthermore, the most relevant actors of the scenario (market roles as well as systems and devices) are defined. This is done in an iterative process to ensure completeness.

Because of the system complexity it is necessary to make a selection of use cases. The following two criteria for this selection process are

- relevance according to the work package scope, i.e. the Microgrid scenario in case of WP3,
- relevance with respect to ICT beyond the state-of-the-art.

If a use case is selected, it will be described in further detail. Also at this step the focus is on the ICT relevance. This means, the selected use cases are detailed to a level which is sufficient to identify relevant

ICT requirements. The detailed description of each use case is based on a use case template which is a simplified version of the IntelliGrid template in [2], [8].

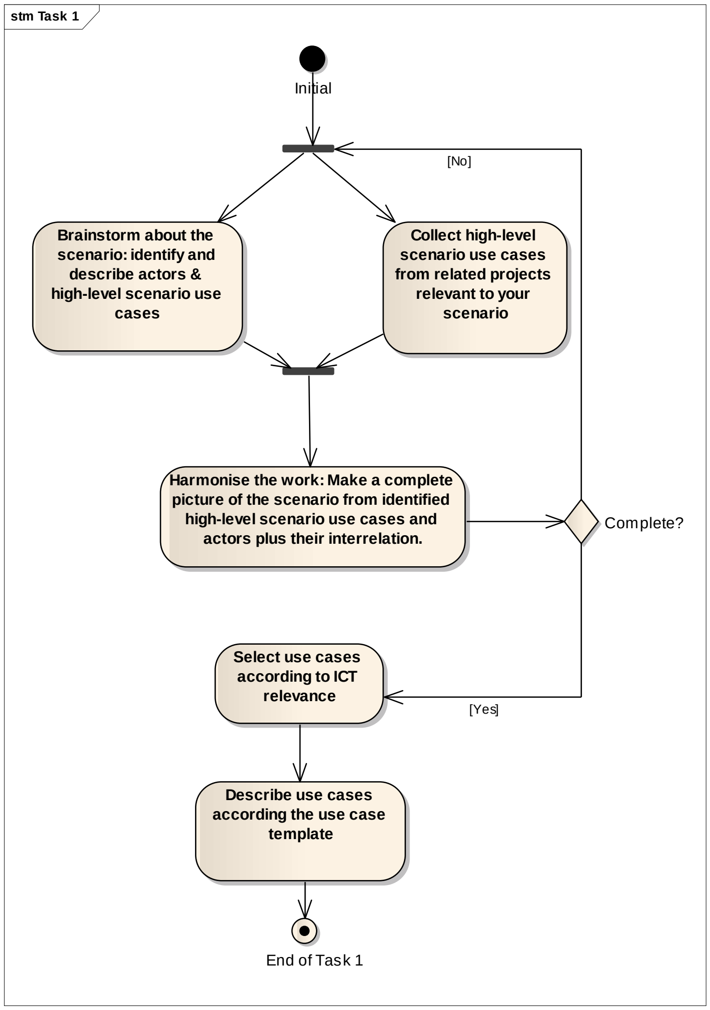

Figure 1: Methodology for Task 3.1

3. The Microgrid Scenario

This chapter describes the Microgrid scenario in detail. We start by a definition and describe the main use cases and actors involved in the scenario. The use cases are described at a high-level to make a comprehensive and complete picture of the Microgrid scenario. A detailed description of these high-level use cases is given in the Chapter 4 and Chapter 5.

3.1 Definition

A Microgrid comprises local low-voltage (LV) and even medium-voltage (MV) distribution systems with distributed energy resources (DERs, e.g. micro turbines, fuel cells, photovoltaic) and storage devices (flywheels, energy capacitors and batteries) in order to satisfy the demands of energy consumers (Figure 2). Larger Microgrids allow also for aggregation of consumers as well as DERs, analogous to a Virtual Power Plant (VPP).

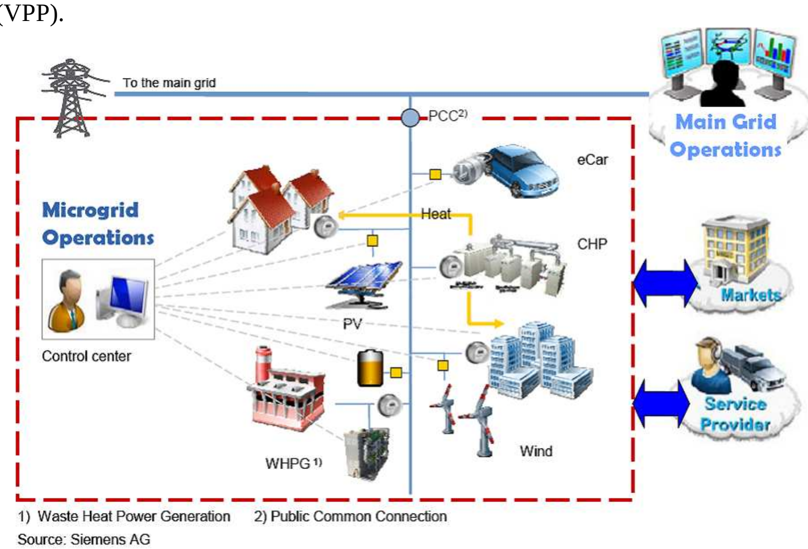

Figure 2: Microgrid Overview

The difference between a Microgrid and a passive grid penetrated by micro-sources lies mainly in the way of management and coordination of available resources. Microgrids can be operated in a semi-autonomous way, if interconnected to the grid, or in an autonomous way (islanding mode), if disconnected from the main grid. The operation of such locally balanced micro-sources can provide distinct benefits to the overall Smart Grid performance, if managed and coordinated efficiently.

To the Microgrid operator, the overlaying power grid appears as just one generator/load, depending on the actual electricity flow. Analogously, to the overlaying grid operator, the Microgrid appears as just one generator/load. Electricity can be traded within the Microgrid as well as between the Microgrid and the overlaying grid.

Microgrids can be disconnected from the overlaying grid in the presence of disturbances over the latter one, thereby providing enhanced reliability and high power quality to its users. Microgrids will comprise a plurality of distributed generation sources, be them renewable (e.g., solar PV, wind micro-turbines) or based on co-generation (micro-CHP). Microgrids will benefit from the deployment of efficient and cost-effective energy storage technology, which will provide an additional degree of flexibility to the Microgrid operators (in particular in the presence of a large number of renewable energy sources).

The size of a Microgrid can vary and range from residential to campus or community wide systems. Furthermore, at remote locations which are not integrated into a power system off-grid Microgrids can be used for electrification (e.g. on geographical islands).

Although Microgrids are faced today with regulatory hurdles, they are aligned with the governmental goals for an increased share of renewable energy and higher reliability by providing cost-efficiency at the same time.

In any case, for efficiency reasons and consistency of the whole electrical system, the Microgrid development should be contiguous to the smart distribution network.

In summary, the following definition for the term "Microgrid" is used in FINSENY:

Microgrids comprise local low-voltage and even medium-voltage distribution systems with distributed energy resources and storage devices in order to satisfy the demands of energy consumers. Such systems can be operated in a semi-autonomous way, if interconnected to the grid, or in an autonomous way (islanding mode), if disconnected from the main grid.

3.2 Comparison to Virtual Power Plants

Virtual Power Plants (VPPs) share essential features with Microgrids. Hence, we compare both approaches briefly in this chapter to understand their commonalities and differences.

The EU project FENIX [6] used the following definition of the term "Virtual Power Plant" which was also adopted by the Expert Group 1 of the EU Commission Task Force for Smart Grids in [10]:

A Virtual Power Plant (VPP) aggregates the capacity of many diverse Distributed Energy Resources (DER), it creates a single operating profile from a composite of the parameters characterizing each DER and can incorporate the impact of the network on aggregate DER output. There are two types of VPP, the Commercial VPP (CVPP) and the Technical VPP (TVPP).

FENIX introduced the terms CVPP and TVPP by using the following definitions:

Commercial VPP (from [10])
A CVPP has an aggregated profile and output which represents the cost and operating characteristics for the DER portfolio. The impact of the distribution network is not considered in the aggregated CVPP profile. Services/functions from a CVPP include trading in the wholesale energy market, balancing of trading portfolios and provision of services (through submission of bids and offers) to the system operator. The operator of a CVPP can be any third party aggregator or a Balancing Responsible Party (BRP) with market access; e.g. an energy supplier.

Technical VPP (from [10])
The TVPP consists of DER´s placed in the same distribution network region. The TVPP includes the real-time influence of the local network on DER aggregated profile as well as representing the cost and operating characteristics of the portfolio. Services and functions from a TVPP include local system management for Distribution System Operator (DSO), as well as providing Transmission System Operator (TSO) system balancing and ancillary services. The operator of a TVPP requires detailed information on the local network.

From the definitions several commonalities can be seen between Microgrids and VPPs. Both provide an aggregation platform for DERs to integrate them in the overall operation of the power system. Furthermore, also the Microgrid acts as market role and participates on energy markets.

In contrast to VPPs a Microgrid is generally intended to balance supply and demand. It always contains a distribution network which has to be managed. Furthermore, an important difference is the ability of the Microgrid to run autonomously in islanding mode. To support this mode the Microgrid requires a well planned mix of generation, intelligent loads and also storage devices to achieve an energy balance of supply and demand.

In summary, Microgrids comprise and extend the essential commercial and technical functions of VPPs. Hence, also some identified use cases in Chapter 4 and Chapter 5 are relevant for VPPs and we believe that a subset the ICT requirements which will be derived in the subsequent task is certainly valid for VPPs.

3.3 Related work

The following projects had a special influence on the selection of use cases in WP3:

- "Microgrids/More Microgrids", EU, http://www.microgrids.eu/default.php
(islanding mode, flexible AC distribution system, inclusion of renewables into a microgrid, forecasting supply and demand)

- "Fenix- Flexible Electricity Networks to Integrate the expected Energy Evolution", EU, http://www.fenix-project.org/
(Technical Virtual Power Plant, Commercial Virtual Power Plant)

- "AlpEnergy -Virtual Power Systems as an Instrument to Promote Transnational Cooperation and Sustainable Energy Supply in the Alpine Space"; EU, http://www.alpenergy.net
(Technical Virtual Power Plant, Microgrid islanding mode, Data acquisition and monitoring, demand side management, price induced load shift, smart metering, load balancing etc.)

- "E-Energy -ICT-based energy system of the future", GE , http://www.e-energy.de/en/index.php
(Virtual Power Plant, Data acquisition and monitoring, demand side management, price induced load shift, smart metering, energy market place, load balancing etc.)

- "INTEGRAL - Integrated ICT-platform based Distributed Control (IIDC) in electricity grids with a large share of Distributed Energy Resources and Renewable Energy Sources", EU, http://www.integral-eu.com/
(DER/RES aggregation, balancing power, emergency mode)

- "ADDRESS- Active Distribution network with full integration of Demand and distributed energy RESourceS", EU, www.addressfp7.org
(Load balancing, SRP-based services, CRP-based services)

- "DISPOWER - Distributed Generation with High Penetration of Renewable Energy Sources", EU, http://www.dispower.org/
(Integration of distributed generation, energy trading, ancillary services)

- "Open Node - Open Architecture for Secondary Nodes of the Electricity SmartGrid", EU, www.opennode.eu
(Smart metering, grid automation, load management)

- "Miracle- Micro-Request-Based Aggregation, Forecasting and Scheduling of Energy Demand, Supply and Distribution", EU, http://wwwdb.inf.tu-dresden.de/miracle/index.html
(Forecasting demand –focus on housholds, Aggregation DERs, micro-request-handling)

3.4 Main Actors in the Microgrid

This section collects all main actors of the Microgrid scenario who occur multiple times in different use cases. Actors are grouped into "people & organization" and "systems & devices" in the following.

3.4.1 People & Organizations

The diagram in Figure 3 provides an overview of all actors in the group "People & Organization".

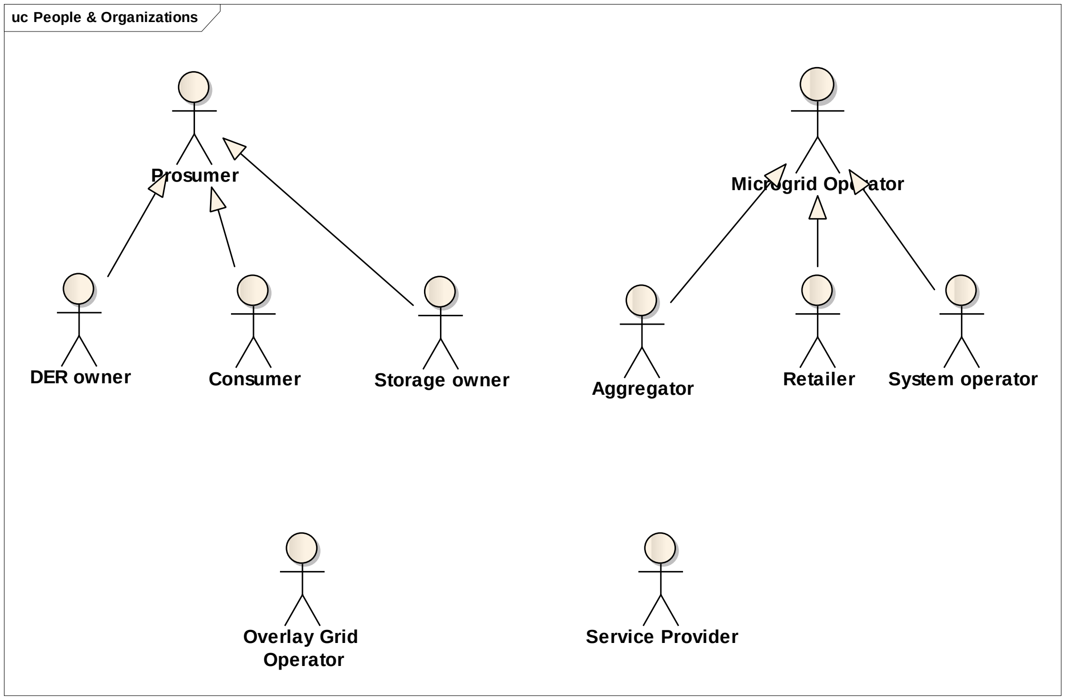

Figure 3: Microgrid actors - People & Organizations

Grouping (Community) '		*Group Description*
People & Organizations		
Actor Name	*Actor Type (person, organization, device, system, or subsystem)*	*Actor Description*
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
Overlay Grid Operator	Organization	The Overlay Grid Operator is the operator of the grid to which the Microgrid has a connection point. The Overlay Grid Operator is a Grid Operator. The term „Grid Operators“, refers to the undertakings of operating, building, maintaining and planning of the electric power transmission and distribution networks [9].
Prosumer	Person/ Organization	The term Prosumer comprises the roles of Consumer, DER owner and Storage owner.
Service Provider	Person/ Organization	The Service Provider provides different kinds of services to the Microgrid Operator to support him in the operation of the Microgrid. This includes e.g. weather forecasts or energy market analysis.

Table 1: Microgrid actors - People & Organizations

Grouping (Community)		*Group Description*
Prosumer		
Actor Name	*Actor Type (person, organization, device, system, or subsystem)*	*Actor Description*
DER Owner	Person/ Organization	The DER Owner (or DG Owner) operates a Distributed Energy Resource (DER) (or Distributed Generation (DG)) which is connected to the Microgrid.
Consumer	Person/ Organization	A consumer of electricity which is a private, business building, large industrial / manufacturing industry or transportation system. The consumer acts as a customer. The consumer may operate Smart Appliances (an electrical load with some intelligence to control it) which are flexible in demand.
Storage Owner	Person/ Organization	Provider of storage capacity for storing and delivering energy.

Table 2: Microgrid actors - Prosumer

Grouping (Community)		*Group Description*
Microgrid Operator		
Actor Name	*Actor Type (person, organization, device, system, or subsystem)*	*Actor Description*
Retailer	Organization	Entity selling electrical energy to consumers – could also be a grid user who has a grid connection and access contract with the TSO or DSO [9].
Aggregator	Organization	Market participant purchasing/selling electricity products on behalf of two or more consumers/generators/DERs [9]. In a small Microgrid the Microgrid Operator acts also as Aggregator. In a large Microgrid the Aggregator might be an own legal entity and the Microgrid Operator contracts with this entity.
System Operator	Organization	Responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system of the Microgrid.

Table 3: Microgrid actors – Microgrid Operator

3.4.2 Systems & Devices

The diagram in Figure 4 provides an overview of all actors in the group “Systems & Devices”.

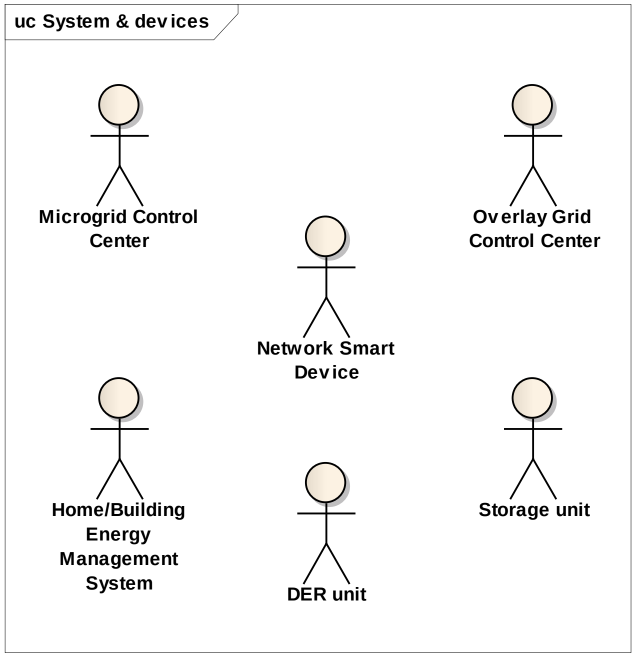

Figure 4 : Main actors - Systems & Devices

Grouping (Community) '		*Group Description*
System & Devices		
Actor Name	*Actor Type (person, organization, device, system, or subsystem)*	*Actor Description*
Microgrid Control Center	System	The control system comprehending different subsystems of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.
Overlay Grid Control Center	System	Control center from which the overlay grid is operated. All required supervision and control functions are carried out here.
DER Unit	Device	Distributed Energy Resource including Distributed Generation (small PV, wind, etc.) which is connected to the Microgrid. The device provides some degree of intelligence to be monitored and controlled.
Storage Unit	Device	Storage unit provides an electricity reserve to the Microgrid. The device provides some degree of intelligence to be monitored and controlled.
Home/Building Energy Management System	System	System acting at the interface between Smart Home/Building and the Microgrid. It communicates in-house with Smart Appliances and to the outside with the Microgrid Control Center. It aggregates the services of the Smart Appliances in the household and provides them to the Microgrid. Furthermore, it can implement some level of intelligence to fulfill the services.
Network Smart Device	Device	An intelligent electrical device in the Microgrid that can be supervised and controlled (e.g. sensors, circuit-breakers or switches)

Table 4: Microgrid actors – System & Devices

3.5 High-Level Use Cases in the Microgrid

To give an overview of the Microgrid scenario we describe the identified high-level use cases in this chapter. We divide between business use cases and control & management use cases. Business use cases describe the interactions with other market roles to negotiate and to contract energy or ancillary services. Control & management use cases describe the actions taken to run a function of the Microgrid. In general, a business use case relies on one or more control & management use case to fulfil the contractual obligations. A certain overlapping of use cases in both categories was intentionally chosen to avoid white spots.

We identified four business use cases and nine control & management use cases. For providing an overview the UML package diagram for the Microgrid scenario, the diagram for business and for control & management use cases are depicted in Figure 5, Figure 6 and Figure 7, respectively. Furthermore, Table 5 provides an overview and a short description of all identified high-level use cases.

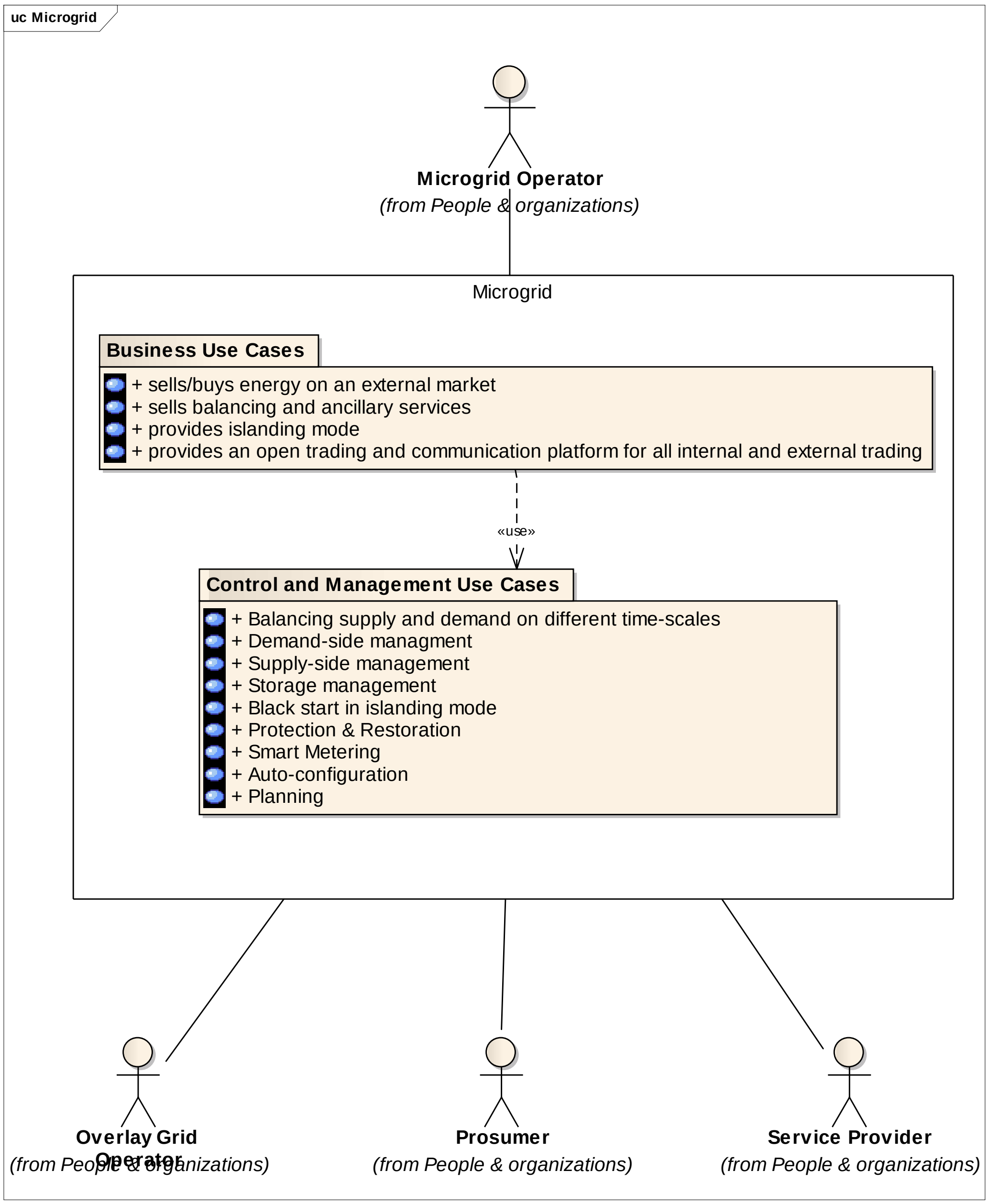

Figure 5 : UML package diagram for Microgrid scenario

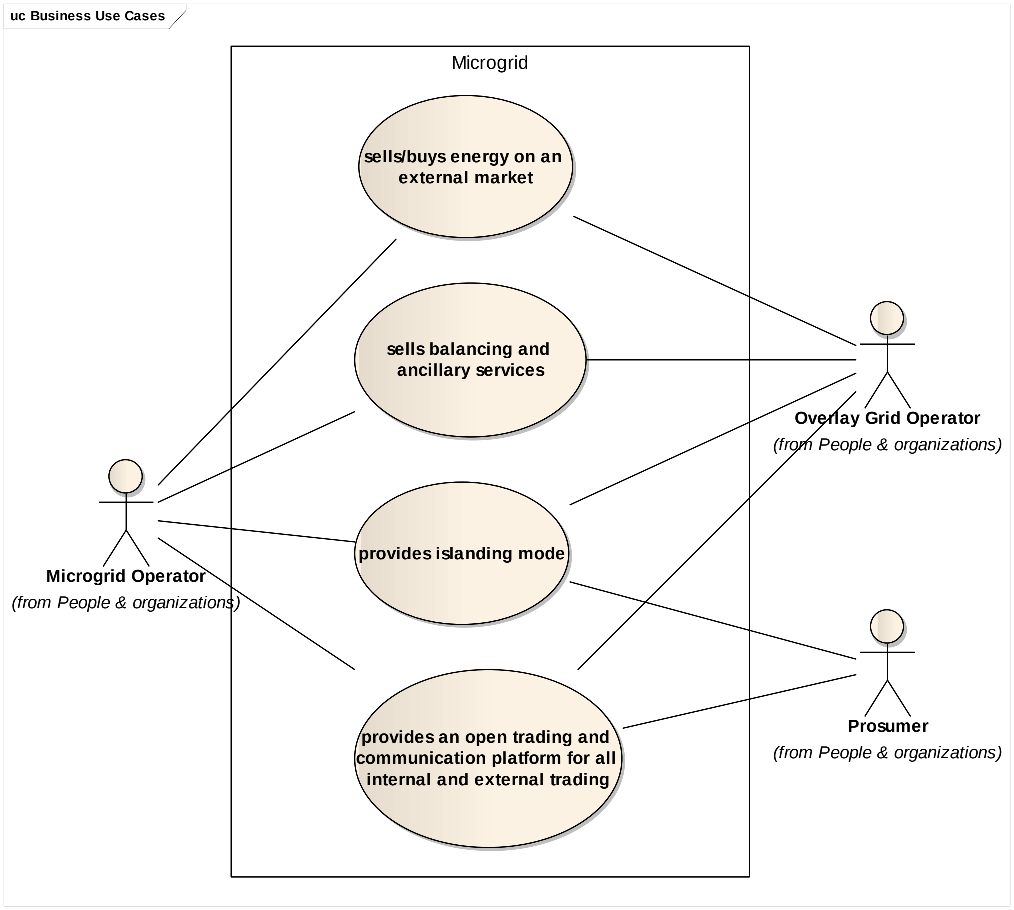

Figure 6 : Diagram of Business Use Cases

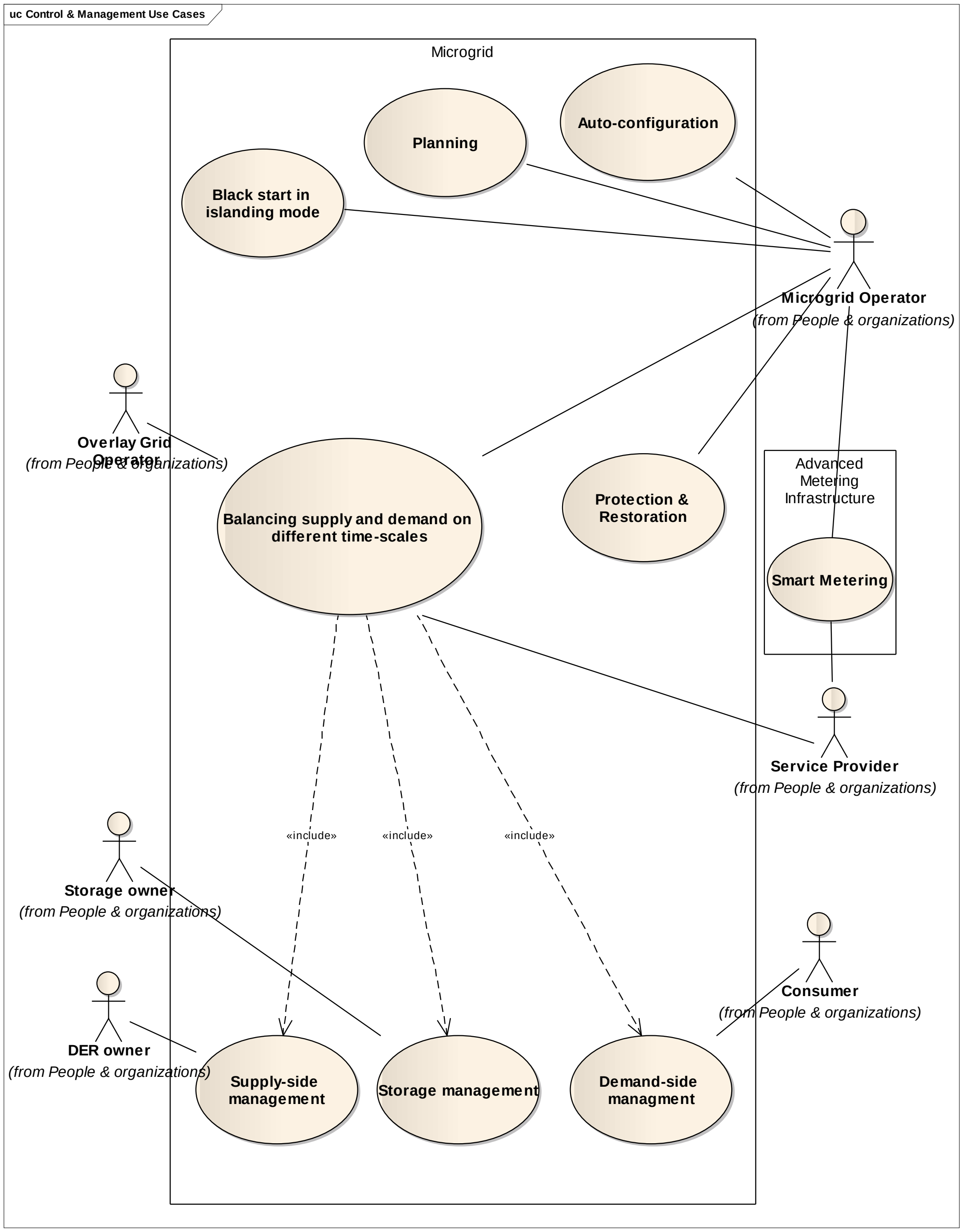

Figure 7 : Diagram of Control & Management Use Cases

High-level Use Case	Description
Business Use Cases	
Microgrid Operator sells/buys energy on external market	The Microgrid operator acts as an aggregator for all his contracted prosumers inside the Microgrid and represents them towards an external market (e.g. wholesale market). This use case is described in detail in Chapter 4.2.
Microgrid Operator sells balancing and ancillary services	The Microgrid operator sells balancing or ancillary services for the stabilization of the electric power network or the consumption of CO_2 or other climate related budgets. This use case is described in detail in Chapter 4.3.

Microgrid provides Islanding Mode	The Microgrid operator provides the service to go in islanding mode to the overlay grid operator. This use case is described in detail in Chapter 4.4.
Microgrid provides an open trading and communication platform for all internal and external trading	This use case comprises supply-side players such as micro-sources and central generators as well as demand-side players such as storage devices and normal end consumers, both inside and outside of the Microgrid. Selling and buying of energy on the internal and external markets under various optimization strategies is the main purpose of this use case. In contrast to the use case "Microgrid Operator sells/buys energy on external market", this use case takes into account all different markets inside and outside the Microgrid. The Microgrid operator is no longer an aggregator for all prosumers in the Microgrid, but provides an open trading platform for all internal and external trading of the prosumers in the Microgrid. The openness of this market platform ensures the competition between all market participants inside and outside of the Microgrid. This use case is described in more detail in Chapter 4.4. The scope of this work package is primarily on the stable operation of the Microgrid and we focus on the control and management use cases. Hence, this use case is not studied in detail. In FINSNEY Work Package 6 addresses electronic marketplaces in detail.
Control & Management Use Cases	
Balancing supply and demand on different time-scales	Reliable and efficient performance of a Microgrid is based on the central tasks of load balancing and power stabilization. Besides a permanent balance between power generation and consumption electrical stability is mainly handled through voltage and frequency control. Control methods can vary from direct control to agent-based approaches. This use case is described in detail in Chapter 5.1.
Demand-side Management	Demand-side management includes the planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage [9]. This includes also automated processes for load management. This use case is described in detail in Chapter 5.2.
Supply-side Management	Supply-side management includes the planning, implementation, and monitoring of utility activities designed to monitor and control Distributed Energy Resources (DERs). This use case is described in detail in Chapter 5.3.
Storage Management	Storage devices are very important in the Microgrid scenario to ensure the balancing of (volatile) supply and demand. It includes a broad field of different kinds of solutions from pumped-storage to electric vehicles. From ICT perspective we see overlap with demand-side as well as supply-side management. Hence, detailed use cases for storage management are not studied in the Microgrid scenario. Furthermore, Electric Mobility is studied in FINSENY by Work Package 5 in detail.
Black Start in Islanding Mode	Black start in islanding mode describes the restoration procedure of the Microgrid after a general system black out using predefined rules and exploiting autonomous agent concepts. This use case is described in detail in Chapter 5.4.
Protection & Restoration	Improvement in the utility reliability and power quality can be done by minimizing the effect of faults and interruption for the supply of the customers. One of the ways is to enhance the coordination between the protection systems and the switches. The general practice for alleviating outages or faults in power systems is

	the isolation of the faulted part of the power system. In the process of isolation, some un-faulted areas loose power. Restoring power, as soon as possible, to these out-of-service areas is essential. That process is called restoration. It entails a fast and efficient switch operation scheme that isolates the faulted area and restores the remaining parts of the system. Fault indicators (FI) and over-current protective relays are the main devices used for fault detection and isolation in distribution networks. When a permanent fault occurs, the operator knows its occurrence from the information delivered by FIs. Then, orders to the breakers and switches will be sent for localizing, isolating the faulty section and re-energizing the same sections of the network. The fault treatment processes need protection systems which are coordinated by ICT infrastructure. In FINSENY this use case is also studied in Work Package 2 “Distribution Network”. Hence, it is not studied in detail in the Microgrid scenario.
Smart Metering	The Microgrid relies on the availability of an Advanced Metering Infrastructure for Smart Metering. Without it the functions or services on supply-side and demand-side cannot be metered and accounted. Furthermore, Smart Metering is often seen as a prerequisite of Smart Grids and provides the first step for encouraging the customer to participate more actively in energy management. In this work package we will not study the use cases of smart metering in any depth because it is not the primary scope of the Microgrid scenario. However, to draw a complete picture it is shown in the overview of the identified control and management use cases. Other projects, e.g. the European project OPEN Meter [11], study smart metering in detail. For example, use cases of smart metering are described in D1.1 [12] of the OPEN Meter project. Furthermore, a short overview of the work in support to the Smart Metering Mandate M/441 is given in [10].
Auto-configuration	When new devices (e.g. DERs or intelligent appliances) or sub-systems (e.g. Home/Building Energy Management Systems) are installed in the Microgrid they automatically configure itself. All monitoring and control functions of the devices can be used after auto-configuration in a secure and trusted manner by the Microgrid control center. This use case is described in detail in Chapter 5.5.
Planning	For the design and update of the Microgrid infrastructure planning tools and simulations are used which take different possible changes into account (e.g. w.r.t. DERs, grid topology, population, regulation, etc.). This use case is described in detail in Chapter 5.6.

Table 5: Overview on high-level use cases

4. Detailed description of Business Use Cases

4.1 Types of Markets

For the description of the business use cases in this chapter, first it is important to understand the different types of today's and possible future markets which may be relevant for the Microgrid scenarios:

- Future (Regional) Retail Market
- General Wholesale Market comprising the main energy market for general national and international trading and the spot energy market for short-term trading
- The balancing market for rebalancing supply and demand in case of upcoming power shortages.
- The market for ancillary services to provide additional services like frequency control, voltage support etc..

4.1.1 Future (Regional) Retail Market

The retail market does not exist right now but probably will in the future as a centralized marketplace operated by an organization (e.g. eBroker providing online brokerage services for electrical power etc.) It will be connected to the general wholesale market described in 4.1.2 and provides a "gate" and a communication platform for the microgrid electricity and service trading to external markets in the overlay distribution network. The energy trade and the services trade are two defined types of the trade between the microgrid and the overlay grid [13].
The Retail Market offers an interface for a Microgrid Operator towards the Overlay Grid Operator in order to buy or sell energy from and to the external markets.
Trading inside the microgrid is not respected here since it is assumed that all microgrid prosumers having a contract with the Microgrid Operator (MO) will trust the MO that he will represent all his customers towards the external markets, and will distribute the internal resources to his customers in the best way respecting the internal energy generation and consumption. No internal trading inside the Microgrid is assumed. An overall trading platform taking into account open trading inside and outside the microgrid is described briefly as an alternative in Chapter 3.5.

4.1.2 General Wholesale Market

This market will be the overall energy market available for all players on the energy supply and demand side. In principle, it is already available today. It will support all users and organizations that generate or consume electrical energy.

4.1.2.1 Main Energy Market

The task of this sub-market of the general wholesale market is to deal with the energy bids and offers nationally and even internationally in order to provide electrical power in the best and most suitable way concerning business aspects.
Figure 7 [15] provides an overview of today's electricity market transactions:

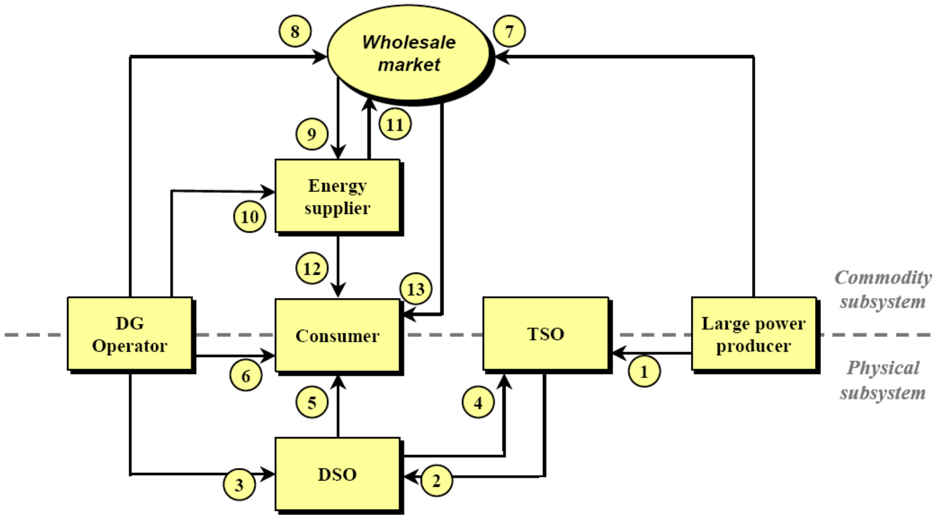

Figure 8 : Transactions on the wholesale market [15]

The physical subsystem comprises both the hardware physically producing and transporting electricity to customers, and the equipment using the electricity. In contrast, the commodity subsystem includes the actors involved in the production, trade or consumption of electricity, in supporting activities or their regulation, and their mutual relations [15].

In the following table, the financial transactions and information exchanges between the energy market actors to efficiently allocate costs and benefits are shortly explained:

Actor		Offers	To	Expects in return
1	TSO	Connection to and use of transmission network	Large power producer	Connection charge + in some jurisdictions use of system charge
2	TSO	TN-DN power transmission services	DSO	Use of system charges on behalf of their customers
3	DSO	Connection to and use of distribution network	DG operator	Connection charge + in some jurisdictions use of system charge
4	TSO	DN-TN power transmission services	DSO	Use of system charges on behalf of their customers
5	DSO	Power distribution services	Consumer	System (TS+DS) charges
6	DG operator	Power (physical)	Consumer	Full cost coverage (auto-production)
7	Large power producers	Power (commodity)	Wholesale market	Contract price
8	DG operator (consolidator)	Power (commodity)	Wholesale market	Contract price
9	Wholesale market	Power (commodity)	Energy supplier	Contract price
10	DG operator	Power (commodity)	Energy supplier	Contract price (often based on PPA)
11	Energy supplier	Power (commodity)	Wholesale market	Contract price
12	Energy supplier	Power (commodity)	Consumer	Contract price
13	Wholesale	Power (commodity)	(Large)	Contract price

	market		consumer	

Table 6 : Transactions on the wholesale market [15]

The main energy market deals with the day-ahead and long-term schedules and plans for the energy trading.

4.1.2.2 Spot Energy Market

The spot energy market today is the platform for short-term and even instant trading of energy and power resources. It negotiates prices for power within fractions of a second and can provide it within a few minutes to its buyers.
Spot markets can be either privately operated or controlled by industry organizations or government agencies. Also in the future some kind of spot market will exist.

4.1.3 Balancing Market and Regulation

An elegant and efficient way of balancing and regulating the electricity system is the establishment of a separate and additional balancing market [15]. According to [15], in many European control areas the ongoing liberalisation of the energy market has led to the establishment and today’s availability of these separate markets in parallel to the general wholesale market. The market rewards the cooperation for the stabilization of the electric power network. Balance is reached when the supply (production and import) is equal to the demand (consumption and export).
The controller of the balancing market is the TSO who also is the single buyer on this market. Access to the supply side of the balancing market is mainly limited to the large power producers, but DG operators and energy suppliers also have access.
As soon as a situation of power shortage arises, the TSO corrects this by buying the lowest priced offer in the balancing market. Most offers come from the large power producers. The TSO may charge the energy supplier(s) that caused the imbalance on basis of the (relatively high) price that it has paid on the balancing market.
Vice versa, in case of a surplus of produced electricity the TSO accepts and receives the highest bid in the balancing market for adjusting generation devices downwards. Also in this case the energy supplier(s) pay the TSO so-called “imbalance charges”. Handling these imbalance charges is arranged in the energy contracts between all market players.
In case a large power producer does not comply with its contracts, e.g. there is a malfunctioning of a generating facility, it has to pay for the balancing costs itself, as large power producers are responsible for their own energy program. To stimulate market players to make their forecasts of electricity production and demand as accurate as possible and to act in accordance with these energy programs, the price for balancing power (imbalance charges) must be above the market price for electricity. Because balancing power is typically provided by units with high marginal costs, this is in practice always automatically the case.
Table 1 shows a classification for providing stabilization and balance in a national electrical network. In these markets, incomes are higher than in the general wholesale market for the same energy amount traded.

	Balance and Regulation Services		
Service	Definition	Nature	Providers
Primary Regulation	Generators adapt performance automatically in case of frequency changes (<30 sec)	Unpaid & mandatory	All generators
Secondary Regulation	Regulated performance to avoid changes in frequency (<= 100 sec)	Paid & Facultative	Generation groups enabled by network operator and integrated in regulation areas.

Tertiary Regulation	Power variation with respect to plan. Response in no longer than 15 minutes, duration of at least 2 hours (<15 min)	Paid & Facultative (Mandatory offer)	Generators and pumping units authorized by the OS

Table 7 : Regulation and Balancing

For participation in the regulation and balancing, different requirements have to be fulfilled. For instance, with respect to response time, these are:

- for the Secondary Regulation participants should be able to start or increase power generation in less than 100 seconds
- for the Tertiary Regulation participants should be able to start or increase power generation in less than 15 minutes, and remain producing energy at least for two hours.

4.1.4 Market for Ancillary Services

In addition to regulation, ancillary services are all services necessary for the operation of a transmission or distribution system [15]. It comprises compensation for energy losses, frequency control (automated, local fast control and coordinated slow control), voltage and flow control (reactive power, active power, and regulation devices), and restoration of supply (black start, temporary island operation). These services are provided by generators and system operators and are required to provide system reliability and power quality.
There is not yet a separate market for all ancillary services today- it may be an additional market that comes up in the near future. The value of the most feasible ancillary services may be relatively low, but such services will represent incremental revenue opportunities for DGs, usually in circumstances where constraints restrict network development, e.g. environmental, planning, and terrain related constraints. An example for environmental restrictions may also be the CO_2 production control.

Ancillary service	Large power producers	DG operators
Compensation for power losses	+	+
Frequency control	+	
Voltage support (active power)	−	+
Reactive power	−	+
Black start	+	+
Reserve	+	+

Table 8: Possible suppliers of ancillary services on distribution level [15]

4.2 Microgrid Operator sells and buys energy on external markets

Use Case Name

Microgrid Operator sells and buys energy on the external markets

Use Case ID

FINSENY/WP3/BUC-1

Scope and Objectives

In this use case, the Microgrid Operator acts as an aggregator for all his contracted prosumers inside the microgrid. He negotiates contracts with his customers (consumers) to represent them towards the (external) wholesale market. DERs or small power plants could also be aggregated (e.g. in VPPs) to reduce the complexity of negotiations and contracts.
The use case comprises supply-side players such as micro-sources as well as demand-side players such as normal end consumers and storage devices in the microgrid. The task is to sell energy produced inside the microgrid and not required microgrid-internally, as well as to buy energy from the wholesale market in times when sufficient energy cannot be produced inside the microgrid. Selling and buying of energy for

the microgrid members on the external wholesale market under various optimization strategies (see below) is the main purpose of this use case. The Microgrid Operator performs bids and offers to the wholesale market based on the bids and offers of the aggregated microgrid prosumers.

The following different ingredients for optimization are possible:

- Revenue optimization based on price profile of external energy suppliers
- Business Interaction based on Demand Response Optimization
- Business Interaction with DERs

4.2.1 Revenue Optimization based on Price Profile of External Energy Suppliers

Use Case Name

Revenue Optimization based on Price Profile of External Energy Suppliers

Use Case ID

FINSENY/WP3/BUC-1.1

Scope and Objectives

The Microgrid Operator uses a variety of strategies and control services to accomplish the goals for revenue optimization for his aggregated customers:

- Forecasting energy production & consumptions on different time scales
- Revenue optimization based on Price Profile
- Business Interactions with DER owners and Consumers
- Prosumer data acquisition and analysis
- Price (cost & earnings) forecasting

The Microgrid Operator has to adjust internal generation and consumption based on the current and next term market and price conditions. From the current and forecasted electricity generation and consumption of its own customers he develops an offering and bidding strategy to achieve the optimal revenue for his Microgrid customers. For this purpose he will further develop incentives for his customers to influence generation and consumption. To achieve this task, credible data have to be collected from all stakeholders and from the energy market.

Influencing the non-variable generation is easier than variable-output generation - from e.g. wind power or PV’s – because the latter is based on e.g. numerical weather prediction data, further fed into statistical data modeling tools.

Use Case Diagram

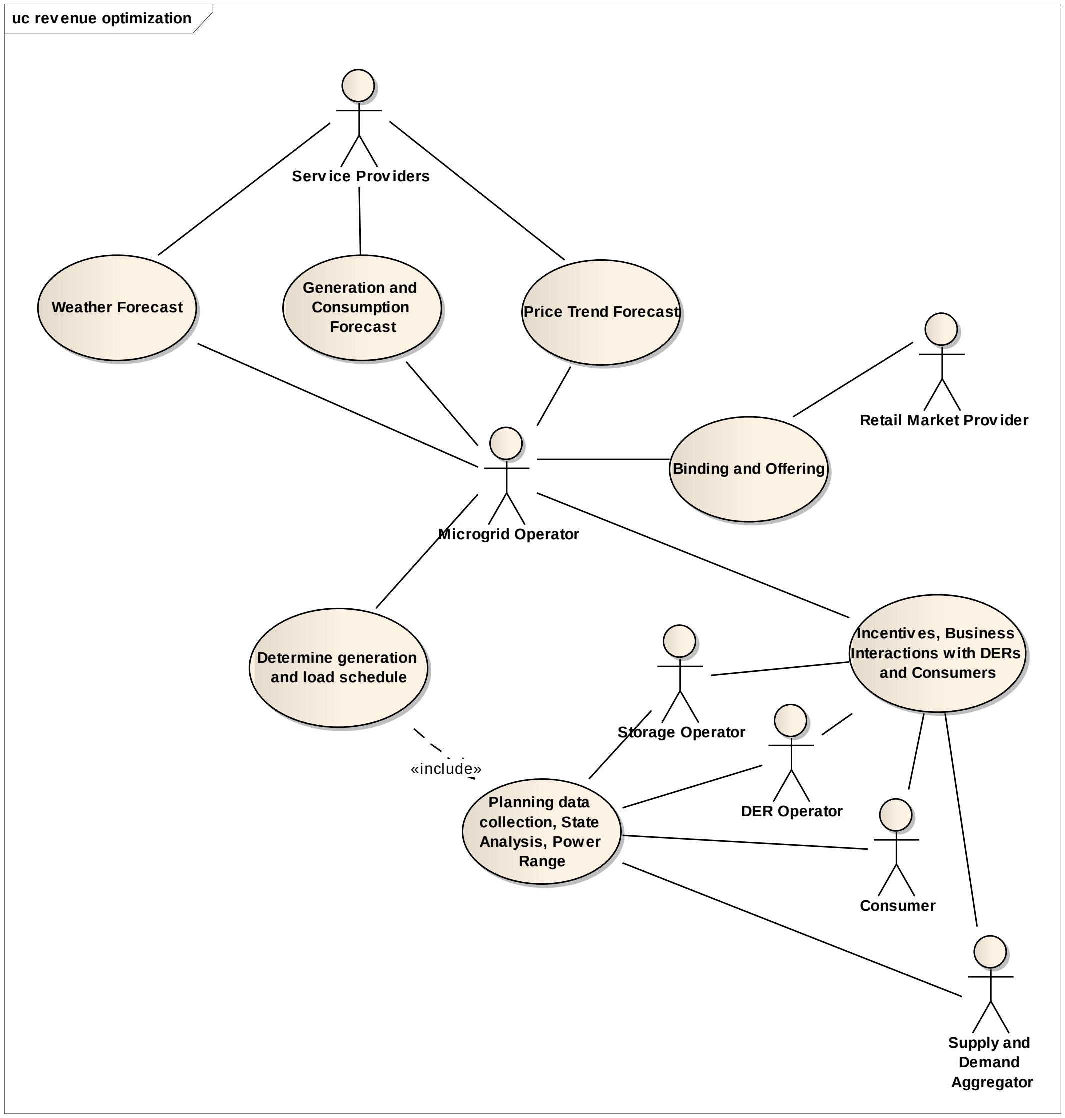

Figure 9: Diagram of Use Case "Revenue Optimization based on Price Profile of External Energy Suppliers"

Actors of Use Case

Grouping (Community) ’		Group Description
Actor Name	**Actor Type (person, organization, device, system, or subsystem)**	**Actor Description**
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
Service Provider	Person/ Organization	The Service Provider provides different kinds of services to the Microgrid Operator to support him in the operation of the Microgrid. This includes e.g. weather forecasts or energy market analysis.
Retail Market Provider	Organization	Delivers a trading platform offered by the Retail Market Owner for all Smart Grid Operators
Supply and Demand Aggregator	Organization	Aggregates on demand-side several households, commercial buildings, or residential areas and on supply-side several generation units. In a small Microgrid the Microgrid Operator acts also as Aggregator. In a large Microgrid the Aggregator might be an own legal entity and the Microgrid Operator contracts with this entity.
Consumer	Person/ Organization	A consumer of electricity which is a private, business building, large industrial / manufacturing industry or transportation system. The consumer acts as a customer. The consumer may operate Smart Appliances (an electrical load with some intelligence to control it) which are flexible in demand.
Storage Owner	Person/ Organization	Provider of storage capacity for storing and delivering energy
DER Owner	Person/ Organization	The DER Owner (or DG Owner) operates a Distributed Energy Resource (DER) (or Distributed Generation (DG)) which is connected to the Microgrid.

Table 9: Actors of Use Case “Revenue Optimization based on Price Profile of External Energy Suppliers”

ICT relevance of Use Case

ICT Criteria	Activity	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Planning data collection; consumption & generation parameter adjustments; Incentive negotiations with the customer	Non-real-time, asynchronous data transport; reliable control information flow; transaction-based protocols for incentive (price) negotiations
Data and context management (e.g. volume, models, mining, grade of distribution)	Planning data collection system, e.g. access to contract database (CDB)	Reliable mass data communication system, data models should be based on IEC 61850 and IEC 61968.
Processing (demand,	Forecasting, Planning & Revenue	High demand for computing resources

ICT Criteria	Activity	Requirement
grade of distribution)	optimization	for calculation and simulation models on weather and price forecasts, optimization & behavioural models
Service integration (openness, standard interfaces)	Retail market, bidding & offering and weather forecast services	Seamless integration of internal & external services, open interfaces and data models

Table 10: ICT Relevance of Use Case "Revenue Optimization based on Price Profile of External Energy Suppliers"

Assumptions of Use Cases

Low level Use Case	Preconditions or assumptions
State analysis & subsequent actions	The actual state is available
Continuous determination of power control range	The actual range on energy resources is available
Forecasting energy production & consumption on different time scales	Forecasting data are available
Business interactions based on DR optimization	Incentives for customers are defined
Business Interactions with DERs	Incentives for DER owners are defined

Table 11: Assumptions of Use Case "Revenue Optimization based on Price Profile of External Energy Suppliers"

4.2.2 Business Interaction based on Demand Response Optimization

Use Case Name:

Business Interaction based on Demand Response Optimization

Use Case ID

FINSENY/WP3/BUC-1.2

Scope and Objectives

An aggregator role is given to the Microgrid Operator whose goal is to manage consumers' available flexibility. In order to optimize for different dimensions, Microgrid Operator needs to interact with consumers via their Home/Building Energy Management System and external actors (Overlay Grid Operator). Business interaction comprises information flows regarding marketing, billing, agreement, settlement, forecasting and other issues. The objective of this use case is to reach agreement between relevant players that can both enable and exploit the demand response optimization. Increased price elasticity on the demand side in conjunction with higher demand bid elasticity should be of great interest to achieve a more efficient energy market and revenue optimization on the Microgrid for all microgrid prosumers.

There are two main alternatives to realize this sub use case. These alternatives were initially defined as services in deliverable 1.1 of the ADDRESS project [14]. These are:

1) Short-term load shaping for market optimization
2) Capacity reservation for managing short-term risks

Use Case Diagram

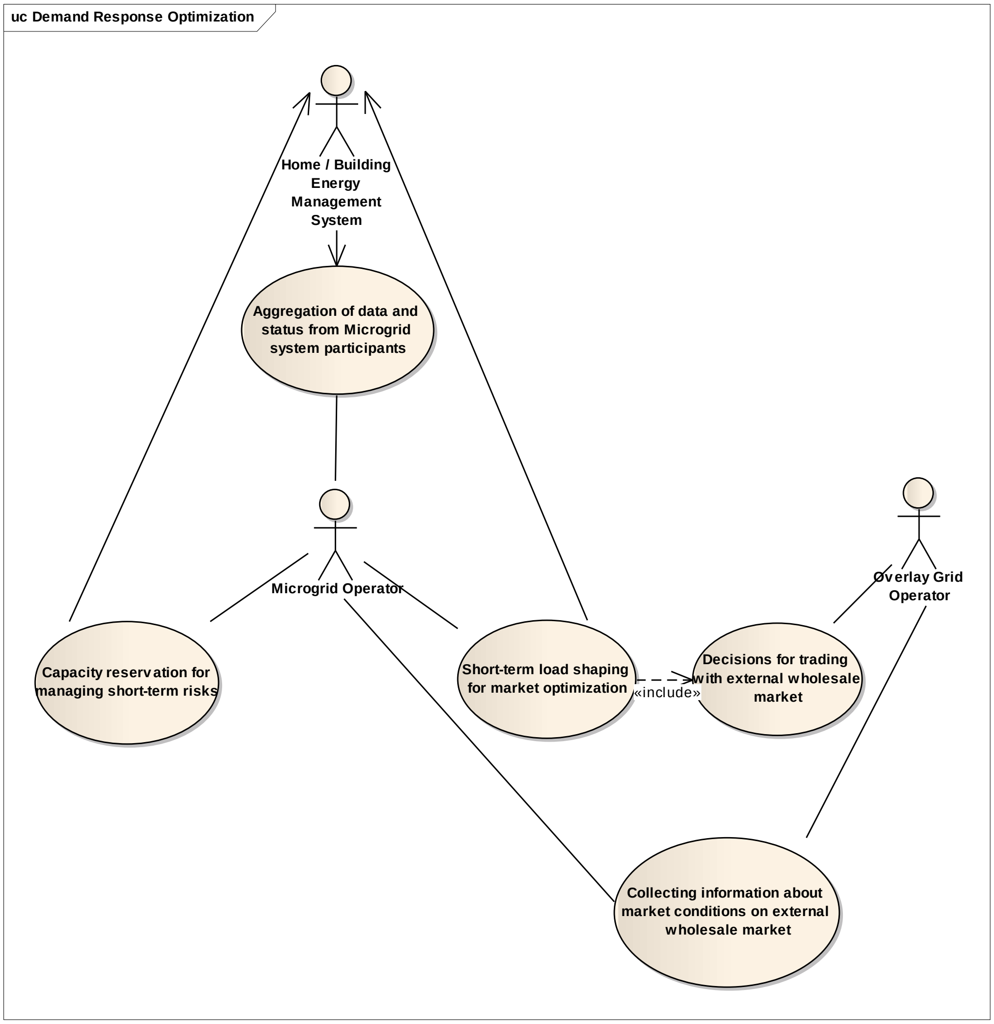

Figure 10: Diagram of Use Case "Business Interaction based on Demand Response Optimization"

4.2.2.1 Alternative 1: Short-term load shaping for market optimization

Microgrid Operator that distributes power within the microgrid seeks ways to optimally match its demand, given the conditions on the external wholesale market. This could mean to sell back or buy electricity on the wholesale markets. The alternative is already included in the former UML diagram.
In order to achieve this without the risk of causing an imbalance, the Microgrid Operator attempts to use the demand response services (active demand [14]).

Actor (Stakeholder) Roles (Alternative 1)

Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
Overlay Grid	Organization	The Overlay Grid Operator is the operator of the grid to which

Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Operator		the Microgrid has a connection point. The Overlay Grid Operator is a Grid Operator. The term „Grid Operators“, refers to the undertakings of operating, building, maintaining and planning of the electric power transmission and distribution networks [9].
Home/Building Energy Management System	System	System acting at the interface between Smart Home/Building and the Microgrid. It communicates in-house with Smart Appliances and to the outside with the Microgrid Control Center. It aggregates the services of the Smart Appliances in the household and provides them to the Microgrid. Furthermore, it can implement some level of intelligence to fulfill the services.

Table 12: Actors of Use Case "Alternative 1: Short-term load shaping for market optimization"

ICT relevance (Alternative 1)

ICT Criteria	Activity	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Short-term load shaping for market optimization	Reliable communication with overlay grid operator and wholesale market participants
Data and context management (e.g. volume, models, mining, grade of distribution)	Short-term load shaping for market optimization	Access to contract database
Processing (demand, grade of distribution)	Short-term load shaping for market optimization	
Service integration (openness, standard interfaces)	Short-term load shaping for market optimization	Access to open interfaces for accessing the wholesale market participants

Table 13: ICT Relevance of Use Case "Alternative 1: Short-term load shaping for market optimization"

Assumptions (Alternative 1)

Low level Use Case	Preconditions or assumptions
Business Interaction for short-term load shaping for market optimization	Realization of an electronic marketplace

Table 14: Assumptions of Use Case "Alternative 1: Short-term load shaping for market optimization"

4.2.2.2 Alternative 2: Capacity reservation for managing short-term (business) risks

A Microgrid Operator that sells power within the microgrid knows that during some periods of the year it is valuable to have some reserve available in order to mitigate adverse events like wholesale price spikes in periods of high demand. This reserve could be provided as a specific capacity for power demand increase or decrease, from the Microgrid Operator. This alternative is also integrated in the UML diagram presented above.

Actor (Stakeholder) Roles (Alternative 2)

Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
Overlay Grid Operator	Organization	The Overlay Grid Operator is the operator of the grid to which the Microgrid has a connection point. The Overlay Grid Operator is a Grid Operator. The term „Grid Operators“, refers to the undertakings of operating, building, maintaining and planning of the electric power transmission and distribution networks [9].
Home/Building Energy Management System	System	System acting at the interface between Smart Home/Building and the Microgrid. It communicates in-house with Smart Appliances and to the outside with the Microgrid Control Center. It aggregates the services of the Smart Appliances in the household and provides them to the Microgrid. Furthermore, it can implement some level of intelligence to fulfill the services.

Table 15: Actors of Use Case "Alternative 2: Capacity reservation for managing short-term (business) risks"

ICT relevance (Alternative 2)

ICT Criteria	Activity	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Capacity reservation for managing short-term (business) risks	Reliable communication with overlay grip operator and wholesale market participants
Data and context management (e.g. volume, models, mining, grade of distribution)	Capacity reservation for managing short-term (business) risks	Access to contract database
Processing (demand, grade of distribution)	Capacity reservation for managing short-term (business) risks	
Service integration (openness, standard interfaces)	Capacity reservation for managing short-term (business) risks	Access to open interfaces for accessing the wholesale market participants

Table 16: ICT Relevance of Use Case "Alternative 2: Capacity reservation for managing short-term (business) risks"

Assumptions (Alternative 2)

Low level Use Case	Preconditions or assumptions
Business interaction for capacity reservation for managing short term risks	Realization of an electronic marketplace

Table 17: Assumptions of Use Case "Alternative 2: Capacity reservation for managing short-term (business) risks"

4.2.3 Business Interaction with DERs

Use Case Name:

Business Interaction with DERs

Use Case ID

FINSENY/WP3/BUC-1.3

Scope and Objectives

The Microgrid Operator has a contract with the Overlay Grid that forces to comply with an agreed energy profile in order to import and/or export energy to Overlay Grid. In order to comply with Overlay Grid contract, Microgrid operator must build contracts with the microgrid DERs according to the energy profile for energy production. Prosumers'-Microgrid contracts enable dynamic modification of energy supply and storage of DERs that are controlled directly from prosumers. The Microgrid Operator balances supply & demand by triggering dynamic energy modification option within the prosumers-microgrid contracts.

Use Case Diagram

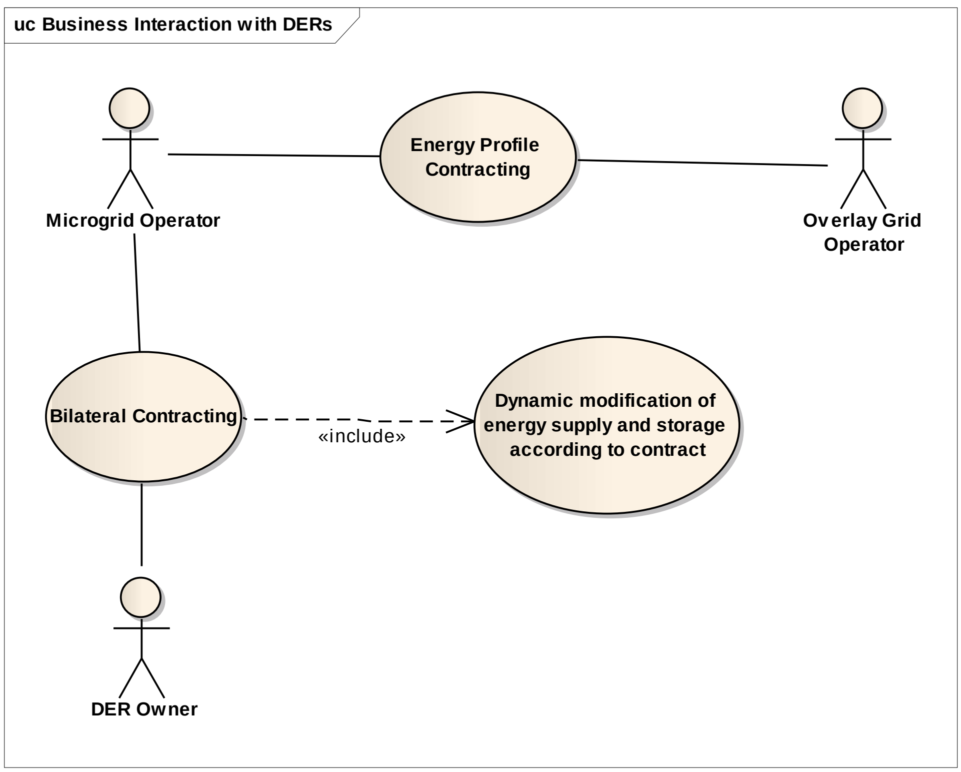

Figure 11: Diagram of Use Case "Business Interaction with DERs"

Actor (Stakeholder) Roles of Use Case

Grouping (Community) '		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
DER Owner	Person/ Organization	The DER Owner (or DG Owner) operates a Distributed Energy Resource (DER) (or Distributed Generation (DG)) which is connected to the Microgrid.
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the

Grouping (Community) '		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
		Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
Overlay Grid Operator	Organization	The Overlay Grid Operator is the operator of the grid to which the Microgrid has a connection point. The Overlay Grid Operator is a Grid Operator. The term „Grid Operators“, refers to the undertakings of operating, building, maintaining and planning of the electric power transmission and distribution networks [9].

Table 18: Actors of Use Case "Business Interaction with DERs"

ICT relevance of Use Case

ICT Criteria	Activity	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Energy Profile Contract	Reliable communication to Contract Database
Data and context management (e.g. volume, models, mining, grade of distribution)	Bilateral contract negotiation	Common high level data semantics for exchanging control information among microgrid operator and prosumers
Processing (demand, grade of distribution)	-	-
Service integration (openness, standard interfaces)	-	-

Table 19: ICT Relevance of Use Case "Business Interaction with DERs"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
	-

4.3 Microgrid Operator sells Balancing and Ancillary Services

Use Case Name:

Microgrid Operator sells balancing and ancillary services

Use Case ID

FINSENY/WP3/BUC-2

Scope and Objectives

As described in Chapter 4.1.3 and 4.1.4, the cooperation for the electrical network stabilization and balancing is rewarded. Incomes are bigger for the same energy amount traded, so it would be interesting for the Microgrid Operator point of view to participate, if possible, in this market instead of the retail market. These could be possible for microgrids where generation can be modulated by choice, e.g. fuel generators, biogas, geothermic, or water turbines.

From the System Operator point of view it would also be interesting to manage regulation in local areas instead of national networks; the reason is that it is very common that the general trend goes against local trend in some local points. For example, we can have some small towns near big cities where people live but do not work, as they do in the capitals, that means that during the diary peak periods those towns have a very low energy demand. If regulation is only national, we can have a near generator uploading energy to the network just in the moment when it is less necessary in that area.
An important aspect that could be controlled by ancillary services, regulation rules and incentives is the optimization of CO_2 consumption or other climate related conditions. The Microgrid Operator may use incentives for the generators/producers and consumers to optimize the total Microgrid CO_2 budget by predominantly using green power generation methods:

- switching on the fly – if possible – to green generation
- reducing consumption of the CO_2 -extensive generation sites

The CO_2 budget of the Microgrid is usually defined in contracts with external government organizations.
The objective of this use case is to increase the incentives for all key players in the market by supporting balance and ancillary services.

Use Case Diagram

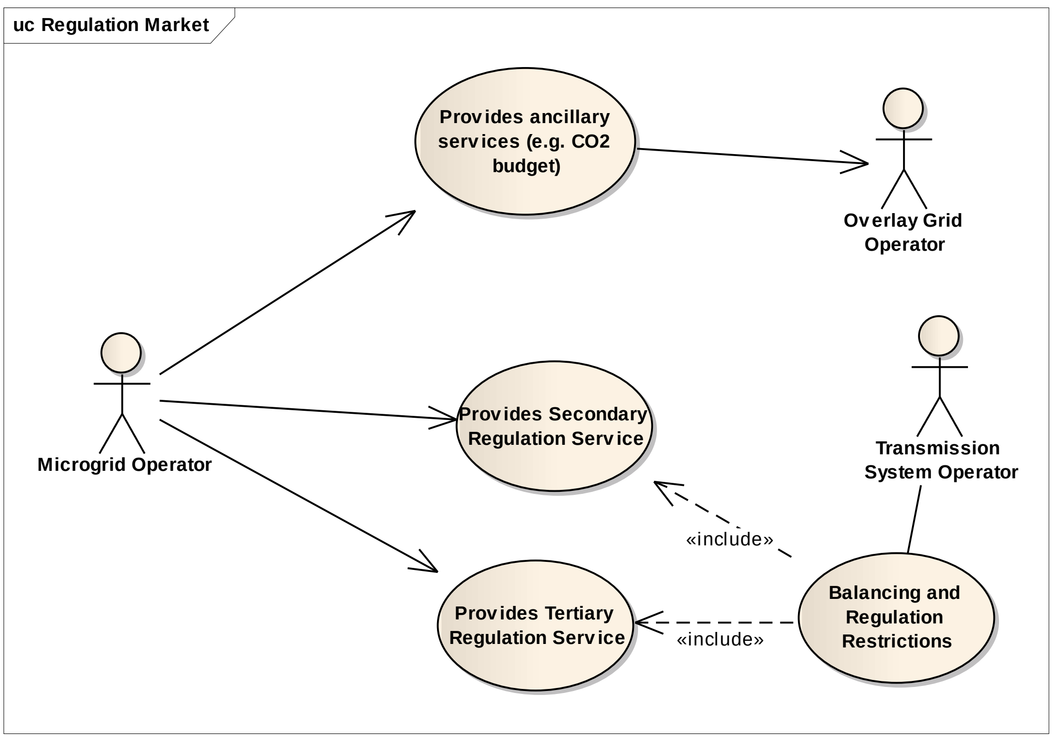

Figure 12: Diagram of Use Case "Microgrid Operator sells Balancing and Ancillary Services"

Actor (Stakeholder) Roles of Use Case

Grouping (Community) '		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the

Grouping (Community) '		Group Description
Actor Name	**Actor Type (person, organization, device, system, or subsystem)**	**Actor Description**
		outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
Overlay Grid Operator	Organization	The Overlay Grid Operator is the operator of the grid to which the Microgrid has a connection point. The Overlay Grid Operator is a Grid Operator. The term „Grid Operators“, refers to the undertakings of operating, building, maintaining and planning of the electric power transmission and distribution networks [9].
Transmission System Operator	Organization	Operates Transmission Network and check technical restrictions in regulation market.

Table 20: Actors of Use Case "Microgrid Operator sells Balancing and Ancillary Services"

ICT relevance of Use Case

ICT Criteria	*Use Case*	*Requirement*
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Secondary Regulation Tertiary Regulation	High Bandwidth, prioritized data. The latency of the communication must be very low for both markets. Low level of distribution.
Data and context management (e.g. volume, models, mining, grade of distribution)	Secondary Regulation Tertiary Regulation	Low data volume, medium context management with medium or low degree of distribution. (From the Microgrid point of view)
Processing (demand, grade of distribution)	Secondary Regulation Tertiary Regulation	High demand for computing resources for matching bids, low degree of distribution.

Service integration (openness, standard interfaces)	Secondary Regulation	Integration with existing regulation market systems.
	Tertiary Regulation	

Table 21: ICT Relevance of Use Case "Microgrid Operator sells Balancing and Ancillary Services"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Secondary Regulation	5.3.2.7 Secondary reserve
Tertiary Regulation	5.3.2.8 Tertiary reserve

Table 22: Assumptions of Use Case "Microgrid Operator sells Balancing and Ancillary Services"

4.4 Microgrid provides Islanding Mode

Use Case Name:

Microgrid provides Islanding Mode

Use Case ID

FINSENY/WP3/BUC-3

Scope and Objectives

The Microgrid Operator provides a new service to the Overlay Grid Operator: The microgrid with all its producers / consumers can switch to islanding mode whenever the Overlay Grid Operator requests this service. A reason for the Overlay Grid Operator to initiate the switch to islanding mode could be, for instance, an emergency case in the overlay network.

The service may be part of a business contract between the two operators. The service itself is realized by the corresponding control and management use case "Switching to/from Islanding Mode" in Chapter 5.1.6.

As an incentive for the microgrid operator to invest in the possibility of being independent from the overlay grid (at least for some time), the overlay grid operator might pay some money for the time when no overlay grid resources are available for the microgrid.

Use Case Diagram

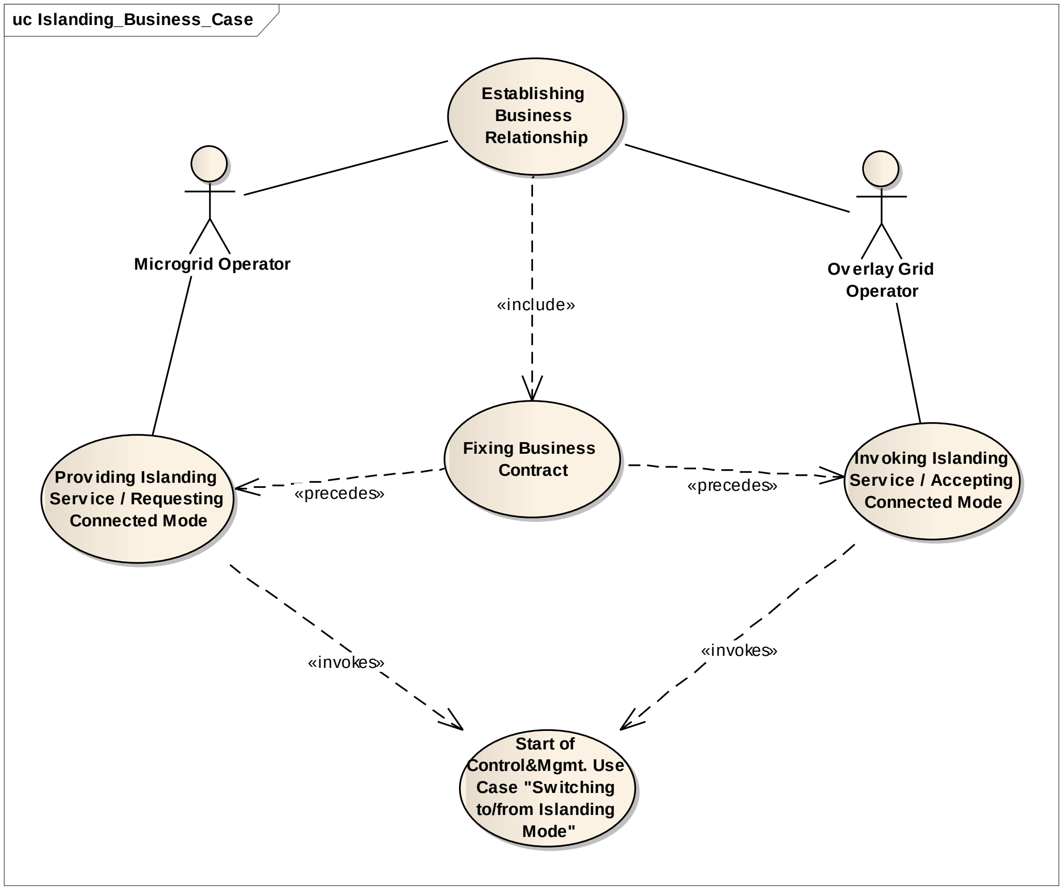

Figure 13: Diagram of Use Case "Microgrid provides Islanding Mode"

Actor (Stakeholder) Roles of Use Case

Grouping (Community) '		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
Overlay Grid Operator	Organization	The Overlay Grid Operator is the operator of the grid to which the Microgrid has a connection point. The Overlay Grid Operator is a Grid Operator. The term „Grid Operators", refers to the undertakings of operating, building, maintaining and planning of the electric power transmission and distribution networks [9].

Table 23: Actors of Use Case "Microgrid provides Islanding Mode"

ICT relevance of Use Case

ICT Criteria	Activity	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Invoking Islanding or Connected Mode (Switch to alternative mode in Microgrid)	Transmission and Evaluation of switch request may be handled in real-time or in regular communication conditions. If “real time” is required, the trans-mission for message “Switch Request” is in the order of <1sec.. When regular communication conditions are sufficient, the switch request may be initiated in a time <1 min. The communication must be reliable (ACKs must be sent) and is using low bandwidth (<128 kbit/s)
Data and context management (e.g. volume, models, mining, grade of distribution)	Switching to Islanding or Connected Mode	Data models should be based on IEC 61850. Data of overlay grid should be saved.
Processing (demand, grade of distribution)	Decision for islanding mode	High demand for computing resources for calculation and simulation models
Service integration (openness, standard interfaces)	Mode Switch	Seamless integration of additional services to support new mode

Table 24: ICT Relevance of Use Case “Microgrid provides Islanding Mode”

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Mode Switching in Microgrid	Corresponding Control&Mgmt UC must be available

Table 25: Assumptions of Use Case “Microgrid provides Islanding Mode”

5. Detailed description of Control & Management Use Cases

5.1 Balancing supply and demand on different time-scales

Use Case Name

Balancing supply and demand on different time-scales

Use Case ID

FINSENY/WP3/CUC-1

Scope and Objectives

Reliable & efficient performance of a Microgrid is based on the central tasks of load balancing and power stabilization. DERs or small power plants could be aggregated (e.g. VPP) as well as the demand (consumers) to ease the burden of load balancing.

Besides a permanent balance between power generation and consumption electrical stability is mainly handled through voltage and frequency control. Energy efficiency is e.g. reached by minimizing the losses, which are smaller the nearer generation and consumption is.

The Microgrid Operator (MO) has to achieve the overall load balance and system stability. Solutions to stability problems of one category should not be at the expense of another. The control services rely on different methods (from direct control to agent-based approaches) and data models are different for DERs (e.g. PV, wind, CHP, biogas), storage and consumption.

For a Microgrid two main modi operandi have to be considered:
- Connected (to the Overlay grid)
- Islanding (autonomous Microgrid)

The simpler way to maintain stability within a Microgrid will be a permanent interconnection with an electrical distribution network. But even in this situation the Microgrid operator may try to keep an internal load balance for efficiency and / or economic reasons.

For the operational task to balance, stabilize and optimize the Microgrid the MO uses forecasting information and the status reports from the demand-side, supply-side and storage management systems. In addition he uses all available information on the power grid.

For this main control task it will be necessary to receive real-time measurements of all energy generators, consumers and storage devices. The control services act on different time-scales and will detect all electrical imbalances, and if the difference between energy consumed and produced exceed a predetermined threshold. In case of an electrical instability the MO uses a bunch of automated and semi-automated ancillary services. In case of a load imbalance the MO will change generation and storage capacity as well as consumption dependent on the actual situation.

Use Case Diagram

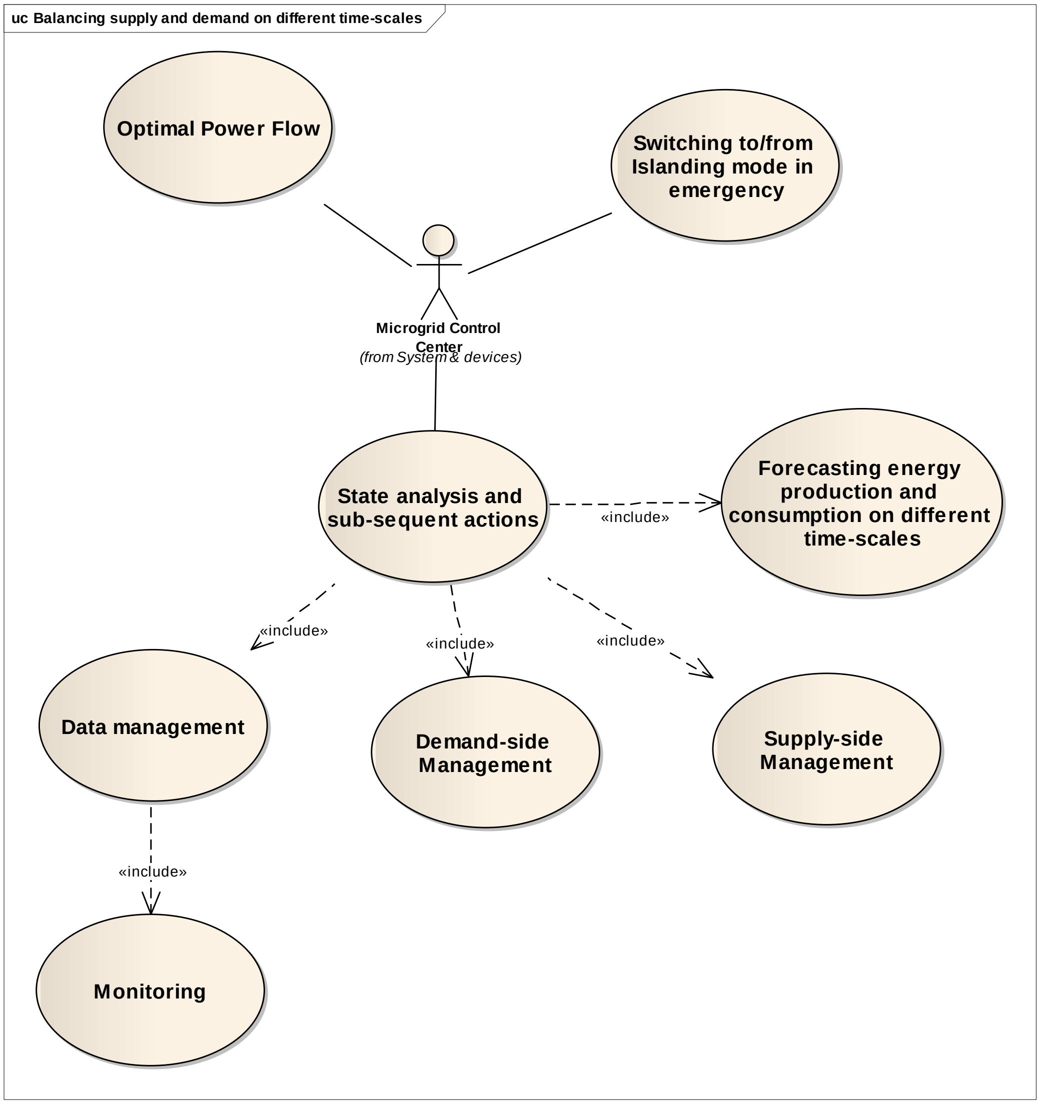

Figure 14: Diagram of Use Case "Balancing supply and demand on different time-scales"

Actor (Stakeholder) Roles of Use Case

Grouping (Community) '		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Control Center	System	The control system comprehending different subsystems of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.

Table 26: Actors of Use Case "Balancing supply and demand on different time-scales"

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Forecasting energy production and consumption on different time-scales	Medium BW for collecting forecast & planning data, non real-time

	Supply-side & Demand-side Management	Low BW for remote control, prioritized data & strict real-time
Data and context management (e.g. volume, models, mining, grade of distribution)	Forecasting & Optimal Power Flow	High demand for context-based data management
	Demand Side & Supply Side	
Processing (demand, grade of distribution)	State analysis	High Demand for computing resources.
	Forecasting	High demand for computing resources for calculation and simulation models. High Distribution.
	Monitoring	Low demand for computing resources. High Distribution.
	Demand-side & Supply-side	Low demand for computing resources. High Distribution.
Service integration (openness, standard interfaces)	Forecasting	Seamless integration of 3rd-party services

Table 27: ICT Relevance of Use Case "Balancing supply and demand on different time-scales"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Forecasting energy production & consumption on different time scales	A system collects all data that can affect energy consumption and/or generation.
Demand-side Management	All equipments necessary to monitor and control the power consumption.
Supply-side Management	All equipments necessary to monitor and control the power generation.
State analysis & subsequent actions	Data processing and Microgrid state analysis
Switching to/from islanding mode	Capability to use the islanding mode
Optimal Power Flow	Optimized power flow and intelligent loss minimization

Table 28: Assumptions of Use Case "Balancing supply and demand on different time-scales"

5.1.1 Forecasting energy production and consumption on different time-scales

Use Case Name

Forecasting energy production and consumption on different time-scales

Use Case ID

FINSENY/WP3/CUC-1.1

Scope and Objectives

The Microgrid operator may have to forecast generation and consumption in order to plan for possible imbalance situations in advance. This requires that he has detailed information about short and long-term generation and consumption profiles, e.g. Numerical Weather Predictions (NWP) and expected consumer consumption during absence periods.
The Microgrid operator uses a variety of strategies and methods to accomplish the output generation forecasting and the load forecasting.

From the weather forecast service, the capacity plans and the mid-term availability of the Microgrid's (aggregated) demand-, supply-side and storage resources the Microgrid operator develops an ahead load balancing schedule.
Generation and consumption can be forecasted within various time horizons with different precision. Needed data are gathered from e.g. past statistics, planned up-times, prosumer vacation/travel times and maintenance schedules.
Non-variable generation from e.g. fuel generators, biogas, geothermal, or water turbines is more predictable than the variable-output generation.
Forecasting of variable-output generation - from e.g. wind power or PVs - is tedious and has to be based on DERs availability and numerical weather prediction data, which are then fed into statistical data modelling tools.
Consumption (Load) forecasts will be based on available past consumer data statistics, expected/planned needs (daily, weekly and monthly periods, etc.), expected weather forecasts, vacation/travel times, and storage level.

Use Case Diagram

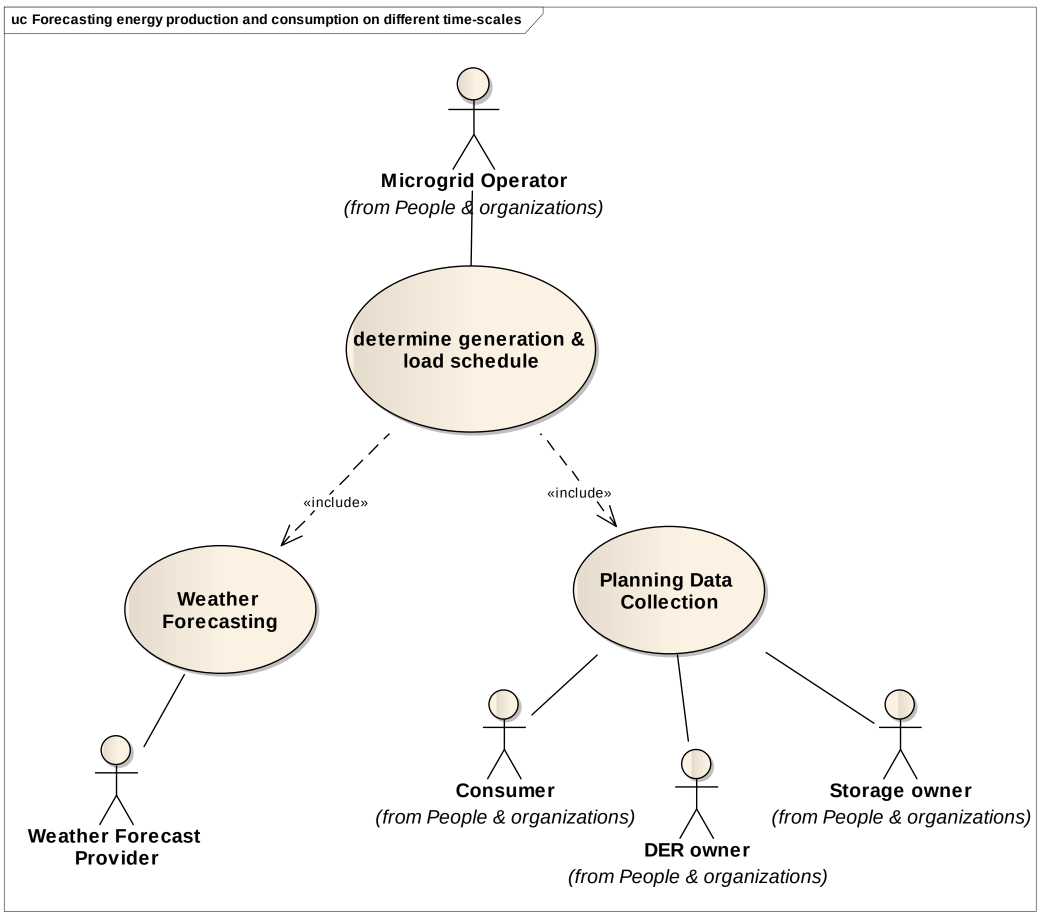

Figure 15: Diagram of Use Case "Forecasting energy production and consumption on different time-scales"

Actor (Stakeholder) Roles of Use Case

Grouping (Community) '		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description

Grouping (Community) '		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
DER Owner	Person/ Organization	The DER Owner (or DG Owner) operates a Distributed Energy Resource (DER) (or Distributed Generation (DG)) which is connected to the Microgrid.
Consumer	Person/ Organization	A consumer of electricity which is a private, business building, large industrial / manufacturing industry or transportation system. The consumer acts as a customer. The consumer may operate Smart Appliances (an electrical load with some intelligence to control it) which are flexible in demand.
Storage Owner	Person/ Organization	Provider of storage capacity for storing and delivering energy
Weather Forecast Provider	Organization	Collect and provide weather forecast data on different timescales

Table 29: Actors of Use Case "Forecasting energy production and consumption on different time-scales"

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Planning Data collection	Medium BW for collecting forecast & planning data, non real-time
Data and context management (e.g. volume, models, mining, grade of distribution)	Determine generation & load schedule	High demand for context-based and filtered data management
Processing (demand, grade of distribution)	Determine generation & load schedule	High demand for computing resources for calculation and simulation models
Service integration (openness, standard interfaces)	Weather Forecasting	Seamless integration of 3rd-party services

Table 30: ICT Relevance of Use Case "Forecasting energy production and consumption on different time-scales"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Planning Data Collection	Auto-configuration

Table 31: Assumptions of Use Case "Forecasting energy production and consumption on different time-scales"

5.1.2 Monitoring

Use Case Name

Monitoring

Use Case ID

FINSENY/WP3/CUC-1.2

Scope and Objectives

A rich monitoring tool is the prerequisite to determine state and performance of the Microgrid.
It has to provide

- data collection, to collect measured data on different time-scales from DERs, Home/Building Energy Management Systems, inverters, switches, substations, and also forecasting and regulation data
- provision of a large variety of graphical data representations
- data logging, to allow comparison between historical data and recent ones

Data, to be collected, are e.g. voltage, current, frequency, phase angle, active and reactive power, and state of the control elements. These data need different monitoring approaches depending on their time horizons. A measurement of these quantities could be time-critical and partially need high sample rates. Further measurements are sent only when they exceed thresholds or every time a state change occurs.

The task is to optimize the data collection to find a compromise between getting precise enough system states and not overloading the monitoring network.

The monitoring protocols have to support all time scales with high reliability. All information collected will be stored in a high-performance database for further processing.

Use Case Diagram

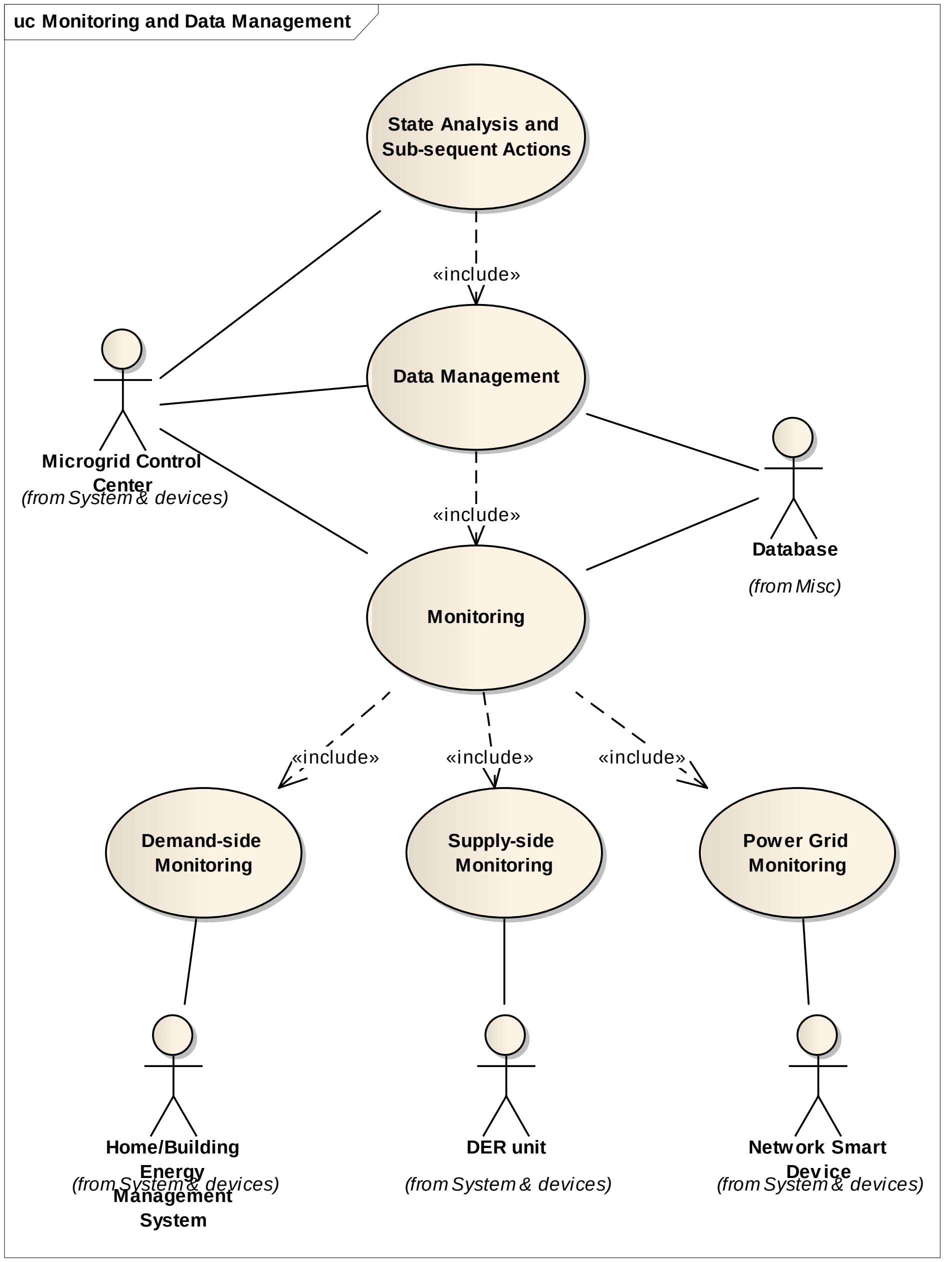

Figure 16: Diagram of Use Case "Monitoring"

Actor (Stakeholder) Roles of Use Case

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Control Center	System	The control system comprehending different subsystems of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.
Home/Building Energy Management System	System	System acting at the interface between Smart Home/Building and the Microgrid. It communicates in-house with Smart Appliances and to the outside with the Microgrid Control Center. It aggregates the services of the Smart Appliances in the household and provides them to the Microgrid. Furthermore, it can implement some level of intelligence to fulfill the services.
DER Unit	Device	Distributed Energy Resource including Distributed Generation (small PV, wind, etc.) which is connected to the Microgrid. The device provides some degree of intelligence to be monitored and controlled.
Network Smart Device	Device	An intelligent electrical device in the Microgrid that can be supervised and controlled (e.g. sensors, circuit-breakers or switches)
Database	System	Database of Microgrid Control Center

Table 32: Actors of Use Case "Monitoring"

ICT relevance of Use Case

ICT Criteria	*Use Case*	*Requirement*
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Supply Side Monitoring	Partially strict real-time, high volume; Protocol Types: Transaction-based, Request/Response, publish/Subscribe; Traffic Management
	Demand Side Monitoring	
	Power Grid Monitoring	
Data and context management (e.g. volume, models, mining, grade of distribution)	Supply Side Monitoring	CIM of monitored data
	Demand Side Monitoring	
	Power Grid Monitoring	
Processing (demand, grade of	Supply Side Monitoring	Interface to the Database:

distribution)	Demand Side Monitoring	High data volume
	Power Grid Monitoring	
Service integration (openness, standard interfaces)	Supply Side Monitoring	Conformance to Standards
	Demand Side Monitoring	
	Power Grid Monitoring	

Table 33: ICT Relevance of Use Case "Monitoring"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Supply-side Monitoring	5.5.3 Registration of DERs owned by the DER owner at the Microgrid Control Center
Demand-side Monitoring	5.5.4 Registration of a Home/Building Energy Management System at the Microgrid Control Center
Power Grid Monitoring	5.5.2 Registration of devices owned by the Microgrid Operator at the Microgrid Control Center

Table 34: Assumptions of Use Case "Monitoring"

5.1.3 Data management

Use Case Name

Data Management

Use Case ID

FINSENY/WP3/CUC-1.3

Scope and Objectives

Data management is one of the key features of a Microgrid where high volumes of real-time and historical, static and dynamic operational data are distributed and/or replicated for parallel processing and access.

Transforming and analyzing this data into useful business and operational intelligence is one of the biggest challenges for the Microgrid.

The Microgrid's Data Management System classifies, processes, correlates and filters the monitored data, and provides meaningful state information of the Microgrid which in turn can be used by all control and management applications.

That means billions of data points have to be instantaneously processed, coordinated, manipulated and interpreted if the Microgrid Operator wants to take full advantage of all resources.

Use Case Diagram

See Chapter 5.1.2, page 46

Actor (Stakeholder) Roles of Use Case

See Chapter 5.1.2, page 46

ICT relevance of Use Case

ICT Criteria	*Use Case*	*Requirement*

Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Data Management	Service Bus supporting QoS
Data and context management (e.g. volume, models, mining, grade of distribution)	Data Management	High-performance database supporting structured and unstructured data Flexible information retrieval (rich query functionalities, complex event processing); Distributed data processing
Processing (demand, grade of distribution)	Data Management	
Service integration (openness, standard interfaces)	Data Management	Flexible data access for third-party modules

Table 35: ICT Relevance of Use Case "Data management"

<u>Assumptions of Use Case</u>

Use Case	*Preconditions or assumptions*
Data Management	See 5.1.2 Monitoring, page 46

Table 36: Assumptions of Use Case "Data management"

5.1.4 State analysis and sub-sequent actions

5.1.4.1 State analysis and sub-sequent actions for providing ancillary services

<u>Use Case Name</u>

State analysis and sub-sequent actions for providing ancillary services

<u>Use Case ID</u>

FINSENY/WP3/CUC-1.4.1

<u>Scope and Objectives</u>

Based on the collected and processed data to determine the Microgrid's state the Microgrid Operator will have to manage DERs and consumers in order to guarantee the network stability.

The stability of the Microgrid - in connected as well as in islanding mode - is affected by voltage and frequency fluctuations, which must stay within predefined acceptable limits. In order to ensure stability in any event the Microgrid Operator will have to monitor all network elements and act accordingly when a deviation exceeds preset thresholds.

For this task the MO can rely on a set of Ancillary Services provided on Demand- and Supply-side, e.g. Active Power Voltage Control, Primary, Secondary and Tertiary Reserve, Load Shedding or Shifting.

<u>Use Case Diagram</u>

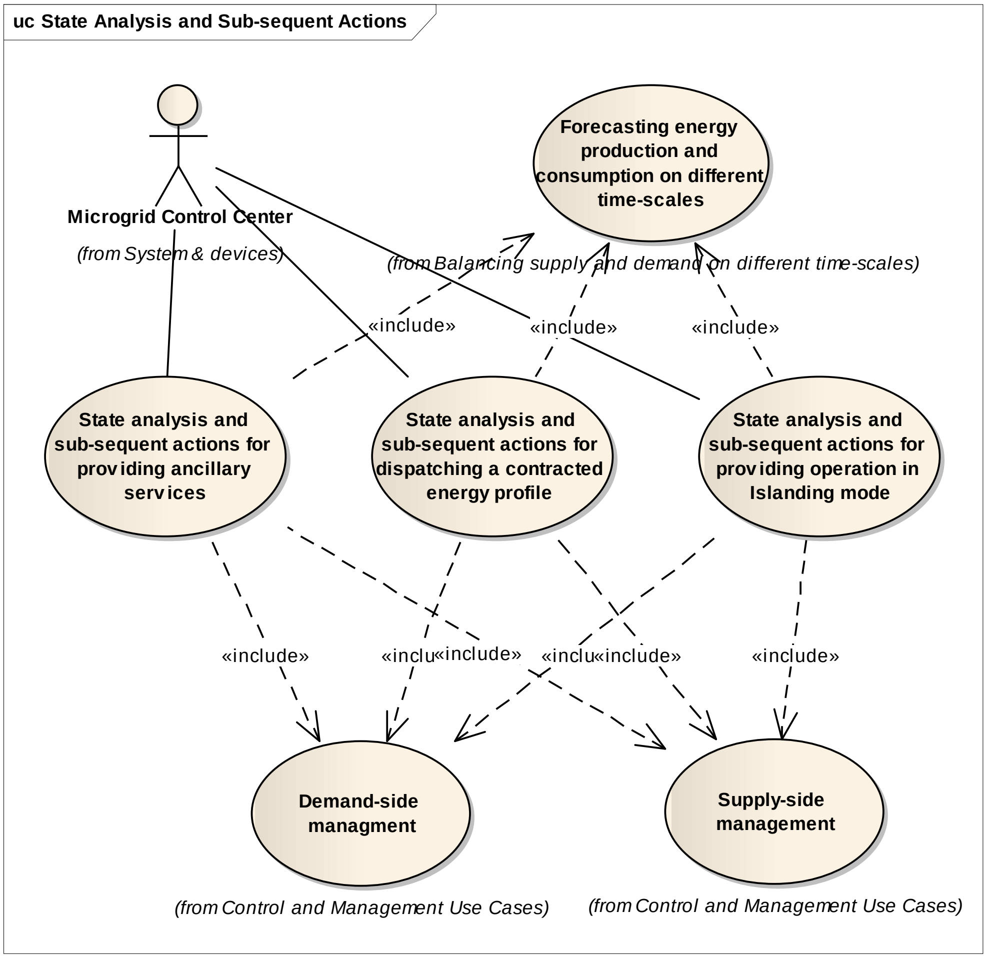

Figure 17: Diagram of Use Case "State analysis and sub-sequent actions for providing ancillary services"

Actor (Stakeholder) Roles of Use Case

Grouping (Community) '		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Control Center	System	The control system comprehending different subsystems of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.

Table 37: Actors of Use Case "State analysis and sub-sequent actions for providing ancillary services"

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	State analysis and sub-sequent actions for providing ancillary services	

Data and context management (e.g. volume, models, mining, grade of distribution)	State analysis and sub-sequent actions for providing ancillary services	Data mining
Processing (demand, grade of distribution)	State analysis and sub-sequent actions for providing ancillary services	High processing power for state calculation
Service integration (openness, standard interfaces)	State analysis and sub-sequent actions for providing ancillary services	

Table 38: ICT Relevance of Use Case “State analysis and sub-sequent actions for providing ancillary services”

Assumptions of Use Case

Use Case	Preconditions or assumptions
State analysis and sub-sequent actions for providing ancillary services	5.1.3 Data management

Table 39: Assumptions of Use Case “State analysis and sub-sequent actions for providing ancillary services”

5.1.4.2 State analysis and sub-sequent actions for dispatching a contracted energy profile

Use Case Name

State analysis and sub-sequent actions for dispatching a contracted energy profile

Use Case ID

FINSENY/WP3/CUC-1.4.2

Scope and Objectives

Microgrid Operator has a contract about import and export of energy profile with the Overlay Grid operator. Contract can be static (e.g. 96 values of kWh per day for every 15 minutes) or dynamic according to an optimization objective (e.g. minimize import / export). The contract is the result of negotiations and market interaction as described in high level use case “4.2 Microgrid Operator sells and buys energy on external markets” (see page 26). In order to dispatch the energy profile, Microgrid Operator combines an efficient mixture of the functions described in high level use cases “5.2 Demand-side management” (see page 60) and “5.3 Supply-side management” (see page 65). Such a mixture can comprise functions like “Automated Load Shifting”, “Price-based Load Shifting”, “Secondary reserve” and “Tertiary reserve”.

In order to effectively utilize the above functions and coordinate each one ahead of time, Microgrid Operator should implement a coordination function (Energy Profile Coordination). The above functions are effective in different time-scales; therefore the coordinator should take this into account and use these functions accordingly. Moreover, the coordinator assesses data that are produced by Forecasting and Monitoring functions which are described in use cases “5.1.1 Forecasting energy production and consumption on different time-scales” (see page 43) and “5.1.2 Monitoring” (see page 46), accordingly.

Use Case Diagram

See Chapter 5.1.4, page 50

Actor (Stakeholder) Roles of Use Case

See Chapter 5.1.4, page 50

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism,	Dispatching a contracted Energy Profile	

ICT Criteria	Use Case	Requirement
grade of distribution)		
Data and context management (e.g. volume, models, mining, grade of distribution)	Dispatching a contracted Energy Profile	Data mining
Processing (demand, grade of distribution)	Dispatching a contracted Energy Profile	Medium demand for computing resources for calculation and simulation models
Service integration (openness, standard interfaces)	Dispatching a contracted Energy Profile	Standard interfaces for invoking other services

Table 40: ICT Relevance of Use Case "State analysis and sub-sequent actions for dispatching a contracted energy profile"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
State analysis and sub-sequent actions for dispatching a contracted energy profile	5.1.3 Data management

Table 41: Assumptions of Use Case "State analysis and sub-sequent actions for dispatching a contracted energy profile"

5.1.4.3 State analysis and sub-sequent actions for providing operation in Islanding mode

Use Case Name

State analysis and sub-sequent actions for providing operation in Islanding mode

Use Case ID

FINSENY/WP3/CUC-1.4.3

Scope and Objectives

If the Microgrid has no connection to any other electrical network, or the Microgrid Operator has to switch to the islanding mode because a critical imbalance occurs he immediately has to take the necessary actions to balance the internal demand and supply. These actions could include load and generation shedding.

Use Case Diagram

See Chapter 5.1.4, page 50

Actor (Stakeholder) Roles of Use Case

See Chapter 5.1.4, page 50

ICT relevance of Use Case

ICT Criteria	*Use Case*	*Requirement*
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	State analysis and sub-sequent actions for providing operation in Islanding mode	
Data and context management (e.g. volume, models, mining, grade of distribution)	State analysis and sub-sequent actions for providing operation in Islanding mode	Data mining
Processing (demand, grade of distribution)	State analysis and sub-sequent actions for providing operation in Islanding mode	High processing power for state calculation

Service integration (openness, standard interfaces)	State analysis and sub-sequent actions for providing operation in Islanding mode	

Table 42: ICT Relevance of Use Case "State analysis and sub-sequent actions for providing operation in Islanding mode"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
State analysis and sub-sequent actions for providing operation in Islanding mode	5.1.3 Data management

Table 43: Assumptions of Use Case "State analysis and sub-sequent actions for providing operation in Islanding mode"

5.1.5 Optimal Power Flow (Intelligent loss minimization)

Use Case Name

Optimal power flow (intelligent loss minimization)

Use case ID

FINSENY/WP3/CUC-1.5

Scope and Objectives

This use case describes how power flow optimization (intelligent loss minimization) can be achieved. A variety of different techniques can be utilized in order to achieve an optimized power flow. This section only describes those that are controlled directly by the MG operator. References to other sections of this document will be included and their relevance for this UC will be explained.

In order to achieve an intelligent loss minimization the following aspects can be utilized by the Microgrid operator.

- Controlling the voltage of the network within the given limits (by OLTC or other technologies that exist nowadays in HV/MV transformers and will exist also in MV/LV transformers in the future). If the voltage is always kept to the maximum, currents of constant power consumers will decrease and therefore also the losses. This could be explained by the relation that enables to evaluate the total real power losses (P_{Loss}). For a one system phase, it can be expressed as follows:

$$P_{Loss} = \sum_{i=1}^{n} r_i I^2 = \sum_{i=1}^{n} r_i \frac{P_i^2 + Q_i^2}{|V_i|^2}$$

-

  where r_i, P_i, Q_i, V_i, are respectively the resistance, real power, reactive power and voltage of branch i, and n is the total number of branches in the system. This carefully needs to be optimized as there are also constant resistance consumers increasing their current with increasing voltage (e.g. light bulbs).
- Another method that can achieve multi objective optimization for operation of microgrid including losses reduction is microgrid reconfiguration. This can be achieved by balancing loads (exchange between feeders). Microgrid reconfiguration is a process that consists in changing the status of the network switches in order to re-supply the non-energized areas after a fault occurrence, or to optimize given criteria (such as grid losses) in normal operation. In a more constrained energy environment, the electric operators are more and more interested in the minimization of active energy losses and consequently in the network reconfiguration process enhancement for this purpose. The reconfiguration for loss minimization is basically a complex combinatorial optimization problem, since the normal open sectionalizing switched must be determined appropriately among a huge population.
- Without changing the network configuration it is possible to influence load flows by controlling active and reactive power injections and consumptions at dedicated points in the network. This is done in the HV and EHV networks with regulating transformers, Statcoms, FACTS etc. and may be done within a Microgrid by utilizing the flexibility in active and reactive power supply / demand of DER units and controllable loads. The Microgrid operator needs to calculate the

optimal load flow and request actions from DER units and controllable loads. The ICT relevance and UC diagram are the same as described in 5.3.2.1 and 5.3.2.1.

Use Case Diagram

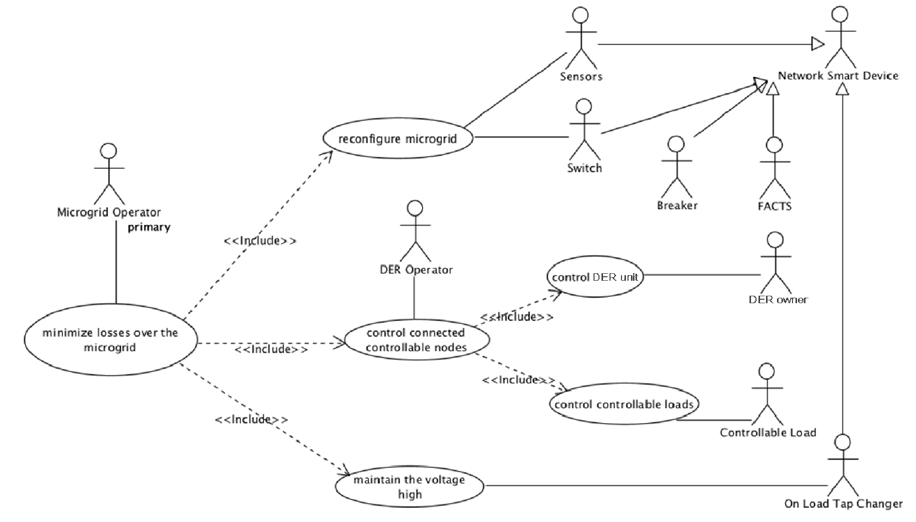

Figure 18: Diagram of Use Case "Optimal Power Flow (Intelligent loss minimization)"

Actor (Stakeholder) Roles of Use Case

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
DER Owner	Person/ Organization	The DER Owner (or DG Owner) operates a Distributed Energy Resource (DER) (or Distributed Generation (DG)) which is connected to the Microgrid.
Network Smart Device	Device	An intelligent electrical device in the Microgrid that can be supervised and controlled (e.g. sensors, circuit-breakers or switches)
Microgrid Control Center	System	The control system comprehending different subsystems of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.
DER Unit	Device	Distributed Energy Resource including Distributed Generation (small PV, wind, etc.) which is connected to the Microgrid. The device provides some degree of intelligence to be monitored and controlled.

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Controllable load	Device	Controllable (Interruptible) load: Refers to program activities that, in accordance with contractual arrangements, can interrupt consumer load at times of seasonal peak load by direct control of the utility system operator or by action of the consumer at the direct request of the system operator.

Table 44: Actors of Use Case "Optimal Power Flow (Intelligent loss minimization)"

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Microgrid Operator invokes Islanding mode	Transmission and Evaluation of disconnection from overlay grid may be handled in real-time: - Transmission for messages for state analysis in the microgrid in the order of "ms" - medium to high bandwidth required, depending on the devices in the microgrid
	Microgrid switching from connected mode to islanding mode	Transmission of new schedules and strategies inside isolated microgrid must be handled in real-time to avoid short outage of energy supply inside microgrid systems - Transmission for message "Switch_islanding_control" in the order of "ms" - eventually medium bandwidth sufficient (< 1 Mbit/s) Transmission of required data and actions less critical (some seconds), medium bandwidth probably sufficient (< 1 Mbit/s)
Data and context management (e.g. volume, models, mining, grade of distribution)	Switching to and from Islanding Mode	New context must be initiated and configured
Processing (demand, grade of distribution) Processing (demamd, grade of distribution)	Switching to Islanding Mode	High demand for computing resources for calculation and simulation models in Microgrid Control Centre
	Switching to Connected Mode	Medium processing demand for adaptation to electrical parameters in Overlay Grid
Service integration (openness, standard interfaces)	islanding mode	same as in connected mode

Table 45 : ICT Relevance of Use Case "Optimal Power Flow (Intelligent loss minimization)"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Construction of the new optimal network configuration	Assuming that efficient ICT systems will be available in the future, all states of switches will be monitored and controlled. Assuming that an intelligent local center run optimization based on loss reduction objective and electro-technical constraints.
Reduction of losses in MG with an appropriate location of distributed generators.	Robust system configuration for suddenly disconnecting DG from the microgrid in case of fault or violation of operation constraints.

Table 46: Assumptions of Use Case "Optimal Power Flow (Intelligent loss minimization)"

5.1.6 Switching to/from Islanding Mode

Use Case Name

Switching to and from Islanding Operation

Use Case ID

FINSENY/WP3/CUC-1.6

Scope and Objectives:

This use case comprises two alternatives:

a) the Microgrid is in connected mode and switches to islanding mode
b) the Microgrid is in islanding mode and switches to connected mode.

The reason for the switching is of no importance for this use case. The use case only deals with the switching operation itself.

Switching from connected mode to islanding mode may cause problems in the Microgrid, when the balance between supply-side and demand-side cannot be achieved in case the internal power generation inside the Microgrid is not sufficient. If so, the Microgrid Operator has to initiate suitable countermeasures to avoid longer-term problems inside the energy provision to his Microgrid customers. The different actions possible here are presented in the use case "State Analysis and sub-sequent actions for providing operation in Islanding mode" (5.1.4.3). This use case includes voltage control within the microgrid. When the overlaying grid is disconnected the short circuit is reduced which results in a more weak voltage profile.

In case of switching from islanding to connection mode, a new adaptation to frequency and voltage level in the Overlay Grid must be initiated.

Use Case Diagram

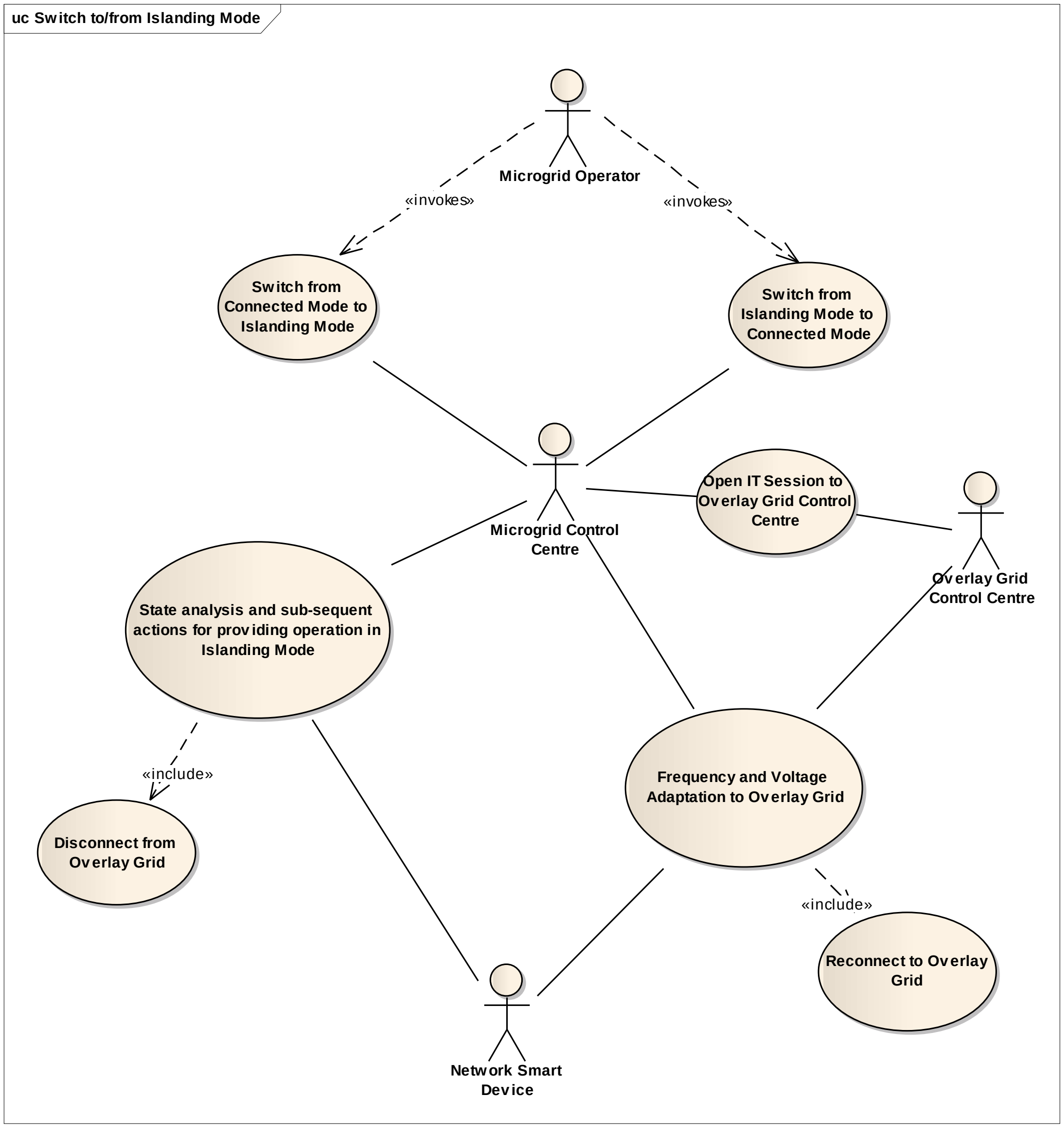

Figure 19: Diagram of Use Case "Switching to/from Islanding Mode"

Actor (Stakeholder) Roles of Use Case

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
Microgrid Control Center	System	The control system comprehending different subsystems of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Overlay Grid Control Center	System	Control center from which the overlay grid is operated. All required supervision and control functions are carried out here.
Network Smart Device	Device	An intelligent electrical device in the Microgrid that can be supervised and controlled (e.g. sensors, circuit-breakers or switches)

Table 47: Actors of Use Case "Switching to/from Islanding Mode"

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Microgrid Operator invokes Islanding mode	Transmission and Evaluation of disconnection from overlay grid may be handled in real-time: - Transmission for messages for state analysis in the microgrid in the order of "ms" - medium to high bandwidth required, depending on the devices in the microgrid
	Microgrid switching from connected mode to islanding mode	Transmission of new schedules and strategies inside isolated microgrid must be handled in real-time to avoid short outage of energy supply inside microgrid systems - Transmission for message "Switch_islanding_control" in the order of "ms" - eventually medium bandwidth sufficient (< 1 Mbit/s) Transmission of required data and actions less critical (some seconds), medium bandwidth probably sufficient (< 1 Mbit/s)
Data and context management (e.g. volume, models, mining, grade of distribution)	Switching to and from Islanding Mode	New context must be initiated and configured
Processing (demand, grade of distribution) Processing (demamd, grade of distribution)	Switching to Islanding Mode	High demand for computing resources for calculation and simulation models in Microgrid Control Centre
	Switching to Connected Mode	Medium processing demand for adaptation to electrical parameters in Overlay Grid
Service integration (openness, standard interfaces)	islanding mode	same as in connected mode

Table 48: ICT Relevance of Use Case "Switching to/from Islanding Mode"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Switching to Islanding Mode	Microgrid can provide sufficient power over the time in islanded mode

Table 49: Assumptions of Use Case "Switching to/from Islanding Mode"

5.2 Demand-side management

Use Case Name

Demand side management (DSM)

Use Case ID

FINSENY/WP3/CUC-2

Scope and Objectives

Demand side management (DSM) is the process of managing the consumption of energy with to goal to increase the grid reliability and stability. Various controlling scenarios and functions take place in order to achieve energy consumption management. Monitoring energy consumption is a reusable and horizontal function which is necessary for other DSM scenarios. Intelligent Load Shedding, Automated Load Shifting and Price-based Shifting are alternative ways to control energy consumption on different times-scales.

Use Case Diagram

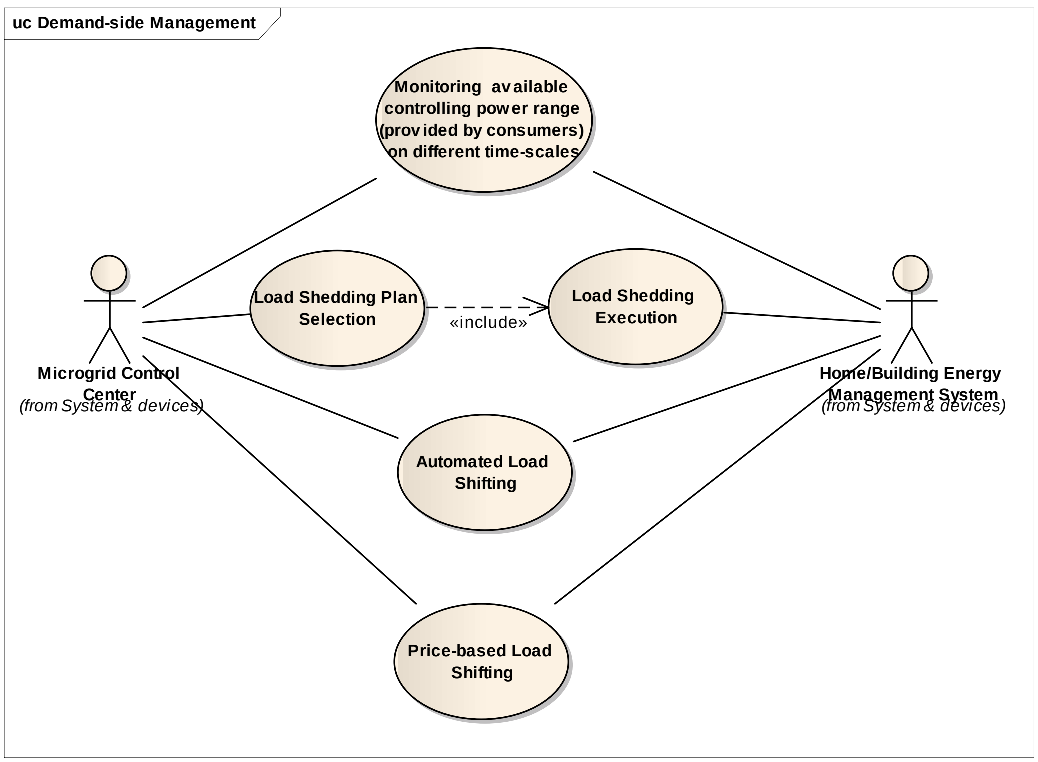

Figure 20: Diagram of Use Case "Demand-side management"

Actor (Stakeholder) Roles of Use Case

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid	System	The control system comprehending different subsystems

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Control Center		of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.
Home/Building Energy Management System	System	System acting at the interface between Smart Home/Building and the Microgrid. It communicates in-house with Smart Appliances and to the outside with the Microgrid Control Center. It aggregates the services of the Smart Appliances in the household and provides them to the Microgrid. Furthermore, it can implement some level of intelligence to fulfill the services.

Table 50: Actors of Use Case "Demand-side management"

ICT relevance of Use Case

See Sub Use Cases

Assumptions of Use Case

See Sub Use Cases

5.2.1 Continuous determination of available controlling power range on different time-scales

Use Case Name

Continuous determination of available controlling power range on different time-scales

Use Case ID

FINSENY/WP3/CUC-2.1

Scope and Objectives

The Microgrid operator has to monitor its own imbalance position and available options to balance it. For this purpose he needs to have a defined amount of control power (depending on the extension of the microgrid) which is either committed by flexible consumers making their loads controllable or power suppliers committing a certain capacity of their DER for control power.

If the control power is provided by flexible consumers making their devices available for load shifting or load shedding an energy management system has to aggregate the availability of the several devices and send the data to the monitoring database which checks the deviations from what is committed. It calculates scenarios on different time scales (e.g. 15 min-4 hours) to provide available options for the Microgrid Operator.

Use Case Diagram

See Chapter 5.2, page 60

Actor (Stakeholder) Roles of Use Case

See Chapter 5.2, page 60

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of	Monitoring available control power on different time-scales	High demand for collecting data about availability, real-time, update from all devices each 15 minute needed

ICT Criteria	Use Case	Requirement
distribution)		
Data and context management (e.g. volume, models, mining, grade of distribution)	Monitoring available control power on different time-scales	Demand for context-based and filtered data management
Processing (demand, grade of distribution)	Monitoring available control power on different time-scales	High demand for computing resources for calculation and simulation models
Service integration (openness, standard interfaces)	Monitoring available control power on different time-scales	Standard interface to energy management system, integration into other components of microgrid operation

Table 51: ICT Relevance of Use Case "Continuous determination of available controlling power range on different time-scales"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Monitoring available control power on different time-scales	Monitoring

Table 52: Assumptions of Use Case "Continuous determination of available controlling power range on different time-scales"

5.2.2 Control services

5.2.2.1 Intelligent load shedding in critical operations

Use Case Name

Intelligent load shedding in critical operation

Use Case ID

FINSENY/WP3/CUC-2.2.1

Scope and Objectives

When Microgrid energy production and consumption comes to imbalance because of either unexpected demand increase or sudden generation drop, then immediate action must take place. Load shedding is a real-time control means to abruptly decrease demand by shutting down loads. In order to minimize the severity of the problems that abrupt load shedding causes, Microgrid Operator prior to load shedding elaborates plans that prioritize loads according to their significance and their characteristics (e.g. time dependence, locality dependence). At the time the Microgrid reaches an instability situation, the problem has to be assessed and a predefined load shedding plan must be selected and executed in real-time. Under this scenario, a careful and intelligent load selection for shutting down loads takes place after automatic assessment of the problem situation. After the assessment and identification of the proper load shedding plan, controllable loads are being shutting down according to the plan, via the exchange of control signals.
Load shedding use case utilizes functions from high level use cases "5.1.2 Monitoring" (see page 46) and "5.1.4 State analysis and sub-sequent actions" (see page 50). Moreover use case comprises the following functions:

- **Load Shedding Plan Selection**. Within the boundaries of this function Microgrid Operator selects the most appropriate load shedding plan to execute according to given time, severity and locality data of the critical situation.
- **Load Shedding Execution**. This function carries out the transmission of the proper control signals to consumers that executes in real-time the load shedding procedures.

Use Case Diagram

See Chapter 5.2, page 60

Actor (Stakeholder) Roles of Use Case

See Chapter 5.2, page 60

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Load Shedding Execution	Reliable communication with very low latency among control entities
Data and context management (e.g. volume, models, mining, grade of distribution)	Load Shedding Plan Selection	High demand for context-based and filtered data management
Processing (demand, grade of distribution)	Load Shedding Plan Selection	High demand for computing resources for calculation and simulation models
Service integration (openness, standard interfaces)	Load Shedding Execution	Publish open interfaces servicing higher level entities

Table 53: ICT Relevance of Use Case "Intelligent load shedding in critical operations"

Assumptions of Use Case

Use Case	Preconditions or assumptions
Monitoring	Use case "5.1.2 Monitoring" (see page 46) is necessary for monitoring the distribution of load and assessing the problem situation.
State Analysis and Subsequent Actions	Use case "5.1.4 State analysis and sub-sequent actions" (see page 50) is necessary for assessing grid state and command load shedding procedures.

Table 54: Assumptions of Use Case "Intelligent load shedding in critical operations"

5.2.2.2 Automated Load Shifting

Use Case Name

Automated Load Shaping

Use case ID

FINSENY/WP3/CUC-2.2.2

Scope and Objectives

In this use case we assume an infrastructure at the consumers' premises where there exists an Home/Building Energy Management System that interacts with selected loads which can be controlled and scheduled remotely. Microgrid Control Center directly signals the Energy Management System in order to modify either with increase or reduction the energy consumption at the consumers' premises. This control function has the objective to shift loads in order properly balance and stabilize the grid. Control actions are initiated by Microgrid Operator and directly affect load scheduling in time dimension, if not overridden by the consumer itself. Consumers voluntarily and partially assign control of their loads to Microgrid Operator on the specific extent they wish. Financial incentives can be the main motivation of consumers but also environmental awareness and others.

Use case exploits services of the high level use cases "5.2 Demand-side management" (see page 60), "5.3 Supply-side management" (see page 65) and "5.1.4 State analysis and sub-sequent actions" (see page 50). Moreover, use case comprises the function Signal Load Shifting. This function control signals originated by Microgrid Control Centre to Home/Building Energy Management System conveying commands for scheduling controllable load operation.

Use Case Diagram

See Chapter 5.2, page 60

Actor (Stakeholder) Roles of Use Case

See Chapter 5.2, page 60

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Automated Load Shifting	Reliable communication with transactional nature. Time-scale is secondary control.
Data and context management (e.g. volume, models, mining, grade of distribution)	Automated Load Shifting	High demand for context-based and filtered data management
Processing (demand, grade of distribution)	Automated Load Shifting	High demand for computing resources for calculation and simulation models
Service integration (openness, standard interfaces)	Automated Load Shifting	Publish open interfaces servicing higher level entities

Table 55: ICT Relevance of Use Case "Automated Load Shifting"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Monitoring	Use case "5.1.2 Monitoring" (see page 46) is necessary for monitoring the distribution of load and assessing the problem situation.
State Analysis and Subsequent Actions	Use case "5.1.4 State analysis and sub-sequent actions" (see page 50) is necessary for assessing grid state and command load shifting procedures.
Forecasting	Use case "5.1.1 Forecasting energy production and consumption on different time-scales" (see page 43)

Table 56: Assumptions of Use Case "Automated Load Shifting"

5.2.2.3 Price-based Load Shifting

Use Case Name

Price-based Load Shifting

Use Case ID

FINSENY/WP3/CUC-2.2.3

Scope and Objectives

Microgrid operator manages consumers' available flexibility for increasing or decreasing consumption by providing price incentives. Prices are transmitted to the Home/Building Energy Management System and consumers modify their load profile and schedule in response to the price incentive.

Use case exploits services of the high level use cases "5.2 Demand-side management" (see page 60), "5.3 Supply-side management" (see page 65) and "5.1.4 State analysis and sub-sequent actions" (see page 50). Moreover, use case comprises the function Signal Prices. This function transmits signals originated by Microgrid Control Center to Home/Building Energy Management System which convey price information.

Use Case Diagram

See Chapter 5.2, page 60

Actor (Stakeholder) Roles of Use Case

See Chapter 5.2, page 60

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Price-based Load Shifting	Reliable communication with transactional nature. Time-scale is tertiary control.
Data and context management (e.g. volume, models, mining, grade of distribution)	Price-based Load Shifting	High demand for context-based and filtered data management
Processing (demand, grade of distribution)	Price-based Load Shifting	High demand for computing resources for calculation and simulation models
Service integration (openness, standard interfaces)	Price-based Load Shifting	Publish open interfaces servicing higher level entities

Table 57: ICT Relevance of Use Case "Price-based Load Shifting"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Monitoring	Use case "5.1.2 Monitoring" (see page 46) is necessary for monitoring the distribution of load and assessing the problem situation.
State Analysis and Subsequent Actions	Use case "5.1.4 State analysis and sub-sequent actions" (see page 50) is necessary for assessing grid state and command load shifting procedures.
Forecasting	Use case "5.1.1 Forecasting energy production and consumption on different time-scales" (see page 43)

Table 58: Assumptions of Use Case "Price-based Load Shifting"

5.3 Supply-side management

Use Case Name

Supply-side management

Use Case ID

FINSENY/WP3/CUC-3

Scope and Objectives

This section about supply-side management gathers all aspects related to monitoring and control of decentralized supply. Therefore, supply-side management describes the most relevant use cases which are somehow related to DER units. This contains use cases about monitoring the state of DER units as well as use cases about controlling the active and reactive power generation. Goals of these use case reach from secure operation of the microgrid via optimized power quality within the MG until ancillary services offered to the overlay grid operator by control of DER units. Some of these use cases may be based on similar technical principles, but are pursuing different goals. Therefore, they will be listed separately in order to be able to separately examine the ICT requirements at a later stage.

Use Case Diagram

Figure 21: Diagram of Use Case "Supply-side management"

Actor (Stakeholder) Roles of Use Case

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Control Center	System	The control system comprehending different subsystems of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
DER Unit	Device	Distributed Energy Resource including Distributed Generation (small PV, wind, etc.) which is connected to the Microgrid. The device provides some degree of intelligence to be monitored and controlled.
Overlay Grid Operator	Organization	The Overlay Grid Operator is the operator of the grid to which the Microgrid has a connection point. The Overlay Grid Operator is a Grid Operator. The term „Grid Operators“, refers to the undertakings of operating, building, maintaining and planning of the electric power transmission and distribution networks [9].

Table 59: Actors of Use Case “Supply-side management”

ICT relevance of Use Case

See Sub Use Cases

Assumptions of Use Case

See Sub Use Cases

5.3.1 Continuous determination of available control power on different time-scales

Use Case Name

Continuous determination of available controlling power range on different time-scales

Use Case ID

FINSENY/WP3/CUC-3.1

Scope and Objectives

The Microgrid operator has to monitor its own imbalance position and available options to balance it. For this purpose he needs to have a defined amount of control power (depending on the extension of the microgrid) which is either committed by flexible consumers making their loads controllable or power suppliers committing a certain capacity of their DER for control power.

If the control power is provided by power suppliers committing a certain capacity of their DER in a certain time for control power, the Microgrid Control Center has to aggregate the availability of the several DERs and check the deviations from what is committed. It calculates scenarios on different time scales (e.g. 15 min-4 hours) to provide available options for the Microgrid Operator.

Use Case Diagram

See Chapter 5.3, page 65

Actor (Stakeholder) Roles of Use Case

See Chapter 5.3, page 65

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Continuous determination of available controlling power range on different time-scales	Low demand for collecting data about availability (e.g. once per hour) needed as safety check.
Data and context	Continuous determination of	Demand for context-based and filtered

ICT Criteria	Use Case	Requirement
management (e.g. volume, models, mining, grade of distribution)	available controlling power range on different time-scales	data management
Processing (demand, grade of distribution)	Continuous determination of available controlling power range on different time-scales	High demand for computing resources for calculation and simulation models
Service integration (openness, standard interfaces)	Continuous determination of available controlling power range on different time-scales	Standard interface to energy management system, integration into other components of microgrid operation

Table 60: ICT Relevance of Use Case "Continuous determination of available control power on different time-scales"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Continuous determination of available controlling power range on different time-scales	5.1.2 Monitoring

Table 61: Assumptions of Use Case "Continuous determination of available control power on different time-scales"

5.3.2 Control services

5.3.2.1 Active Power Voltage Control

Use Case Name

Active Power Voltage Control

Use Case ID

FINSENY/WP3/CUC-3.2.1

Scope and Objectives

In order to keep the voltage along the lines within the Microgrid as constant as possible, the Microgrid Control Center controls all DER units and flexible demand. In this use case only the active power is controlled. This works best in networks with mostly ohmic characteristic of lines (X/R << 1, typically MV to LV level).

Use Case Diagram

See Chapter 5.3, page 65

Actor (Stakeholder) Roles of Use Case

See Chapter 5.3, page 65

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Active Power Voltage Control	Grid data is static, not transmitted Capabilities should be described with data < 10 kB
Data and context management (e.g. volume, models, mining, grade of	Active Power Voltage Control	High demand for detailed network data and capabilities of assets and DER + active demand units

ICT Criteria	Use Case	Requirement
distribution)		
Processing (demand, grade of distribution)	Active Power Voltage Control	High demand for computing resources for calculation and simulation models
Service integration (openness, standard interfaces)	Active Power Voltage Control	Should be standardized, not dependent on manufacturer

Table 62: ICT Relevance of Use Case "Active Power Voltage Control"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
-	-

5.3.2.2 Reactive Power Voltage Control

Use Case Name

Reactive Power Voltage Control

Use Case ID

FINSENY/WP3/CUC-3.2.2

Scope and Objectives

This is the first out of three use cases that are based on the control of reactive power generation / consumption of DER units. It is only used internally by the Microgrid Operator to stabilize the voltage in the Microgrid.
In order to keep the voltage along the lines within the Microgrid as constant as possible, the Microgrid Control Center controls all DER units and flexible demand. In this use case only the reactive power is controlled. This works best in networks with mostly reactive characteristic of lines (X/R >> 1, typically HV to MV level).
The benefit of using ICT in this use case is an optimal utilization of different DER units that are able to provide this service. Example: Two DER units next to each other can both supply reactive power to keep the voltage constant, both are PV plants. As there is a shadow over one of them it is not operating at nominal power. This plant is more suitable to provide reactive power. The other one – operating at nominal power – would have to reduce the active power generation in order to produce reactive power (thermal limit of inverter is given by apparent power)

Use Case Diagram

See Chapter 5.3, page 65

Actor (Stakeholder) Roles of Use Case

See Chapter 5.3, page 65

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Reactive Power Voltage Control	Grid data is static, not transmitted Capabilities should be described with data < 10 kB
Data and context management (e.g. volume, models, mining, grade of distribution)	Reactive Power Voltage Control	High demand for detailed network data and capabilities DER + active demand units
Processing (demand, grade of distribution)	Reactive Power Voltage Control	High demand for computing resources for calculation and simulation models
Service integration	Reactive Power Voltage Control	Should be standardized, not dependent

ICT Criteria	Use Case	Requirement
(openness, standard interfaces)		on manufacturer

Table 63: ICT Relevance of Use Case "Reactive Power Voltage Control"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
-	-

5.3.2.3 Reactive Power Compensation

Use Case Name

Reactive Power Compensation

Use Case ID

FINSENY/WP3/CUC-3.2.3

Scope and Objectives

The second out of three reactive power related use cases is also a service only used within the Microgrid or – more exactly – at the interface to the overlay grid, but the optimization is carried out within the Microgrid and may be of special importance in disconnected (islanding) mode.

The Microgrid has a contracted maximum and minimum power factor. He uses the flexibility of DER units to keep the power factor within the given limits and therefore reduces the requirement to install other kinds of compensation systems. Hence, it does not completely replace an adequate planning of reactive power needs of the network but it introduces flexibility and therefore reduces the need for installations.

ICT is needed to coordinate the capabilities of all DER units in an optimal way (not every unit can deliver this service at the same time or at the same price).

Use Case Diagram

See Chapter 5.3, page 65

Actor (Stakeholder) Roles of Use Case

See Chapter 5.3, page 65

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Reactive Power Compensation	Grid data is static, not transmitted Capabilities should be described with data < 10 kB
Data and context management (e.g. volume, models, mining, grade of distribution)	Reactive Power Compensation	High demand for detailed network data and capabilities of assets and DER + active demand units
Processing (demand, grade of distribution)	Reactive Power Compensation	High demand for computing resources for calculation and simulation models
Service integration (openness, standard interfaces)	Reactive Power Compensation	Should be standardized, not dependent on manufacturer

Table 64: ICT Relevance of Use Case "Reactive Power Compensation"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
-	-

5.3.2.4 Voltage Var Control

Use Case Name

Voltage Var Control

Use Case ID

FINSENY/WP3/CUC-3.2.4

Scope and Objectives

The last reactive power related UC is a service offered to the overlay grid operator and can therefore only be offered in connected mode.
As described in FENIX project [6], the microgrid provides reactive power (both capacitive and inductive) to the overlay grid in order to increase voltage stability and optimize load flows as requested by the Overlay Grid Control Center.

Use Case Diagram

See Chapter 5.3, page 65

Actor (Stakeholder) Roles of Use Case

See Chapter 5.3, page 65

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Voltage Var Control	Status of DER units in the order of < 10 kB
Data and context management (e.g. volume, models, mining, grade of distribution)	Voltage Var Control	Rather low (only DER capabilities and contracts)
Processing (demand, grade of distribution)	Voltage Var Control	Medium, no network simulation required
Service integration (openness, standard interfaces)	Voltage Var Control	Should be standardized, not dependent on manufacturer

Table 65: ICT Relevance of Use Case “Voltage Var Control”

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
-	-

5.3.2.5 Enhance Local Power Quality

Use Case Name

Enhance Local Power Quality

Use Case ID

FINSENY/WP3/CUC-3.2.5

Scope and Objectives

Disturbances of power quality in a network regarding harmonics caused by DER units or other electrical devices can be minimized by optimizing the power electronics of the DER units or filters.
In order to enhance the local power quality regarding harmonics, the Microgrid Control Center controls all DER units. In case of insufficient power quality the devices enhance the local power quality with regard to harmonics. This may be done by preliminarily switching to a different operating point, increasing or reducing power, changing control algorithm of devices etc..

Use Case Diagram

See Chapter 5.3, page 65

Actor (Stakeholder) Roles of Use Case

See Chapter 5.3, page 65

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Enhance Local Power Quality	Grid data is static, not transmitted Capabilities should be described with data < 10 kB
Data and context management (e.g. volume, models, mining, grade of distribution)	Enhance Local Power Quality	High demand for detailed network data and capabilities of assets and DER + active demand units
Processing (demand, grade of distribution)	Enhance Local Power Quality	High demand for computing resources for calculation and simulation models
Service integration (openness, standard interfaces)	Enhance Local Power Quality	Should be standardized, not dependent on manufacturer

Table 66: ICT Relevance of Use Case "Enhance Local Power Quality"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
-	-

5.3.2.6 Primary reserve

Use Case Name

Primary reserve

Use Case ID

FINSENY/WP3/CUC-3.2.6

Scope and Objectives

The Microgrid provides primary reserve power to the system. Therefore, Microgrid Control Center and DER units need to form a pool that can be offered at the reserve power markets. Currently this is not allowed but in the future it is quite likely to be required (as less conventional plants will be available for this).
Offers in reserve power markets are likely to take place on a regular basis (tertiary requirements), but within the Microgrid pooling may be a very dynamic process (primary requirements). Activation of this service is likely to remain an automatic process as it is today.

Use Case Diagram

See Chapter 5.3, page 65

Actor (Stakeholder) Roles of Use Case

See Chapter 5.3, page 65

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Primary reserve	Status of DER units in the order of < 10 kB
Data and context management (e.g. volume, models, mining, grade of distribution)	Primary reserve	Rather low (only DER capabilities and contracts)
Processing (demand, grade of distribution)	Primary reserve	Medium, no network simulation required
Service integration (openness, standard interfaces)	Primary reserve	Should be standardized, not dependent on manufacturer

Table 67: ICT Relevance of Use Case "Primary reserve"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
-	-

5.3.2.7 Secondary reserve

Use Case Name

Secondary reserve

Use Case ID

FINSENY/WP3/CUC-3.2.7

Scope and Objectives

The Microgrid provides secondary reserve power to the system. To the external system the Microgrid acts as one entity (represented by its Microgrid Control Center) and internally it optimizes the use of DER units and flexible demand for this purpose.

Use Case Diagram

See Chapter 5.3, page 65

Actor (Stakeholder) Roles of Use Case

See Chapter 5.3, page 65

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Secondary reserve	Status of DER units in the order of < 10 kB
Data and context management (e.g. volume, models, mining, grade of distribution)	Secondary reserve	Rather low (only DER capabilities and contracts)
Processing (demand,	Secondary reserve	Medium, no network simulation

ICT Criteria	Use Case	Requirement
grade of distribution)		required
Service integration (openness, standard interfaces)	Secondary reserve	Should be standardized, not dependent on manufacturer

Table 68: ICT Relevance of Use Case "Secondary reserve"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
-	-

5.3.2.8 Tertiary reserve

Use Case Name

Tertiary reserve

Use Case ID

FINSENY/WP3/CUC-3.2.8

Scope and Objectives

The Microgrid provides tertiary reserve power to the system. To the external system the Microgrid acts as one entity (represented by its Microgrid Control Center) and internally it optimizes the use of DER units and flexible demand for this purpose.

Use Case Diagram

See Chapter 5.3, page 65

Actor (Stakeholder) Roles of Use Case

See Chapter 5.3, page 65

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Tertiary reserve	Status of DER units in the order of < 10 kB
Data and context management (e.g. volume, models, mining, grade of distribution)	Tertiary reserve	Rather low (only DER capabilities and contracts)
Processing (demand, grade of distribution)	Tertiary reserve	Medium, no network simulation required
Service integration (openness, standard interfaces)	Tertiary reserve	Should be standardized, not dependent on manufacturer

Table 69: ICT Relevance of Use Case "Tertiary reserve"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
-	-

5.4 Black Start in Islanding mode

Use Case Name

Microgrid Black Start

Use Case ID

FINSENY/WP3/CUC-4

Scope and Objectives

If a system disturbance provokes a general black out such that the Microgrid (MG) was not able to separate and continue in islanding mode, and if the system is unable to restore operation in a specified time, a first step in system recovery will be a local Black Start.

Two types of Black Start (BS) functions are needed:

- Local Black Start of the Microgrid after a general system black out;
- Grid reconnection during Black Start.

The strategy to be followed is a matter for investigation and involves the cooperation of the various system controllers both central and local, using predefined rules and exploiting autonomous agent concepts. The restoration process for any power system is a very complicated process. The related restoration tasks are usually carried out manually, according to predefined guidelines. They have to be completed fast in a real time basis under extreme stressed conditions. In a Microgrid, the whole procedure is much more simple because there are not many loads, switches and large, difficult to control, generation units. In addition, the power electronic interfaces of the distributed resources and loads offer considerable flexibility. Thus, the idea of creating a totally automatic system for restoration seems quite realistic.

A special feature of the Microgrid central controller concerns re-connection during Black Start, helping in this way the upstream DMS system that is managing the distribution network. During faults on the main grid the Microgrid may be disconnected from the main utility and will continue to operate with as much connected DG, as possible. During reconnection the issue of out-of phases reclosing needs to be carefully considered. The development of local controllers in close co-ordination with the Microgrid Central Controller functions need to be developed and evaluated from the dynamic operation point of view through studies to be performed in the simulation platform. These Black Start functions contribute to assure an important advantage for power system operation in terms of reliability as a result from the presence of a very large amount of dispersed generation.

The restoration procedure in a MG has some similarities with the approach adopted on a medium sized power system, namely: the need for several sources with Blackstart capabilities and standby power supply and a monitoring and control scheme embedded in the Microgrid Control Center (MGCC). Blackstart functionalities can be based on a set of rules identified in advance and embedded in the Central Controller.

Use Case Diagram

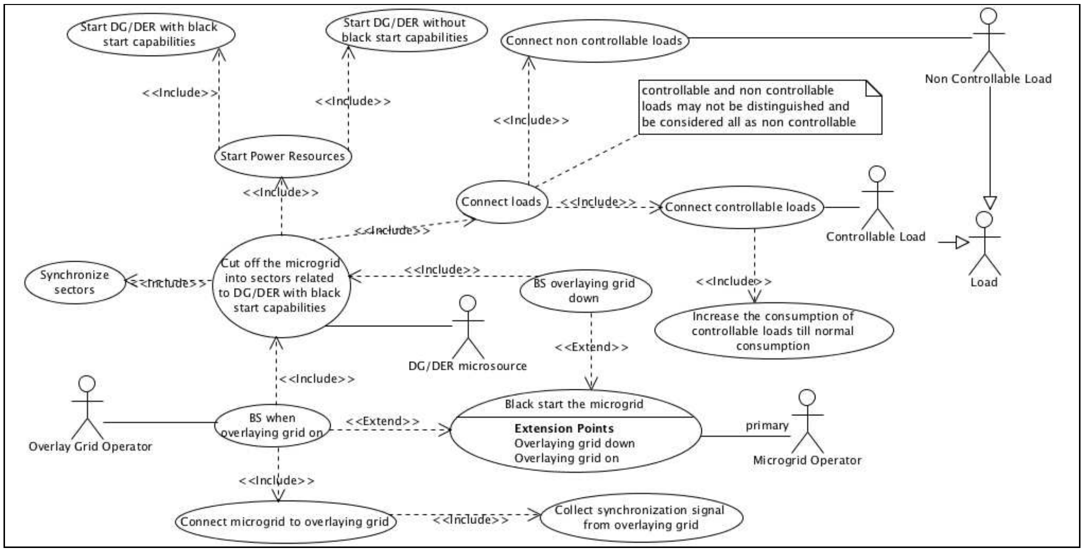

Figure 22: Diagram of Use Case "Black Start in Islanding mode"

Actor (Stakeholder) Roles of Use Case

Grouping (Community)		*Group Description*
Actor Name	*Actor Type (person, organization, device, system, or subsystem)*	*Actor Description*
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
Overlay Grid Operator	Organization	The Overlay Grid Operator is the operator of the grid to which the Microgrid has a connection point. The Overlay Grid Operator is a Grid Operator. The term „Grid Operators“, refers to the undertakings of operating, building, maintaining and planning of the electric power transmission and distribution networks [9].
Consumer	Person/ Organization	A consumer of electricity which is a private, business building, large industrial / manufacturing industry or transportation system. The consumer acts as a customer. The consumer may operate Smart Appliances (an electrical load with some intelligence to control it) which are flexible in demand.
Microgrid Control	System	The control system comprehending different

Grouping (Community)		*Group Description*
Actor Name	*Actor Type (person, organization, device, system, or subsystem)*	*Actor Description*
Center		subsystems of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.
Overlay Grid Control Center	System	Control center from which the overlay grid is operated. All required supervision and control functions are carried out here.
DER Unit	Device	Distributed Energy Resource including Distributed Generation (small PV, wind, etc.) which is connected to the Microgrid. The device provides some degree of intelligence to be monitored and controlled.
Network Smart Device	Device	An intelligent electrical device in the Microgrid that can be supervised and controlled (e.g. sensors, circuit-breakers or switches)

Table 70: Actors of Use Case "Black Start in Islanding mode"

ICT relevance of Use Case and required ICT properties

ICT Criteria	Activity	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Cutting of the microgrid Building of the microgrid Connection of all the MS to the MG Synchronisation of the small islanded microgrid LCs connect controllable loads to the MG Synchronization of the MG with the overlay network	Communication between the MGCC and active Network Devices Communication between the MGCC and all the MSs. Bidirectional communication between all the MCs and with the MGCC Bidirectional communication between LCs, MCs, and the MGCC. Bidirectional communication between MGCC and the Control Centre Overlay Grid
Data and context management (e.g. volume, models, mining, grade of distribution)		
Processing (demand, grade of distribution)	Energization of Microgrid Transformers (MGT)	Remote control from the MGCC to inverters associated with the storage devices.
Service integration (openness, standard interfaces)		

Table 71: ICT Relevance of Use Case "Black Start in Islanding mode"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Set in the MGCC of predetermined rules and conditions that define a sequence of control actions carried out during the restoration procedure	It is also required availability for: - Bidirectional communication between the MGCC and MC / LC. - Updated information, obtained before disturbance on the status of load/generation in the MG and about availability of MS to BS. - Automatic load disconnection after system collapse in order to avoid large frequency and voltage deviations when energizing the network. - Overlay Grid/MG transformer disconnection from the Overlay network, before starting the BS procedure. - MG area separation.

Table 72: Assumptions of Use Case "Black Start in Islanding mode"

5.5 Auto-configuration

Use Case Name

Auto-configuration

Use Case ID

FINSENY/WP3/CUC-5

Scope and Objectives

When new devices (e.g. DERs or intelligent appliances) or sub-systems (e.g. Home/Building Energy Management Systems) are installed in or at the edge of the Microgrid they automatically configure itself (also frequently denoted as Plug&Play). The Microgrid operator can access the devices in a secure and trusted manner. Based on the ownership different access rights control the access of the Microgrid Operator to the device. The devices can describe their capabilities to the Microgrid operator and specify their services for monitoring and control.

Auto-configuration is needed for different devices and systems, e.g. plug&play of Smart Appliances in house, registration of devices owned by the Microgrid Operator at the Microgrid Control Center, registration of DERs owned by the DER owner at the Microgrid Control Center or registration of a Building/Home Energy System at the Microgrid Control Center. These sub use cases are described in detail in the following subsections.

Use Case Diagram

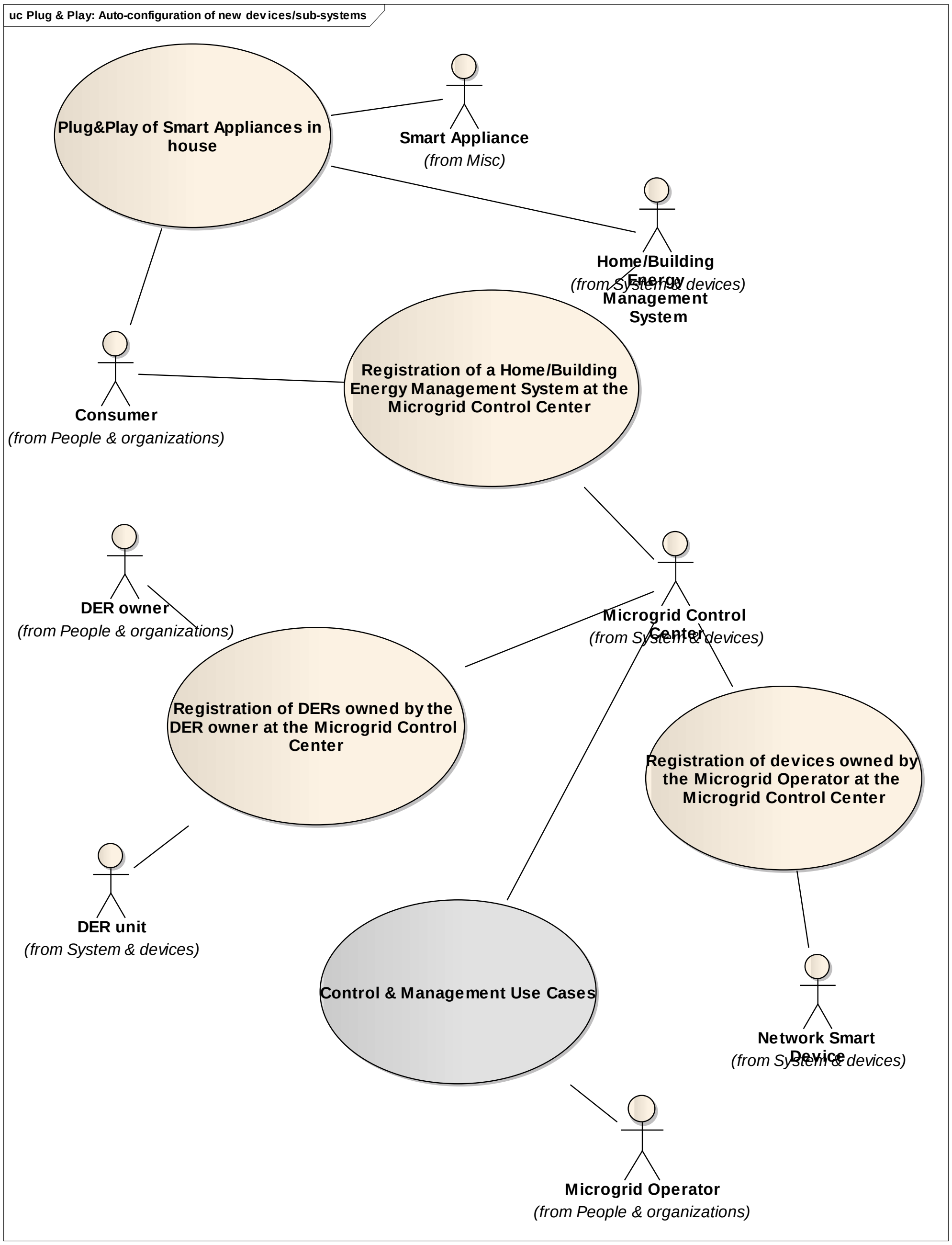

Figure 23: Diagram of Use Case "Auto-configuration"

Actor (Stakeholder) Roles of Use Case

See Sub Use Cases

ICT relevance of Use Case

See Sub Use Cases

Assumptions of Use Case

See Sub Use Cases

5.5.1 Plug&Play of Smart Appliances in house

Use Case Name

Plug&Play of Smart Appliances in house

Use Case ID

FINSENY/WP3/CUC-5.1

Scope and Objectives

Smart Appliances in the building also support the Plug&Play functionality to the customer. These devices interact not directly with the Microgrid Control Center. Thus, this use case is not in the focus of this work package.

Use Case Diagram

See Chapter 5.5, page 78

Actor (Stakeholder) Roles of Use Case

Grouping (Community) ,		Group Description
In-House		
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Consumer	Person/ Organization	A consumer of electricity which is a private, business building, large industrial / manufacturing industry or transportation system. The consumer acts as a customer. The consumer may operate Smart Appliances (an electrical load with some intelligence to control it) which are flexible in demand.
Network Smart Device	Device	An intelligent electrical device in the Microgrid that can be supervised and controlled (e.g. sensors, circuit-breakers or switches)

Table 73: Actors of Use Case "Plug&Play of Smart Appliances in house"

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)		Omitted, use case is out of the scope of WP3!
Data and context management (e.g. volume, models, mining, grade of distribution)		Omitted, use case is out of the scope of WP3!
Processing (demand, grade of distribution)		Omitted, use case is out of the scope of WP3!
Service integration (openness, standard interfaces)		Omitted, use case is out of the scope of WP3!

Table 74: ICT Relevance of Use Case "Plug&Play of Smart Appliances in house"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
	Omitted, use case is out of the scope of WP3!

5.5.2 Registration of devices owned by the Microgrid Operator at the Microgrid Control Center

Use Case Name

Registration of devices owned by the Microgrid Operator at the Microgrid Control Center

Use Case ID

FINSENY/WP3/CUC-5.2

Scope and Objectives

The Microgrid Operator installs a new device or replaces an existing device in its Microgrid. The device is owned by the Microgrid Operator and can be used without any restrictions by the Microgrid Operator for any purpose.

The devices register at the Microgrid Control Center. After registration the Microgrid operator can access the devices in a secure and trusted manner. The devices can describe their capabilities to the Microgrid Control Center and specify their services with respect to monitoring and control.

If the device replaces an old device the Microgrid Control Center is reconfigured accordingly. If the device is new and provides new functions they are added and enabled in the Microgrid Control Center.

Use Case Diagram

See Chapter 5.5, page 78

Actor (Stakeholder) Roles of Use Case

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
Microgrid Control Center	System	The control system comprehending different subsystems of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.
Network Smart Device	Device	An intelligent electrical device in the Microgrid that can be supervised and controlled (e.g. sensors, circuit-breakers or switches)

Table 75: Actors of Use Case "Registration of devices owned by the Microgrid Operator at the Microgrid Control Center"

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Plug&Play: Registration of devices owned by the Microgrid Operator at the Microgrid Control Center	- Auto configuration of network address (e.g. DHCP, Auto IP or NDP for IPv6) - Multi-homing for increased reliability
Data and context management (e.g. volume, models,	Plug&Play: Registration of devices owned by the Microgrid Operator at the Microgrid Control	- Integration of the device into the control center without any manual configuration

ICT Criteria	Use Case	Requirement
mining, grade of distribution)	Center	- Common information model for describing the capabilities of the device - Central or distributed discovery mechanism of devices and their capabilities with rich query functionalities
Processing (demand, grade of distribution)	Plug&Play: Registration of devices owned by the Microgrid Operator at the Microgrid Control Center	Low demand for computing resources at the devices and the Microgrid Control Center
Service integration (openness, standard interfaces)	Plug&Play: Registration of devices owned by the Microgrid Operator at the Microgrid Control Center	Support of standards, e.g. IEC 61850

Table 76: ICT Relevance of Use Case "Registration of devices owned by the Microgrid Operator at the Microgrid Control Center"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
	-

5.5.3 Registration of DERs owned by the DER owner at the Microgrid Control Center

Use Case Name

Registration of DERs owned by the DER owner at the Microgrid Control Center

Use Case ID

FINSENY/WP3/CUC-5.3

Scope and Objectives

The DER owner likes to offer the services of his DER unit (e.g. supplying energy) to the Microgrid Operator. Before doing so the DER unit has to be registered at the Microgrid Control Center. After registration the Microgrid operator can access the devices in a secure and trusted manner. The devices can describe their capabilities to the Microgrid Control Center and specify their services with respect to monitoring and control. Furthermore, access rights are defined based on contractual agreements which define the level of monitoring and control of the DER unit from the Microgrid Control Center.

Use Case Diagram

See Chapter 5.5, page 78

Actors of Use Case

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the

Grouping (Community) ,		Group Description
Actor Name	**Actor Type (person, organization, device, system, or subsystem)**	**Actor Description**
		outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
Microgrid Control Center	System	The control system comprehending different subsystems of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.
DER Owner	Person/ Organization	The DER Owner (or DG Owner) operates a Distributed Energy Resource (DER) (or Distributed Generation (DG)) which is connected to the Microgrid.
DER Unit	Device	Distributed Energy Resource including Distributed Generation (small PV, wind, etc.) which is connected to the Microgrid. The device provides some degree of intelligence to be monitored and controlled.

Table 77: Actors of Use Case "Registration of DERs owned by the DER owner at the Microgrid Control Center"

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Plug&Play: Registration of DERs owned by the DER owner at the Microgrid Control Center	- Remote access to the device in the private LAN - Auto configuration of network address (e.g. DHCP, Auto IP or NDP for IPv6) - Multi-homing for increased reliability
Data and context management (e.g. volume, models, mining, grade of distribution)	Plug&Play: Registration of DERs owned by the DER owner at the Microgrid Control Center	- Integration of the device into the control center without any manual configuration - Common information model for describing the capabilities of the device - Central or distributed discovery mechanism of devices and their capabilities with rich query functionalities - Secure and trusted access by a third party depending on specified access rights
Processing (demand, grade of distribution)	Plug&Play: Registration of DERs owned by the DER owner at the Microgrid Control Center	Low demand for computing resources at the devices and the Microgrid Control Center
Service integration (openness, standard interfaces)	Plug&Play: Registration of DERs owned by the DER owner at the Microgrid Control Center	Support of standards, e.g. IEC 61850

Table 78: ICT Relevance of Use Case "Registration of DERs owned by the DER owner at the Microgrid Control Center"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
	-

5.5.4 Registration of a Home/Building Energy Management System at the Microgrid Control Center

Use Case Name

Registration of a Home/Building Energy Management System at the Microgrid Control Center

Use Case ID

FINSENY/WP3/CUC-5.4

Scope and Objectives

A Home/Building Energy Management System acts at the interface between the Smart Home and the Microgrid. It communicates with the Microgrid Control Center and provides services to it which are aggregated by all Smart Appliances in the household. Before doing so the Home/Building Energy Management System has to be registered at the Microgrid Control Center.

After registration the Microgrid operator can access the Home/Building Energy Management System in a secure and trusted manner. The Home/Building Energy Management System can describe aggregated capabilities of the Smart Appliances in the Smart Home to the Microgrid Control Center and specify its services with respect to monitoring and control. Services by single Smart Appliances could also be described to the Microgrid Control Center (it is assumed that this is an exception because aggregation should be used to reduce complexity). Furthermore, access rights are defined based on contractual agreements which define the level of monitoring and control of the Home Energy Gateway from the Microgrid Control Center.

Use Case Diagram

See Chapter 5.5, page 78

Actors of Use Case

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the traditional model plus the role of an Aggregator.
Microgrid Control Center	System	The control system comprehending different subsystems of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.
Home/Building Energy Management System	System	System acting at the interface between Smart Home/Building and the Microgrid. It communicates in-house with Smart Appliances and to the outside with the Microgrid Control Center. It aggregates the services of the Smart Appliances in the household and provides them to the Microgrid. Furthermore, it can implement

Grouping (Community) ,		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
		some level of intelligence to fulfill the services.
Network Smart Device	Device	An intelligent electrical device in the Microgrid that can be supervised and controlled (e.g. sensors, circuit-breakers or switches)

Table 79: Actors of Use Case "Registration of a Home/Building Energy Management System at the Microgrid Control Center"

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Plug&Play: Registration of a Home Energy Gateway at the Microgrid Control Center	- Remote access to the device in the private LAN - Auto configuration of network address (e.g. DHCP, Auto IP or NDP for IPv6) - Multi-homing for increased reliability
Data and context management (e.g. volume, models, mining, grade of distribution)	Plug&Play: Registration of a Home Energy Gateway at the Microgrid Control Center	- Integration of the device into the control center without any manual configuration - Common information model for describing the capabilities of the device - Central or distributed discovery mechanism of devices and their capabilities with rich query functionalities - Secure and trusted access by a third party depending on specified access rights
Processing (demand, grade of distribution)	Plug&Play: Registration of a Home Energy Gateway at the Microgrid Control Center	Low demand for computing resources at the devices and the Microgrid Control Center
Service integration (openness, standard interfaces)	Plug&Play: Registration of a Home Energy Gateway at the Microgrid Control Center	Support of standards, e.g. IEC 61850

Table 80: ICT Relevance of Use Case "Registration of a Home/Building Energy Management System at the Microgrid Control Center"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
Registration of a Home Energy Gateway at the Microgrid Control Center	FINSENY/WP3/CUC-5.1

Table 81: Assumptions of Use Case "Registration of a Home/Building Energy Management System at the Microgrid Control Center"

5.6 Long-term planning of Microgrid infrastructure design and upgrading

Use Case Name

Long-term Planning of Microgrid Infrastructure Design and Upgrading

Use Case ID

FINSENY/WP3/CUC-6

Scope and Objectives

The Microgrid Operator establishes a planning tool that accesses the data of a comprehensive Microgrid Data Base (MG-DB) – this DB may be the monitoring DB and contains all actual management and configuration data and details of all devices and entities inside the Microgrid. In case of new devices, customers, generators and status information the MG-DB is immediately updated.
In addition, a forecast service is taken into account (data of an F-DB) to respect future expectations for e.g. customers, generated power etc.
An offline simulation is started (planning tool) to check the proper operation of the whole Microgrid in case of integration of the new entities. In case of a negative result of the simulation (expectation of problems in the Microgrid) suitable countermeasures are to be found and tested with the simulation tool.
For the planning of the future infrastructure, updated data of future consumption and regulation changes are to be taken into account.

Use Case Diagram

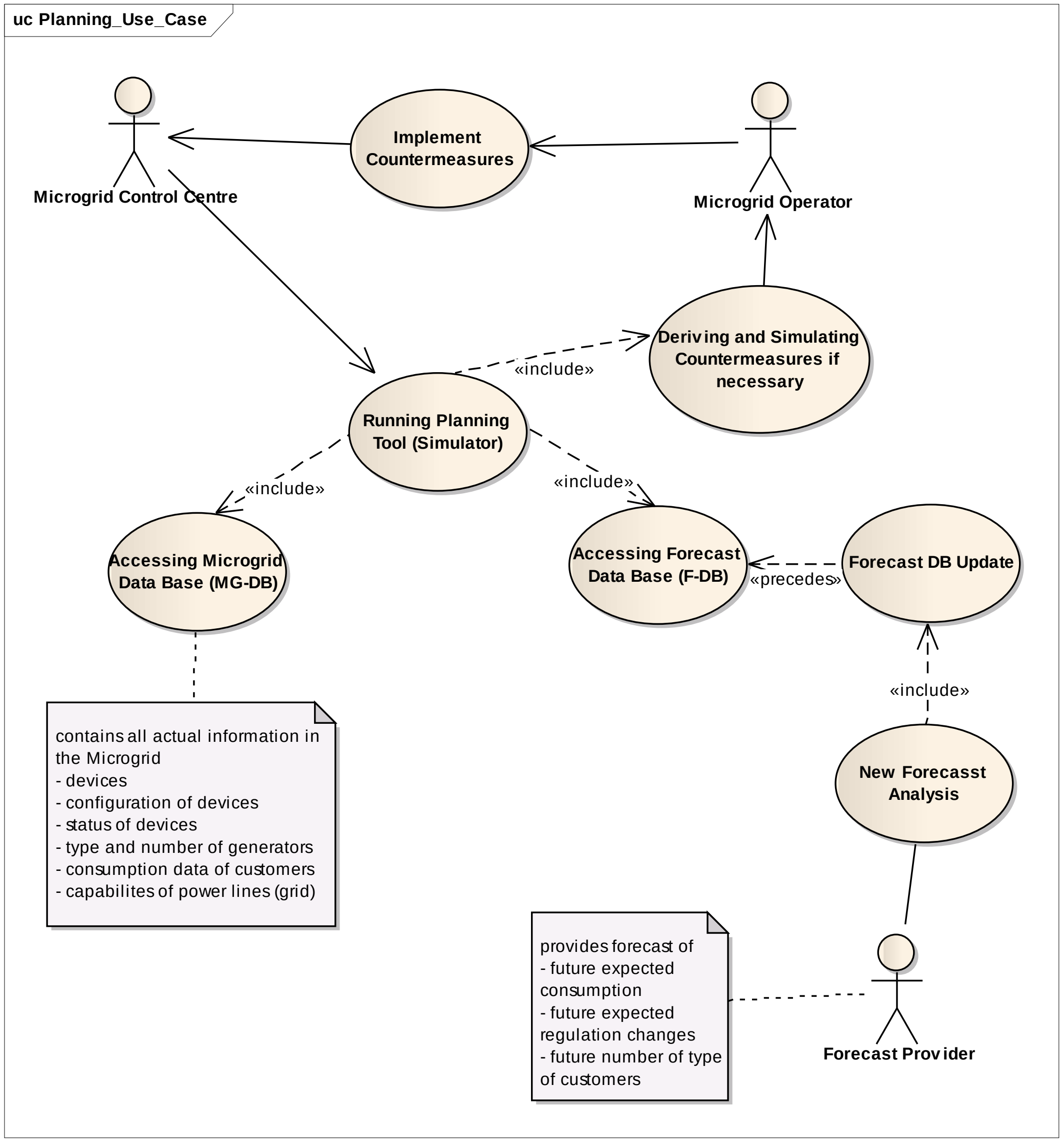

Figure 24: Diagram of Use Case "Long-term planning of Microgrid infrastructure design and upgrading"

The objective of this use case is to prepare the microgrid for new circumstances and/or challenges in time.

Actor (Stakeholder) Roles of Use Case

Grouping (Community) '		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
Microgrid Operator	Organization	The Microgrid Operator is responsible for the operation of the Microgrid and contracting with prosumers in the Microgrid and outside the Microgrid. Further, it is responsible for pricing policies inside the Microgrid and trading with the outside energy market places. The Microgrid Operator takes over the roles of the System Operator and the Energy Retailer in the

Grouping (Community) '		Group Description
Actor Name	Actor Type (person, organization, device, system, or subsystem)	Actor Description
		traditional model plus the role of an Aggregator.
Forecast Provider	Person, Organization	The Forecast Provider may be an independent service provider that observes actual and future technical and business tendencies in the electricity network and power provision.
Microgrid Control Center	System	The control system comprehending different subsystems of the Microgrid operator to ensure the control & management tasks of the Microgrid and the aggregation of supply and demand.

Table 82: Actors of Use Case "Long-term planning of Microgrid infrastructure design and upgrading"

ICT relevance of Use Case

ICT Criteria	Use Case	Requirement
Communication (e.g. QoS, bandwidth, latency, reliability, determinism, grade of distribution)	Implement Countermeasures in microgrid devices Access to F-DB and MG-DB	Since the planning is for long-term evolution, there is no special or challenging communication requirement. Low-bandwidth communication links with a delay in the order of minutes are sufficient.
Data and context management (e.g. volume, models, mining, grade of distribution)	Access to F-DB and MG-DB	High demand for context-based and filtered data management
Processing (demand, grade of distribution)	planning tool / simulation	Very high demand for computing resources for planning and simulation models
Service integration (openness, standard interfaces)	Forecast Models for future technical and business tendencies in the electricity network and power provision.	Seamless integration of 3rd-party services (e.g. technical consultant service, business forecast)

Table 83: ICT Relevance of Use Case "Long-term planning of Microgrid infrastructure design and upgrading"

Assumptions of Use Case

Low level Use Case	Preconditions or assumptions
	Suitable planning tool for electrical grids available

Table 84: Assumptions of Use Case "Long-term planning of Microgrid infrastructure design and upgrading"

6. Conclusion

The Microgrid scenario has been carefully explored by the Task 3.1 and a series of relevant and ICT-prone use cases have been evaluated up to a level where the potential impact on prominent ICT requirements is recognizable.

The evaluation process followed a systematic methodological approach which has been established by the IntelliGrid project and subsequent work (IEC/PAS 62559). Careful discussions between all FINSENY WP's on the methodology as well as focus and range of use cases lead to a consistent approach throughout the project.

For the Microgrid scenario two main views have been applied, a business and a control & management view. A certain overlapping of use cases in both categories was intentionally chosen to avoid white spots.

The two criteria for the use case selection process were

- relevance according to the work package scope, i.e. the Microgrid scenario in case of WP3,
- relevance with respect to ICT beyond the state-of-the-art.

The detailed description of each use case was based on a use case template which is a simplified version of the IntelliGrid template.

The selected use cases will be described in further detail in Task 3.2 to fully identify all ICT requirements.

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