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

Work Package 07

## JRA1 - Use Case/Scenario Identification, Analysis and Selection

Deliverable D7.1

### D-JRA1.1 ERIGrid scenario descriptions

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Grant Agreement No:	<b>654113</b>
Funding Instrument:	<b>Research and Innovation Actions (RIA) – Integrating Activity (IA)</b>
Funded under:	<b>INFRAIA-1-2014/2015: Integrating and opening existing national and regional research infrastructures of European interest</b>
Starting date of project:	<b>01.11.2015</b>
Project Duration:	<b>54 month</b>

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Contractual delivery date:	<b>30.06.2016</b>
Actual delivery date:	<b>02.07.2016</b>
Name of lead beneficiary for this deliverable:	<b>18 VTT Technical Research Centre of Finland</b>
Deliverable Type:	<b>Report (R)</b>
Security Class:	<b>Public (PU)</b>
Revision / Status:	<b>released</b>

## Document Information

Document Version: 04  
Revision / Status: released

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## Document History

Revision	Content / Changes	Resp. Partner	Date
1	First draft/content list	VTT, OFF, DTU, CRES, TEC, UST	27.05.16
2	Internal review version	VTT, OFF, DTU, CRES, TEC, UST	17.06.16
3	Complete version	VTT, OFF, DTU, CRES, TEC, UST	30.06.16
4	Editorial work, review and minor improvements	AIT	01.07.16

Everybody please state revision index and short description of what has been done + partners involved and date.

## Document Approval

Final Approval	Name	Resp. Partner	Date
Review WP Level	Arjen van der Meer	TUD	27.06.16
Review WP Level	Ata Khavari, Mihai Calin	DERlab	28.06.16
Review Steering Com. Level	Thomas Strasser	AIT	02.07.16

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**Abbreviations**

<i>AC</i>	Alternating Current
<i>AD</i>	Abstract Data
<i>BMS</i>	Battery Management System
<i>BRP</i>	Balancing Responsible Party
<i>CCS</i>	CO <sub>2</sub> Capture and Storage
<i>COBRAcable</i>	COpenhagen-BRussels-Amsterdam cable
<i>DC</i>	Direct Current
<i>DD</i>	Direct Data
<i>DER</i>	Distributed Energy Resource
<i>DG</i>	Distributed Generation
<i>DMS</i>	Distribution Management System
<i>DR</i>	Demand Response
<i>DRES</i>	Distributed Renewable Energy Resource
<i>DP</i>	Direct Physical
<i>DSO</i>	Distribution System Operator
<i>EHS</i>	European Electricity Highways
<i>EMS</i>	Energy Management System
<i>ENTSOE</i>	European Network of Transmission System Operators for Electricity
<i>EU</i>	European Union
<i>EV</i>	Electric Vehicle
<i>EVSE</i>	Electric Vehicle Supply Equipment
<i>FRT</i>	Fault Ride Through
<i>GPS</i>	Global Positioning System
<i>HIL</i>	Hardware-in-the-Loop
<i>HV</i>	High Voltage
<i>HVDC</i>	High Voltage Direct Current
<i>ICC</i>	Information, processing, or Communication Container
<i>ICT</i>	Information and Communication Technology
<i>ID</i>	Identifier
<i>IEC</i>	International Electrotechnical Commission
<i>IED</i>	Intelligent Electronic Device
<i>IRP</i>	Integrated Research Programme
<i>JRA</i>	Joint Research Activity
<i>LV</i>	Low Voltage
<i>MAS</i>	Multi-Agent System
<i>MV</i>	Medium Voltage
<i>NA</i>	Networking Activity
<i>OLTC</i>	On-Load Tap Changer

<i>PAS</i>	Publicly Available Specification
<i>PHES</i>	Pumping Hydroelectric Energy Storage
<i>PMU</i>	Phasor Measurement Unit
<i>PV</i>	Photovoltaic
<i>RES</i>	Renewable Energy Resource
<i>SCADA</i>	Supervisory Control and Data Acquisition
<i>SGAM</i>	Smart Grid Architecture Model
<i>SOC</i>	State of Charge
<i>TA</i>	Trans-national Access
<i>TSO</i>	Transmission System Operator
<i>TYNDP</i>	Ten-Year Network Development Plan
<i>URSES</i>	Uncertainty Reduction in Smart Energy Systems
<i>VPP</i>	Virtual Power Plant
<i>V2G</i>	Vehicle-to-Grid

## **Executive Summary**

This report summarizes the work conducted within ERIGrid Task JRA1.1 “Identification of high-level scenarios”. The report presents the overall flow of work in the project, taken alignments and methodological viewpoints. As an outcome, it presents three system configurations which will serve as a basis for further development in the project.

The system configurations are presented as separate documents which can be easily applied in the project work. The documents are included as an appendix of the report.

## 1 Introduction

### 1.1 Purpose and Scope of the Document

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

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

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

- Needs for high-level research infrastructures
- Needs for supporting technology validation and roll-out phases
- Potential of integration of infrastructures

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

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

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

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

### 1.2 Structure of the Document

This report summarizes the work taken within task JRA1.1. The report is outlined as follows: first it explains the approach used and decisions made during the project work, describes some earlier development on the area of high-level scenarios, introduces the system configuration work done within the working groups and finally discusses the experiences and further use of system configurations developed. As an outcome, the three system configuration templates are included in appendix in the same format they will be utilized during the course of ERIGrid project.

## 2 Approach and Terminology

The work of ERIGrid JRA1 has been initiated with the intention to define ERIGrid scenarios. These scenarios are meant to be higher-level circumstance descriptions which will provide a basis for more detailed use case and test case definitions.

As a term, *scenario* often refers to some visionary descriptions of future development and the factors influencing it. The aim can be in predicting or otherwise surveying future perspectives. Scenarios obviously apply long view perspectives where many uncertainties are present. In the context of ERIGrid, scenarios reaching to 2050 are of interest. In many cases, scenario work can feed in to political processes and decision making on different levels.

The e-Highway2050 project has defined methodology for quantification of scenarios [1]. The purpose has been to evolve from qualitative scenarios towards more quantitative ones. An outcome of this project was that one high-level scenario can lead to multiple static system configurations.

In the course of ERIGrid, *generic system configurations* have been considered more useful than traditional high-level scenarios. A system configuration approach allows including more detailed and quantitative data in the descriptions and providing a better technical basis for developing the use cases and test cases. Whereas high-level scenarios give some qualitative statements about the progress, system configuration uses quantitative data such as numbers of components, size of the system, etc. At the same, the system configuration becomes more complex due to the amount of data but also more local due to dimensions and local parameters.

The system configurations allow development of *use cases*, which give a description of a process leading to a specific objective. In other words, use case defines the actions needed to obtain some goal. Use cases are often described from an external perspective in a neutral manner, utilizing a formal methodology. Use cases can also be thought to define the interfaces of the process with its environment, inputs and eventual outputs.

Use cases can be defined from two perspectives: behavioural perspective and interaction perspective. Behavioural perspective is always function-type; it defines the behaviour of the process internally and towards external stakeholders. In the interaction perspective, most interest is on interactions between components and describing them, for instance by means of sequences.

IEC PAS 62559 [2] defines how to apply formal use cases for describing requirements in various domains. It also provides a standardized process for forming the use cases:

1. Identification of stakeholders, actors and components
2. Specification of a sequence of actions between actors or components
3. Identification of non-functional requirements

IEC PAS 62559 is closely linked with Smart Grid Architecture Model (SGAM) and the way it describes system structures and interactions. Furthermore, a use case can be mapped into SGAM model in a stepwise approach, starting from use case mapping of the function layer and then continuing through the layers.

*Test cases* with reference to system configurations require information on system parameters, ranges of parameters, system functionalities and quantitative measure. They also require information on test procedures and design of experiments. Test cases define the actual test setup; which are the combinations and series to be tested and which are the prevailing circumstances in which the tests are performed.

## 2.1 Generic System Configuration Structures

Following discussions within the project group and in technical workshops, the ERIGrid focus has been defined to be on system configurations rather than traditional high-level scenarios. It was established that the approach of ERIGrid requires more formal descriptions for components and their interactions.

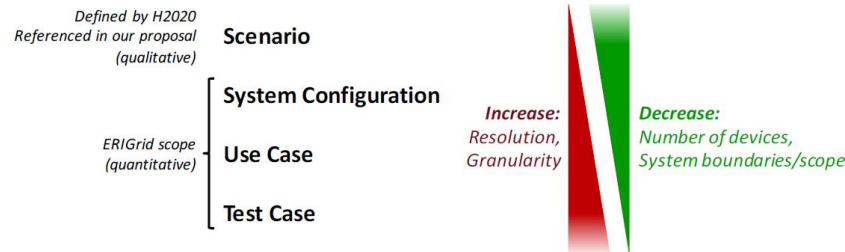


Figure 1: Scope of ERIGrid within the architecture definition levels

Following definitions have been used during this work:

- *System Configuration* defined as an assembly of (sub-)systems, components, connections, domains, and attributes relevant to a particular test case.
- *Scenario* defined as a compilation of System configuration, Use Cases, and holistic test cases in a shared context.
- *Use Case* defined as a specification of a set of actions performed by a system, which yields an observable result that is, typically, of value for one or more actors or other stakeholders of the system.
- *Test Case* defined as a set of conditions under which a test can determine whether or how well a system, component or one of its aspects is working given its expected function.
- *System* defined as a set of interrelated elements considered in a defined context as a whole and separated from their environment.

In the context of ERIGrid, system configurations, use cases and test cases form a logical chain that can be applied throughout the project. In particular, development work related to research infrastructure and to simulation environments can be better supported with a quantitative system configuration approach.

Thus ERIGrid applies system configurations which also refer to known high-level scenarios related projects. System configuration has been defined to include following information:

- Domains
- Components
- Connectivity
- Constraints
- Attributes
- Associated use cases
- Reference to high-level scenarios

### 2.1.1 Domains

Domains normally include infrastructure-specific operation areas such as electricity, heat, primary energy resources or Information and Communication Technology (ICT). Definition of domains can be challenging in many smart grid development areas as the domains become more interlinked and even overlapping. It was also clearly observed that many components are multi-domain components, meaning they belong to several domains and act as an interface between them. Connectivity modelling is closely linked to this issue. Domains are also divided into subdomains or areas in which the components are categorized on a more detailed level.

### 2.1.2 Components

Components are the items that the system is eventually composed of. The type of components varies a lot depending on the domain and the actual function of the component. Components can be practical technical devices, but they can also be more abstract entities or even small subsystems. Typical examples of components are Distributed Energy Resource (DER) units and the energy market as a larger system entity.

### 2.1.3 Connectivity

Connectivity defines how and where components are connected. There are two categories in connectivity: intra-domain connectivity in which components belong to same domain, and inter-domain connectivity in which some component is acting as an interface between the domains. For instance, a smart meter is a classic example of inter-domain connectivity; being connected to the electrical system and the ICT system at the same time and managing the interactions between them.

To describe different connectivity, following types have been used:

- DP – Direct Physical coupling (intra-domain)
- IP – Indirect Physical coupling (either mediated, e.g. by a power converter by other technique; also applicable to 'equivalenced' components)
- DD – Direct Data: direct field-related data for real-time control and decision purposes; e.g. as recorded in the field, is transferred from/to this component
- AD – Abstract Data, such as aggregated or stored field data or otherwise abstracted and data, such as configuration data: only highly processed information is transferred from/to this component/domain
- ICC – Information, processing, or Communication Container: as processing or communication function, no relevance of information content

An illustration of connectivity has been developed in the form of connectivity matrix (see Figure 2) in which domains and components are listed and their connectivity is mapped using the above listed connectivity types. Such a matrix can serve to map both intra-domain and inter-domain connectivity. For the purpose of inter-domain connectivity, the presentation can still be developed to better indicate the interface component.

Relating to the connectivity analysis, stakeholder roles have also been used. They indicate the relations between stakeholders and components or domains:

- *(R)esponsible*: Stakeholder is responsible for Domain/Component
- *(D)irective*: Stakeholder directs Components or other Stakeholders
- *(O)wnership*: Stakeholder owns component
- *(O)perates*: Stakeholder operates component
- *(T)ransactive*: Stakeholder executes transactions with respect to component/domain
- *(I)nformational*: Stakeholder acquires information from component/domain
- *(M)anufacturer*: Stakeholder produces component or system

### 2.1.4 Constraints

Constraints describe limitations to component or system functionality. Constraints can be caused by operational circumstances (for instance a regulatory framework), technical limits (for instance voltage, frequency), prevailing legislation or rules (for instance grid codes), dependencies from other components (for instance availability of communication connection), interoperability (for instance access to right format data) or other practical issues that can limit operation.

	Electrical power system								Heat system								Control system								ICT		
	- Distribution network	-- Lines	-- Loads	-- Transformers	-- DER units	-- Storage units	-- Electric vehicles	-- Household appliances	- District heating	-- Pipes	-- Pumps	-- Valves	-- Storage tanks	-- Heat exchangers	-- Heat pumps	-- Measurements	- Central control	-- Coordinated voltage control	-- Load control	- Local control	-- Local voltage control	-- Local frequency control	-- DG unit controls	- Metering systems	- Communication systems	- Data management systems	
Electrical power system																											
- Distribution network																DP											
-- Lines			DP	DP	DP	DP/IP	DP/IP	DP								DP								DP		AD	
-- Loads		DP																DD			DD	DD			DD		
-- Transformers		DP			(DP)													DD			DD	DD		DD	DD		
-- DER units		DP		(DP)				(DP)										DD			DD	DD	DD	DD	DD	DD	
-- Storage units		DP/IP																DD			DD	DD		DD	DD	DD	
-- Electric vehicles		DP/IP																DD			DD	DD		DD	DD		
-- Household appliances		DP	DP		(DP)		DP											DD			DD	DD		DD	DD		
Heat system																											
- District heating																											
-- Pipes											DP	DP	DP	DP												AD	
-- Pumps										DP						DD									DD		
-- Valves										DP						DD									DD		
-- Storage tanks										DP						DD									DD		
-- Heat exchangers										DP						DD									DD		
-- Heat pumps		DP	DP													DD									DD		
-- Measurements											DD	DD	DD	DD	DD			DD			DD	DD					
Control system																											
- Central control																											
-- Coordinated voltage control					DD	DD	DD	DD											DD		ICC			DD	ICC	AD	
-- Load control			DD													DD			DD					DD	ICC	AD	
- Local control																											
-- Local voltage control				DD	DD	DD	DD	DD								DD			ICC				ICC		DD		
-- Local frequency control				DD	DD	DD	DD	DD								DD							ICC		DD		
-- DG unit controls						DD															ICC	ICC		DD			
ICT																											
- Metering systems		DP	DD	DD	DD	DD	DD		DD									DD	DD		DD	DD	DD		ICC	AD	
- Communication systems						DD	DD	DD										ICC	ICC					ICC	ICC		
- Data management systems		AD	DD	DD	DD	DD	DD			AD	DD	DD	DD	DD				AD	AD		AD	AD		AD	ICC		

Figure 2: Example of connectivity matrix structure

## 2.1.5 Attributes

Attributes define the characteristics of individual component. Practically, there are two attribute types. Global attributes include some information on prevailing circumstances which is common to multiple components, for instance outdoor air temperature. Component attributes are specific to certain component and can be very detailed attributes which cannot be applied in other components. For instance DER unit technical details are obviously component attributes.

## 2.1.6 Associated Use Cases and Scenarios

As a basis for ERIGrid JRA1 work, a survey for scenarios has been conducted to gather ideas among partners and their research infrastructures. The purpose was to identify a set of scenarios which could then be processed towards common ERIGrid scenarios and use cases. The structure as well as the results of this survey are explained in Section 2.3. The outcome of the survey turned out to list potential use cases in addition to scenarios. Within the system configuration approach, developed ERIGrid system configurations map the most relevant use cases based on the survey.

## 2.1.7 Reference to High-Level Scenarios

Higher-level scenarios have been produced in multiple European research project, for instance e-Highway2050 and ELECTRA IRP. The ERIGrid system configurations refer to such higher-level scenarios as a part of their definition.

## 2.2 Background on High-Level Scenarios defined in other Projects

As mentioned in the previous paragraphs the term *scenario* normally applies to a high level de-

scription of a future situation and the corresponding pathways that may lead to that particular future from the present. Certainly, the ERIGrid consortium has considered that this broad concept is of little value when trying to define use cases and test cases for smart grid technologies validation. As it was agreed in the ERIGrid workshop held in Roskilde on 2<sup>nd</sup> February 2016, in the ERIGrid context the term *scenario* must be replaced by the term *system configuration*. Obviously, ERIGrid System Configurations can be located in the framework of several high level scenarios whose definitions are clearly out of the scope of ERIGrid. Other projects or sources like e-Highway2050, ELECTRA IRP, evolVDSO or GridTech are referred for high level scenario definitions.

## 2.2.1 e-Highway2050 Project

One of the most recognized recent developments of scenarios has been done in the e-Highway2050 project [3]. This analysis is one of the few publicly available studies on energy scenarios: transparent, developed by a broad international consortium (which reduces the possibility of being biased), based on a comprehensive review of existing scenarios and inputs from key stakeholders, etc.

The e-Highway2050 study started from a detailed review of national studies and policies within the EU, which was based on results of two questionnaires distributed among ENTSO-E members. The first referred to national data related to load, generation and transmission development. The second one was related to national policies and studies and was divided into energy demand and efficiency, generation, storage, and general framework.

Further the study reviewed the existing scenario studies, comprising 16 studies, which resulted in more than 40 scenarios. Next step was setting the boundary conditions by definition of a set uncertainties and options, where:

- *Uncertainties* are factors, which cannot be directly influenced by decision-makers. Combinations of uncertainties constitute *futures*.
- *Options* introduce controllable factors (choices) into the scenario. Combination of the options in a scenario creates a *strategy*.

Table 1: Summary of e-Highway2050 futures [3]

Main Uncertainty	Possible Values	Future 1 Green Globe	Future 2 Green EU	Future 3 EU-Market	Future 4 Big is beautiful	Future 5 Small things matter
<b>Energy and Climate Policy</b>						
International Climate Agreement	Global agreement / EU alone	Global agreement	EU alone	EU alone	Global agreement	EU alone
Dependency on fossil fuels from outside Europe	High/Medium/Low	Medium	Low	Medium	Medium	Medium
Joint transnational initiatives	Difficult/Common	Common	Common	Difficult	Common	Difficult
Fuel Costs	High/Low	Low	High	High	Low	High
CO2 cost	High/Low	High	High	Low	High	Low
<b>Technological development</b>						
Storage technology maturity	Small scale/Large scale/All	All tech mature	All tech mature	All tech mature	Large-scale	Small-scale
CCS maturity	Yes/No	Yes	No	Yes	Yes	No
Electrification in Transport - Heating - Industry	Residential/Large scale/All	All	All	All	Large scale (commercial, industry&freight)	Residential (Homes, person vehicles)
<b>Economic</b>						
Demographic change	Growth/Migration only	Growth	Growth	Migration only	Growth	Migration only
GDP growth in EU	High/Medium/Low	High	Medium	High	Medium	Low
<b>Socio-political perceptions</b>						
Public perceptions to RES	Positive/Indifferent	Positive	Positive	Indifferent	Indifferent	Positive
Public perceptions to Nuclear	Positive/Indifferent/Negative	Negative	Indifferent	Indifferent	Positive	Negative
Public perceptions to Shale gas	Positive/Indifferent/Negative	Negative	Negative	Indifferent	Positive	Negative
Shift towards 'greener' behaviours	Major shift/Minor shift	Major	Major	Minor	Minor	Major
<b>Assumptions - Constant Uncertainties</b>						
RES technology / DSM technology	Mature	Mature	Mature	Mature	Mature	Mature

Table 2: Summary of e-Highway2050 strategies [3]

Main Options	Strategy 1 MARKET LED	Strategy 2 LARGE SCALE RES	Strategy 3 LOCAL SOLUTIONS	Strategy 4 100% RES	Strategy 5 CARBON FREE CCS & NUCLEAR	Strategy 6 NO NUCLEAR
Deployment of centralized RES	Medium	High	Low	High	Low	High
Deployment of de-centralized RES (including CHP and Biomass)	Medium	Low	High	High	Low	High
Deployment of centralized Storage	Medium	High	Low	high	Low	High
Deployment of de-centralized Storage	Medium	Low	High	High	Low	High
Deployment of nuclear plants	Medium	Medium	Low	No	High	No
Deployment of fossil fuel plants with CCS	Medium	No CCS	No CCS	No CCS	High	High
Deployment of fossil fuel plants without CCS	Medium	Low	Low	No	Low	Low
Increase of energy efficiency (include DSM and flexibility)	Medium	Low	High	High	Low	High
Increase of funds and better coordination of RDD activities (at EU level)	Medium	High	Low	High	Medium	High
Electricity imports from outside Europe	Medium	High RES (Desertec)	Medium	High RES (Desertec)	Low	Medium
Permitting framework (incl EU nature legislation)	Convergent and Strong framework	Convergent and Strong framework	Heterogeneous framework at EU level	Convergent and Strong framework	Heterogeneous framework at EU level	Convergent and Strong framework
Assumptions - Constant Option						
EU Policy for GHG reduction emissions	Strong	Strong	Strong	Strong	Strong	Strong

The identified uncertainties and options were ranked from most important to less important, based on their relevance. Combination of *Futures* and *Strategies* create a number of Scenarios as it is shown in:

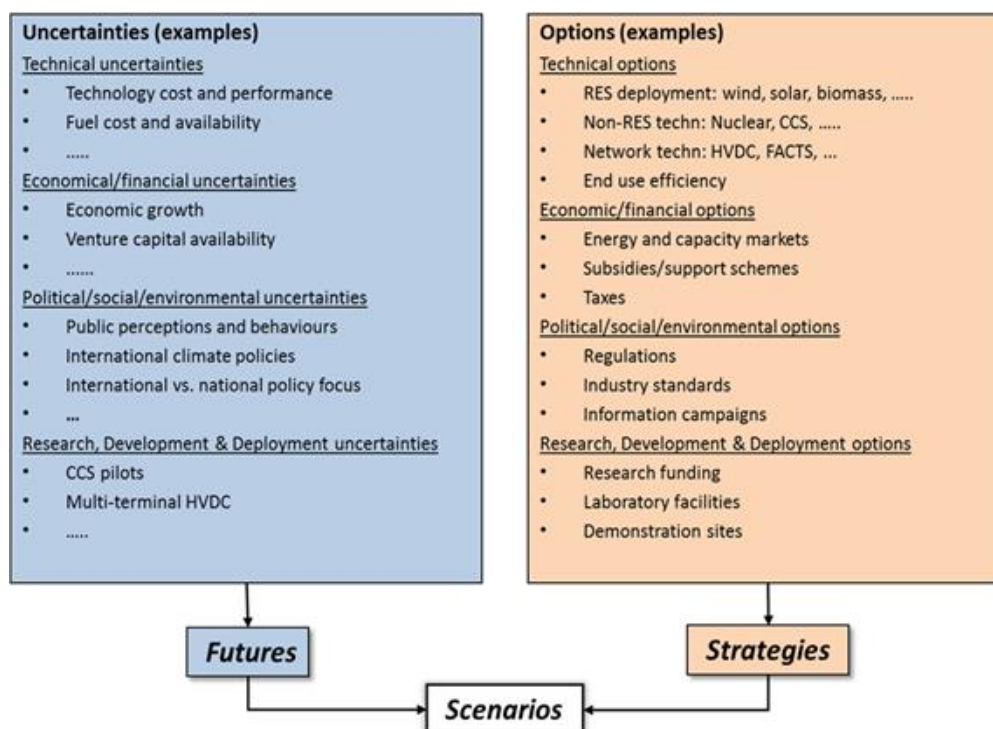


Figure 3: Formation of scenarios based on futures and strategies [3]

Based on this methodology the study identified altogether five possible futures, which can be achieved by pursuing six relevant strategies. Combination of these generates in total 30 scenarios as it is presented in:

Table 3: Summary of e-Highway2050 scenarios [3]

Criteria (options / uncertainties)	x-1	x-2	x-3	x-4	x-5	x-6	x-7	x-8	x-9	x-10	x-12	x-13	x-14	x-16	x-17
	Large Scale RES, Green Globe	Local solutions & Green globe	100% RES, Green globe	Green revolution & no nuclear	Large Scale RES & No emission	Local solutions	"100% RES"	Pure Market	local solutions & market	Big & Market	100% RES, Big EU	Big, Nuc & CCS	No nuc & Big	"Small and local"	100% RES & small
Level of centralized renewable	60%	20%	60%	40%	60%	20%	60%	30%	20%	40%	60%	30%	40%	25%	40%
	High	Low	High	M/H	High	Low	High	Medium	Low	M/H	High	L/M	M/H	Low	M/H
Level of decentralized renewable	20%	60%	40%	40%	15%	60%	40%	20%	60%	20%	40%	5%	20%	60%	60%
	M/L	High	High	High	Low	High	High	M/L	High	M/L	High	Low	M/L	High	High
Level of renewable	80%	80%	100%	80%	75%	80%	100%	50%	80%	60%	100%	35%	60%	85%	100%
Level of Fossil fuel plants with CCS	0%	0%	0%	15%	0%	0%	0%	20%	0%	15%	0%	30%	30%	0%	0%
	No	No	No	Medium	No	No	No	Medium	No	Medium	No	Yes-High	Yes-High	No	No
Level of Fossil fuel plants without CCS			0%	5%	5%		0%	10%		5%		5%		5%	
			Low	Low	Low		Low	Medium		Low		Low		Low	
Level of Fossil fuel	0%	0%	0%	20%	5%	0%	0%	30%	0%	20%	0%	35%	30%	5%	0%
Level of nuclear	20%	20%	0%	0%	20%	20%	0%	20%	20%	20%	0%	30%	0%	10%	0%
	Medium	Med	No	No	Medium	Medium	No	Medium	Medium	Medium	No	High	No	Low	No
Level of centralized storage	High	Low	High	High	High	Low	High	Medium	Low	Medium	High	Low	High	Low	High
Enabling EU international exchanges	High	Medium	High	Medium	High	Medium	High	Medium	Medium	Medium	High	Low	Medium	Medium	High
New use emerging (including DSM)	High	Low	High	High	High	Low	High	Medium	Low	Medium	High	Medium	High	Low	High
New use	High	High	High	High	High	High	High	High	High	High	High	High	High	Low	Medium
Population (demographic changes)	Growth	Growth	Growth	Growth	Growth	Growth	Growth	Migration only	Migration only	Growth	Growth	Growth	Growth	Migration only	Migration only
GDP increase	High	High	High	High	Medium	Medium	Medium	High	High	Medium	Medium	Medium	Medium	Low	Low
Energy efficiency	Low	High	High	High	Low	High	High	Medium	High	Medium	High	Low	High	High	High

Table 4: Categorization and selection of scenarios [3]

Futures	Strategies	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Strategy 6
		MARKET LED	LARGE SCALE RES SOLUTIONS	LOCAL SOLUTIONS	100% RES	NUCLEAR & CCS	WITHOUT NUCLEAR
Future 1	Green Globe	NUC	X-1	X-2	X-3	NUC	X-4
Future 2	Green EU	CCS	X-5	X-6	X-7	CCS	CCS
Future 3	EU- Market	X-8	No Policy	X-9	No Policy	No Policy	No Policy
Future 4	Big is beautiful	X-10	CCS	Illogical	X-12	X-13	X-14
Future 5	Small things matter	NUC/CCS	Illogical	X-16	X-17	NUC	CCS

The elimination of spurious scenarios that involve contradictions between the defined futures and strategies, reduced the number of scenarios from 30 to 15 (marked in green in the previous table). The following step was to identify representative scenarios which had contrasted impacts (i.e. differ from each other), to cover a wide scope of possible futures in a set of limited cases. Each e-Highway2050 scenario is one alternative image of how the future of European Electricity Highways (EHS) could unfold. The following scenarios were selected:

- Big and market (x-10).
- Large fossil fuel with CO<sub>2</sub> Capture and Storage (CCS) and nuclear (x-13).
- Large scale Renewable Energy Resources (RES) & no emission (x-5).
- 100%RES (x-7).
- Small and local (x-16)

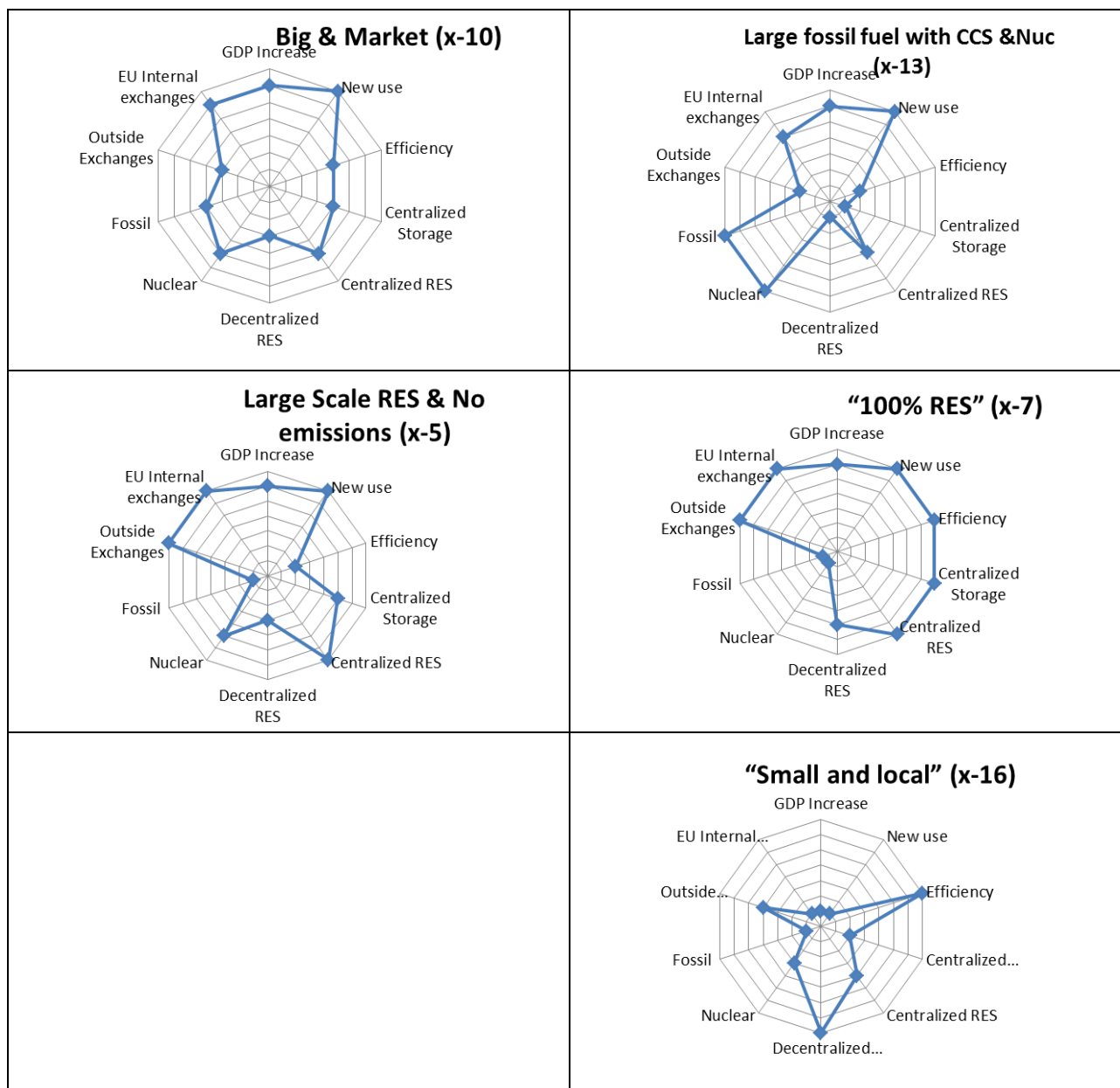


Figure 4: Profiles for chosen scenarios [3]

The e-Highway2050 scenarios are not predictions about the future; one scenario will not be more likely to happen than another or is more preferred than another. The e-Highway2050 project develops an envelope of five equally probable scenarios for all equally possible ways to achieve the EU 2050 targets. It is reasonable to assume that any scenario achieving the 2050 goals will land within the stipulated envelope. It is within that envelope where the ERIGrid system configurations are formulated matching many of the possible high-level scenarios.

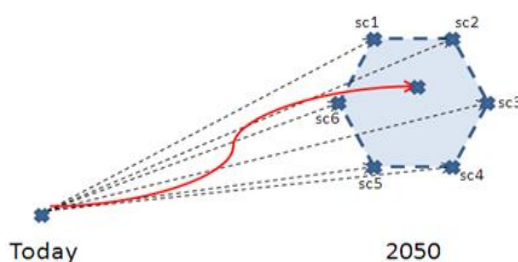


Figure 5: Illustration of scenarios development path [3]

### 2.2.2 ELECTRA Integrated Research Programme

ELECTRA IRP ([www.electrairp.eu](http://www.electrairp.eu)) is another reference project which tries to propose operational solutions to possible futures (2030+). This smart grid Integrated Research Programme (IRP) does not present itself a unique scenario, but focuses its effort in designing control strategies that will allow the use of decentralized and intermittent generation, connected at all levels within the electrical network for the provision of ancillary services. From this point of view it can be said that ELECTRA IRP builds solutions to problems related to a number of clear and indisputable trends that fit multiple future scenarios. The set of assumptions that constitute the so-called “ELECTRA scenario” are the following [4]:

- Generation will shift from classical dispatchable units to intermittent renewables.
- Generation will substantially shift from central transmission system connected generation to decentralized distribution system connected generation.
- Generation will shift from few large units to many smaller units.
- Electricity consumption will increase significantly.
- Electrical storage will be a cost-effective solution for offering ancillary services.
- Ubiquitous sensors will vastly increase the power system’s observability.
- Large amounts of fast reacting distributed resources (can) offer reserves capacity.

Again, the ERIGrid System Configurations (especially those dealing with the “distribution grid” and “vertical integration”) fit well within the ELECTRA IRP scenario, which in practice means that the many of the derived use cases and test cases in ERIGrid are aligned with ELECTRA IRP developments and a mutual benefit can result (particularly the clear synergy ERIGrid/ELECTRA IRP).

### 2.2.3 evolvdSO Project

The definition of the high-level scenarios within the evolvdSO project ([www.evolvdso.eu](http://www.evolvdso.eu)) [5] is based on the analysis of the potential evolution of the electricity grid to determine which could be the requirements to be fulfilled in the future. This potential evolution considers three main aspects:

- *Generation mix*: including all the parameters related to the installed capacity by technology and split due to the different voltage levels.
- *Evolution of demand*: peak load, energy consumption and load type (residential, industrial, commercial or agricultural).
- *Degrees of technological freedom*: considering the use of new or existing flexibility assets, demand response, etc.

These aspects were considered as the key parameters for the comparison of the different options and the identification of the main drivers and the uncertainties expected for the future evolution. Starting from this framework and for every country analysed (Belgium, Germany, France, UK, Ireland, Italy and Portugal), three time horizons were considered.

- *Short-term*: up to 4 years
- *Medium-term*: between 8 and 10 years
- *Long-term*: 20 years

And for every time horizon, taking as main variable the expected boost of RES at a distribution level (Distributed Renewable Energy Source (DRES)), also three different “futures” were outlined:

- *Under expected*: foreseeing a delay in the implementation of DRES.
- *Most likely*: Expected degree of implementation of DRES and the future with the highest possibilities to happen.
- *Over expected*: covering the most extreme case of DRES penetration.

The ERIGrid System Configuration “Distribution Grid” fits completely in these evolVDSO scenarios.

## 2.2.4 GridTech Project

The aim of the GridTech project ([www.gridtech.eu](http://www.gridtech.eu)) [6] was to determine which technologies, in which locations and to what extent can contribute to the future development of the European grid while contributing to maintain a secure and sustainable electricity supply and facilitating the creation of a European electricity market. This has been accomplished by combining a top-down approach methodology applied to seven target countries (Austria, Bulgaria, Germany, Ireland, Italy, Netherlands, Spain) and in three time horizons (2020, 2030 and 2050).

Starting from a baseline scenario (S0), the effects of transmission grid technologies (starting from High Voltage Direct Current (HVDC)) on cross-border/inter-zonal system expansion with respect to S0 can be specifically evaluated by the analysis of the dedicated transmission grid technologies-oriented scenario (S1) implemented over the years (up to 2050). Also, the penetration of Demand Response (DR) is not taken into account in the baseline scenario (S0), as it is fully considered in the dedicated electricity demand oriented scenario (S3), in order to evaluate the impact of DR penetration increase over the years 2020 to 2050 in the different European countries. Analogously, the impact of additional bulk energy storage (starting from Pumping Hydroelectric Energy Storage (PHES)) with respect to the baseline scenario (S0) is evaluated by the analysis of the dedicated energy storage oriented scenario (S2) in which bulk storage expansion is particularly taken into account over the years (up to 2050) in different European countries, where present [6]. The summary of the main factors considered and the four scenarios analysed in GridTech is shown in Table 5.

The GridTech scenarios seem to be a proper foundation for the ERIGrid System Configuration “Vertical Integration”.

Main factors/Scenarios	S0 (baseline)	S1 (TGT-oriented)	S2 (EST-oriented)	S3 (EDT-oriented)
Economic and financial conditions	Favourable	Favourable	Favourable	Favourable
Market and regulatory framework	European	European	European	European
CO <sub>2</sub> penalty tax level	Moderately increasing	Moderately increasing	Moderately increasing	Moderately increasing
Fossil fuel price level	Moderate	Moderate	Moderate	Moderate
Generation mix approach	National/European	National/European	National/European	National/European
RES penetration	High	High	High	High
CCS deployment	Low/limited	Low/limited	Low/limited	Low/limited
Bulk storage expansion	no	no	yes	no
Cross-border/inter-zonal transmission expansion	no	yes	no	no
Total electricity demand	High/moderate	High/moderate	High/moderate	High/moderate
Demand response penetration	Not present	Not present	Not present	Present
Electric vehicles penetration	Partially present	Partially present	Partially present	Partially present
Heat pumps penetration	Partially present	Partially present	Partially present	Partially present
Efficiency measures	Limited/present	Limited/present	Limited/present	Limited/present

Table 5: Summary of GridTech scenarios [6]

## 2.2.5 Overview of the Ten-Year Network Development Plan-2014

The Ten-Year Network Development Plan (TYNDP) 2014 is an ongoing activity by ENTSO-E based on the 2030 horizon analysis exploration. The results of the analysis are public and can be

found in [7]. The TYNDP is a continuously evolving process that began with the pilot TYNDP in 2010. The current version of the analysis is the outcome of 2 years work which started in 2012. The major novelties in the 2014 version are:

- Exploration of longer-run horizon scenarios through to the year 2030
- New clustering rule to define projects of pan-European significance.
- Quantification of every project's benefit assessment
- Appraisal of the interconnection target capacities
- Easier and more frequent opportunities for stakeholder participation

It is worth noting that via Regulation (EU) 347/2013, in force since April 2013, the role of TYNDP is strengthened and is mandated as the sole instrument for the selection of projects of common interest. Also via encouragement by ENTSO-E, there was a substantial involvement of stakeholder during several phases, with the organization of several workshops, public consultations and bilateral meetings for the production of the current version of the analysis.

The concept of TYNDP is divided into 4 visions for the year 2030. These visions do not constitute a forecast per se of the future situation but possible future states selected as wide-ranging alternatives, or as boundaries within which, with a high level of certainty, the 2030 actual pathway will evolve. The span of the four visions was selected so as to fulfil the expectations of the various stakeholders and their major differences relate to:

- The trajectory towards the Energy Map 2050 (regular pace for visions 3 and 4 whilst accelerating pace for 1 and 2).
- Fuel and CO<sub>2</sub> prices favour coal in Vision 1 and 2 while they favour gas in 3 and 4.
- In terms of generation mix development strategy visions 1 and 3 are bottom-up approaches based on each country's policies whilst visions 2 and 4 assume a consistent top-down pan-European approach.

Furthermore, all the scenarios assume significant RES generation development, supplying 40% to 60% (depending on the vision) of the total annual demand, paired with a huge reduction in CO<sub>2</sub> emissions (-40% to -80% compared to 1990).

#### **2.2.5.1 TYNDP 2014 Vision 4**

Of the four visions of the plan vision 4 is the most interesting one for our project and it was also used as a reference for the analysis of the off-shore wind farms configuration scenario. The specific vision is named "green revolution" due to the fact that it reflects the most ambitious path towards the 2050 European energy goals with 60% of load supplied by RES in 2030, a goal met by all countries playing as a team. Also, in vision 4 the power supply is optimized (in contrast with vision 3), with a requirements for additional investments. In particular, for the wind power which is related to one of the three ERIGrid system configurations, there is a prediction of possible increase from 105 to 431GW. In terms of CO<sub>2</sub> emissions, vision 4 predicts a reduction as high as 80% in the ENTSO-E perimeter compared to the year 1990.

The key features of vision 4 in terms of generation and load framework are the following:

- Electricity demand is the highest of all four visions
- There is a full exploitation of demand response
- Electric plug-in vehicles allow for both charging and generation in a flexible fashion
- Full implementation of smart grid technologies
- Carbon Capture and Storage is commercially deployed

Last but not least, in economic and policy terms the main features of vision 4 are the following:

- Favourable economic and financial conditions
- Energy policy at European level
- R&D research schemes at European level
- High CO<sub>2</sub> prices and low primary energy prices

## **2.3 ERIGrid Scenario Survey**

### **2.3.1 Survey Purposes and Conduction**

To gather a common understanding of scenarios which are interesting to ERIGrid partners and their research infrastructures, a survey was conducted among first actions of the JRA1 work. The purpose was to define a set of scenarios that should be considered in more detail, as well as to produce background on common interests.

The survey was taken by means of a simple web form, which enables easy presentation of the results. Overall, 13 partners completed the survey and provided more than 30 different scenarios. The structure of the survey included the following:

- Information provider name and affiliation
- Scenario title
- Developed in (project/network/etc.)
- Published on
- Link or reference
- Short description of the scenario
- Relevance for ERIGrid

### **2.3.2 Survey Results**

Generally, the contributions mention multiple times some aspects that are commonly of interest in the research area of smart grids. The majority of the results relate to Medium Voltage (MV)/Low Voltage (LV) distribution grids and their management. Some topics were especially raised:

- Voltage and frequency control on different grid levels
- Integration of storage units and renewable energy resources
- Microgrid solutions
- Methods for energy management and active distribution grid operation

However, some foreseen scenarios on ICT-related topics and interoperability were not as commonly mentioned as expected. For instance, there were not many cyber-security or infrastructure resilience related scenarios submitted. Similarly, operation of ICT systems was not commonly highlighted.

Overall, it was observed that most of the data submitted was more of a use case type than actual scenario type. While this can be due to light instructions given, it can also illustrate complexity of the topic and definitions. Within the project it was also decided to focus on generic system configurations as explained above. Thus some parts of the survey data served also for a bottom-up approach, in which the system configurations used the data to gather characteristic and parameter information. Eventually, system configurations associated most relevant scenarios as use cases.

The full list of scenarios for which the information was collected is as follows:

- Regionally-specific scenario with regard to unit distribution
- Optimal ICT penetration for the extension of the complete German distribution grid under different scenarios
- Copenhagen-BRussels-Amsterdam cable (COBRACable)

- Interoperability of two micro-grid platforms
- Coordinated voltage control
- Frequency/power balance control
- Aggregator validation
- Use of flexibility in active power networks
- Restoration reserves procurement using distributed control
- Distribution network subjected to local voltage issues
- Low observability of distribution systems
- Smart autonomous energy management in smart building
- Smart metering for smart grids
- Electric Vehicle (EV) and Electric Vehicle Supply Equipment (EVSE) integration into smart grid systems
- Direct Current (DC) House
- Grid support by Distributed Generation (DG) and Storage
- Emission trading and optimisation schemes with the use of Multi-Agent Systems (MAS)
- Distributed tracking of distribution grid topology
- Integration of RES
- Distribution network subjected to local overloads
- Uncertainty Reduction in Smart Energy Systems (URSES) research project
- Operation and control of off-grid systems
- Optimal operation of microgrids
- Multi-energy system (Nordhavn)
- Monitoring, control and automation in smart grids
- Intentional or virtual islanding operation of distribution network
- New architectures for smart grids: microgrids
- Remote controlling decentralised Photovoltaic (PV) installations
- Coordinated voltage and frequency control using a high share of renewables

Detailed descriptions for the scenarios are presented in the Annex of this report.

### 2.3.3 Survey Analysis

Summaries of these scenario descriptions are included as an Annex of this report. Data produced by this survey has been analysed. The survey was conducted with relatively brief instructions in order to gather wide information. Thus, the level of details varies in answer sets. Some of the scenarios were more general, whereas some were directly based on a specific project or business case and were thereby more detailed.

Relevance to ERIGrid was well defined and most of the scenarios were clearly suitable within the ERIGrid scope and objectives. Relevance to ERIGrid has been defined to include aspects such as:

- Needs for high-level research infrastructures
- Needs for system testing
- Supporting technology validation and roll-out phases
- Justifying joint use of research infrastructures
- Need of co-simulation tools and methods
- Potential for remote testing and remote connections
- Development of testing procedure

The data has been categorized in different ways to draw conclusions on it. One method was to consider the actual application area and domains. With this method, four categories have been identified:

1. Interoperability / information exchange related
  - ICT penetration, smart metering, smart building interface, etc.
2. Grid control and management related
  - Voltage control, frequency control, reserves, EV integration, etc.
  - Microgrids, islanding, automation, etc.
3. Aggregator / ancillary service related
  - Aggregator business, validation, trading and optimisation, grid support functions, etc.
4. Holistic approach related
  - Flexibilities in energy systems, multi-energy systems, etc.

The data can also be categorized in many other ways, for instance according to their needs in terms of ERIGrid consortium and capabilities:

- Use of co-simulation and real-time Hardware-in-the-Loop (HIL) etc.
- Use of facilities throughout the partner group
- Orientation on technical solutions / ICT / processes etc.

Categorization always depends on the eventual objectives. For instance test setups should be independent from the use cases and system configurations. Thus categorization has not been developed further here. The survey outcomes have served as an input for system configuration development as well as formation of use cases during later phases of work taken.

## **2.4 Linking Generic System Configurations with High-Level Scenarios**

The generic system configurations are considered to apply some high-level scenarios as a background, providing the overall circumstances in which the system configuration actually takes place. At the same, high-level scenarios provide understanding of current progress; what is the current status and what are the future expectations affecting the system configuration. High-level scenarios can also better explain the higher-level drivers of a specific system configuration; for instance, a need for more renewable energy resources.

ERIGrid system configurations can be linked to multiple high-level scenarios at the same time, combining their characteristics. However it is impossible to apply fully contradictory scenarios in same system configuration. Thereby it is typically most feasible to rely on a set of scenarios provided by one project or initiative and to base the work upon them. Within JRA1, the work has been focused around scenarios provided by the e-Highway2050 and ELECTRA IRP projects.

### 3 Generic System Configurations

As explained in previous chapter, ERIGrid JRA1 work has focused on developing generic system configurations that allow development of use cases and test cases within the project, as well as supporting the work on infrastructure development, simulation environment development and the actual development of methodology for describing system configurations, use cases and test cases.

The work has been organized as three *working groups*, each addressing a system area. The decision on these three system areas has been taken in a technical workshop, utilizing also the outcomes of scenario survey. Three working groups have been:

- Distribution grid
- Transmission grid and offshore wind
- Vertical integration

The working groups have developed *system configurations* for their dedicated system areas as well as templates for describing them. The final description templates are included in an Annex of this report.

Some aspects have been considered challenging during the work in all three working groups. First of all, terminology has been difficult to define and maintain uniform in three different scenarios. It has also been observed that only little prior work has been done in this area and thereby there are not many references for similar system configuration development. In comparison, for high-level scenarios there are lot of examples. Another challenge has been the level of details. These system configurations are meant to be rather generic, so that they enable various use cases and test cases and do not constraint their further development. However, technical configuration always requires some details as well. The main focus in system configurations is to define the components and their correct parameters for defining the system operation. Actual values will be defined according to the use case. Defining the prevailing circumstances and constraints is important as it defines the operational environment for use cases. In addition, it is important to define the interactions between components in the system configuration. This has been addressed by developing connectivity matrixes.

The templates apply similar hierarchy for the structure, starting from domain information and proceeding to more local information (such as areal/level) and finally to individual components. Parameters are defined for each component as well as for the whole system as global parameters. Some components are clearly multi-domain components, as explained earlier, and have been difficult to define within the current templates.

#### 3.1 Distribution Grid

System configuration “Distribution grid” considers the electricity distribution system at MV and LV voltage levels. The area covered by this configuration starts at the High-Voltage (HV)/MV transformer, where also the responsibility area of Distribution System Operator (DSO) typically starts. On the LV side, the configuration is limited to customer interface (metering point) or at the connection point of each active component or DER unit. However, the configuration also needs to consider components beyond the network connection point to the degree they impact on the state of the distribution grid. Hence components like control systems for DER units or controllable loads are included in the configuration.

The distribution grid as a domain includes a significant number of control-related challenges and developments. Communication is also increasingly present for monitoring and control purposes. One issue faced in this work was how to present these different layers. It could be possible to build up separate layers for the power system, communication system and control systems. This would enable more detailed presentation of each system and especially their interfaces. Eventually, con-

trol systems and ICT have been included as separate domains in this configuration. Multi-domain components are located in domain interfaces, for instance smart meters which are physically connected to the power domain but also connected to ICT domain in terms of data and control.

This system configuration includes a long list of traditional power system components such as lines, loads, transformers and switches. They all belong to the electrical power system domain. Some active components such as DER units, storage units, EV charging stations or Intelligent Electronic Devices (IED) are also present; they are also physically connected to the electrical power system domain, but they are also connected to control and ICT domains via their controllers and communications.

The system configuration also includes a heat system domain. The purpose of including heat system is to be able to represent aspects of cross-impacts between heat and electricity; for instance in CHP production, heat exchangers, heat pumps, etc. Heat system parametrisation is left very generic with the main focus to include connectivities.

The control domain includes various controllers connected with components. They have been categorized to central (coordinated) and local control methodologies. ICT domain includes metering systems, communication and data management areas. Stakeholders and markets have also been presented as separate domains, indicating different roles and markets within the scope of this system configuration.

Connectivity has been mapped by means of a matrix in which all domains and components beyond have been listed and their connectivities have been marked with categories as explained in previous chapter. The full connectivity matrix is included in the configuration document in the Annex.

The system configuration associates scenarios or use cases based on the conducted survey. They have been categorized into four groups:

1. System services from controllable resources
  - Coordinated voltage control
  - EV integration into smart grid systems
  - Grid support by DG and storage
  - Low power factor exchanges in primary/secondary substations
  - Use of flexibility in active power networks
  - Coordinated voltage and frequency control using a high share of renewables
2. ICT infrastructure
  - Smart metering for smart grids
  - Monitoring, control and automation in smart grids
  - Distributed tracking of distribution grid topology
3. Microgrids and islanding
  - Unintentional islanding occurrence
  - Operation and control of off-grid systems
  - Optimal operation of microgrids
  - New architectures for smart grids: microgrids
4. Multi-energy systems
  - Multi-energy system (Nordhavn)

The system configuration aligns with high-level scenarios from e-Highway2050 (especially x-7 “100% RES” and x-16 “Small and Local” as well as the ELECTRA scenario.

### **3.2 Transmission Grid and Offshore Wind**

The offshore wind power plant scenario has been selected because it is a predominant future sce-

nario with special operation characteristics and impact on transmission grids. For specifying the system configuration, the following assumptions have been made:

- A meshed HVDC network will be adopted because it seems a cost effective solution for hosting high-power wind generation and, as a topic, it presents an additional research interest.
- Alternating Current (AC) grid parts are assumed for the connections of the wind power plants to the HVDC hubs and an aggregated representation for the on-shore substations/connections.
- More than one connection to the shore may be used because it adds extra benefits in terms of services and allows the wind power plant to participate in various processes of operation and the energy market. Also, this increases the number of applicable use cases.
- Interconnection with different control areas (different countries) so as to increase diversity of operating characteristics and processes at the ends of the system.
- Simple configuration with the minimum possible number of components that at the same time satisfy the abovementioned requirements.
- Hierarchical control structure based on levels, with each level assigned with specific roles for the system's protection, operation and optimisation.
- The system is assumed to have specific role(s) in the energy and ancillary services market which help to establish concrete interconnections with the 'Market' domain.
- The interconnection with other physical domains such as weather conditions is more specific since there's only one RES technology involved. Nevertheless, the effects of weather conditions are considered only as a boundary of the system and are not analytically modelled.

Based on example scenarios the system configuration is extended according to the aforementioned assumptions. To this end, components given in the basic scenario have been identified followed by components for possible extensions to the basic scenario. For those components, attributes and domains have been identified as well as the connections between.

One of the most crucial discussion topics was the importance of considering onshore wind power plants together with the offshore scenario. The former is (and will be) the predominant wind-production scenario of the future but taking into account only the share of a scenario for selecting it, it means that other large-scale technologies should also be considered. Thus, only the offshore wind power plant scenario is considered, not just for its contribution to the RES share but also for its technical characteristics. Specifically, the incorporation of meshed HVDC grids is a value added for the selection of the scenario.

The topology of the system was also an important discussion topic. Among different options such as pure AC, radial DC, and meshed DC configurations, the meshed scenario has been selected which is technologically the most promising solution for bulk transmission of offshore wind power.

HVDC onshore fault ride-through protection was also identified as a serious challenge from an operational as well as testing and simulation perspectives.

A third discussion point was the way of modelling the onshore connection points and, in general, the overall onshore transmission grid's behaviour in combination with the selected scenario. To this end, aggregation of production/consumption at various grid nodes (at transmission level) and simplified representation of the transmission grid has been agreed. With the use cases in mind (e.g., fault ride-through, energy balancing, active power control, stability to a lesser extent) this is a plausible assumption.

### 3.3 Vertical Integration

The vertical integration scenario and system configuration provides a possible background for use cases requiring coordination and integration of transmission and distribution grid related tasks. In principle, it includes all domains used in other system configurations; however, in this system configuration often abstractions and aggregations of usually included components are employed, as the full detail may overload a given test requirement.

Due to its cross-cutting nature, vertical integration system configuration sets lot of attention on connectivity of components, their information exchange as well as roles of stakeholders.

The use cases associated with this system configuration have been categorized as follows:

- Grid control and management related
  - Frequency/power balance control
  - Smart metering for smart grids
  - Coordinated voltage control
  - Restoration reserves procurement using distributed control
  - EV integration into smart grid systems
  - Monitoring, control and automation in smart grids
  - Demand Response (DR)
- Aggregator/ancillary service related
  - Aggregator validation
  - Emission trading and optimization schemes with the use of MAS
  - Grid support by DG and storage
  - Distributed tracking of distribution grid topology

#### 4 Harmonised Presentation of System Configuration Structures

The system configurations presented in previous chapter share many common features but also have certain differences in structure. Initially, all working groups started on the same definition of system configuration; however, development of the description structure and the template was one of the purposes of these working groups. Thus the final products have some differences according to needs of each system area.

Three working groups worked on defining a system configuration based upon the following:

- Component-centric description
- Sub-systems can be viewed as components
- Components are found within- or on the border- of domains
- Components are connected
- Components have attributes
- Components and scenarios have constraints

The three groups worked in parallel and a common description method was found by comparing the work of the three work groups and under the principles of:

- Reducing the amount of repeated information
- Follow the concepts of *holistic testing*

A system configuration is defined by the following:

- A table or multiple tables that cluster components by system/sub-system and denote any specific attributes of the components that are not shared across components in the same domain. Components are assigned a component Identified (ID).
- A connectivity table, which lists the component IDs and denotes which kind of connection it has in a specific domain.
- An attribute table that describes the common attributes of components within the defined domains.
- A table listing constraints which are attribute related or scenario (global) related.
- One or more figures showing the system/component topology.

The overall hierarchy of the system configuration structures is similar; starting from the high level of **domain**, progressing through some intermediate levels ending up in **components** and their **attributes**. Intermediate levels or **subdomains** have been defined a bit differently in the system configurations and are called **areas**, **levels**, **subsystems** or **systems**.

Connectivities can be represented through mapping of components into primary domains and sub-domains as illustrated in Figure 6.

ID	Component	Primary Domain 1		Primary Domain 2		Primary Domain 3	Primary Domain 4
		Subdomain 1	Subdomain 2	Subdomain 3	Subdomain 4		

Figure 6: Example of domain hierarchy for connectivity of components

Harmonization of structures for system configurations, use cases as well as test cases takes place in ERIGrid work package NA5 which includes addressing the methodology of providing such descriptions. Joint actions have been taken on reviewing these configuration descriptions and discussing their harmonization. Harmonisation should follow two principles; reducing amount of repeated information and following the component-centric description of a system, including also connectivity.

## 5 Discussion and Future Outlook

This report draws together the work taken within JRA1.1 “Identification of relevant scenarios”. The work has progressed from defining the approach and terminology, continued with definition of three system configuration for ERIGrid purposes and finally considered experiences and harmonization of the structures. The work has been conducted with different manners, for instance using participant survey for gathering background information and ideas on relevant scenarios, organizing working groups for developing each system configuration. General brainstorming has also taken place in order to define the approach and terminology.

The approach of generic system configurations has been used throughout the work. System configuration methodology was considered to serve ERIGrid purposes better than typical scenarios due to better support for use case work, simulation environment development and use of research infrastructures.

Three system configurations cover the areas of transmission grid with offshore wind power, distribution grid and vertical integration. Each configuration is described in a separate document.

Main observations from the working groups indicate that the work on system configurations has been challenging especially in methodological perspectives. A generally applicable structure of description is difficult to achieve. At the same, the level of details is challenging to define. System configuration should give some quantitative data, but at the same be generic enough to be widely applied. It should provide the circumstances in which use cases can be built. Some really fundamental questions regarding for instance the purpose of system configurations, their support for use case construction or terminological aspects were also constantly faced during the work.

### 5.1 Links within ERIGrid

The work of this task is closely linked with most of the ERIGrid activities.

- Within JRA1, system configurations form the basis on which more detailed use cases are constructed. Implementation of these use cases will then be planned within JRA1.
- JRA2 focuses on simulation based methods. This work sets the background on requirements for simulation development. The system configurations do directly define the circumstances which need to be modelled for simulation purposes. Use cases will then give more concrete cases for simulations.
- JRA3 addresses development integrated laboratory use. Similarly to simulation, this work defines the basic requirements for development.
- JRA4 will directly demonstrate the scenarios and use cases in integrated research infrastructure. This work clearly sets the basis and the further developed use cases will define the actual demonstration cases.
- NA3 manages the transnational access, meaning the external user group visits to partner facilities. This work supports by providing a platform that can be applied for new use cases.
- NA5 considers holistic system integration and testing procedures and has been closely linked with this work. Development of methodology has been taken jointly with NA5. This work provides an important feedback channel by providing practical experiences and examples for using the system configuration structures.

The high-level structure of ERIGrid shown in Figure 7 also depicts the relations of JRA1 work.

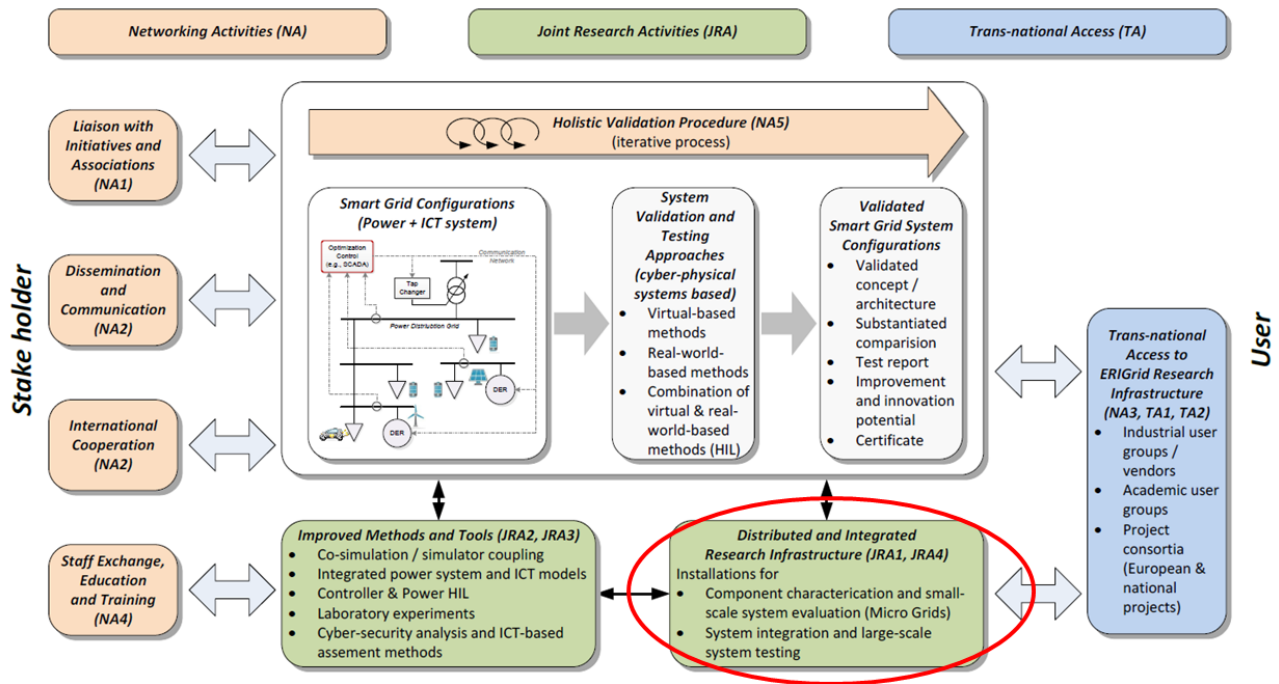


Figure 7: Overall view of ERIGrid activities

## 5.2 Conclusions

Within ERIGrid project, this task constructed rather practical descriptions for the system configurations. The information structures used were developed in co-operation with task NA5.2, which takes a more detailed look on the methodology itself.

As an outcome, the work has promoted important discussion around terminology and generic project alignments. The system configurations as well as use cases built later on them will act as a basis for development in the frameworks in other research tasks in ERIGrid but also beyond. It is also assumed that they support ERIGrid Trans-national Access (TA) partners by providing a framework that can be applied easily for new use cases.

## 6 References

- [1] "Knowledge Article: e-Highway2050 – Methodology for 2050 scenario quantification" (<http://www.gridinnovation-on-line.eu/Articles/Library/e-Highway-2050--Methodology-For-2050-Scenario-Quantification.kl>)
- [2] IEC 62559-2:2015 Use case methodology – Part 2: Definition of the templates for use cases, actor list and requirements list, 2015.
- [3] D. H. Fernandes and B. Bakken, "D1.2 Structuring of uncertain-ties, options and boundary conditions for the implementation of EHS", Deliverable, e-Highway2050 project, 2013.
- [4] Deliverable D3.1, "Specification of Smart Grids high level functional architecture for frequency and voltage control", ELECTRA Integrated Research Programme, 2015.
- [5] Deliverable D1.1, "Development of methodologies and tools for new and evolving DSO roles for efficient DRES integration in distribution networks", EvolvDSO project, 2014.
- [6] Deliverable D4.1, "Description of the GridTech Scenarios for the Development of the European Electricity System", GridTech project, 2014.
- [7] ENTSO-E, "10 Year Network Development Plan 2014" ([https://www.entsoe.eu/major-projects/ten-year-network-development-plan/tyndp-2014/Documents/TYNDP%202014\\_FINAL.pdf](https://www.entsoe.eu/major-projects/ten-year-network-development-plan/tyndp-2014/Documents/TYNDP%202014_FINAL.pdf))

## 7 Annex

### 7.1 Annex 1: System configuration “Distribution Grid”

#### 7.1.1 Domains

The system configuration covers following domains:

- Electrical power system
- Heat system
- Control systems
- ICT
- Stakeholders
- Markets

The electrical power system can be considered to have subdomains within the distribution system level (for instance Distribution, DER, Customer premise).

Control systems are highly interlinked between the domains and components. The control system domain includes local controllers for instance at DG units or on-load tap changers as well as control logic built around central controllers and communication.

The ICT domain includes various systems such as Supervisory Control and Data Acquisition (SCADA) or Distribution Management System (DMS) where data is used for monitoring and controlling the system.

Stakeholders include multiple different actors such as DSOs, DER owners, individual customers, aggregators, market operators, etc.

Markets include traditional energy markets on different basis such as day-ahead or hourly markets, but also different reserve markets, ancillary services, etc.

#### 7.1.2 Components

<i>Domain</i>	<i>Area</i>	<i>Level</i>	<i>Component</i>	<i>Parameters</i>
<b>Electrical power system</b>	Distribution network (MV/LV)	Lines	<ul style="list-style-type: none"> <li>• Overhead conductors</li> <li>• Cables</li> </ul>	<ul style="list-style-type: none"> <li>• Electrical parameters</li> <li>• Physical parameters</li> <li>• Economic parameters</li> </ul>
		Loads	<ul style="list-style-type: none"> <li>• ZIP load types</li> <li>• Controllable loads (P/Q)</li> <li>• EV charging</li> </ul>	<ul style="list-style-type: none"> <li>• Nominal power</li> <li>• Power factor</li> <li>• Voltage level</li> <li>• Load profile</li> <li>• Type (Z, I, P)</li> <li>• Controllability</li> <li>• External communication</li> <li>• Current harmonics profile</li> </ul>
		Transformers	<ul style="list-style-type: none"> <li>• Transformer unit</li> <li>• Tap changer</li> <li>• Voltage controller</li> </ul>	<ul style="list-style-type: none"> <li>• Nominal power</li> <li>• Voltage levels</li> <li>• Electrical values</li> <li>• Losses</li> <li>• Tap changer steps</li> <li>• Controller type (On-Load Tap Changer (OLTC) or other)</li> </ul>

		DER units	<ul style="list-style-type: none"> <li>• Energy source</li> <li>• Generator</li> <li>• Inverter</li> <li>• Controller</li> <li>• Protection devices</li> <li>• External communication interface</li> </ul>	<ul style="list-style-type: none"> <li>• Power range</li> <li>• Power factor</li> <li>• Voltage level</li> <li>• Short-circuit contribution</li> <li>• Electrical values</li> <li>• Controllability</li> <li>• Ramp rates</li> <li>• Protection settings</li> <li>• Communication protocols</li> </ul>
		Storage units	<ul style="list-style-type: none"> <li>• Storage unit</li> <li>• Inverter</li> <li>• Protection system</li> <li>• Management system (Battery Management System (BMS), etc.)</li> <li>• Power to x</li> </ul>	<ul style="list-style-type: none"> <li>• Capacity</li> <li>• Peak power charge/discharge</li> <li>• SOC status</li> <li>• Voltage level</li> <li>• DC voltage</li> <li>• Controllability</li> <li>• Ramp rates</li> <li>• Communication protocols</li> </ul>
		IEDs	<ul style="list-style-type: none"> <li>• Protection relays</li> <li>• Controllers</li> <li>• Measurement units</li> </ul>	<ul style="list-style-type: none"> <li>• Interface and protocol</li> <li>• Functionalities</li> <li>• Data model</li> </ul>
		Electric vehicles	<ul style="list-style-type: none"> <li>• Vehicle</li> <li>• Charging station</li> <li>• Charging management system</li> <li>• Charging operator</li> </ul>	<ul style="list-style-type: none"> <li>• Capacity</li> <li>• Peak power charge/discharge</li> <li>• State of Charge (SOC) status</li> <li>• Voltage level</li> <li>• DC voltage</li> <li>• Vehicle-to-Grid (V2G) capabilities</li> <li>• Controllability</li> <li>• Ramp rates</li> <li>• Communication protocols</li> </ul>
		Household appliances	<ul style="list-style-type: none"> <li>• Heat pumps</li> <li>• EV charging</li> <li>• Microgeneration</li> <li>• Storages</li> <li>• Smart meter</li> <li>• Home automation</li> <li>• Customer applications</li> </ul>	<ul style="list-style-type: none"> <li>• Load profiles</li> <li>• Generation profiles</li> <li>• Nominal power</li> <li>• Controllability</li> </ul>
<b>Heat system</b>	District heating	Pipes	<ul style="list-style-type: none"> <li>• Pipes</li> <li>• Connectors</li> </ul>	<ul style="list-style-type: none"> <li>• Thermal parameters</li> <li>• Physical parameters</li> <li>• Economic parameters</li> </ul>
		Pumps	<ul style="list-style-type: none"> <li>• Motor</li> <li>• Drive system</li> </ul>	<ul style="list-style-type: none"> <li>• Electrical parameters</li> <li>• Thermal parameters</li> </ul>
		Valves	<ul style="list-style-type: none"> <li>• Valves</li> <li>• Control system</li> </ul>	<ul style="list-style-type: none"> <li>• Operation time</li> </ul>
		Storage tanks	<ul style="list-style-type: none"> <li>• Tanks</li> </ul>	<ul style="list-style-type: none"> <li>• Capacity</li> </ul>
		Heat exchangers	<ul style="list-style-type: none"> <li>• Exchanger</li> </ul>	<ul style="list-style-type: none"> <li>• Rated power</li> <li>• Efficiency rate</li> </ul>
		Measurements	<ul style="list-style-type: none"> <li>• Measurement devices</li> </ul>	<ul style="list-style-type: none"> <li>• Temperature</li> <li>• Pressure</li> <li>• Flow</li> </ul>

<b>Control system</b>	Central control	Coordinated voltage control	<ul style="list-style-type: none"> <li>• Tap changers</li> <li>• Compensation units</li> <li>• Reactive power control</li> <li>• Storage units</li> <li>• Generator control</li> </ul>	<ul style="list-style-type: none"> <li>• Power rates</li> <li>• Power factor limits</li> <li>• Ramp rates</li> <li>• Control capability</li> </ul>
		Load control	<ul style="list-style-type: none"> <li>• Direct load controllers</li> </ul>	<ul style="list-style-type: none"> <li>• Power rates</li> <li>• Power factor limits</li> <li>• Ramp rates</li> </ul>
	Local control	Local voltage control	<ul style="list-style-type: none"> <li>• Tap changers</li> <li>• Compensation units</li> <li>• Reactive power control</li> <li>• Generator control</li> </ul>	<ul style="list-style-type: none"> <li>• Power rates</li> <li>• Power factor limits</li> <li>• Ramp rates</li> </ul>
		Local freq. control	<ul style="list-style-type: none"> <li>• Load control</li> <li>• Generator control</li> </ul>	<ul style="list-style-type: none"> <li>• Power rates</li> <li>• Ramp rates</li> </ul>
		DG unit controls	<ul style="list-style-type: none"> <li>• Reactive power control</li> <li>• Generator control</li> </ul>	<ul style="list-style-type: none"> <li>• Power rates</li> <li>• Power factor limits</li> <li>• Ramp rates</li> </ul>
<b>ICT</b>	Metering system	Smart meters	<ul style="list-style-type: none"> <li>• Measurement unit</li> <li>• Communication unit</li> </ul>	<ul style="list-style-type: none"> <li>• Meter type</li> <li>• Measuring capabilities (power quality etc.)</li> <li>• Control capabilities</li> <li>• Communication channel</li> <li>• Communication protocol</li> </ul>
	Measurement system	Phasor measurement units (PMUs)	<ul style="list-style-type: none"> <li>• Voltage and current sensors</li> <li>• Phasor Measurement Unit (PMU) algorithm</li> <li>• Com. network</li> <li>• Time synchronisation (e.g., by Global Positioning System (GPS) or using communications network)</li> </ul>	<ul style="list-style-type: none"> <li>• Sensor types</li> <li>• PMU configuration (list and format of measurements collected by each PMU)</li> <li>• PMU accuracy (from calibration testing)</li> <li>• PMU locations</li> <li>• Communications protocols</li> </ul>
	Communication systems	Communication links	<ul style="list-style-type: none"> <li>• Physical communication media</li> <li>• Routers</li> </ul>	<ul style="list-style-type: none"> <li>• Bandwidths</li> <li>• Delays</li> <li>• Jitter</li> <li>• Errors</li> <li>• Package losses</li> <li>• Protocols</li> <li>• Information models</li> <li>• Redundancy</li> <li>• Time synchronisation</li> <li>• Security and encryption</li> </ul>
	Data management	Management systems	<ul style="list-style-type: none"> <li>• Energy Management System (EMS)</li> <li>• DMS</li> <li>• SCADA</li> <li>• Market systems</li> <li>• Home autom. systems</li> </ul>	<ul style="list-style-type: none"> <li>• Interfaces</li> <li>• Modularity / interoperability</li> <li>• Protocols</li> <li>• Information models</li> </ul>
<b>Stakeholders</b>	Actors	System operators	<ul style="list-style-type: none"> <li>• DSOs</li> <li>• Transmission System Operators (TSO)</li> </ul>	---

		Market actors	<ul style="list-style-type: none"> <li>Balancing Responsible Parties (BRP)</li> <li>Aggregators</li> <li>Virtual Power Plant (VPP) operators</li> <li>EV charging operators</li> </ul>	---
		Others	<ul style="list-style-type: none"> <li>Regulators</li> <li>Researchers</li> <li>Policy/decision making</li> </ul>	---
		Prosumers	<ul style="list-style-type: none"> <li>Individual customers</li> <li>DG owners</li> </ul>	---
<b>Markets</b>	Energy markets	Energy	<ul style="list-style-type: none"> <li>Market operators</li> <li>Retailers</li> <li>BRPs</li> </ul>	<ul style="list-style-type: none"> <li>Market type/timescale</li> <li>Volumes</li> </ul>
		Ancillary services	<ul style="list-style-type: none"> <li>Aggregators</li> <li>Charging operators</li> <li>VPPs</li> </ul>	<ul style="list-style-type: none"> <li>Market type</li> <li>Service level (customer/local/system level)</li> </ul>

### 7.1.3 Connectivity

Electrical power system	- Distribution network																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														</
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### 7.1.4 Component Attributes

<i>Type of Components</i>	<i>Attributes</i>	<i>Additional Information</i>
<b>Electricity related</b>	Energy cost	€/MWh
	Capacity cost	€/MW
	Voltage	V
	Current	A
	Active Power	W
	Reactive power	VA <sub>r</sub>
	Power rating	VA
	Nominal Voltage	V
	Cost	€
<b>Primary sources / generation related</b>	GHG emission	CO <sub>2</sub> kg
	Fuel Cost	€/unit
	Renewable / Non-renewable	---
	Conventional / Non-conventional	---
	Intermittency / Controllability	---
	Availability	---
	Dependency / Strategic	Related to fossil fuels
	Onshore	Wind, solar, geothermal, nuclear
	Offshore	Wind, wave, tidal
	Cost	---
<b>Generation / consumption related</b>	Voltage levels	Depending on the country. HV/MV/LV, Transport/Distribution
	Power/Sizes	micro<100kW, mini<1MW, small<10MW, medium<100MW, big>100MW
	Power range	WT up to 10 MW, PV panels up to 350W DC, Parabolic/linear Fresnel up to 300MW, Stirling dish up to 25kW, OWC up to 1MW, solar tower up to 200MW
	Cost	Energy production, Capacity, infrastruc- ture, IRR, amortization, operational costs, incentives
	Ramping performance	on-peak, base energy
	Efficiency	PV panels around 15%, Wind tur- bines 59.3%, OCW around 25%)
	Reliability	---
	Onshore	Power plants, PV panels...
	Offshore	WECs, Wave converters
<b>Stakeholder related</b>	Type of producer	Coal, solar, wind etc.
	Ownership of stakeholder	Public / private / public-private joint

		venture
	Owned entities	Other components & quantity
	Financial capability	How financially solid
	Required security level	---
	Generation capacity	of producers
	Consumer type	Domestic consumer, industrial premise, etc.
	Regulator authority type	Country specific standards/ compliance with European norms/ compliance with international norms
	Energy consultants / research institute	Level of participation in grid dynamics / decision making
<b>Global Attributes</b>	Temperature	---
	Weather related data	Wind statistics, solar radiation profiles

### 7.1.5 Constraints

<i>Global Constraints (domain related)</i>		
<i>Domain</i>	<i>Constraint</i>	<i>Additional Information</i>
<b>Electrical power system</b>	Voltage limits	Violations to be avoided
	Frequency limits	Violations to be avoided
	Quality indices	Violations to be avoided
	Power transfer capabilities	Line capabilities
<b>Heat system</b>	Temperature limits	Violations to be avoided
	Pressures, flows, etc.	Violations to be avoided
	Pipe capabilities	Pipe capabilities
<b>Control system</b>	Communication performance	Delays, reliability, availability etc.
	Overall control delays	Whole control loop delays
<b>ICT</b>	Latency requirements	Especially important for protection applications
	Time synchronisation requirements	Especially important for protection applications
<b>Stakeholders</b>	Access issues	Access to data, control etc.
	Interest conflicts	---
<b>Markets</b>	Business models	Lack of proven business models
	Market structures and rules	Varying depending on area

### 7.1.6 Use Cases

Use cases are based on the JRA1 survey and within this system configuration they have been categorized into four groups:

1. System services from controllable resources
2. ICT infrastructure
3. Microgrids and islanding
4. Multi-energy systems

#### ***System services from controllable resources:***

<b><i>Coordinated voltage control</i></b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	In this scenario a centralized coordinated voltage control algorithm is implemented in a distribution network, as a solution to the voltage rise problem due to DG production. The algorithm will be receiving real-time measurements from selected nodes of the network, solving an optimization problem and transmitting the resulting set-points to all the devices with voltage control capabilities (e.g., DG and storage inverters, tap-changer etc.) in the network.
<b>Actors:</b>	Central control system, measurements, local controllers, communication system
<b>How (functions)</b>	Central control based on measurements from the system. Measurements are used to optimally control the system and to transfer the control signals back to controllers.
<b>Components</b>	DG unit, storage unit, transformer, metering system, control system
<b>Relevant Attributes</b>	Electrical: grid voltage
<b><i>EV integration in the smart grid</i></b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	A smart grid with a massive penetration of electric vehicles where a granular control of EVs load management is performed. This allows the optimisation of hosting capacity, and additionally can consider the local connection of distributed energy resources (DER) that can benefit from the EV penetration via a positive feedback loop. No grid reinforcement is carried out to cope with the massive presence of EVs in the network. Bidirectional energy flow from grid to vehicle (G2V) and vehicle to grid (V2G) is available.
<b>Actors:</b>	DER operator, EV charging operator, DSO
<b>How (functions)</b>	EV load management for managing peak loads and avoiding network investments.
<b>Components</b>	EV charger, DER unit, control system,
<b>Relevant Attributes</b>	Electrical: Voltage, power ratings
<b><i>Grid support by DG and storage</i></b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	In this scenario various methods for providing grid support by distributed generation and storage systems will be developed and tested. These functions could include voltage control (e.g., Q(U) and $\cos\phi(P)$ control), frequency control (P(f) droop, virtual inertia etc.), among other work.
<b>Actors:</b>	DER operator, storage operator, DSO
<b>How (functions)</b>	Providing various grid support functions with DG and storage
<b>Components</b>	DG unit, DG inverter, DG controller, storage unit, storage inverter, storage controller
<b>Relevant Attributes</b>	Electrical: Voltage, frequency, fault current level

<b>Low power factor exchanges in primary/secondary substations</b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	<p>TSO agreements and protection devices often impose restrictions in terms of reactive power flows. The introduction of local DG controllers based on reactive power injection may significantly impact on the power factor of the power exchanged with the upper stream network:</p> <ol style="list-style-type: none"> <li>1. loads balance active power production and in case of DG=load, only reactive power is exchanged with the upper stream network</li> <li>2. DG is participating to voltage control even for under voltage mitigation (production of reactive power). Positive reactive power cannot be balanced with capacitors.</li> </ol>
<b>Actors:</b>	DSO, DG operator
<b>How (functions)</b>	DG unit providing reactive power control as a service
<b>Components</b>	DG unit, DG inverter, DG control system
<b>Relevant Attributes</b>	Electrical: reactive power, voltage
<b>Use of flexibility in active power networks</b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	<p>This scenario studies the use of flexible resources to maintain power quality in a distribution network characterized by volatile and intermittent distributed production, along with demanding loads such as electric vehicles and modern household appliances. Specific challenges include smart EV charging, microgrid operation, and network flexibility, e.g. in terms of thermal and chemical storage (possibly including V2G/V2H).</p>
<b>Actors:</b>	DSO, DG operator, EV charging operator, aggregator
<b>How (functions)</b>	Use of multiple flexible resources in order to maintain system quality and stability.
<b>Components</b>	Loads, EV chargers, DG units, storage units
<b>Relevant Attributes</b>	Electrical: voltage, frequency, voltage quality indices
<b>Network reconfiguration for post-fault restoration and demand response</b>	
<b>Relevance for SC</b>	Medium
<b>Definition (what)</b>	<p>With enhanced remote control and automation capabilities, DSOs can implement new methods for post-fault restoration. This can include:</p> <ul style="list-style-type: none"> <li>• Automated fault location and minimal circuit isolation for permanent faults.</li> <li>• The use of demand response to automatically trip demand (or generation) to eliminate thermal or voltage constraints following reconfiguration (e.g. following the closure of a normally-open point to restore customers after a fault).</li> <li>• Voltage reduction to reduce instantaneous demand by controlling tap-changers or tripping one of two parallel transformers in primary substations. The trigger for initiating these schemes could be provided from the TSO to assist with transmission system frequency control.</li> </ul>
<b>Actors:</b>	DSO, TSO, communication system
<b>How (functions)</b>	Flexible network operation: remote control of network switching elements and transformers.
<b>Components</b>	Loads, DG units, Transformer unit, Tap changer
<b>Relevant Attributes</b>	Electrical: voltage, frequency
<b>Protection of networks with high levels of converter-connected generation</b>	
<b>Relevance for SC</b>	Medium

<b>Definition (what)</b>	The presence of DG can present additional challenges in protecting distribution systems: bi-directional power flows, protection “blinding”, and sympathetic tripping. Protection is especially challenging for scenarios with high-levels of converter-interfaced generation because of the typically small converter fault current contribution and the fact that and converter responses during faults may not be well known. Therefore, improved methods of protecting future distribution systems – involving real-time coordination – are required.
<b>Actors:</b>	DSO, communication system
<b>How (functions)</b>	Real-time coordination of distribution system protection.
<b>Components</b>	Protection Systems, DG units, DG inverter, DG controller
<b>Relevant Attributes</b>	Electrical: Voltage, current, fault current level

**ICT infrastructure:**

<b>Smart metering for smart grids</b>	
<b>Relevance for SC</b>	Medium
<b>Definition (what)</b>	Smart metering brings intelligence to the last mile of the grid and it is seen as a key enabler for many smart grid applications, with interfaces with many smart grid areas such as building/home automation and demand side management. The Advanced Metering Infrastructure (AMI) provide services for the customer, the supplier and network operator and is used for automated meter reading and billing and a range of other functionalities (network monitoring and control, demand response, etc.). The AMI system will enable and encourage stronger and direct involvement of consumers in their energy usage and management (including also management and market participation of variable and non-programmable generation).
<b>Actors:</b>	AMI operator, DSO, retailer
<b>How (functions)</b>	New services are available resulting from the use of AMI data.
<b>Components</b>	Smart meter, building automation system, communications system.
<b>Relevant Attributes</b>	Electrical: Voltage, current, active power, reactive power.
<b>Monitoring, control and automation in Smart Grids</b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	Ever more operational data from the network is available in the control centres. Alongside the improved opportunity to, directly or in-directly, control network components, load and generation, this provides new opportunities for functionality in future control centres. Among such features are: <ul style="list-style-type: none"> <li>• Congestion and over-load prediction and mitigation</li> <li>• On-line risk assessment and fault mitigation</li> <li>• Automated fault response</li> <li>• Improved monitoring, event detection, and protection by utilization of PMUs</li> </ul>
<b>Actors:</b>	DSO, system providers
<b>How (functions)</b>	Improved measurement and control loops by means of ICT.
<b>Components</b>	IEDs, control system, measurement system, communications system
<b>Relevant Attributes</b>	Electrical: component load conditions
<b>Distributed tracking of distribution grid topology</b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	With the electrification of transport and heating, services to the distribution grid become more relevant such as power flow capping and voltage control. The effi-

	<p>ciency of these services is very much dependent on the location at which they are delivered. This means that an aggregator will need to know at which point of the grid each flexible unit under its control is connected at a particular point in time, i.e. it needs dynamically updated information about the grid topology within the area of its operation. This information would be important for all stages of the aggregation process: Service scheduling, service delivery and validation of compliance by the aggregated units.</p> <p>The use case concerns embedded intelligence in distribution grid substations designed to make real-time topology information available locally in real time, for control purposes.</p>
<b>Actors:</b>	Aggregator, DSO
<b>How (functions)</b>	Embedded intelligence in distribution grid substations for the real-time tracking of topology information
<b>Components</b>	IEDs, data management systems.
<b>Relevant Attributes</b>	Grid connection point, topology

### ***Microgrids and islanding:***

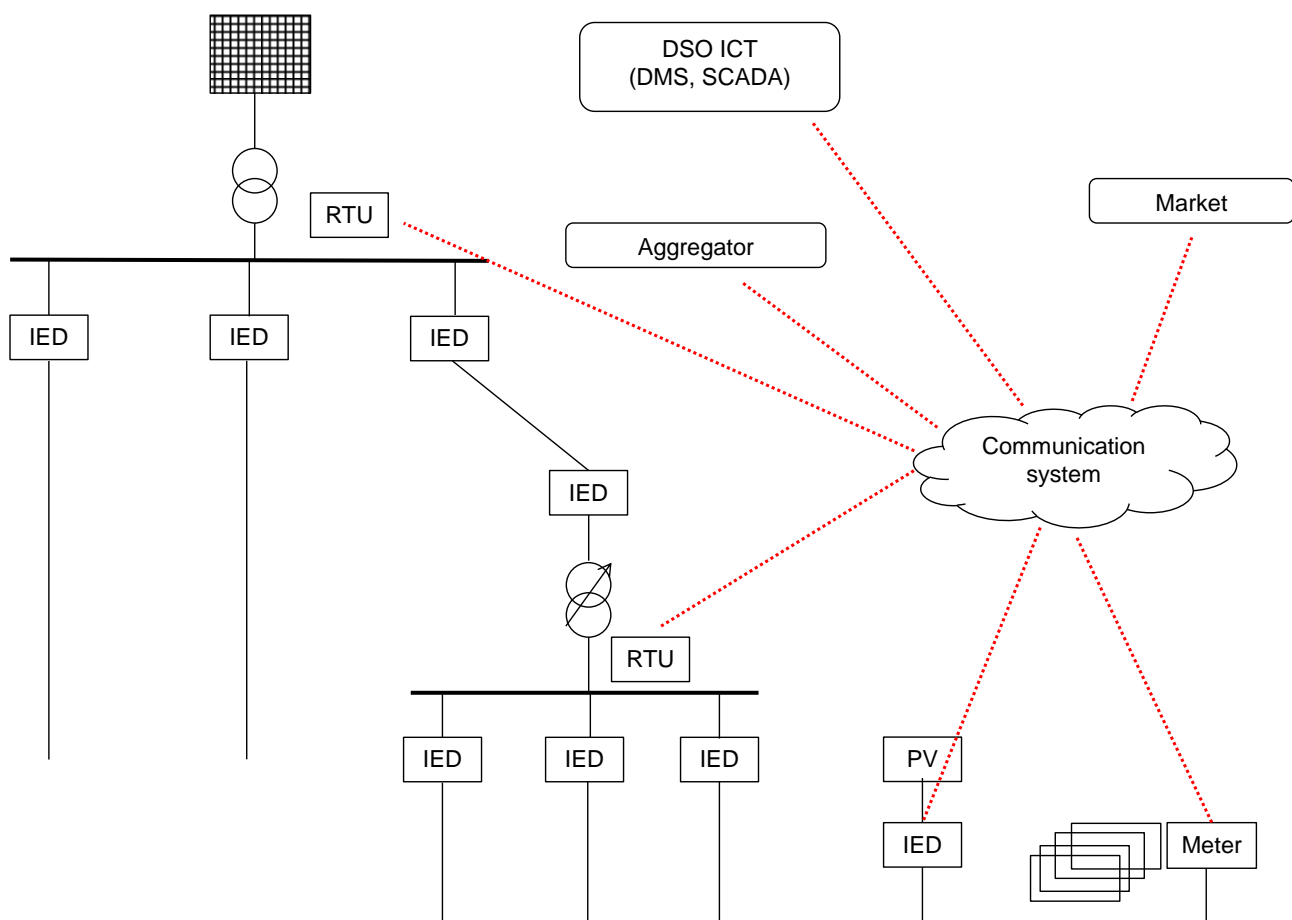
<b>Unintentional islanding occurrence</b>	
<b>Relevance for SC</b>	Medium
<b>Definition (what)</b>	Similar power levels of DG and loads, as well as DG participating in frequency control, may results in situations in which some portions of a non-supplied network (due to a failure) remain operating as an island and are thereby still energized by local DG. This can easily lead to concerns with safety and power quality.
<b>Actors:</b>	DG operator, DSO
<b>How (functions)</b>	
<b>Components</b>	DG unit, DG inverter, DG connection equipment, loads
<b>Relevant Attributes</b>	Electrical: power balance, voltage, frequency, other characteristics
<b>Operation and control of off-grid systems</b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	The operation and control of off-grid systems incorporating DER is required. Combining renewable sources (e.g. PV or wind turbines) with diesel-based systems has several financial, environmental and technical benefits. However, the operation and control faces several challenges that need to be tackled (technical minimum of the diesel generator, curtailment of PV, stability etc.).
<b>Actors:</b>	DG operator, DSO
<b>How (functions)</b>	Active control of multiple components to maintain off-grid system stability
<b>Components</b>	DG unit, DG inverter, control system
<b>Relevant Attributes</b>	Electrical: Voltage, frequency
<b>Optimal operation of microgrids</b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	This use case refers to optimisation of the operation of microgrids by means of a central controller. The objective of the implementation was the maximisation of profits and reduction of CO2 emissions in a microgrid via alternative solutions of optimal control such as model-predictive and stochastic-optimal-predictive control.
<b>Actors:</b>	DSO
<b>How (functions)</b>	Central control within microgrid

<b>Components</b>	Communications system, IEDs, management system
<b>Relevant Attributes</b>	---

**Multi-energy systems:**

<b>Multi-energy system (Nordhavn)</b>	
<b>Relevance for SC</b>	Low
<b>Definition (what)</b>	<p>A new neighbourhood is currently being developed on the site of the former industrial port of Copenhagen (Nordhavn). At the end of development, around the year 2040, the area is planned to support 40.000 residents and 50.000 workplaces and should be self-sustaining with energy. Integration of the different energy infrastructures and enabling the exchange of energy between them have been identified as key capabilities for achieving this goal.</p> <p>The combined operation of district heating and electricity networks (e.g. for storing excess wind power generation as heat, or to substitute heat pumps with other sources of heat in case of low wind generation) will be simulated and tested in the laboratory and in the field as part of the project.</p>
<b>Actors:</b>	DSO, district heating operator
<b>How (functions)</b>	Interfacing heating and electricity networks as a means of flexibility
<b>Components</b>	Electricity distribution network, district heating network, wind power, heat pumps
<b>Relevant Attributes</b>	---

### 7.1.7 Graphical Presentation of the Overall System Configuration



## 7.2 Annex 2: System Configuration “Transmission Grid and Offshore Wind”

### 7.2.1 Domains

- Electricity (transmissions system: voltage levels above 150 kV sub-transmission, 220 / 380 kV transmission)
- Primary sources
- ICT
- Control system
- Legal/business

### 7.2.2 Components

<i><b>Subsystem</b></i>	<i><b>Components</b></i>
<b>C1 - Transmission system</b>	C1.1 - Conducting equipment (cables and lines)
	C1.2 - Transformation substations
	C1.3 - Electronic Converter stations
	C1.4 - Loads
	C1.5 - Connectivity nodes
	C1.6 - AC Line Segments
	C1.7 - DC Line Segments
	C1.8 - Generation plants
	C1.9 - FACTS (Flexible Alternating Transmission)
	C1.10 - Rotating compensators
	C1.11 - ICT system dedicated to transmission network operation and monitoring
	C1.12 - Cross border connections
	C1.13 - Internal market system
<b>C2 - Off-shore Wind Power Plant</b>	C2.1 - Topological Island (network segment that connect offshore plant with sub-marine cable)
	C2.2 - Generation plant (collection of equipment for purposes of generation - turbines)
	C2.3 - Rectifier Inverter (AC-DC conversion equipment that can be used to control the power plant injection)
	C2.4 - ICT system dedicated to control and monitoring of the production plant
	C2.5 - Connection node with DC submarine cable
<b>C3 - Intermediate connection system (COBRAcable)</b>	C3.1 - Submarine DC cables system
	C3.2 - Onshore section of DC cables system
	C3.3 - DC cable terminals (connection station with AC transmission grid)
	C3.4 - Rectifier + Inverter
	C3.5 - Connection nodes for offshore power plants
	C3.6 - Line Commutated Converters (Twenties Project)
	C3.7 - ICT system dedicated to HVDC system monitoring/operation and communication with connected plants/devices
<b>C4 - Market</b>	C4.1 - Market Management System
	C4.2 - Market Agreement

C4.3 - Market Participants
C4.4 - Measurement Points - estimation of system state and available reserve
C4.5 - Production
C4.6 - Internal Trade
C4.7 - Consumption
C4.8 - IPP (Independent Power Producer)
C4.9 - Control Area Program
C4.10 - System Operator
C4.11 - Consumption Responsible party
C4.12 - Production Responsible party
C4.13 - Balance Responsible party
C4.14 - Billing agent
C4.15 - Market operator
C4.16 - Balance supplier
C4.17 - Consumer
C4.18 - Control area operator
C4.19 - Control block operator
C4.20 - Coordination centre operator
C4.21 - Grid access provider
C4.22 - Grid operator
C4.23 - Meter administrator
C4.24 - Party connected to grid
C4.25 - Producer
C4.26 - Profile maintenance party
C4.27 - Meter operator
C4.28 - Metered data collector
C4.29 - Metered data responsible
C4.30 - Metering point administrator
C4.31 - Resource Provider
C4.32 - Scheduling coordinator
C4.33 - Capacity Trader
C4.34 - Interconnection Trader
C4.35 - Nomination Validator
C4.36 - Market information aggregator
C4.37 - Information receiver
C4.38 - Reserve Allocator
C4.39 - Bidding Area
C4.40 - Interconnector
C4.41 - MOL Responsible

### 7.2.3 Connectivity

<i>Domains/ Connectivity Type</i>	<i>Explanation</i>
<b>DP</b>	Direct physical coupling (intra-domain)
<b>IP</b>	Indirect physical coupling (either mediated, e.g., by a power converter by other technique; also applicable to 'equivalenced' components)
<b>DD</b>	Direct Data: direct field-related data for real-time control & decision purposes; e.g., as recorded in the field, is transferred from/to this component
<b>AD</b>	Abstract Data, such as aggregated or stored field data or otherwise abstracted and data, such as configuration data: only highly processed information is transferred from/to this component/domain
<b>ICC</b>	Information, processing, or Communication Container: as processing or communication function, no relevance of information content
<b>(R)esponsible</b>	Stakeholder is responsible for Domain/Component
<b>(D)irective</b>	Stakeholder directs Components or other Stakeholders
<b>(O)wnership</b>	S. owns component
<b>(OP)erates</b>	S. Operates component
<b>(T)ransactive</b>	S. executes transactions with respect to component/domain
<b>(I)nformational</b>	S. acquires information from
<b>(M)anufactures</b>	S. produces or produces component

**Connectivity table:**

<i>Component ID</i>	<i>Electricity – Transmission System</i>	<i>ICT</i>	<i>Control Systems</i>	<i>Legal/Business</i>	<i>Primary sources</i>
C1.1	DP				
C1.2	DP				
C1.3	DP				
C1.4	IP	DP		IP	
C1.5	DP				
C1.6	DP				
C1.7	DP				
C1.8	DP			IP	DP

<i>Component ID</i>	<i>Electricity – Transmission System</i>	<i>ICT</i>	<i>Control Systems</i>	<i>Legal/Business</i>	<i>Primary sources</i>
C4.9	IP	DP			
C4.10	O,OP				
C4.11	IP	DP	DP	DP	
C4.12	DP	DP	DP	DP	
C4.13				DP	
C4.14				DP	
C4.15				DP	
C4.16				DP	

C1.9	DP				
C1.10	DP				
C1.11		DP			
C1.12	DP				
C1.13	DP				
C2.1	DP				
C2.2	DP				
C2.3	DP				
C2.4		DP	DP		
C2.5	DP				
C3.1	DP				
C3.2	DP				
C3.3	DP				
C3.4	DP				
C3.5	DP				
C3.6	DP				
C3.7		DP			
C4.1		DP		DP	
C4.2				DP	
C4.3				DP	
C4.4		DP			
C4.5	DP	DP	DP	DP	
C4.6				DP	
C4.7	IP	DP	DP		
C4.8			DP		

C4.17				DP	
C4.18	OP			DP	
C4.19	OP			DP	
C4.20	OP			DP	
C4.21				DP	
C4.22	OP			DP	
C4.23		DP		DP	
C4.24	DP			DP	
C4.25	DP	DP	DP	DP	
C4.26				DP	
C4.27		OP		DP	
C4.28		DD		DP	
C4.29		OP		DP	
C4.30		OP		DP	
C4.31				DP	
C4.32				DP	
C4.33				DP	
C4.34				DP	
C4.35				DP	
C4.36		AC,D C		DP	
C4.37		ICC			
C4.38				DP	
C4.39				DP	
C4.40	DP				
C4.41		DC		DP	

#### 7.2.4 Component Attributes

Type of Components	Attributes	Additional Information
Electricity related	Energy cost	€/MWh
	Capacity cost	€/MW
	Voltage	---
	Current	---
	Active Power	---
	Reactive power	---
	Power rating	---
	Nominal Voltage	---
	Cost	---

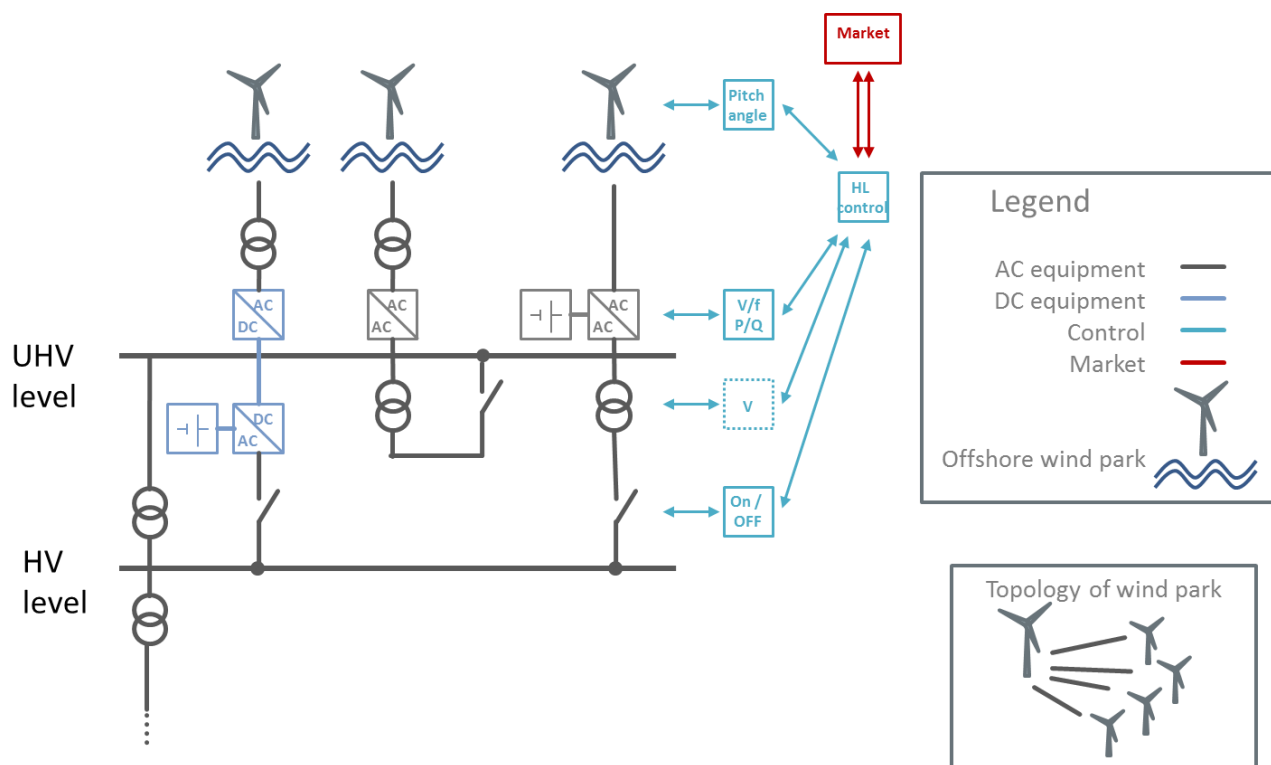
<b>Primary sources/ generation related</b>	Renewable / Non-renewable	---
	Conventional / Non-conventional	---
	Intermittency / Controllability	---
	Availability	---
	Onshore	---
	Offshore	---
	Cost	---
<b>Generation / consumption related</b>	Voltage levels	Above 150 kV
	Power/Sizes	micro<100kW, mini<1MW, small<10MW, medium<100MW, big>100MW
	Power range	---
	Cost	Energy production, Capacity, infrastructure, IRR, amortization, operational costs, incentives
	Ramping performance	on-peak, base energy
	Efficiency	PV panels around 15%, Wind turbines 59.3%, OCW around 25%)
	Reliability	---
	Onshore	Power plants, PV panels, etc.
	Offshore	---
<b>Business related</b>	Role of actor	---
	Ownership of stakeholder	Public / private / public-private joint venture
	Owned entities	Other components & quantity
	Financial capability	How financially solid
	Required security level	---
	Generation capacity	of producers
	Consumer type	Generic load
	Regulator authority type	Country specific standards/ compliance with European norms/ compliance with international norms
	Energy consultants / research institute	Level of participation in grid dynamics / decision making

### 7.2.5 Constraints

<b>Global Constraints (domain related)</b>		
<b>Domain</b>	<b>Constraint</b>	<b>Additional Information</b>
<b>Electrical transmission system</b>	Voltage limits	Violations to be avoided
	Frequency limits	Violations to be avoided

	Quality indices	Violations to be avoided
	Power transfer capabilities	Line capabilities
	Converter valve protection	---
<b>ICT</b>	Reliability	Latency
<b>Control system</b>	Time response	---
	Reliability	---
<b>Legal/business</b>	Market regulations	---
	Grid code compliance	Notably the Network code on HVDC Connections by ENTSO-E
<b>Primary sources</b>	Availability	Curtailment during Fault-Ride Through (FRT) operation

### 7.2.6 Diagrams



High-level representation of an offshore wind power plant connected to the shore. Left: HVDC connection, middle: medium voltage AC connection, right: High-voltage AC connection.

### 7.3 Annex 3: System Configuration “Vertical Integration”

#### 7.3.1 Domains

- D01 - Electricity
- D02 - ICT
- D03 - Stakeholders
- D04 - Heat
- D05 - Transport
- D06 - Primary sources

#### 7.3.2 Components

<i><b>Primary Domain</b></i>	<i><b>Subdomain</b></i>	<i><b>System</b></i>	<i><b>Component</b></i>
<b>D01 - Electricity</b>	C1 - Transmission Network (HV)	C11 - Thermal Power Plants	<ul style="list-style-type: none"> <li>• C111 - Nuclear power plants</li> <li>• C112 - Fossil-fuel power plants</li> </ul>
		C12 - Connectors	<ul style="list-style-type: none"> <li>• C121 - Air-Lines</li> <li>• C122 - Cables</li> <li>• C123 - HV-DC links</li> <li>• C124 - Supplying Grid</li> <li>• C125 - Connected Grids</li> </ul>
		C13 - Loads	<ul style="list-style-type: none"> <li>• C131 - ZIP-Loads (Equivalent-Model)</li> <li>• C132 - Controllable loads (P/Q)</li> </ul>
		C14 - RES	<ul style="list-style-type: none"> <li>• C141 - Wind park</li> <li>• C142 - PV park</li> <li>• C143 - Ocean Thermal Energy Conversion systems (OTEC) <ul style="list-style-type: none"> <li>– C1431 - turbine</li> <li>– C1432 - condenser</li> <li>– C1433 - evaporator</li> </ul> </li> <li>• C144 - Wave energy conv. systems <ul style="list-style-type: none"> <li>– C1441 - OWC</li> <li>– C1442 - buoys</li> <li>– C1443 - absorbers</li> <li>– C1444 - attenuators</li> </ul> </li> <li>• C145 - Hydro power plants</li> </ul>
		C15 - Substations Components	<ul style="list-style-type: none"> <li>• C153 - Transmission Substation</li> <li>• C154 - Transformer (OLTC)</li> <li>• C155 - HV-DC terminals</li> <li>• C156 - Switches/Breaker</li> </ul>
		C16 - Other	<ul style="list-style-type: none"> <li>• C161 - Hybrid systems</li> <li>• C162 - Storage <ul style="list-style-type: none"> <li>– C1621 - Power to gas (P2G)</li> <li>– C1622 - Batteries</li> <li>– C1623 - Pumped hydro-elec. storage</li> <li>– C1624 - Flywheels</li> <li>– C1625 - CAES</li> <li>– C1626 - SMES</li> </ul> </li> <li>• C163 - Compensators/FACTS <ul style="list-style-type: none"> <li>– C1631 - Capacitors</li> <li>– C1632 - Reactors</li> <li>– C1633 - SVC</li> <li>– C1634 - STATCOM</li> </ul> </li> </ul>

	C2 - Distribution Networks (MV, LV)	C21 - Power Plant (Gas/Diesel)	<ul style="list-style-type: none"> <li>• C211 - Fossil-fuel power plants</li> </ul>
		C22 - Loads	<ul style="list-style-type: none"> <li>• C221 - ZIP-Loads</li> <li>• C222 - Controllable loads (P/Q) <ul style="list-style-type: none"> <li>– C2221 - Charging spot</li> </ul> </li> </ul>
		C23 - DER	<ul style="list-style-type: none"> <li>• C231 - Wind park</li> <li>• C232 - Micro Wind turbines</li> <li>• C233 - Solar park</li> <li>• C234 - CHP</li> <li>• C235 - Microgrid (PCC-equivalent)</li> <li>• C236 - Small hydro (flowing water/in stream)</li> <li>• C237 - Storage <ul style="list-style-type: none"> <li>– C2371 - Power to heat</li> <li>– C2372 - Batteries</li> </ul> </li> </ul>
		C24 - Connectors	<ul style="list-style-type: none"> <li>• C241 - Air lines</li> <li>• C242 - Cables</li> </ul>
		C25 - Substation	<ul style="list-style-type: none"> <li>• C251 - Distribution Substation <ul style="list-style-type: none"> <li>– C2511 - Collector substation</li> <li>– C2512 - Converter Substation</li> <li>– C2513 - Switching substation</li> </ul> </li> <li>• C252 - Transformer (OLTC)</li> <li>• C253 - Switches, Breaker</li> <li>• C254 - Capacitors, Reactors</li> </ul>
<b>D02 - ICT</b>	C3 - Market	C31 - Energy Market Applications (Traders)	<ul style="list-style-type: none"> <li>• C311 - Participant Market Management (Market Participant Registration, Market Participant Prudent Management)</li> </ul>
		C32 - Market operation applications	<ul style="list-style-type: none"> <li>• C321 - Billing &amp; Settlement</li> <li>• C322 - Day Ahead Market</li> <li>• C323 - Real time Market</li> <li>• C324 - Bilateral transmission Capacity</li> <li>• C325 - Available Transmission Capacity Calculation</li> </ul>
	C4 - Utility	C41 - Business	<ul style="list-style-type: none"> <li>• C411 - Business Operation Systems</li> <li>• C412 - Utility Customer Applications (Customer Relationship Management Systems) <ul style="list-style-type: none"> <li>– C4121 - AMI Database,</li> </ul> </li> <li>• C413 - External IT applications</li> </ul>
		C42 - Maintenance	<ul style="list-style-type: none"> <li>• C421 - EMS (Energy Management Systems) {TSO, BRP}</li> <li>• C422 - DMS (Distribution Management Systems) {System monitoring, operation, management outage management, modelling &amp; analysis tools}</li> <li>• C423 - Engineering and maintenance applications</li> <li>• C424 - SCADA (incl. State Estimator, OPF, etc.)</li> <li>• C425 - Data Acquisition and Control front ends ( gateways) <ul style="list-style-type: none"> <li>– C4251 - Mapping services</li> </ul> </li> </ul>

			<ul style="list-style-type: none"> <li>– C4252 - Data Concentrator</li> <li>• C426 - Application interfaces (common information models, component interfaces, etc.)</li> <li>• C427 - VPP software</li> <li>• C428 - Advanced metering infrastructure (includes applications for Pricing options, customer options, utility operations, emergency demand response)</li> </ul>
		C43 - Field Devices	<ul style="list-style-type: none"> <li>• C431 - Control devices (e.g., power converters, OLTCs, switchgear (relays, breakers, IED))</li> <li>• C432 - Substation/DER/hydro devices</li> <li>• C433 - Control centres</li> <li>• C434 - Measurement devices (e.g., PMU, smart meters)</li> </ul>
	C5 - Customer	C51 - Local Networks	<ul style="list-style-type: none"> <li>• C511 - Home Area Networks</li> <li>• C512 - Neighbourhood Area Network</li> <li>• C513 - Wide Area Networks</li> <li>• C514 - Internet</li> </ul>
<b>D03 - Stakeholders</b>	N/A	N/A	<ul style="list-style-type: none"> <li>• C601 - TSO's</li> <li>• C602 - BRP</li> <li>• C603 - DSO's</li> <li>• C604 - Aggregator (Data-Aggregator (e.g., for energy efficiency), control aggregator)</li> <li>• Sometimes part of BRP; control flexibility 'fleet' (also EV fleet)</li> <li>• C605 - Equipment manufacturers</li> <li>• C606 - Electric Vehicle Supply Equipment (EVSE) owner</li> <li>• C607- Consumers</li> <li>• C608 - Metering (data) service provider</li> <li>• C609 - Regulators, Policy Makers, environmental groups</li> <li>• C610 - Research institutes</li> <li>• C611 - Universities</li> <li>• C612 - Energy consultants</li> <li>• C613 - Technology companies</li> <li>• C614 - Large Synchronous Generator operator</li> <li>• C615 - DER operators</li> <li>• C616 - HVDC terminal operators</li> <li>• C617 - E-mobility service provider (EMSP)</li> <li>• C618 - fleet manager</li> <li>• C619 - Charging station equip. owner</li> <li>• C620 - E-mobility clearing house (EMCH)</li> <li>• C621 - Flexibility provider</li> <li>• C622 - Energy Market participant</li> <li>• C623 - Energy Market Operator</li> <li>• C624 - Certification bodies (data sharing, feedback on security, performance, source of algorithms)</li> </ul>

<b>D04 - Heat</b>	C7 - Distribution	C71 - Local	<ul style="list-style-type: none"> <li>• C711 - Heat Pump</li> <li>• C712 - CHP</li> <li>• C713 - Electric Heating</li> <li>• C714 - Light bulb</li> <li>• C715 - Heat storage</li> </ul>
<b>D05 - Transport</b>	C8 - Distribution	C81 - Local	<ul style="list-style-type: none"> <li>• C811 - Battery Electric Vehicle (BEV)</li> <li>• C812 - Plug-in Hybrid Electric Vehicle (PHEV)</li> <li>• C813 - Charging post (smart meter)</li> <li>• C814 - Smart Charger</li> <li>• C815 - Charging Station</li> </ul>

### 7.3.3 Connectivity

<i>Domains/ Connectivity Type</i>	<i>Explanation</i>
<b>DP</b>	direct physical coupling (intra-domain)
<b>IP</b>	indirect physical coupling (either mediated, e.g. by a power converter by other technique; also applicable to 'equivalenced' components)
<b>DD</b>	Direct Data: direct field-related data for real-time control & decision purposes; e.g., as recorded in the field, is transferred from/to this component
<b>AD</b>	Abstract Data, such as aggregated or stored field data or otherwise abstracted and data, such as configuration data: only highly processed information is transferred from/to this component/domain
<b>ICC</b>	Information, processing, or Communication Container: as processing or communication function, no relevance of information content
<b>(R)esponsible</b>	Stakeholder is responsible for Domain/Component
<b>(D)irective</b>	Stakeholder directs Components or other Stakeholders
<b>(O)wnership</b>	S. owns component
<b>(OP)erates</b>	S. Operates component
<b>(T)ransactive</b>	S. executes transactions with respect to component/domain
<b>(I)nformational</b>	S. acquires information from
<b>(M)anufactures</b>	S. produces or produces component

<i>Primary Domain</i>	<i>Comp. #</i>	<i>Component</i>	<i>Electricity - Transmission</i>	<i>Electricity - Distribution</i>	<i>Electricity - Conversion</i>	<i>ICT - Market &amp; Enterprise</i>	<i>ICT - Operations</i>	<i>Stakeholders</i>	<i>Heat Distribution</i>	<i>Transport (local)</i>	<i>Energy Resource or Consumer</i>
D01	C111	Nuclear power plants									
D02	C112	Fossil-fuel power plants									

D01	C121	Air-Lines	DP								
D01	C122	Cables	DP								
D01	C123	HV-DC links	DP								
D01	C124	Suppling Grid	DP								
D01	C125	Connected Grids									
D01	C131	ZIP-Loads (Equivalent-Model)	DP		DP						DP
D01	C132	Controllable loads (P/Q)	DP		DP						DP
D01	C141	Wind park	IP		DP						DP
D01	C142	PV park	IP		DP						DP
D01	C143	Ocean Thermal Energy Conversion systems (OTEC) (turbine/condenser/evaporator)	IP		DP						DP
D01	C144	Wave energy conversion systems (OWC, buoys, absorbers, attenuators)	IP		DP						DP
D01	C145	Hydro power plants									
D01	C153	Transmission Substation	DP	DP							
D01	C154	Transformer (OLTC)	DP	DP							
D01	C155	HV-DC terminals	DP								
D01	C156	Switches/Breaker	DP								
D01	C161	Hybrid systems	DP								
D01	C162	Storage	IP		DP						
D01	C1621	Power to gas (P2G)	IP		DP						
D01	C1622	Batteries	IP		DP						
D01	C1623	Pumped Hydroelectric Storage	IP		DP						
D01	C1624	Flywheels	IP		DP						
D01	C1625	CAES	IP		DP						
D01	C1626	SMES	IP		DP						
D01	C163	Compensators/FACTS	DP								
D01	C1631	Capacitors	DP								
D01	C1632	Inductors	DP								
D01	C1633	SVC	DP								
D01	C1634	STATCOM	DP								
D01	C211	Fossil-fuel power plants									
D01	C221	ZIP-Loads	x	DP	DP						

D01	C222	Controllable loads (P/Q)	x	DP	DP						
D01	C2221	Charging spot	x	DP	DP						
D01	C231	Wind park	x	DP	DP						
D01	C232	Micro Wind turbines	x	DP	DP						
D01	C233	Solar park	x	DP	DP						
D01	C234	CHP	x	DP	DP						
D01	C235	Microgrid (PCC-equivalent)		IP	DP						DP
D01	C236	Small hydro (flowing water/in stream)		IP	DP						DP
D01	C237	Storage	x	IP	DP						
D01	C2371	Power to heat	x								
D01	C2372	Batteries	x								
D01	C241	Distribution Air lines	DP								
D01	C242	Distribution Cables	DP								
D01	C251	Distribution Substation (incl. Collector substation, Converter Substation, Switching substation)	DP				DD				
D01	C252	Transformer (OLTC)	DP	DP							
D02		Trading application				DD		AD			AD
D02		Market database and clearing system	AD			DD		AD			
D02	C311	Participant Market Management (Market Participant Registration, Market Participant Prudent Management)									
D02	C321	Billing & Settlement,									
D02	C322	Day Ahead Market									
D02	C323	Real time Market									
D02	C324	Bilateral transmission Capacity									
D02	C325	Available Transmission Capacity Calculation									
D02	C411	Business Operation Systems	AD			DD, AD	AD				AD
D02	C412	Utility Customer Applications (Customer Relationship Management Systems)		AD		AD	AD	AD			

D02	C4121	AMI Database, MDM Software		AD				AD			
D02	C413	<i>External IT applications</i>									
D02	C421	EMS (Energy Management Systems) {TSO,BRP}					DD, AD				
D02	C422	DMS (Distribution Management Systems) {System monitoring, operation, management outage management, modelling & analysis tools}					DD, AD				
D02	C423	Engineering & maintenance applications	AD	AD					AD		
D02	C424	SCADA (incl. (State Estimator, OPF, etc.)	DD	DD			DD				
D02	C425	Data Acquisition and Control front ends (gateways)				AD	AD				
D02	C4251	Mapping services (e.g., protocol mapping)				AD	AD				
D02	C4252	Data Concentrator		AD			DD				
D02	C426	Application interfaces (Common Information Models, Component interfaces, etc.)									
D02	C427	VPP software									
	C428	Advanced metering infrastructure (includes applications for pricing options, customer options, utility operations, emergency demand response)									
D02	C431	Control devices (e.g., power converters, OLTCs, switchgear (relays, breakers, IED, capacitor banks)		IP, DD			DD				
D02	C432	Substation / DER / Hydro devices		IP, DD			IP, DD				
D02	C433	Control Centres									
D02	C434	Measurement devices (e.g., PMU, RTU, Smart Meters)									
D02	C511	Home Area Networks				ICC	ICC				
D02	C512	Neighbourhood Area Network				ICC	ICC				

D02	C513	Wide Area Networks				ICC	ICC				
D02	C514	Internet									
D03	C601	TSO's	R,D, O,O P,I								
D03	C602	Balance Responsible (BRP)			R,D, O, OP ,I						
D03	C603	DSO's		R,D, O, OP,I							
D03	C604	Aggregator (Data-Aggregator (e.g., for energy efficiency), control aggregator, Sometimes part of BRP; control flexibility 'fleet' (also EV fleet))				R,O, OP, D	R, O, OP, D				
D03	C605	Equipment manufacturers									
D03	C606	Electric Vehicle Supply Equipment (EVSE) owner									
D03	C607	Consumers									
D03	C608	Metering (data) service provider									
D03	C609	Regulators, Policy Makers, environmental groups									
D03	C610	Research institutes									
D03	C611	Universities									
D03	C612	Energy consultants	I	I	I			I		I	I
D03	C613	technology companies	M	M	M						
D03	C614	Large Synchronous Generator operator									
D03	C615	DER operators									
D03	C616	HVDC terminal operators									
D03	C617	E-mobility service provider (EMSP)									
D03	C618	fleet manager									
D03	C619	charging station equipment owner									
D03	C620	e-mobility clearing house (EMCH)									
D03	C621	flexibility provider									
D03	C622	Energy Market partici-									

		pant									
D03	C623	Energy Market Operator									
D03	C624	Certification bodies									
D04	C711	Heat Pump		DP							DP
D04	C712	CHP		DP							DP
D04	C713	Electric Heating		DP							DP
D04	C714	Light bulb		DP							DP
D04	C715	Heat storage		IP							DP
D05	C811	Battery Electric Vehicle (BEV)		IP						DP	
D05	C812	Plug-in Hybrid Electric Vehicle (PHEV)		IP						DP	
D05	C813	Charging post (smart meter)		IP, DD			DD				
D05	C814	Smart Charger		IP			DD				
D05	C815	Charging Station		DP			DD, AD			DP, AD	

### 7.3.4 Component Attributes

<i>Type of Components</i>	<i>Attributes</i>	<i>Additional Information</i>
<b>Electricity related</b>	A001 - Energy cost	€/MWh
	A002 - Capacity cost	€/MW
	A003 - Voltage	---
	A004 - Current	---
	A005 - Active Power	---
	A006 - Reactive power	---
	A007 - Power rating	---
	A008 - Nominal Voltage	---
	A009 - Frequency	---
	A010 - Power factor	---
<b>Primary sources / generation related</b>	A101 - GHG emission	---
	A102 - Fuel Cost	---
	A103 - Renewable / Non-renewable	---
	A104 - Conventional / Non-conventional	---
	A105 - Intermittency / Controllability	---
	A106 - Availability	---
	A107 - Dependency / Strategic	Related to fossil fuels
	A108 - Onshore	Wind, solar, geothermal, nuclear
	A109 - Offshore	Wind, wave, tidal

<b>Generation / consumption related</b>	A201 - Voltage levels	Depending on the country. Spain: LV<1kV, MV<110kV, HV>100kV. Transport/Distribution
	A202 - Power/Sizes	micro<100kW, mini<1MW, small<10MW, medium<100MW, big>100MW
	A203 - Power range	WT up to 10 MW, PV panels up to 350W DC, Parabolic/linear Fresnel up to 300MW, Stirling dish up to 25kW, OWC up to 1MW, solar tower up to 200MW
	A204 - Cost	Energy production, Capacity, infrastructure, IRR, amortization, operational costs, incentives
	A205 - Ramping performance	on-peak, base energy
	A206 - Efficiency	PV panels around 15%, Wind turbines 59.3%, OCW around 25%)
	A207 - Reliability	---
	A208 - Onshore	Power plants, PV panels...
	A209 - Offshore	WECs, Wave converters
	A210 - Activation time	---
	A211 - droop (V/Q)	---
	A212 - Unit flexibility	---
	A213 - Availability	---
	A214 - Location	---
	A215 - Consumption	---
	A216 - Baseline consumption	---
<b>ICT related</b>	A301 - Number of participants	---
	A302 - Organisational or individual participants	---
	A303 - main commodities : Energy (MWh), Power (MW)	---
	A304 - trade interval: 5, 15, 60 min.	---
	A305 - transactions: bids, offers, derivatives	---
	A306 - customer data	---
	A307 - Number of primary EMS sites	---
	A308 - type of smart meters (residential, industrial, commercial)	---
	A309 - power consumption data	---
	A310 - communication interval: real time/ interval based	---
	A311 - Communication quality	---
	A312 - Data Availability	---

	A313 - Control Architecture type	---
	A314 - Data Integrity,	---
	A315 - Data consistency,	---
	A316 - Data completeness,	---
	A317 - Data accuracy	---
	A318 -Latency	---
	A319 - Bandwidth	---
	A320 - Security	---
	A321 - Reliability	---
	A322 - Firewalls	---
	A323 - Routing	---
	A324 - Meter availability	---
	A325 - Interoperability	---
	A326 - Data privacy	---
<b>Stakeholder related</b>	A401 - Type of producer	Coal, solar, wind etc.
	A402 - Ownership of stakeholder	Public / private / public-private joint venture
	A403 - Owned entities	Other components & quantity
	A404 - Financial capability	How financially solid
	A405 - Required security level	---
	A406 - Generation capacity	of producers
	A407 - Consumer type	Domestic consumer, industrial premise, etc.
	A408 - Regulator authority type	Country specific standards/ compliance with European norms/ compliance with international norms
	A409 - Energy consultants / research institute	Level of participation in grid dynamics / decision making
<b>Transport related</b>	A501 - PCC-Voltage	Charging post connection point: 230 V, 400 V (3-ph)
	A502 - Power supply	Single-phase, three phase, DC
	A503 - Charging power	Charging mode, Battery type & size
	A504 - Charging time	Charging mode
	A505 - Plug-type characteristics	Inductive; wired (plug type: SAE J1772, VDE-AR-E 2623-2-2, EV Plug Alliance, CHAdeMO, etc.)
	A506 - Number of Vehicles / Fraction of total vehicle fleet	Roaming energy
	A507 - Driving patterns / profiles	Regional distribution of driving need, Sectoral specific patterns
	A508 - Plug-in profiles (connectivity)	Concent. of vehicles & charging posts
<b>Global attributes</b>	A601 - Service cost	---

**For simulation purposes:**

Attribute	Domain		Voltage Level			Power Level (nominal power)	Type		Quantity	Related
	TS	DS	HV	MV	LV		Passive	Active		
Power Plant	X	X		X		Medium/big		X	4-6 (TS)	Vctrl
Lines/Cable	X	X	X	X	X	---	X		37(LV) 16(MV) 9(HV)	---
Loads	X	X	X	X	X	All	X		5(HV) 20(MV) 14(LV)	---
RES	X	X		X		Medium		X	1-2 (TS)	---
Grid (sup./Con)	X		X			Big	X		0-3 (TS/DS)	---
Compensator	X		X			Big	X		3(TS)	---
DER		X		X	X	Small		X	0-100%(DS)	---
Transformer	X	X	X	X	X	Small/ medium/big	X (DS)	X (TS)	6 (TS) 6(MV/LV)	---
Switch/Breaker					X	---		X	3(LV)	---

Component	General Attributes	Type	Data exchange type					Security
			Control/ Technical	Organisational	Communication	Interface/Informational	Device	
C311 - Participant Market Management (Market Participant Registration, Market Participant Prudent Management)	<ul style="list-style-type: none"> <li>A301 - Number of participants</li> <li>A302 - Organisational or individual participants</li> </ul>	System		X				
C321 - Billing & Settlement	<ul style="list-style-type: none"> <li>A303 - main commodities: Energy (MWh), Power (MW)</li> <li>A304 - trade interval: 5, 15, 60 min.</li> <li>A305 - transactions: bids, offers,</li> </ul>	System	X	X		X		
C322 - Day Ahead Market		System						
C323 - Real time Market		System						
C324 - Bilateral transmission Capacity		Application						

C325 - Available Transmission Capacity Calculation	<ul style="list-style-type: none"> <li>derivatives</li> <li>A306 - customer data</li> </ul>	Application						
C411 - Business Operation Systems	---	System		X	X	X		
C412 - Utility Customer Applications (Customer Relationship Management Systems)		Application						
C413 - External IT applications		Application						
C421 - EMS (Energy Management Systems) {TSO,BRP} {Real-time SCADA applications, Generation Dispatch and Control, Energy Scheduling and Accounting, Transmission Security Management}	<ul style="list-style-type: none"> <li>A307 - Number of primary EMS sites</li> </ul>	System	X	X	X	X		
C422 - DMS (Distribution Management Systems) {System monitoring, operation, management outage management, modelling & analysis tools}	---	System	X	X	X	X		
C423 – Eng. & maintenance applications	---	System		X		X		
C424 - SCADA (incl. (State Est., OPF, etc.))	---	System	X	X	X	X		
C428 - Advanced metering infrastructure {includes applications for Pricing options, customer options, utility operations, Emergency demand Response}	<ul style="list-style-type: none"> <li>A308 - type of smart meters (residential, industrial, commercial)</li> <li>A309 - power consumption data</li> <li>A310 - communication interval: real time/ interval based</li> </ul>	System	X	X	X	X		
C425 - Data Acquisition and Control front ends ( gateways)	---	System	X	X	X	X		
C4251 - mapping services	---	Communication				X		
C4252 - Data Concentrator	---					X		
C426 - Application interfaces (common information models, component interfaces, etc.)	---	Interface				X		
C427 - VPP software	---	System	X	X	X	X		

C431 - Control devices (e.g., power converters, OLTCs, switchgear (relays, breakers.), IED, Substation / DER / Hydro devices	---	Devices	X		X		X	
C433 - Control Centres	---	System	X	X	X	X	X	
C434 - Measurement devices (e.g., PMU, Smart Meters)	---	Devices	X			X	X	
C511 - Home Area Networks	---	Communication			X			
C512 - Neighbourhood Area Network,	---	Communication			X			
C513 - Wide Area Networks	---	Communication			X			
C514 - Internet	---	Communication			X			

**Other ICT attributes:**

- A311 - Communication quality
- A312 - Data Availability
- A313 - Control Architecture type
- A314 - Data Integrity,
- A315 - Data consistency,
- A316 - Data completeness,
- A317 - Data accuracy
- A318 -Latency
- A319 - Bandwidth
- A320 - Security
- A321 - Reliability
- A322 - Firewalls
- A323 - Routing
- A324 - Meter availability
- A325 - Interoperability
- A326 - Data privacy

**7.3.5 Reference to High-Level Scenario**

e-Highway2050 (not specific)

### 7.3.6 Constraints

<b>Global Constraints (domain related)</b>		
<b>Domain</b>	<b>Constraint</b>	<b>Additional Information</b>
Electricity	Power	Upper / Lower
ICT	Existing infrastructure	---
	Security Resilience	---
	Robustness	---
	Timing behaviour	---
Stakeholder	---	---
Heat	---	---
Transport	---	---
<b>Specific Constraints (related to component)</b>		
<b>Component</b>	<b>Constraint</b>	<b>Additional Information</b>
---	---	---
<b>Indirect Constraints</b>		
<b>Cause</b>	<b>Constraint</b>	<b>Additional Information</b>
---	Driving range	---
---	Battery energy density	---
---	Battery power density	---

### 7.3.7 Use cases

#### **Grid control and management related:**

<b>Frequency (Power Balance) Control</b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	Current status: decentralized primary response / centralized secondary/tertiary response at transmission level; Future: could be done in a distributed way, involving distributed resources, adding virtual inertia
<b>Actors:</b>	D03C614-Large Synchronous Generator operator (currently), D03C615-DER operators (future case), D03C604-Aggregators by demand response of loads (future case), D03C603-DSO (future emergency case- disconnect part of the network to avoid collapse), C616- HVDC terminal operators (future case)
<b>How (functions)</b>	Inertial control (generator primary control), Virtual inertia (Primary control: DER, HVDC, Inverter + batteries), Power balance (secondary control: Aggregators, TSO, DSO, storage, large CHP)
<b>Components</b>	---
<b>Relevant Attributes</b>	Electrical: D01.C*.A009- grid frequency, D01.C*.A003- voltage waveform at inverter
<b>Smart Metering for Smart Grids</b>	
<b>Relevance for SC</b>	Medium (only limited applicability: focus on AMI infrastructure)
<b>Definition (what)</b>	Support provided by smart meter data (LV network monitoring and control/forecast/model accuracy)

<b>Actors:</b>	D03.C603- DSO, D03.C608- Metering operator, D03.C607- Customer, D03.C614, D03.C615- Producer
<b>How (functions)</b>	Metering, data aggregation, verification/forecasting services, database consistency/integrity, data management, Network monitoring etc.
<b>Components</b>	D02.C434- AMI: Smart meter, D02.C C4252- Data Concentrator, D02.- MDM System, D02.C*- ICT infrastructure (communication)
<b>Relevant Attributes</b>	D02.C*.A314- Data integrity, D02.C*.A324-meter availability, D02.C*.A325- interoperability, D02.C*.A326-data privacy
<b>Coordinated Voltage Control</b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	Voltage support by a coordinated strategy at different voltage levels using resources connected to transmission and distribution grids
<b>Actors:</b>	D03.C601- TSO, D03.C603- DSO, D03C604- Aggregator
<b>How (functions)</b>	Interactions of local voltage controllers (Power plant / Wind farm / Substation-OLTC). TSO/DSO interaction: Distribution system voltage support for transmission grid. Virtual Power Plan voltage support: remote injection points for active/reactive power for controlling voltage at a (joint) grid node; local voltage control / combined with secondary voltage control
<b>Components</b>	---
<b>Relevant Attributes</b>	D01.C*.A003- Voltage level, D01.C*.A006- reactive power, D01.C*.A010- power factor, D01.C*.A210- activation time, D01.C11.A211- droop (V/Q), D01.C*.A601- service cost
<b>Restoration Reserves Procurement using Distributed Control</b>	
<b>Relevance for SC</b>	<i>medium (if relevant for any SCs then this one)</i>
<b>Definition (what)</b>	Generic, distributed algorithm for allocating reserves for frequency control during loss of generation (or major tie-line) events. The scenario assumes that future the grid is logically organized into multiple interconnected areas (i.e. cells in a web-of-cells architecture). The areas collaboratively allocate reserves for inertia, frequency containment, and restoration in a fully-distributed manner - i.e. without vertical control.
<b>Actors:</b>	D03.C601- TSO, D03C604- aggregator, D03.C615- DER operator, D03.C*- relevant ICT systems
<b>How (functions)</b>	procurement and dispatch functions (flexibility estimation, aggregation, portfolio optimization, forecasting, state estimation, online control)
<b>Components</b>	C144-Wave energy conversion systems (OWC, buoys, absorbers, attenuators), D01.C141- Wind park, D011.C142- PV park, D01.C143- Ocean Thermal Energy Conversion systems (OTEC) (turbine/condenser/evaporator), D01.C161- Hybrid systems, D01.C162- Storage, D01.C1621- Power to gas (P2G), (D01.C124-Supplying Grid, D01.C1623- Pumped Hydroelectric Storage can be simplified), D01.C1632- Inductors, D01. C1633- SVC, D01.C2221- Charging spot, D01.C232- Micro Wind turbines, (D01.C251- Distribution Substation can be abstracted), D03-{C601- TSO's, C602- Balance Responsible (BRP), C603- DSO's, C604- Aggregator, C608- Metering (data) service provider, C609- Regulators, Policy Makers, environmental groups}
<b>Relevant Attributes</b>	D022.C*.A*- communication features, D022.C*.A*- information processing, D01.C*.A205- ramp rates and D01.C*.A212-unit flexibility
<b>EV integration in the Smart Grid</b>	
<b>Relevance for SC</b>	High

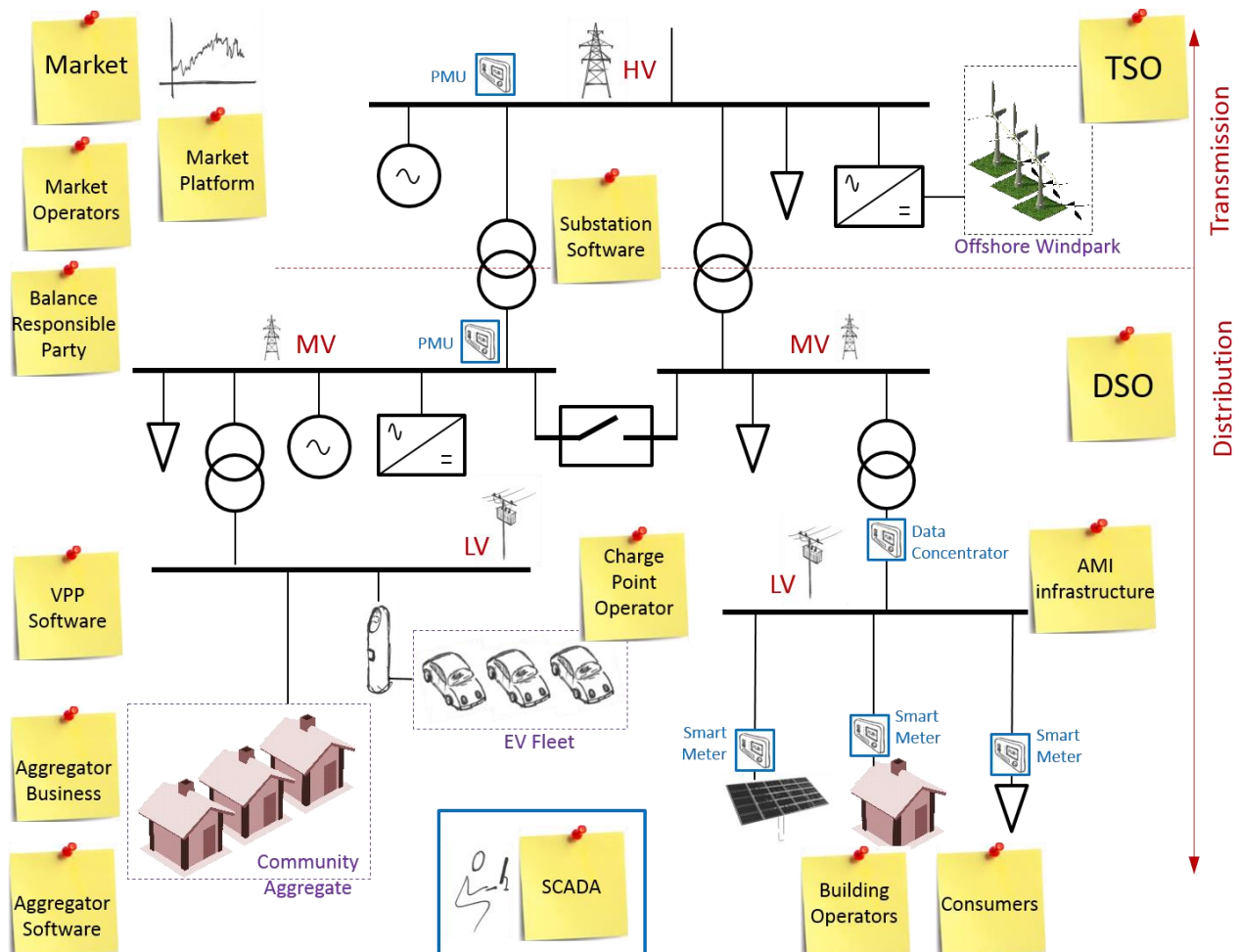
<b>Definition (what)</b>	Centralized control/aggregation (EVPPs), LV to MV provision of ancillary services via EV fleets (voltage and frequency control, peak shaving, load following...)
<b>Actors:</b>	New roles: (D03.C606- Charging spot operators (CSO), D03.C617- E-mobility service provider (EMSP), D03.C607- EV supply equipment operator (EVSE), D03.C608- metering operator, D03.C606- EV user/e-mobility customer, D03.C619-charging station equipment owner, D03.C620- e-mobility clearing house (EMCH), D03.C618- fleet manager Old roles: Grid operators (D03.C601- TSO, D03.C603- DSO), D03.C604- aggregator, D03.C621- flexibility provider, D03.C614, D03.C615- energy supplier, D03.C604- balance responsibility party (BRP)...
<b>How (functions)</b>	Procurement and activation functions (monitoring/location and use status of the EVs, charging post identification and reservation, scheduling), EMS (continuous power regulation of each EVSE, incentive planning), roaming
<b>Components</b>	D01.C222- EV, D01.C2221- charging post, D01.C221- charging station, D02.C434- smart meter, D02.C421- EMS
<b>Relevant Attributes</b>	D02.C*.A320- Security scheme (VPN, certificates), D02.C*.A322- firewalls, D02.C*.A323- routing, EV fleet management issues (D01.C222.A214- EV and charging posts location D01.C222.A213- and availability, D01.C*.A001- energy cost)
<b><i>Monitoring, control and automation in Smart Grids</i></b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	Data management (new measurements, bigger observability of the grid), interaction between centralized/decentralized control schemes for fault prediction, location, mitigation and congestion management
<b>Actors:</b>	D03.C601- TSO / D03.C603- DSO, D03.C608- metering/monitoring-related actors (metered data aggregator, metered data collector, metered data responsible, metering operator)
<b>How (functions)</b>	Wide-area monitoring, real-time measurement/management, remote control, fault detection
<b>Components</b>	D02.C434- PMU/ D02.C431- IED/ RTU/ D02.C434- smart meter/ ??monitoring device, D02.C425- data management system, D02.C424- SCADA
<b>Relevant Attributes</b>	Data-related (D02.C*.A314- integrity, D02.C*.A315- consistency, D02.C*.A316- completeness, D02.C*.A317- accuracy), ICT-attributes (D02.C*.A318- latency, D02.C*.A319- bandwidth, D02.C*.A320- security, D02.C*.A321- reliability)
<b><i>Demand Response (DR)</i></b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	Emergency Demand Response and Ancillary Services Demand Response- in vertical integration case, real-time pricing (indirect control) Not included here: Economic DR (can be a Use Case in Distribution SC); Current: regulated by price (time-of-day)
<b>Actors:</b>	D03.C607- End users, D03.C604- Aggregators, D03.C601- TSO/ D03.C603- DSO, D03.C615- DER operators
<b>How (functions)</b>	Local EMS, Cluster Power control (Aggregator case), TSO/DSO initiate Demand Response, DER operators do local control
<b>Components</b>	---
<b>Relevant Attributes</b>	D01.C*.A001- energy price, D01.C*.A216- baseline consumption, D01.C*.A203- variable generation, etc.

**Aggregator / ancillary service related:**

<b>Aggregator Validation</b>	
<b>Relevance for SC</b>	High
<b>Definition (what)</b>	validation of aggregator's capability to provide ancillary services (seems a test-case)
<b>Actors:</b>	D03.C604- Aggregator, D03.C601- TSO, D03.C624- certification body;
<b>How (functions)</b>	aggregator control system, test case, demand-level/local control functions; DERs, heat pumps as lab equipment perform local control; ancillary service delivery by aggregate resources verified
<b>Components</b>	---
<b>Relevant Attributes</b>	---
<b>Emission trading and optimization schemes with the use of Multi-Agent Systems</b>	
<b>Relevance for SC</b>	Medium/high
<b>Definition (what)</b>	Energy Market participants
<b>Actors:</b>	D03.C622- Energy Market participant, D03.C623- Energy market operator
<b>How (functions)</b>	Trading and optimisation schemes using multi-agent systems to verify functionality, covering aspects of modularity scalability, reconfigurability robustness and pro-activeness.
<b>Components</b>	D?.C?- System agents, D02-C425- data providers. D02.C32x- Market operation applications
<b>Relevant Attributes</b>	D02.C*.A313- Control Architecture type, D02.C*.A312- data availability, D01.C608.A407- prosumer behaviour
<b>Grid support by DG and Storage</b>	
<b>Relevance for SC</b>	Medium/high
<b>Definition (what)</b>	Current: V/Q control, power control, Demand Response; Future: f/P control, islanding support
<b>Actors:</b>	D03.C615- DG operators, D03.C604- Aggregators, D03.C601- TSO / D03.C603- DSO
<b>How (functions)</b>	V/Q control, power control, Demand Response, Load Shedding, f/P control, Provide Virtual inertia, Provide f set point (Islanding case)
<b>Components</b>	---
<b>Relevant Attributes</b>	---
<b>Distributed tracking of distribution grid topology</b>	
<b>Relevance for SC</b>	Low
<b>Definition (what)</b>	With the electrification of transport and heating, services to the distribution grid become more relevant such as power flow capping or voltage control. The efficiency of these services is very much dependent on the location at which they are delivered. This means that an aggregator will need to know at which point of the grid each flexible unit under its control is connected at a particular point in time, i.e. it needs dynamically updated information about the grid topology within the area of its operation.
<b>Actors:</b>	D03.C603- DSO
<b>How (functions)</b>	Service scheduling, service delivery and validation of compliance by the aggregated units.

	The scenario concerns embedded intelligence in distribution grid substations designed to make real-time topology information available locally in real time, for control purposes.
<b>Components</b>	D02.C*- relevant ICT systems, D01.C2xx- MV/LV grid
<b>Relevant Attributes</b>	D01.C*.A0xx- grid parameters, D02.C*.A311- ICT communication quality

### 7.3.8 Graphical Presentation of the Overall System Configuration



## 7.4 Annex 4: Data Produced by ERIGrid Scenario Survey

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*Scenario title:*

- Regionally-specific scenario with regard to unit distribution

*Information provider:*

- OFFIS – Institute for Information Technology

*Developed in (project/network/etc.):*

- Smart Nord research network; D-Flex research project

*Published on:*

- smartnord.de (only available in German)
- POWERENG 2015 Riga

*Link or reference:*

- <http://smartnord.de/downloads/SmartNordFinalReport.pdf> (English, Chapter on Work Group: Scenario Design for Sub-Projects 1-4)
- M. Blank et al., "Regionally-Specific Scenarios for Smart Grid Simulation", 5th International Conference on Power Engineering, Energy and Electrical Drives (POWERENG 2015), May 11-13, 2015, Riga.

*Short description of the scenario:*

- *Rural and urban grid models from low to medium voltage levels with models of consumers, producers and storage devices allocated at grid nodes reflecting the current and future penetration of renewable power units of a specific region*
- assumptions on growth of renewable power units have been made based on national studies
- the regional-specific data has been given by statistical data of the German TSOs of connected units in their control area
- project Smart Nord: evaluation of control strategies for forming and controlling dynamic virtual power plants
- project D-Flex: comparison of control strategies for the coordination of distributed units (centralised vs. decentralised coordination)

*Relevance for ERIGrid:*

- process to obtain scenarios with regard to unit distribution in grid models may be adapted
- 

*Scenario title:*

- Optimal ICT penetration for the extension of the complete German Distribution grid under different scenarios

*Information provider:*

- OFFIS - Institute for Information Technology

*Developed in (project/network/etc.):*

- BMWi- Study "Modern Transmission and Distribution grids for Germany"

*Published on:*

- EDST 2015

*Link or reference:*

- <http://ieeexplore.ieee.org/xpl/abstractAuthors.jsp?reload=true&arnumber=7315211>
- <http://www.bmwi.de/BMWi/Redaktion/PDF/Publikationen/Studien/verteilernetzstudie,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdf>

*Short description of the scenario:*

- grids for Germany: optimal allocation of different SG technologies which can be used for more efficient grid use to enlarge the DER feed-in

*Relevance for ERIGrid:*

- process to obtain scenarios with regard to unit distribution in grid models may be adapted
- 

*Scenario title:*

- COBRACable

*Information provider:*

- TU Delft

*Developed in (project/network/etc.):*

- H2020 Project

*Short description of the scenario:*

- 700MW submarine transmission link between the Netherlands and Denmark. Designed to be compatible with multi-terminal operation
- To be commissioned in 2019
- TSOs (Energienet.dk, TenneT), EU, converter and cable manufacturers
- Offshore wind power plant, RES are involved
- Technology: Voltage Sourced Converter (VSC), DC circuit breakers

*Relevance for ERIGrid:*

- Electrotechnical dynamics ranging from (50µs – 10s)
  - Grid code requirements\
  - DMS via TCP/IP
- 

*Scenario title:*

- DC House

*Information provider:*

- TU Delft

*Developed in (project/network/etc.):*

- TU Delft Campus Project

*Short description of the scenario:*

- DC Building with LED light, USB-C, Solar Panels, Grid inverters, EV Charging, Battery storage, etc. at

TU Delft Campus

- Low Voltage
- To be built 2016/2017

*Relevance for ERIGrid:*

- Integration of customer side technology (EVs, PV, etc.)
  - Grid-interaction via grid inverters
  - Economical optimum is subject to research
- 

*Scenario title:*

- URSES research project

*Information provider:*

- TU Delft

*Developed in (project/network/etc.):*

- Dutch national project

*Short description of the scenario:*

- PMU-based frequency control, blackout prevention, controlled islanding
- Fast controls, Transmission grid, bulk generation sources

*Relevance for ERIGrid:*

- High-end ICT (PMUs, fiber optics) for smart grids
- 

*Scenario title:*

- Interoperability of two micro-grid platforms

*Information provider:*

- Grenoble INP

*Developed in (project/network/etc.):*

- Project PPInterop

*Published on:*

- The project is still in progress until March 2016.

*Short description of the scenario:*

- Two smart grid platforms: PREDIS located at G2Elab, Grenoble, France and PRISMES, located at CEA INES, le Bourget-du-lac, France are taken into consideration.
- The distance between two platforms is estimated to be around 67 km.
- We aim to make these platforms interoperable, to remotely monitor and control in real time the available experimental tools.
- The interoperable platform PREDIS - PRISMES will be the work support of the joint team between CEA and G2Elab on the intelligent management of multi-vector energy networks.

*Relevance for ERIGrid:*

- It is a cooperation/joint research scenario of micro-grids specialized to distributed and renewable energy sources.
- 

*Scenario title:*

- Coordinated Voltage Control

*Information provider:*

- ICCS-NTUA

*Developed in (project/network/etc.):*

- NTUA's research, and EU project Nobel Grid

*Short description of the scenario:*

- In this scenario a centralized coordinated voltage control algorithm is implemented in a distribution network, as a solution to the voltage rise problem due to DG production.
- The algorithm will be receiving real-time measurements from selected nodes of the network, solving an optimization problem and transmitting the resulting set-points to all the devices with voltage control capabilities (e.g. DG and storage inverters, tap-changer etc.) in the network.

*Relevance for ERIGrid:*

- This scenario is very relevant to ERIGrid's goals since it combines power components and the network and also the control of the network.
  - Hardware in-the-Loop testing can be used for this scenario, for both power components (PHIL with hardware inverter) and control elements (CHIL with hardware controller)
- 

*Scenario title:*

- Grid support by DG and Storage

*Information provider:*

- ICCS-NTUA

*Developed in (project/network/etc.):*

- General research

*Published on:*

- IEEE Transactions on Industrial Electronics

*Link or reference:*

- <http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=7063951&newsearch=true&queryText=kotsamopoulos>

*Short description of the scenario:*

- In this scenario various methods for providing grid support by distributed generation and storage systems will be developed and tested.

- These functions could include voltage control (e.g.  $Q(U)$  and  $\cos\phi(P)$  control), frequency control ( $P(f)$  droop, virtual inertia etc), among other work.

*Relevance for ERIGrid:*

- With the increasing integration of distributed generation and storage systems into the grid over the last years, and with even more planned for the near future, it has become a necessity that these systems are capable of providing ancillary services to the grid. (there are already requirements stated in the standards for DG connected to the HV, MV and LV).
  - Such functions can be tested in simulation, conventional lab testing and Hardware in Loop testing (interactions between different components).
- 

*Scenario title:*

- Operation and control of off-grid systems

*Information provider:*

- ICCS-NTUA

*Developed in (project/network/etc.):*

- General Research

*Published on:*

- Electric Power Systems Research

*Link or reference:*

- V. Karapanos, P. Kotsampopoulos, N. Hatziargyriou, "Performance of the linear and binary algorithm of virtual synchronous generators for the emulation of rotational inertia", Electric Power Systems Research, Volume 123, June 2015

*Short description of the scenario:*

- The operation and control of off-grid systems incorporating DER are examined. Introducing renewable sources (e.g., PV or Wind Turbines) to Diesel-based systems has several financial, environmental and technical benefits. However, the operation and control faces several challenges that need to be tackled (technical minimum of the Diesel Generator, curtail of the PV, stability etc.).

*Relevance for ERIGrid:*

- Several off-grid systems exist in Europe ranging from small telecommunications stations to remote islands (e.g. in Greece) and mines. Moreover there are around 1.3 billion people, or 20% of the world's population without access to electricity, creating an emerging energy market for off-grid systems.
  - The aforementioned scenario will be tested in a combined CHIL and PHIL environment. A Hardware PV inverter will be connected to a simulated Diesel Generator and network (PHIL), and a central controller will control the PV and Diesel Generator (CHIL). Therefore, the "holistic testing" approach will be applied as both power and control systems will be tested.
- 

*Scenario title:*

- Frequency (Power Balance) Control

*Information provider:*

- CRES

*Developed in (project/network/etc.):*

- ELECTRA IRP

*Published on:*

- Deliverable D3.1: Specification of Smart Grids high level functional architecture for frequency and voltage control

*Link or reference:*

- <http://www.electrairp.eu>

*Short description of the scenario:*

- The scenario refers to the frequency/balance control of smart grids in order to achieve a stable operation under high RES penetration levels.
- The scenario involves four distinctive sub-scenarios or high-level use cases covering all time scales and control levels.
- These use cases address inertia provision, primary and secondary frequency/balance control as well as short term forecasting and scheduling of flexibility to reduce the effects of imbalances in a system.

*Relevance for ERIGrid:*

- The specific scenario addresses one of the major challenges of the operation of smart grids.
  - It is therefore very relevant to the ERIGrid objectives.
- 

*Scenario title:*

- Emission trading and optimisation schemes with the use of Multi-Agent Systems

*Information provider:*

- CRES

*Developed in (project/network/etc.):*

- DERri

*Published on:*

- Elsevier-Electric Power Systems Research and DERri

*Link or reference:*

- B. S. Skarvelis-Kazakos, E. Rikos, E. Kolentini, L. M. Cipcigan, N. Jenkins, "Implementing agent-based emissions trading for controlling Virtual Power Plant emissions", Elsevier-Electric Power Systems Research 102 (2013) 1-7, [http://www.der-ri.net/uploads/media/FactSheet-CA\\_VPP\\_GF\\_20120717.pdf](http://www.der-ri.net/uploads/media/FactSheet-CA_VPP_GF_20120717.pdf)

*Short description of the scenario:*

- In this scenario a technological solution based on agents is applied to facilitate the participation of a VPP (cluster of microgrids and resources) in an carbon emissions market.
- The basic idea is that the system consists of various levels represented by agents which can optimise the carbon credits across a VPP.

*Relevance for ERIGrid:*

- The specific technological solution is of the most promising ones for optimisation of Distribution Systems, with emphasis on the operation of microgrids and VPPs.

- Also, the solution is applicable to other forms of optimisation problems such as participation in energy market, efficiency improvement etc.
- 

*Scenario title:*

- Optimal Operation of Microgrids

*Information provider:*

- CRES

*Developed in (project/network/etc.):*

- DERri

*Published on:*

- DERri reports, IEEE TRANSACTIONS ON CONTROL SYSTEMS TECHNOLOGY and Elsevier Applied Energy

*Link or reference:*

- A. Parisio, E. Rikos, G. Tzamalīs, and L. Glielmo, "Use of Model Predictive Control for Experimental Microgrid Optimization", Elsevier Applied Energy 115 (2014) 37-46
- A. Parisio, E. Rikos, and L. Glielmo, "A Model Predictive Control Approach to Microgrid Operation Optimization", IEEE Transaction on Control System Technology, Vol. 22, No. 5, September 2014, pp. 1813-1827
- [http://www.der-ri.net/uploads/media/FactSheet-MSPC\\_GF\\_20120717.pdf](http://www.der-ri.net/uploads/media/FactSheet-MSPC_GF_20120717.pdf)
- [http://www.der-ri.net/uploads/media/FactSheet-SOPC\\_GF\\_20120717.pdf](http://www.der-ri.net/uploads/media/FactSheet-SOPC_GF_20120717.pdf)

*Short description of the scenario:*

- This scenario refers to optimisation of the operation of microgrids by means of a central controller.
- The objective of the implementation was the maximisation of profits and reduction of CO2 emissions in a microgrid via alternative solutions of optimal control such as model-predictive and stochastic-optimal-predictive control.

*Relevance for ERIGrid:*

- One of the main features of the operation of microgrids is the central management of it which aims to optimising its performance under different operating condition and scenarios.
  - ERIGrid emphasises on solutions mainly at distribution level.
  - In this respect the scenario of microgrids' optimal management is very important for our analysis
- 

*Scenario title:*

- Aggregator validation

*Information provider:*

- DTU

*Developed in (project/network/etc.):*

- iPower

*Short description of the scenario:*

- In order to provide power system services of the same value as those traditionally provided by large generation units, aggregators of DER units and their infrastructure must be validated. The existing certification procedures for large generation units cannot be applied to aggregators due to their distributed nature and the dynamically changing portfolios. Furthermore, the contribution of each DER unit may vary due to different amounts of available flexibility. Therefore, aggregator validation does not primarily test the capabilities of the physical units in the portfolio, but the ability of the aggregator and its infrastructure to contract sufficient resources and to activate these resources as needed to provide the service when requested. Aggregator validation must therefore be performed in controlled environments - laboratory or simulation - where a variety of standardized operational conditions can be reproduced.
- In this scenario, an aggregator of residential heat pumps is to be validated regarding its ability to provide a contracted active power regulation service (up/down) within a range of operational conditions. These include varying meteorological conditions (influencing the flexibility of the heat pumps) as well as different failure situations such as communication failure, communication congestion and DER unit failure.

*Relevance for ERIGrid:*

- Co-simulation of electrical power system and communication network
  - Interaction of DSO, BRP, TSO, aggregator, market operator, DERs
- 

*Scenario title:*

- Distributed tracking of distribution grid topology

*Information provider:*

- DTU

*Developed in (project/network/etc.):*

- DynTopo

*Published on:*

- project report to be published

*Short description of the scenario:*

- With the electrification of transport and heating, services to the distribution grid become more relevant such as power flow capping or voltage control. The efficiency of these services is very much dependent on the location at which they are delivered. This means that an aggregator will need to know at which point of the grid each flexible unit under its control is connected at a particular point in time, i.e. it needs dynamically updated information about the grid topology within the area of its operation. This information would be important for all stages of the aggregation process: Service scheduling, service delivery and validation of compliance by the aggregated units.
- The scenario concerns embedded intelligence in distribution grid substations designed to make real-time topology information available locally in real time, for control purposes.

*Relevance for ERIGrid:*

- Co-simulation of communication network, geographically dispersed processes and electrical grid
  - Peer-to-peer communication and control
- 

*Scenario title:*

- Multi-energy system (Nordhavn)

*Information provider:*

- DTU

*Developed in (project/network/etc.):*

- Energylab Nordhavn

*Published on:*

- Not published yet

*Link or reference:*

- <http://www.energylabnordhavn.dk>

*Short description of the scenario:*

- A new neighbourhood is currently being developed on the site of the former industrial port of Copenhagen (Nordhavn). At the end of development, around the year 2040, the area is planned to support 40.000 residents and 50.000 workplaces and should be self-sustaining with energy. Integration of the different energy infrastructures and enabling the exchange of energy between them has been identified as key capabilities for achieving this goal.
- The combined operation of district heating and electricity networks (e.g. for storing excess wind power generation as heat, or to substitute heat pumps with other sources of heat in case of low wind generation) will be simulated and tested in the laboratory and in the field as part of the project.

*Relevance for ERIGrid:*

- Multi-energy system
  - Co-simulation of electrical distribution grid, district heating network, energy markets
  - Actors involved: Electrical and thermal aggregators, electrical and district heating network operators, electrical and thermal system responsible, energy markets
- 

*Scenario title:*

- Use of flexibility in active power networks

*Information provider:*

- SINTEF Energy Research

*Developed in (project/network/etc.):*

- Distribution2020
- Nowitech

*Short description of the scenario:*

- This scenario studies the use of flexible resources to maintain power quality in a distribution network characterized by volatile and intermittent distributed production, along with demanding loads such as electric vehicles and modern household appliances.
- Specific challenges include smart EV charging, microgrid operation, and network flexibility, e.g., in terms of thermal and chemical storage (possibly including V2G/V2H).

*Relevance for ERIGrid:*

- The scenario studies robust integration of RES, where the use of flexibility is a means to maintain power

- quality and system integrity at a reasonable cost.
  - Furthermore, it addresses operation of the distribution grid under increasingly demanding conditions (e.g., EV charging).
  - The scenario takes a holistic approach, focusing on system solutions rather than component testing.
- 

*Scenario title:*

- Integration of renewable energy sources

*Information provider:*

- SINTEF Energy Research

*Developed in (project/network/etc.):*

- Nowitech
- Distribution 2020

*Published on:*

- <http://www.sintef.no/en/publication/?pubid=SINTEF+A20593>

*Link or reference:*

- <https://www.sintef.no/projectweb/nowitech>
- [https://www.sintef.no/projectweb/distribution\\_2020](https://www.sintef.no/projectweb/distribution_2020)

*Short description of the scenario:*

- This scenario studies integration of electric energy from intermittent renewable sources such as run-of-river hydro, wind and PV. In the laboratory network, a combination of power converters and generators allow for the emulation of a network dominated by renewable energy sources. Relevant aspects to take into account include:
  - Effects on power quality; the role of inverters and possible mitigation
  - Synthetic maintenance of inertia / virtual synchronous machines
  - Protection and control strategies in the case network faults
  - Provision of short circuit current
  - Congestion management

*Relevance for ERIGrid:*

- A scenario for testing can include the simultaneous operation of distributed generators of different kinds in a distribution grid. The setup allows for investigations into network impact and interaction, protection and control strategies, voltage quality and congestion management and more.
  - The laboratory is flexible regarding grid topology and control.
- 

*Scenario title:*

- Monitoring, control and automation in Smart Grids

*Information provider:*

- SINTEF Energy Research

*Developed in (project/network/etc.):*

- Next Generation Distribution Control Center

- ProOfGrid

*Short description of the scenario:*

- Ever more operational data from the network is available in the control centres. Alongside improved opportunity to, directly or in-directly, control network components, load and generation, this provides new opportunities for functionality in future control centres. Among such features are:
  - Congestion and over-load prediction and mitigation
  - On-line risk assessment and fault mitigation
  - Automated fault response
  - Improved monitoring by utilization of PMUs
- In the new Smart Grid Laboratory, a central monitoring and control platform is being developed. This will enhance the ability to perform real-time monitoring and control of the network, as well as introducing automated responses to network events. The laboratory is flexible regarding grid topology, and can include AC grids, multi-terminal DC grids and combinations of the two.

*Relevance for ERIGrid:*

- The interaction between central and decentralised monitoring and control is one of the major topics to be studied and improved in future Smart Grids. Monitoring and control strategies applying different combinations of central and decentralized functionality can be implemented and tested in the laboratories.
  - HVDC connection can become vital to the European electricity grid in the future. Including these in laboratory networks can be relevant and important.
- 

*Scenario title:*

- Restoration Reserves Procurement using Distributed Control

*Information provider:*

- University of Strathclyde

*Developed in (project/network/etc.):*

- ELECTRA IRP

*Short description of the scenario:*

- A generic, distributed algorithm for allocating reserves for frequency control during loss of generation (or major tie-line) events.
- The scenario assumes that future the grid is logically organised into multiple interconnected areas (i.e. cells in a web-of-cells architecture).
- The areas collaboratively allocate reserves for inertia, frequency containment, and restoration in a fully-distributed manner - i.e. without vertical control. (This is presently a work in progress within the ELECTRA project, so there are no published materials yet.)

*Relevance for ERIGrid:*

- The scenario (and the solution) is applicable to any mixture of reserves sources, e.g. storage, DSR, or RES.
  - The scenario has been mapped to power hardware-in-the-loop laboratory facilities at Strathclyde. This includes provisions for communications-related aspects of the system.
- 

*Scenario title:*

- Distribution network subjected to local voltage issues

*Information provider:*

- RSE

*Developed in (project/network/etc.):*

- GRID4EU (all demonstrators)
- IGREENGrid (all demonstrators)

*Published on:*

- Projects deliverables and related publications

*Link or reference:*

- Projects websites, EN 50160

*Short description of the scenario:*

- Large penetrations of DG in rural networks increase voltage magnitudes and harmonic contents.
- On the other side, the growing presence of non-linear and unbalanced loads determines similar effects (high harmonic distortion and presence of voltage inverse/homopolar components)

*Relevance for ERIGrid:*

- This is one of the most studied scenarios in terms of DG integration and most of the currently developed (or under development) smart grid solutions are devoted to the overtaking of the operational problems related to this scenario.
- 

*Scenario title:*

- Distribution network subjected to local overloads

*Information provider:*

- RSE

*Developed in (project/network/etc.):*

- IGREENGrid (all demonstrators)

*Published on:*

- Projects deliverables and related publications

*Link or reference:*

- Projects websites

*Short description of the scenario:*

- Large penetration of DG may determines occasional lines, cables and transformers overload even for small injection of energy (DG with high power/energy ratio).

*Relevance for ERIGrid:*

- Common scenario in urban/short feeders networks, extremely challenging for the integration of smart grid solutions devoted to hosting capacity increase.
-

*Scenario title:*

- Intentional or virtual islanding operation of distribution network

*Information provider:*

- RSE

*Developed in (project/network/etc.):*

- More Microgrids (all the demonstrators)
- GRID4EU (Czech and French demonstrators)
- IGREENGrid (Italian and French demonstrators)
- Cigré C6.22 (report October 2015)

*Published on:*

- Projects deliverables and related publications

*Link or reference:*

- Projects websites

*Short description of the scenario:*

- Island operation of a distribution network can be intentional for several reasons: failure of the upper stream network, benefits from the local consumption of generated energy, etc.
- In this scenario, a distribution network (microgrid) is operated without a physical connection with the upper stream network (or with zero power exchange in case of virtual island).

*Relevance for ERIGrid:*

- Scenario in which black start functionalities and services to support islanding operation can be evaluated.
- 

*Scenario title:*

- Low power factor exchanges in primary/secondary substations

*Information provider:*

- RSE

*Developed in (project/network/etc.):*

- IGREENGrid (Austrian demonstrator)

*Published on:*

- Projects deliverables and related publications

*Link or reference:*

- Projects websites

*Short description of the scenario:*

- TSO agreements and protection devices often impose restrictions in terms of reactive power flows. The introduction of local DG controllers based on reactive power injection may significantly impact on the power factor of the power exchanged with the upper stream network:

- Loads balance active power production and in case of DG=load, only reactive power is exchanged with the upper stream network
- DG is participating to voltage control even for under voltage mitigation (production of reactive power).
- Positive reactive power cannot be balanced with capacitors.

*Relevance for ERIGrid:*

- Scenario for the evaluation of solutions devoted to the limitation of reactive power exchanges in substations.
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*Scenario title:*

- Unintentional islanding occurrence

*Information provider:*

- RSE

*Developed in (project/network/etc.):*

- IGREENGrid (Italian demonstrator)

*Published on:*

- Projects deliverables and related publications

*Link or reference:*

- Projects websites

*Short description of the scenario:*

- Similar power levels of DG and loads, as well as DG participating in frequency control, may determines situations in which some portions of a non-supplied network (due to a failure) are still subjected to power exchanges between local DG and loads.

*Relevance for ERIGrid:*

- Scenario in which protection devices aimed to avoid unintentional island situations can be tested.
- 

*Scenario title:*

- Low observability of distribution systems

*Information provider:*

- RSE

*Developed in (project/network/etc.):*

- IGREENGrid (LV demonstrators)

*Published on:*

- Projects deliverables and related publications

*Link or reference:*

- Projects websites

*Short description of the scenario:*

- Several control techniques are affected by the accuracy state estimation and accuracy of DG and load forecasting algorithms.
- This scenario is typical of LV grid because of fast load and DG profile variations as well as difficulties of developing appropriate ICT and database technologies.

*Relevance for ERIGrid:*

- Scenario in which the efficacy of smart grid solutions can be evaluated in presence of non or roughly predictable network conditions.
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*Scenario title:*

- Smart Autonomous Energy management in Smart Building

*Information provider:*

- GINP

*Developed in (project/network/etc.):*

- MHI platform in Grenoble INP, several different projects is working on it.

*Published on:*

- Several conferences and journals.

*Short description of the scenario:*

- Energy management in smart building consists of the integration of distributed renewable energy resources and various strategies of optimization of energy usage.
- The demonstrator building allows the tests of different advanced automation and communication technologies.

*Relevance for ERIGrid:*

- Integration of distributed renewable energy resources.
  - Smart Autonomous Energy Management.
  - Integration of advanced automation and communication technologies.
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*Scenario title:*

- "Smart Metering for Smart Grids"

*Information provider:*

- TECNALIA

*Developed in (project/network/etc.):*

- EC Task Force on Smart Grids
- CEN-CENELEC-ETSI Smart Grid Coordination Group (SG-CG)
- Smart Metering Coordination Group (SM-CG)

*Published on:*

- 31 October 2014

*Link or reference:*

- [ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/SGCG\\_Standards\\_Report.pdf](ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/SGCG_Standards_Report.pdf)

*Short description of the scenario:*

- Smart metering brings intelligence to the last mile of the grid and it is seen as a key enabler for many smart grid applications, with interfaces with many smart grid areas like building/home automation and demand side management. The Advanced Metering Infrastructure (AMI) provide services for the customer, the supplier and network operator and is used for automated meter reading and billing and a range of other functionalities (network monitoring and control, demand response, etc.). The AMI system will enable and encourage stronger and direct involvement of consumers in their energy usage and management (including also management and market participation of variable and non-programmable generation).
- Metering at generation, transmission and distribution levels are not considered part of the AMI system, which is focused at the customer premises level.

*Relevance for ERIGrid:*

- Smart metering is a fundamental part of smart grids, being one of the first drivers of its deployment, and probably the smart grid issue closest and most perceived by the end user. Obviously the scope of smart grids is much larger and it would be possible to have smarter distribution and transmission networks without smart metering.
  - AMI fits very well the holistic view of ERIGrid since:
    - It is not just the meter (“network component”) but the entire system: meter, home gateway, concentrator at the secondary substation and even the back-office system.
    - It involves power issues (energy consumed or injected to the network) and communications: low level protocols (PLC, wireless) and data models (DLMS-COSEM, etc.).
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*Scenario title:*

- “EV integration in the Smart Grid”

*Information provider:*

- TECNALIA

*Developed in (project/network/etc.):*

- PlanGridEV project

*Published on:*

- 2014

*Link or reference:*

- <http://www.plangridev.eu>

*Short description of the scenario:*

- Smart grid with a massive penetration of electric vehicles where a granular control of EVs load management is performed.
- This allows the optimisation of hosting capacity, and additionally can consider the local connection of distributed energy resources (DER) that can benefit from the EV penetration via a positive feedback loop.
- No grid reinforcement is carried out to cope with the massive presence of EVs in the network. Bidirectional energy flow from grid to vehicle (G2V) and vehicle to grid (V2G) is available.

*Relevance for ERIGrid:*

- Very high.
  - The scenario fully involves power and communication issues and it makes sense only at system-wide level to really benefit from the load flexibility (demand response) obtained by the deep control and aggregation of the EVs spread across the network.
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*Scenario title:*

- “New architectures for Smart Grids: microgrids”

*Information provider:*

- TECNALIA

*Developed in (project/network/etc.):*

- Microgrids project
- More Microgrids project
- CEN-CENELEC-ETSI Smart Grid Coordination Group (SG-CG)

*Published on:*

- 2003-2005
- 2006-2010
- 2014

*Link or reference:*

- <http://www.microgrids.eu>
- [ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/SGCG\\_Standards\\_Report.pdf](ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/SGCG_Standards_Report.pdf)

*Short description of the scenario:*

- Microgrids, as organized entities interfaced to the distribution grid, will change (are changing) the network architecture.
- The concept includes a variety of implementations involving renewable resources, power electronics and communications, which can be managed and coordinated in an optimized way to distribute electricity to any microgrid user with a minimum cost, and to provide services (in the grid-connected mode) like power balance, voltage control, peak management, etc.
- Multiple microgrids can be operated also in the same system to increase the scale of the services.
- Participation of microgrids in power markets, in principle limited by their size, can be done via aggregators.
- From a domain perspective, microgrids and “Smart Grids in small” and may cover 3 main domains (Distribution, DER and Customer Premises), and then encompass systems from these domains.

*Relevance for ERIGrid:*

- Under the umbrella of Smart Grid, new grid concepts and architectures are included.
  - The microgrid concept is not new but it is still very relevant for future networks.
  - A microgrid can be considered a down-scaled testing platform for control solutions which will be implemented at larger networks.
  - The concept is also aligned with the new ELECTRA IRP Web-of-Cell concept: not all Cells are microgrids, but a microgrid is a type of cell.
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*Scenario title:*

- Remote controlling decentralised PV installations

*Information provider:*

- AIT

*Developed in (project/network/etc.):*

- ISGAN-SIRFN (Smart Grid International Research Facility Network)

*Link or reference:*

- <http://energy.sandia.gov/wp-content/gallery/uploads/Collaborative-Development-and-Comparison-of-Advanced-Interoperability-Certification-Test-Protocols-for-PV-Smart-Grid-Integration-SAND2014-17889C.pdf>

*Short description of the scenario:*

- As greater penetrations of variable renewable energy sources are connected to the electric power system, the ability of grid operators to perform voltage and frequency regulation and respond to grid disturbances with traditional power plants is being eroded. Technically, static converter-based distributed energy resources (DERs), such as PV inverters and energy storage systems (ESS), have the ability to assist grid operators control voltages and system frequency. These capabilities are being added to DERs as more grid codes around the world require advanced functions. These DER interoperability functions are defined generically in the International Electrotechnical Commission (IEC) Technical Report 61850-90-7. The functions include commanded modes as well as autonomous functions, which adjust active and reactive power to support locally-measured grid voltage and frequency.
- Driven by new requirements in Europe and proposed changes in California, inverter and power conditioning system (PCS) manufacturers are adding the advanced functionality to their devices. Large PV inverters and DER devices will likely be monitored and controlled with dedicated supervisory control and data acquisition (SCADA) controller. In order for utilities to control large quantities of small DER devices, an aggregator, gateway, or translator will most likely act as an intermediary between the utility and DER.

*Relevance for ERIGrid:*

- To guarantee the reliable and coordinated advanced interoperable functions in PV inverters and other DERs, harmonized national and international standards are still to be developed by the responsible bodies IEC, CENELEC and national technical committees. To accelerate this process, the SIRFN group, headed by SANDIA national laboratories has drafted and validated a first edition of testing protocols to validate the functional capabilities of the DER with the help of laboratory tests.
- Ultimately, the SIRFN group would like to provide experimentally-validated recommendations to establish and harmonize certification procedures from UL, IEEE, IEC, and other standards-making bodies. With conformance test procedures and associated certification schemes grid operators can rely on the coordinated and stable performance of advanced interoperability functionalities, and manufacturers can list their products once to gain access to multiple markets. These standardized DER capabilities provide the basis for the full integration of PV systems into a future Smart Grid slow dynamics control schemes. Eventually this allows the utility and grid operators to manage a large number of PV systems in a unified way and capture the potential benefits of inverter based DER.

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*Scenario title:*

- Coordinate voltage and frequency control using a high share of renewables

*Information provider:*

- AIT

*Developed in (project/network/etc.):*

- ELECTRA IRP scenarios (Web of Cells)

*Published on:*

- ongoing

*Link or reference:*

- <http://www.electrairp.eu>

*Short description of the scenario:*

- Coordinated voltage and/or frequency control using a high share of DER
- Horizontally organized control structure (i.e., Web of Cell approach)

*Relevance for ERIGrid:*

- Development of proper validation and testing approaches necessary
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*Scenario title:*

- Operation of microgrids

*Information provider:*

- AIT

*Developed in (project/network/etc.):*

- MicroGrids
- More MicroGrids
- CIGRE SC C6

*Published on:*

- previous years

*Link or reference:*

- <http://www.smartgrids.eu/node/14>
- <http://www.microgrids.eu/default.php>
- <http://c6.cigre.org/>

*Short description of the scenario:*

- Operation and control strategies for microgrids

*Relevance for ERIGrid:*

- Validation and testing of microgrid control scenarios
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*Scenario title:*

- ICT integration architectures and approaches for smart grid operation

*Information provider:*

- AIT

*Developed in (project/network/etc.):*

- various projects, e.g., OS4ES

*Published on:*

- ongoing

*Link or reference:*

- <http://www.os4es.eu/>

*Short description of the scenario:*

- Development of ICT-based integration architectures for smart grids with a high share of renewables

*Relevance for ERIGrid:*

- Validation and testing of roll out scenarios
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