INTERPLAN
INTEgrated opeRation PLAnning tool towards the Pan-European Network

Work Package 5

Operation planning and semi-dynamic simulation

Deliverable D5.1

INTERPLAN showcases

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Abbreviations

CANI	Calculation of available & needed inertia
DER	*Distributed Energy Resource*
DG	*Distributed generation*
DIRS	*Determination of inertia related setpoints*
DR	*Demand response*
DRES	*Distributed renewable energy sources*
DSO	*Distribution System Operator*
ENTSO-E	*European Network of Transmission System Operators for Electricity*
EU	*European Union*
EV	*Electric vehicle*
fFRC	*Fast Frequency Restoration Control*
HV	*High voltage*
IRSC	*Inertia related setpoints check*
KPI	*Key Performance Indicator*
LFG	*Load and Generation Forecaster*
LV	*Low voltage*
MV	*Medium voltage*
NC RfG	*Network Code on Requirements for Generators*
RES	*Renewable energy sources*
RoCoF	*Rate of Change of Frequency*
SAIDI	*System Average Interruption Duration Index*
SAIFI	*System Average Interruption Frequency Index*
ToU	*Time of use*
TSO	*Transmission System Operator*
UC	*Use case*
WP	*Work Package*

Executive Summary

The goal of INTERPLAN project is to provide an INTEgrated opeRation PLAnning tool towards the pan-European Network, with a focus on the TSO-DSO interfaces to support the EU in reaching the expected low-carbon targets, while maintaining the network security and reliability. The project involves 6 partners from 5 European countries. At the time of writing this report, the project is at Month 14 under the Grant Management phase.

The purpose of the deliverable D5.1 is to provide a detailed description of work completed under Task 5.1: Definition of showcases.

The base showcase was defined as "*Presentation of base use case(s) with no planning criteria and no controllers for emerging technologies, such as RES, DG, demand response or storages in the frame of chosen scenario, simulation type, test model, and time-series data. The base showcase allows to analyze the operation challenges of the related use case(s) and improvements achieved through the application of planning criteria with related implementation of controllers in the associated showcase",* while the showcase was defined as *"Presentation of use case(s) in the frame of chosen scenario, simulation type, test model, time-series data and planning criteria".*

Establishment the aforementioned definitions allowed to define and describe base showcases and showcases, which form the core of this deliverable and will be used as a basis for further work in Work Packages 5 and 6.
In total, five showcases were proposed:

- Low inertia systems
- Effective DER operation planning through active and reactive power control
- TSO-DSO power flow optimization
- Active and reactive power flow optimization at transmission and distribution networks
- Optimal energy interruption management

For each showcase, a relevant base showcase was created in order to analyze the impact of controllers proposed in the showcases. This analysis will be conducted through using Key Performance Indicators assigned to base showcases and showcases.

Furthermore, members of the consortium have identified beneficiaries of the showcases, such as TSOs, DSOs, aggregators, etc. and have analysed the possible threats to the showcases implementation process.

1. Introduction

1.1 Purpose and scope of the Document

This document falls in scope of Work Package 5: "Operation planning and semi-dynamic simulation". As a result of work completed in Task 5.1[1], showcases and their base showcases have been developed based on the use cases and grid scenarios presented in deliverable D3.2[2] [1].

The main objectives of this deliverable are:
- to provide a "guide" for further work, mainly in WP5 and WP6[3]
- to integrate use cases
- to provide more details on time-series data, grid models and power objects subject to planning to be used in each showcase
- to specify a scenario for each showcase
- to define planning criteria and their link with Key Performance Indicators (KPIs)
- to define possible threats for showcases implementation process
- to identify beneficiaries of INTERPLAN tool

The base showcases and showcases described in this deliverable will be further used in WP5 (Task 5.2[4] and Task 5.3[5]) as well as WP6 activities, and can be subject to change in the future, according to the outcomes arising from the simulation and validation phases.

1.2 Structure of the Document

The deliverable consists of eight chapters. The purpose and scope of the deliverable are described in the first chapter. The second chapter consists of a short description of the INTERPLAN project. In the third chapter, the methodology used to prepare base showcases and showcases is presented. The fourth chapter presents the selected planning criteria and their link with KPIs for showcases. Base showcases are described in the fifth chapter, and showcases are presented in the sixth chapter. The seventh chapter is a summary of the report and an outlook for the future activities. In chapter 8, the references are presented, whereas in the Annex 1, the glossary of the terms and definitions used in the INTERPLAN project can be found.

[1] Task 5.1: Definition of showcases
[2] D3.2: INTERPLAN scenarios and use cases
[3] WP6: INTERPLAN model validation and testing
[4] Task 5.2: Operation planning tool development and semi-dynamic simulation of grid equivalents
[5] Task 5.3: Control system logic development

2. INTERPLAN project

The European Union (EU) energy security policy faces significant challenges as we move towards a pan-European network based on the wide diversity of energy systems among EU members. In such a context, novel solutions are needed to support the future operation, resilience and reliability of the EU electricity system in order to increase the security of supply and also accounting for the increasing contribution of renewable energy sources (RES). The goal of INTERPLAN project is to provide an INTEgrated opeRation PLAnning tool towards the pan-European Network, with a focus on the TSO-DSO interfaces to support the EU in reaching the expected low-carbon targets, while maintaining the network security and reliability. The project involves 6 partners from 5 European countries, namely ENEA (Italy), IEn (Poland), AIT (Austria), DERlab, Fraunhofer (Germany), and FOSS (Cyprus). At the time of writing this report, the project is at Month 14 under the Grant Management phase.
A methodology for a proper representation of a “clustered” model of the pan-European network is provided, with the aim to generate grid equivalents as a growing library able to cover all relevant system connectivity possibilities occurring in the real grid, by addressing operation planning issues at all network levels (transmission, distribution and TSO-DSO interfaces). In this perspective, the chosen top-down approach leads to an “integrated” tool, both in terms of voltage levels, moving from high voltage level down to low voltage level up to end consumer, as well as in terms of developing a bridge between static, long-term planning and operational issues considerations, by introducing controllers in the operation planning phase. In addition to the above, novel control strategies and operation planning approaches are investigated in order to ensure the security of supply and resilience of the interconnected EU electricity power networks, based on a close cooperation between TSOs and DSOs.

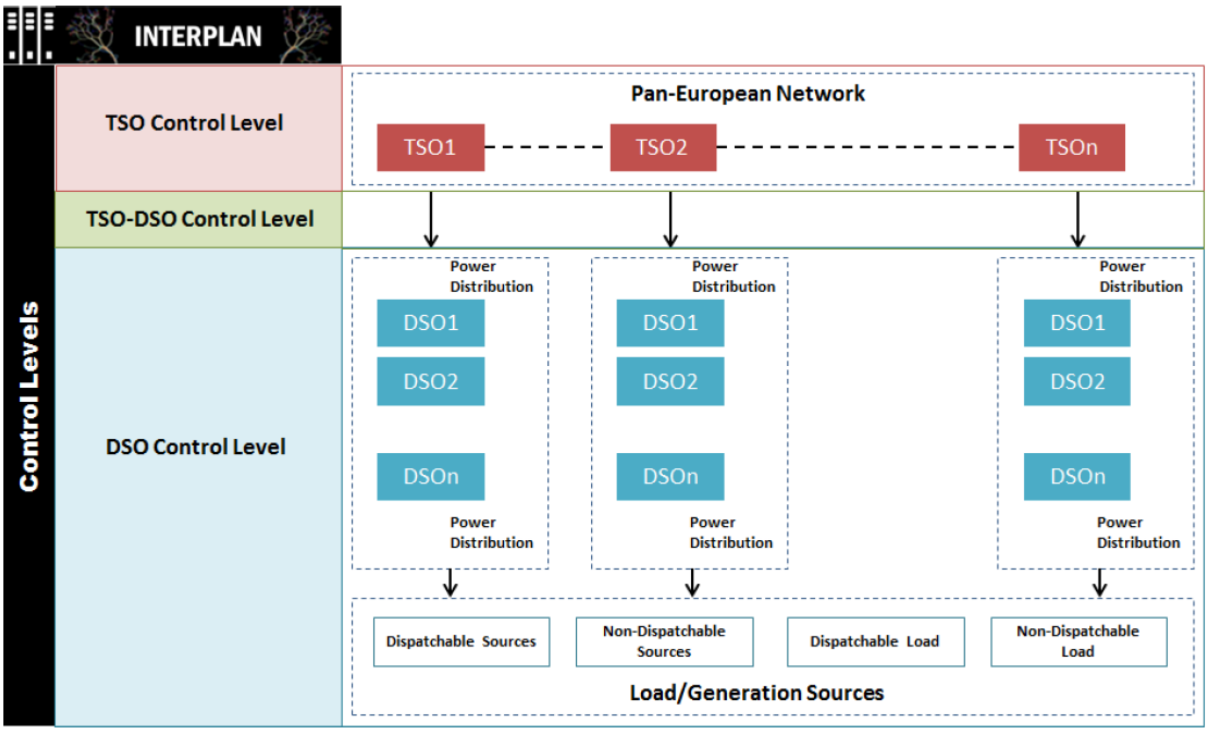


Figure 1: INTERPLAN concept

The basic idea of the INTERPLAN project is to cover the greater number of possible system connections and address interconnectivity issues and challenges that require a thorough assessment of existing grid codes and regulations at European and National level. Current shortcomings to integration of emerging technologies and services, such as renewables, storages, electric vehicles and demand response, as well as associated best practices are identified. Additionally, the developments and findings achieved through the INTERPLAN project are transformed into policy requirements to be addressed to the regulators and grid operators for possible amendments to the grid codes. Based on this analysis, use cases in addition to showcases for corresponding simulations are further developed. The use cases address the main challenges for network operation planning, considering the important role of emerging technologies, such as high share of RES, demand response, high integration of demand response services, and high share of electric vehicles. Examples of these challenges are inertia management and voltage stability.

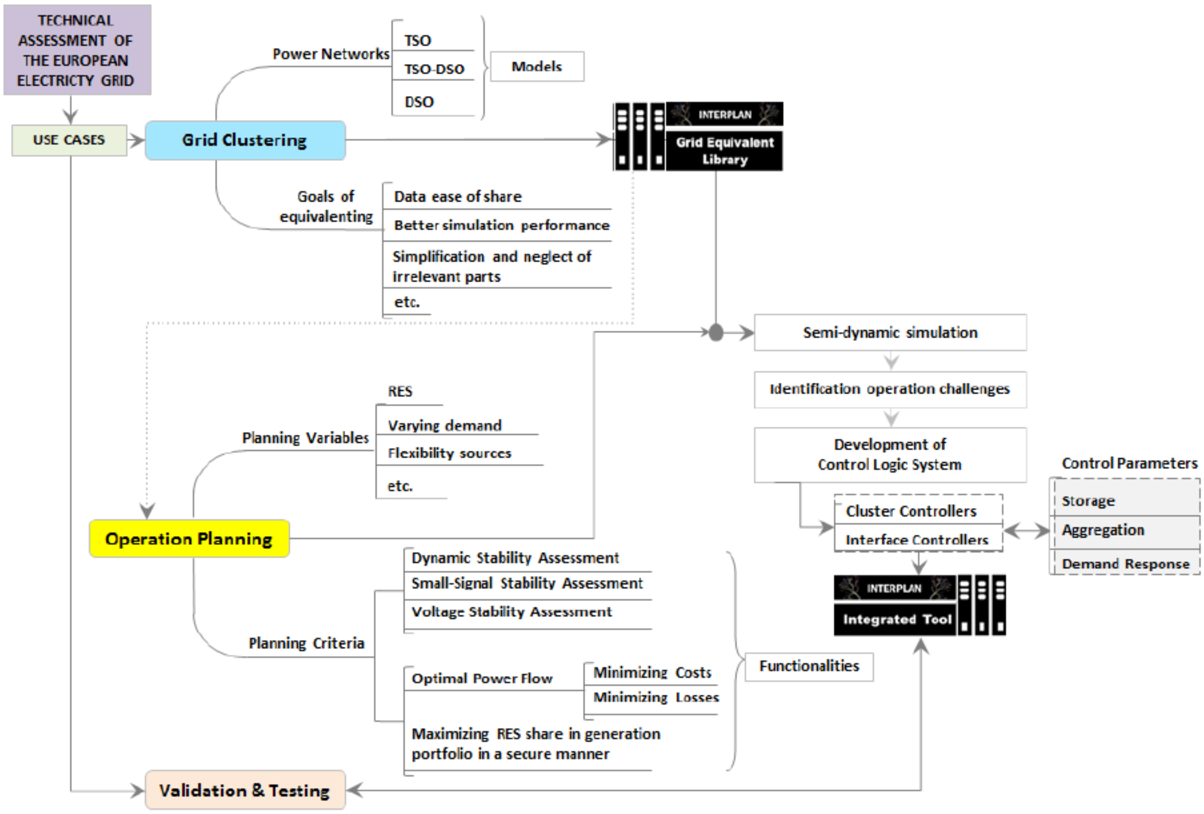


Figure 2: INTERPLAN MindMap

Based on the use cases and EU grid scenarios identified in WP3, a series of showcases were developed, which address issues such as resiliency of the interconnected grid with effective use of local resources. The "grid equivalenting" process, which is conceptually the successive phase of the work, is the process in which we generate a grid equivalent model encompassing a large part of network substituted by a smaller counterpart, having the same dynamic and static properties. To this aim, the network models of previous use cases are designed in a computer based numerical power system simulation environment. Following this, a clustering methodology for transmission and distribution systems up to the end user level is identified, and a detailed approach for generating grid equivalents is developed for different use cases. Dynamic and semi-dynamic simulation scenarios of grid equivalents for each showcase enable analysis of the network behaviour, and eventual operational challenges (e.g. line congestions). The post-processing or parallel-processing of the results, allows to identify operational challenges and shortcomings to be addressed by developing novel control system strategies. These strategies are developed in order to apply adequate intervention measures through appropriate control parameters, such as storage, demand response and aggregation, through cluster and interface controllers. Finally, a validation process is applied through a computer based numerical simulation algorithm, to prove the validity of the proposed concept.

3. Methodology

3.1 Planning criteria definition

Planning criteria were defined based on the expert knowledge of the consortium members. In the next step, chosen planning criteria were thoroughly described through key performance indicators (KPIs), so they can be properly measured and evaluated based on these metrics, during implementation and validation phases of the project.
Concluding step in this part of Task 5.1, was that each use case author has identified possible relations/interlinks between given use cases and the corresponding planning criteria, indicating the strength of their linkage/correlation (Low, Medium, High).
The outcome of these tasks is summarized in chapter 4: Planning criteria.

3.2 Preliminary showcases definition

Based on planning criteria definition and their linkage to the use cases, the preliminary showcases were proposed. The purpose was to identify use cases that could be combined together, as well as possible challenges that could emerge during the showcase implementation process, in the future simulation stage. During this activity, elements such as power system objects subject to planning, applicable scenarios, time-series data, type of simulation and relevant planning criteria were defined for each showcase.

3.3 Final showcases definition and base showcases

The final part of Task 5.1 was dedicated to the design of a showcase template. This allowed to further develop showcases in the following ways:

- scope and description of the showcases, as well as needed grid model description were added
- sequence diagrams were developed, showing inter-dependencies between sub use cases combined within each showcase
- showcase beneficiaries were identified
- time frame and time resolution for time-series data were defined, along with a short time-series data description
- minimal rated power / NC RfG groups were assigned to power system objects subject to planning for the sub use cases involved in showcases.

Additionally, the base showcases were extracted from the preliminary showcases. For each base showcase, a sequence diagram and description were provided.

4. Planning criteria

Planning criteria for showcases have been defined based on the expert knowledge of the consortium members and assigned to the relevant showcases. Also, links between planning criteria and KPIs, described in deliverable D3.2 [1], have been established as shown in Table 1. For further information on KPIs, please refer to deliverable D3.2 [1].

Table 1: Relations between planning criteria and KPIs

Planning criteria		Key Performance Indicators	
ID	**Name**	**ID**	**Name**
1	Minimizing losses	1	Level of losses in transmission and distribution net-works
		7	Power losses
2	Minimizing cost	4	Cost of service/energy interruption
		9	Interrupted Energy Assessment Rate
		19	Generation costs
3	Maximizing share of RES	17	RES curtailment
		27	Share of RES
4	Assuring voltage stability	2	Congestion detection
		10	Voltage Quality: Voltage magnitude variations
		12	Quadratic deviation from global reactive power produc-tion target
		13	Mean quadratic deviations from voltage and reactive power targets at each connection point between TSO and DSO grids
		24	Reactive energy provided by RES and DG
5	Assuring transient stability	6	Response time
		20	Frequency nadir/zenith
		21	Rate of change of frequency
		25	Indication of stability
		26	Oscillation damping
6	Optimize TSO/DSO interac-tion	12	Quadratic deviation from global reactive power produc-tion target
		13	Mean quadratic deviations from voltage and reactive power targets at each connection point between TSO and DSO grids

		16	Transformer loading at TSO-DSO connection point
		22	Quadratic deviation from global active power production target
		23	Mean quadratic deviations from active power targets at each connection point between TSO and DSO grids
7	Maximize DG/RES contribution to ancillary services	14	Level of DG / DRES utilization for ancillary services
8	Assuring frequency stability	5	Frequency restoration control effectiveness
		6	Response time
		20	Frequency nadir/zenith
		21	Rate of change of frequency
		22	Quadratic deviation from global active power production target
		23	Mean quadratic deviations from active power targets at each connection point between TSO and DSO grids
		25	Indication of stability
9	Minimizing energy interruptions	3	SAIDI (System Average Interruption Duration Index)
		8	Energy not supplied
		18	SAIFI (System Average Interruption Frequency Index)

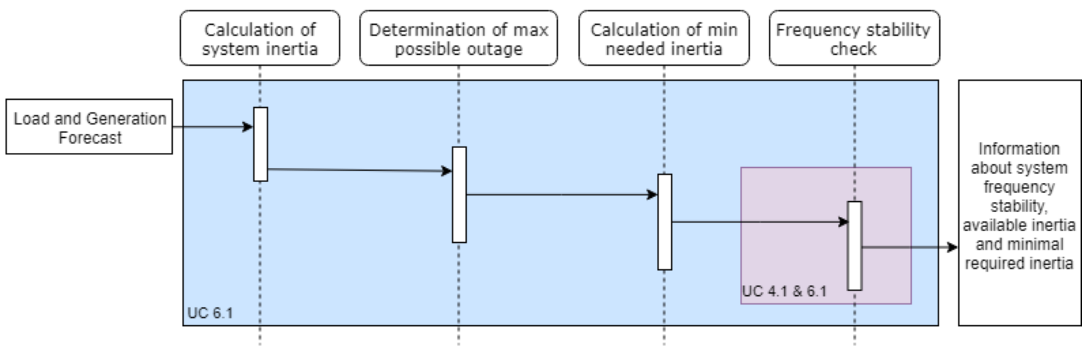
5. Base Showcases

A base showcase is defined as a combination of sub base use case(s) with no planning criteria and no controllers for emerging technologies, such as RES, DG, demand response or storages. Base showcases consist of base sub use cases, described for each use case in deliverable 3.2 [1], and will allow to analyze the operation challenges of the related use case(s). For each showcase, there is a relevant base showcase with the same grid model, scenario, KPIs, simulation environment, simulation type and time-series data, which are described in the individual showcase tables presented in the following chapter.
Descriptions presented below will be used for further development of the base showcases, as well as for their implementation in Task 5.2, in which semi-dynamic and dynamic simulations of grid equivalents will be performed.
Such definitions of the base showcases will allow to evaluate effectiveness, reliability and robustness of the control systems proposed in showcases, which will be developed and implemented in Task 5.3.

5.1 Base showcase 1

ID	BSC1

Sub use cases involved		
ID	**Use case name**	**Sub use case description**
4.1	Fast Frequency Restoration Control	No controllers available. This sub-use case evaluates the network frequency response under specific instability events
6.1	Inertia management	Inertia from spinning masses of generators only

Sequence diagram


Description
For a given time step, total system inertia is calculated based on inertia available from the rotating masses. The biggest possible outage (generator/load) is determined, and based on that, the minimal value of system inertia, which would ensure that the RoCoF is within the statutory limits, is calculated. In the final step, frequency stability is checked through a dynamic simulation,

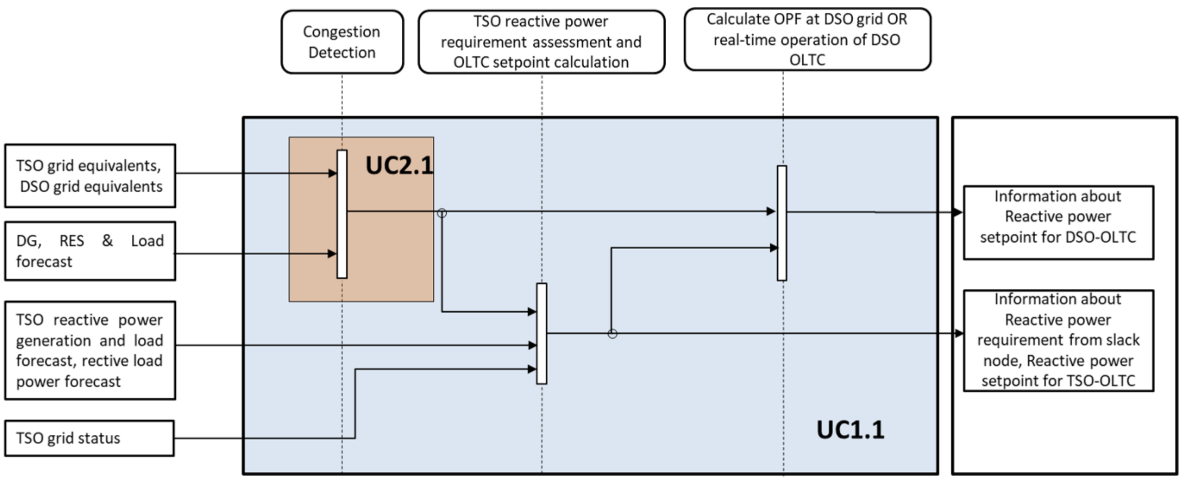
where the event is triggered by a largest possible outage, defined in step two. Output of this base showcase is a set of information for each time step about system frequency stability, as well as available and minimal required inertia.

5.2 Base showcase 2

ID	BSC2

Sub use cases involved		
ID	**Use case name**	**Sub use case description**
1.1	Coordinated voltage/ reactive power control	DG and RES at fixed cos φ = 1 / uncontrolled, OPF with OLTC control. In this scenario, reactive power is provided by a slack (comparison TS as slack or detailed model). OLTC transformers are defined as only voltage regulating tool for the DSO. The OLTC operation is not only conducted by a local control but also can be driven by the optimization tool. Therefore, an OPF is also exercised here to simulate a possible solution.
2.1	Grid congestion management	No controllers available. In this sub-use case, grid congestion issues will be identified under different scenarios.

Sequence diagram



Description

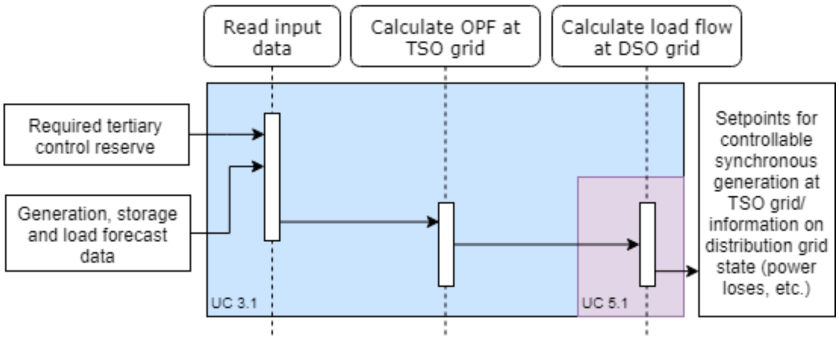
For a given time step, DG and RES are uncontrolled and OPF is performed by means the OLTC control and the active power congestion detection as well. The OLTC transformers are defined as only voltage regulating tool for the DSO. The OLTC operation is not only conducted by a local control but can be also driven by the optimization tool. Therefore, an OPF is also exercised here to simulate a possible solution.

5.3 Base showcase 3

ID	BSC3

Sub use cases involved		
ID	**Use case name**	**Sub use case description**
3.1	Frequency tertiary control based on optimal power flow calculations	DSO does not participate in providing tertiary reserves. TSO will perform OPF calculations at its own network and distribution networks will be considered as grid with no controllable active power.
5.1	Power balancing at DSO level	No controllers available.

Sequence diagram



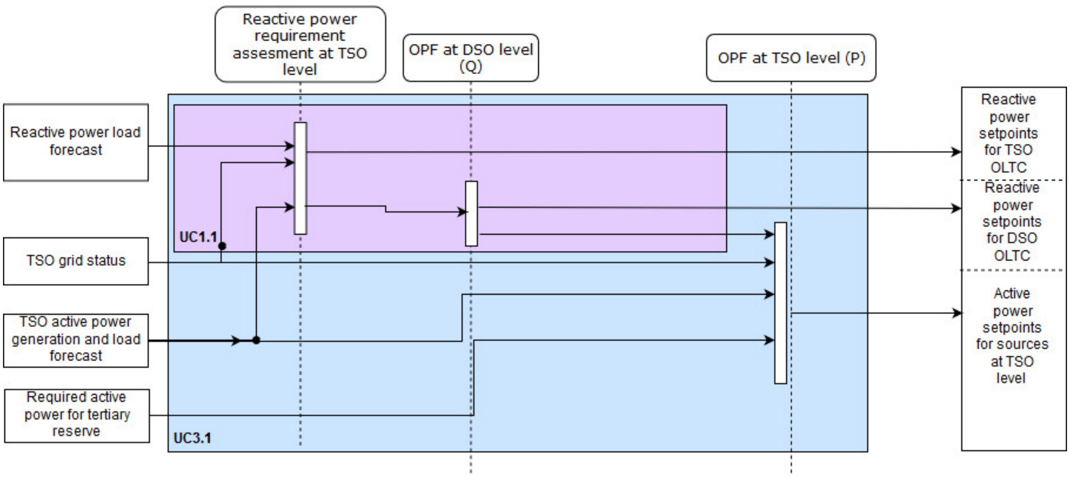
Description
For a given time step, an OPF at the TSO level is calculated, based on required tertiary control reserve as well as on generation, storage and load forecast. Then, a loadflow at the DSO grid is calculated. As an output, a set of setpoints for controllable synchronous generators at TSO grid is obtained as well as information on a distribution grid state (power losses, etc.)

5.4 Base showcase 4

ID	BSC4

Sub use cases involved		
ID	**Use case name**	**Sub use case description**
1.1	Coordinated voltage/ reactive power control	DG and RES at fixed cos φ = 1 / uncontrolled, OPF with OLTC control. In this scenario, reactive power is provided by a slack (comparison TS as slack or detailed model). OLTC transformers are defined as only voltage regulating tool for the DSO. The OLTC operation is not only conducted by a local control but also can be

		driven by the optimization tool. Therefore an OPF is also exercised here to simulate a possible solution.
3.1	Frequency tertiary control based on optimal power flow calculations	DSO does not participate in providing tertiary reserves. TSO will do OPF calculations at its own network and distribution networks will be considered as grid with no controllable active power.

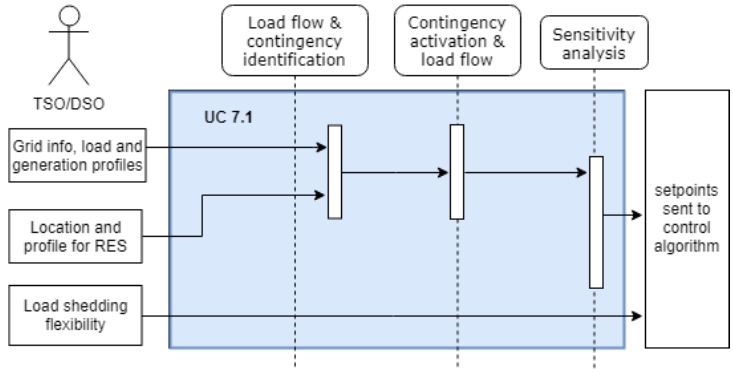
Sequence diagram


Description
For a given time step, an OPF at the TSO level is calculated, based on required tertiary control reserve and voltage control. As an output, a set of setpoints for controllable synchronous generators at TSO grid is obtained. The OLTC transformers are defined as only voltage regulating tool for the DSO. The OLTC operation is not only conducted by a local control but can be also driven by the optimization tool. Therefore, an OPF is also exercised here to simulate a possible solution.

5.5 Base showcase 5

ID	BSC5

Sub use cases involved		
ID	**Use case name**	**Sub use case description**
7.1	Optimal generation scheduling and sizing of DER for energy interruption management	The aim is to perform optimal interruption management to minimize the total energy interrupted in a contingency scenario. The flexibility provided by the interruptible loads and re-dispatch of generation is used to achieve this objective.

Sequence diagram


Description
For a given time step, a load flow is performed and contingencies that can occur in transmission or distribution system are enlisted. They are either specified by a TSO/DSO or can be listed based on peak loaded lines/transformers or the terminals having peak voltage levels. One of the contingencies is activated and load flow is performed. Afterwards, sensitivity analysis is performed towards the heavily loaded line/transformer or bus that could result in a network operational constraint violation. This information is used to prioritize resources that can effectively meet the demand and also to prevent the network constraint violation.

6. Showcases

A showcase, as defined by consortium members, is a presentation of use case(s) in the frame of chosen scenario, simulation type, test grid model, time-series data and planning criteria. Each of those components has been detailed in the showcases descriptions in the subsequent sections of this chapter. Additionally, the showcases beneficiaries have been identified accordingly for each showcase.

Showcases described in this chapter address the utilization of power resources as presented in the tables below titled: “Power system components subject to operation planning”. Division into groups is in line with the Article 5 of Network Code on Requirements for Generators (NC RfG) [2], established by the EU together with ENTSO-E. This NC defines each group by the allowable range of rated power, as well as voltage level of their connection point:

- groups A, B, C - connected below 110 kV and,
- group D - connected at or above 110 kV,

leaving flexibility to the TSOs for selection of the exact thresholds - as presented in Figure 3. There are different requirements for the groups, and therefore it is important to indicate for the showcase the assignment of resources to the groups.

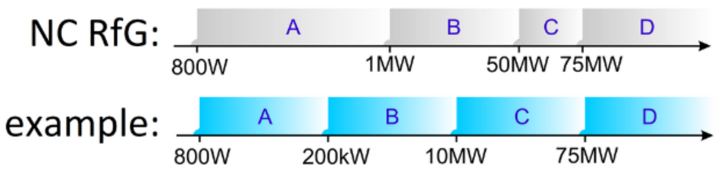


Figure 3: Division of the generators into groups: allowable ranges and example of implementation for Poland [3]

6.1 Showcase 1

ID	SC1
Name	Low inertia systems
Scope	Maintaining frequency stability in low inertia systems through inertia management and fast frequency restoration.
Description	Power systems with low share of synchronous generation, and consequently low total system inertia, are vulnerable to power imbalances. Such systems can experience frequency stability problems, such as high frequency excursions and higher rates of change of frequency. Therefore, the main focus of this showcase is to demonstrate how frequency stability in low inertia systems can be assured through capabilities of other power system objects present in the low inertia grids, such as RES, DG, controllable loads and storage systems. This showcase combines inertia management with fast frequency restoration control. Frequency stability of the first swing in the proposed solution is managed by estimating available and needed inertia for given system conditions, and then utilizing the needed inertia through synthetic inertia and fast frequency response controllers. For further reinforcements, OPF-based

	frequency restoration is added, which, by using available energy sources, brings the frequency to its nominal value.

Showcase beneficiaries	
Type	**What and how can be gained?**
TSO	Being responsible for maintaining frequency stability, the TSO needs to know the total system inertia and the means available for increasing inertia in case of its shortage. This showcase highlights this challenge from a planning perspective. Because effects of synthetic inertia (SI) and fast frequency control activation are presented, this showcase offers a comparison between utilizing converter-connected generation and running synchronous generation solely for the purpose of inertia.
Aggregators	The role of aggregators is to enable synthetic inertia and balancing services available at smaller RES to the TSO. Even though presence of the aggregators is not explicitly shown here, their role and utility in the future system operation can be anticipated from this showcase.
RES owners	ENTSO-E Network Code on Requirements for Generators defines the requirements for RES regarding participation in frequency control as well as provision of synthetic inertia. RES owners can learn from this showcase what can be the demand and utilization level of these functionalities.

Showcase properties	
Scenario	INTERPLAN-3: Large Scale RES
Grid model	The grid model must contain at least one balancing zone with one transmission and at least one distribution grid. It needs to at least the EHV, HV and MV levels for the operation areas of the grid operators. The model needs to be dynamic and the number of nodes (busbars) should be at least 100 or more (for both transmission and distribution levels).
Simulation environment	DIgSILENT PowerFactory
Simulation type	Semi-dynamic and dynamic

Time-series data		
Time frame	**Time resolution**	**Description**
24 h	15 min.	Real/synthetic data for generation and load profiles for 24 hours and resolution of 15 minutes is needed. The generation profile of the RES can be based on real weather forecast data.

Sub use cases involved		
ID	**Use case name**	**Sub use case description**
4.2	Fast Frequency Restoration Control	fFRC is available
6.4	Inertia management	Both synthetic inertia and fast frequency response are available

Sequence diagram
Operation planning, as seen from the perspective of inertia and frequency stability provision is carried out according to the sequence of actions presented in Figure 4. This sequence is repeated for each data point of the available time series, thus the result of the whole planning procedure is a set of vectors of setpoints covering all available and controllable resources for the duration of the planning window. Individual functions are described below. **Load and Generation Forecaster (LGF)** provides necessary data regarding the total demand forecast of the controlled area and generation forecast consisting of weather forecast (or RES output forecast) and must-run units schedule. This information is used by **Calculation of available & needed inertia (CANI), Determination of Droop Setting, and Available Resource List** functions. The **Available Resource List** function collects all the power information per each resource in the grid. This information is used by **Determination of droop settings** to evaluate based on both **Frequency droop contribution setpoint** and **Frequency error threshold setpoint**, the frequency droop characteristic per each resource. To verify the effectiveness of these results, a background dynamic simulation is performed by the functions **Imbalance Detection** and **Frequency Restoration Process**. The dynamic simulation is triggered by an instability event that is detected by the **Imbalance Detection Function.** This function compares the **Tie-Line Active Power flow Set-point Provider** and the **Tie-Line Active Power flow Observation** to determine a balance error signal to be sent to the **Frequency Restoration Process function**. This latter provides active power re-dispatch commands/signals to the controllable non-conventional active devices. The **CANI** function performs two main actions: 1. It calculates the available system inertia H_{sysa} based on the information from the scheduled units. 2. It calculates the necessary inertia H_{sysn} which depends on such factors as the largest single infeed or load present in the load flow. If H_{sysa} is lower than H_{sysn} then **Determination of inertia related setpoints (DIRS)** will choose those RES or storage systems that are forecasted to be in operation and able to provide additional inertia needed by the system. The selection of units which will provide the necessary inertia is based on an optimization objective function considering cost/losses/reliability. Since the dynamic behavior of synthetic inertia is different from conventional inertia, and hence it is impossible to predict RoCoF by a simplified assessment (RoCoF≈1/H_{sys}), it is assumed that information on how different RES provide the inertia is known to the operator in a form of dynamic models

of these RES. If synthetic inertia is not available or not enough, then constrained operation with fast frequency control (substituting virtual inertia) is planned. In such case, the load flow will be slightly altered to match the inertia requirements, which will be addressed in the relevant load flow controllers. **Inertia related setpoints check (IRSC)** performs dynamic simulation in order to validate RoCoF and nadir with additional inertia present in the system. Dynamic simulation also helps to assess the generic frequency stability within a longer time span (approx. up to 15 seconds) in order to validate whether the provision of synthetic inertia does not aggravate stability in this period due to drainage of energy from the rotating masses of wind turbines. The end result of all calculations performed in **IRSC** is the set of setpoints for those resources in the grid whose control mode or operating point requires modification.

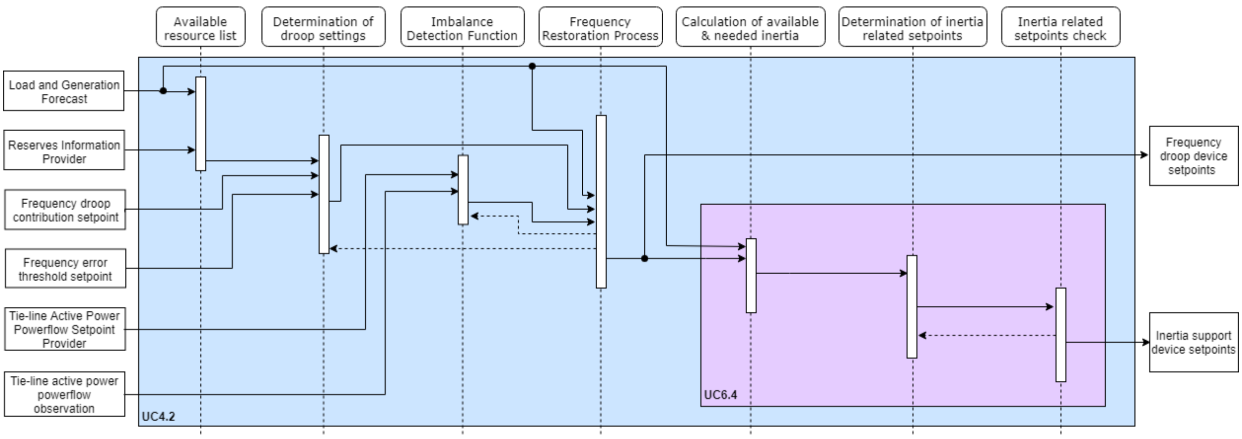


Figure 4: Sequence diagram of showcase 1

Power system components subject to operation planning				
Even though both use cases control the same variables of mostly the same power system objects, conflicts between them do not occur since setpoints regarding fast frequency control are taken into the consideration by inertia management control.				
Power system object	**Rated power [MVA] / NC RfG group**		**Control variable**	
	UC 4	***UC 6***	***UC 4***	***UC 6***
RES	*C, D*	*C, D*	Active power	Active power
Storage units	> 1 MW	> 1 MW	Active power	Active power, SOC
Controllable loads	>1 MW (aggregated)	-	Active power	-
DG	C, D	C, D	-	Active power
Synchronous generators	C, D	C, D	Active power	Active power

KPI coverage by the showcase			
Planning Criteria		**KPI**	
ID	**Title**	**ID**	**Title**
5	Assuring transient stability	6	Response time
		20	Frequency nadir/zenith
		21	Rate of change of frequency
		25	Indication of stability
		26	Oscillation damping
7	Maximize DG/RES contribution to ancillary services	14	Level of DG/DRES utilization for ancillary services
8	Assuring frequency stability	5	Frequency restoration control effectivness
		20	Frequency nadir/zenith
		21	Rate of change of frequency
		25	Indication of stability

6.2 Showcase 2

ID	SC2
Name	Effective DER operation planning through active and reactive power control
Scope	Active and reactive power intelligent control for grid congestion management and coordinated TSO-DSO optimization.
Description	The presence of distributed generation (DG) can significantly impact the power networks, exposing the system to much higher power fluctuations and compromising the system power quality. Ensuring voltage stability and solving power congestions become even more important issues to deal with increasing penetration levels of DG. Therefore, innovative control schemes, involving untapped resources, have to be considered in the future power systems. The main focus of this showcase is to present a control scheme to improve TSO-DSO coordination both in managing the grid for voltage stability and solving the congestion issues occurring at all voltage levels. By applying a coordinated TSO-DSO optimization methodology, this showcase aims to regulate reactive and active power by using TSO and DSO power assets,

	including utilization of the DSO flexibilities, to respect TSO optimization objectives and restore the grid in the presence of congestion events.

Showcase beneficiaries	
Type	**What and how can be gained?**
TSO	This showcase allows the TSO to obtain additional assets to reach its optimization targets and solve congestion issues (i.e., DSO flexible resources).
DSO	This showcase allows DSO to optimize its reactive power flows and also to take advantage of its untapped resources for meeting TSO requirements.
RES, DG and storage owners, aggregators, active consumers and EV owners	RES, DG and storage owners are involved by providing ancillary services also through DER aggregators. Active consumers and EV owners can be also involved in the grid congestion management through proper DR programs (ToU or incentive-based).

Showcase properties	
Scenario	INTERPLAN-2: Small and Local
Grid model	The grid model must contain at least one control area including one transmission and at least one distribution grid. It should include HV, MV and LV levels for the operation areas of the grid operators. The model needs to be static and the number of nodes (busbars) should be 100 or more.
Simulation environment	DIgSILENT Powerfactory
Simulation type	Semi-dynamic

Time-series data		
Time frame	**Time resolution**	**Description**
24 h	15 min.	Real/synthetic data for generation and load profiles for 24 hours and resolution of 15 minutes is needed. The generation profile of the RES can be based on real weather forecast data. Events to simulate congestions are considered for this showcase.

Sub use cases involved		
ID	**Use case name**	**Sub use case description**
1.4	Coordinated voltage/reactive power control	Coordinated TSO-DSO Optimization. Different objective functions may be conceived. Reactive power or voltage setpoints provided by the TSO are followed by the DSO at the TSO/DSO connection points.
2.3	Grid congestion management	In this sub-use case, the tool acts on TSO level, operating on the available resources (e.g. RES, storage, flexible loads, EVs) connected to both TSO and DSO levels to mitigate grid congestion.

Sequence diagram
The operation planning in this showcase is carried out according to the sequence of actions presented in Figure 5.

The sequence is repeated for each data point of the available time series thus the result of the whole planning procedure is a set of vectors of setpoints covering all available and controllable resources for the duration of the planning window. At a certain time, within the specific time frame, a congestion event is simulated to show the effectiveness of the overall showcase.

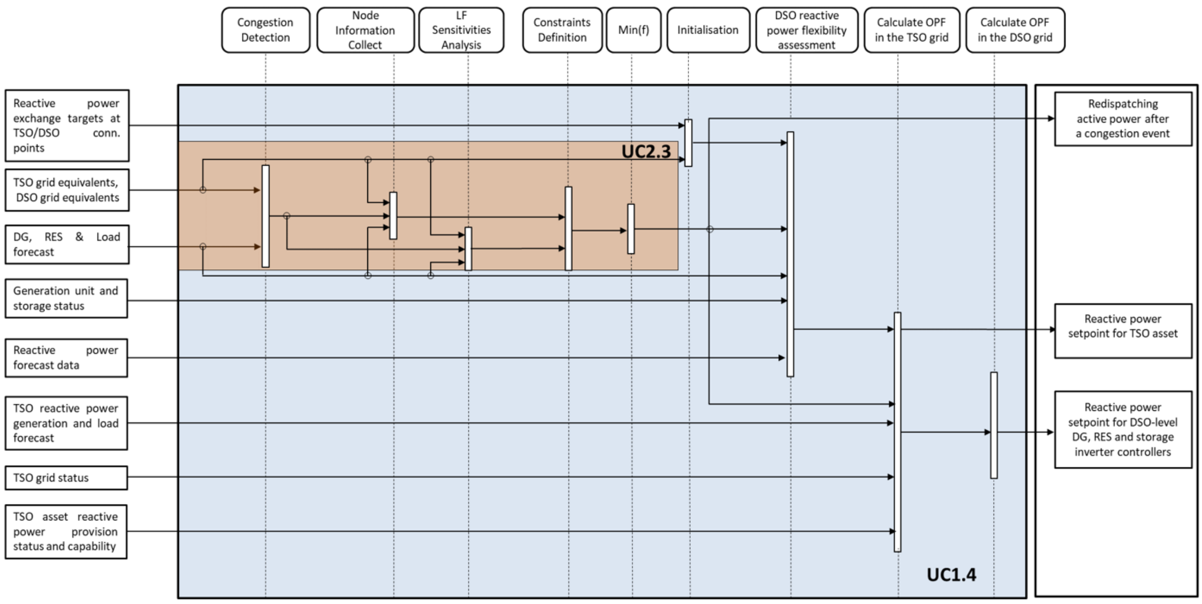


Figure 5: Sequence diagram of showcase 2

As shown in Figure 5, the showcase includes two conceptual levels: congestion assessment level (running four functions: **Congestion Detection**, **Node Information Collect**, **LF Sensitivity Analysis**, **Constraint Definition** and **Min(f)**) and coordinated TSO-DSO optimization level (running four functions: **Initialization**, **DSO reactive power flexibility assessment**, **Calculate OPF in TSO grid**, **Calculate OPF in DSO grid**). The individual actions of the showcase are described below.

Congestion Detection: the TSO periodically, according to a prefixed time step, executes the congestion assessment, verifying the grid status. In the presence of congested lines, the TSO evaluates optimal (restoring) active power for each busbar (see Min(f)). **Node Information Collect**: this action calculates the total resources flexibilities for each busbar. **LF Sensitivity Analysis**: this action runs a function to execute a voltage sensitivity analysis operating a linearization of the system around the functioning point obtained from a load flow calculation. **Constraints Definition**: this action defines limit functions for optimization parameters or variables (e.g. upper and lower limits). **Min(f)**: this optimization function evaluates the optimal active power variation for each busbar to solve the congestion issue. **Initialization**: TSO and DSO select individual optimization objectives for their OPF. **DSO reactive power flexibility assessment**: the DSO assesses the flexibility of its own DER resources, calculating the amount of reactive power flexibility that can be delivered to the DSO/TSO connection points. **Calculate OPF in TSO grid**: the TSO uses an OPF to calculate optimal set points for reactive power assets, including utilization of the DSO flexibilities, and respecting its individual reactive power availabilities and requirements. **Calculate OPF in DSO grid**: by using the TSO set points, the DSO utilizes an OPF to optimally distribute the requested reactive power provision amongst its assets.

Power system components subject to operation planning				
There are no potential conflicts between the use cases combined under this showcase, since setpoints regarding the active power which are triggered during a congestion event, are taken into consideration by coordinated voltage/reactive power control.				
Power system object	**Rated power [MVA] / NC RfG group**		**Control variable**	
	UC 1	***UC 2***	***UC 1***	***UC 2***
RES	B, C, D	B, C, D	Reactive Power	Active Power
DG	B	B	Reactive Power	Active Power
Synchronous generators	C, D	C, D	Reactive Power	Active Power
Storage	>1 MW	>1 MW	Reactive power (SOC)	Active power (SOC)
EVs	>1 MW (aggregated)	>1 MW (aggregated)	Reactive power (SOC)	Active power (SOC)
Controllable load	-	>1 MW (aggregated)	-	Active power

KPI coverage by the showcase			
Planning Criteria		**KPI**	
ID	**Title**	**ID**	**Title**
4	Assuring voltage stability	2	Congestion detection
		10	Voltage Quality - Voltage magnitude variations
		12	Quadratic deviation from global reactive power production target
		13	Mean quadratic deviations from voltage and reactive power targets at each connection point between TSO and DSO grids
		24	Reactive energy provided by RES and DG
3	Maximizing share of RES	27	Share of RES
6	Optimize TSO/DSO interaction	11	Number of tap position changes per time
		12	Quadratic deviation from global reactive power production target
		13	Mean quadratic deviations from voltage and reactive power targets at each connection point between TSO and DSO grids
7	Maximize DG / DRES contribution to ancillary services	14	Level of DG / DRES utilization for ancillary services

6.3 Showcase 3

ID	SC3
Name	TSO-DSO power flow optimization
Scope	Utilization of DSO resources and flexibilities through local usage of electric energy and their participation in tertiary control.
Description	The main focus of this showcase is to present an optimization strategy for energy flow management between transmission and distribution grid, ensuring the balance within a distribution network on one hand and on the other hand for participation of non-synchronous energy resources in the tertiary reserve market and supporting the TSO in keeping the whole network stable.

Showcase beneficiaries	
Type	**What and how can be gained?**
TSO	The TSO will be able to take advantage of available controllable resources at distribution level for ensuring the tertiary reserve and

	accordingly frequency stability. Besides, with support of DSO, the energy flow between transmission and distribution networks will be minimized and the loading of transmission/distribution grid power transformers will be reduced.
DSO	The DSO will be more actively involved in operation planning of the network by utilizing controllable resources located at its network, which will help to ensure a more stable and reliable distribution network.
RES operators, storage operators, aggregators, consumers	The RES operators, storage operators and aggregators specifically connected at distribution level will be more actively involved in balancing and tertiary reserve market. The consumers will also take advantage of incentives by participating in demand response programs.

Showcase properties	
Scenario	INTERPLAN-2 Small and Local
Grid model	The grid model must contain at least one balancing zone with one transmission and at least one distribution grid. It needs to include at least the EHV, HV, MV and LV level for the operation areas of the grid operators. The model needs to be static and the sum of the number of nodes, busbars, terminal, cubicle and substations should be 100 or more in the transmission and distribution level.
Simulation environment	DIgSILENT Powerfactory
Simulation type	Semi-dynamic

Time-series data		
Time frame	**Time resolution**	**Description**
24 h	15 min.	Real/synthetic data for generation and load profiles and for required tertiary reserve for 24 hours and resolution of 15 minutes is needed. The generation profile of the RES can be based on real weather forecast data. No event is considered for this showcase.

Sub use cases involved		
ID	**Use case name**	**Sub use case description**
3.4	Frequency tertiary control based on optimal power flow calculations	DSO participates in providing tertiary reserves. At distribution level distributed energy sources and storages are controllable and demand response mechanism is available.

5.2	Power balancing at DSO level	At distribution level distributed energy sources and storages are controllable and demand response mechanism is available. HV grid (110 kV) is considered to be radial.

Sequence diagram
Active power flow and tertiary control optimizations are carried out in the way presented in Figure 6. First, available flexibilities in the distribution grid are assessed based on required tertiary control reserve as well as forecasted load and generation. Using this information, OPF for transmission grid is performed, providing setpoints for generation, loads and storages connected to the transmission grid, with regards to tertiary control reserve. In the next step, tertiary control OPF at distribution level is calculated. Setpoints obtained from this OPF are sent to the relevant power objects, which are available for tertiary reserve. These set points will serve as constraints on active power flow optimization at distribution level, which aims to ensure local usage of energy through minimization of power flow through the transformers connecting transmission/distribution grids. After TSO positive feedback on the results, the last set of setpoints is sent to the remaining controllable generators, loads and storages connected at distribution level.

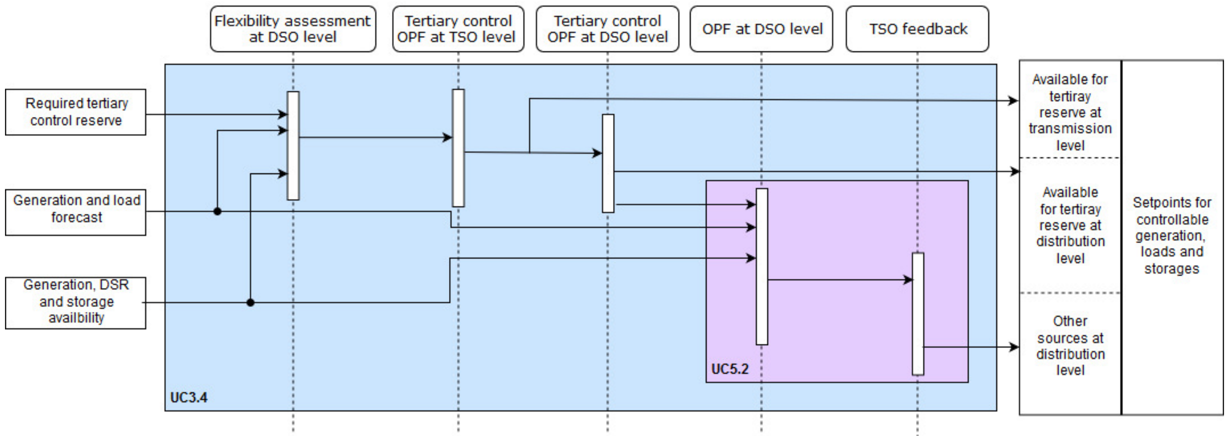


Figure 6: Sequence diagram of the showcase 3

Power system components subject to operation planning
Even though both use cases are controlling the same variables of the same power system objects, conflicts between them do not occur since setpoints regarding tertiary control are not changed by power flow optimization process but they are used as one of the constraints.

Power system object	Rated power [MVA] / NC RfG group		Control variable	
	UC 3	***UC 5***	***UC 3***	***UC 5***
RES	*B, C, D*	*B, C, D*	*Active power*	*Active power*
DG	*B*	*B, C, D*	*Active power*	*Active power*

Synchronous generators	C, D	C, D	*Active power*	*Active power*
Storage	>1 MW	>1 MW	*Active power, SOC*	*Active power, SOC*
EVs	>1 MW	>1 MW	*Active power, SOC*	*Active power, SOC*
Controllable load	>1 MW	>1 MW	*Active power*	*Active power*

KPI coverage by the showcase			
Planning Criteria		**KPI**	
ID	**Title**	**ID**	**Title**
1	Minimizing losses	1	Level of losses in transmission and distribution networks
		7	Power losses
2	Minimizing cost	19	Generating costs
3	Maximizing share of RES	17	RES curtailment
		27	Share of RES
7	Optimize TSO/DSO interaction	16	Transformer loading
		22	Quadratic deviation from global active power exchange target
		23	Mean quadratic deviations from active power targets at TSO/DSO connection points
8	Maximize DG/DRES contribution to ancillary services	14	Level of DG / DRES utilization for ancillary services

6.4 Showcase 4

ID	SC4
Name	Active and reactive power flow optimization at transmission and distribution networks.
Scope	Utilization of both transmission and distribution resources and flexibilities for provision of tertiary reserve (for frequency stability) and improving voltage profiles both in transmission and distribution grids.
Description	The main focus of this showcase is to present an optimization strategy for parallel control of active and reactive power at transmission and distribution grid, for maintaining the voltage quality at both network levels on one hand and on the other hand for participation in the tertiary reserve market and supporting TSO in keeping the whole network stable. The control strategy must

	ensure an optimization of both active and reactive power of all available resources with no conflict in setpoints, considering the constraints.

Showcase beneficiaries	
Type	**What and how can be gained?**
TSO	The TSO will be able to take advantage of available controllable resources at distribution level for ensuring the tertiary reserve and accordingly frequency stability as well as voltage stability. This will help the TSO to reduce costs on grid losses and reactive compensating equipment.
DSO	The DSO will be more actively involved in operation planning of the network by sending setpoints to the controllable resources located in its network which will help to ensure a more stable and reliable distribution network.
RES operators, storage operators, aggregators, consumers	The RES operators, storage operators and aggregators specifically connected at distribution level will be actively involved providing ancillary services. The consumers will also take advantage of incentives by participating in demand response programs.

Showcase properties	
Scenario	INTERPLAN-2 Small and Local
Grid model	The grid model must contain at least one balancing zone with one transmission and at least one distribution grid. It needs to include at least the EHV, HV, MV and LV level for the operation areas of the grid operators. The model needs to be static and the sum of the number of nodes, busbars, terminal, cubicle and substations should be 100 or more in the transmission and distribution level.
Simulation environment	DIgSILENT Powerfactory
Simulation type	Semi-dynamic

Time-series data		
Time frame	**Time resolution**	**Description**
24 h	15 min.	Real/synthetic data for generation and load profiles, required tertiary reserve and reactive power exchange targets at TSO-DSO connection points for 24 hours and resolution of 15 minutes is needed. The generation profile of the RES can be based on real weather forecast data. No event is considered for this show case.

Sub use cases involved		
ID	**Use case name**	**Sub use case description**
3.4	Frequency tertiary control based on optimal power flow calculations	DSO participates in providing tertiary reserves. At distribution level distributed energy sources and storages are controllable and Demand Response mechanism is available.
1.4	Coordinated voltage/reactive power control	Coordinated TSO-DSO Optimization of reactive power. Reactive power or voltage setpoints provided by the TSO are followed by the DSO at the TSO/DSO connection points.

Sequence diagram
Reactive power flow and tertiary control optimizations are carried out as presented in Figure 7.
First, available flexibility in the distribution grid is assessed based on required reactive power for voltage control as well as forecasted load and generation. Using this information, OPF for transmission grid is performed, giving reactive power setpoints for generation, loads and storages, connected to the transmission grid. In the next step, an OPF at distribution level is calculated. Setpoints obtained from this OPF are sent to the relevant power objects, which are available for reactive power control. Then, all the setpoints will serve as constraints for active power flow optimization at both transmission and distribution levels, which aims to provide required active power for frequency tertiary control. This optimization is performed with the similar sequence of actions in reactive power optimization. The final setpoints are sent to the resources, which are available for tertiary reserve.

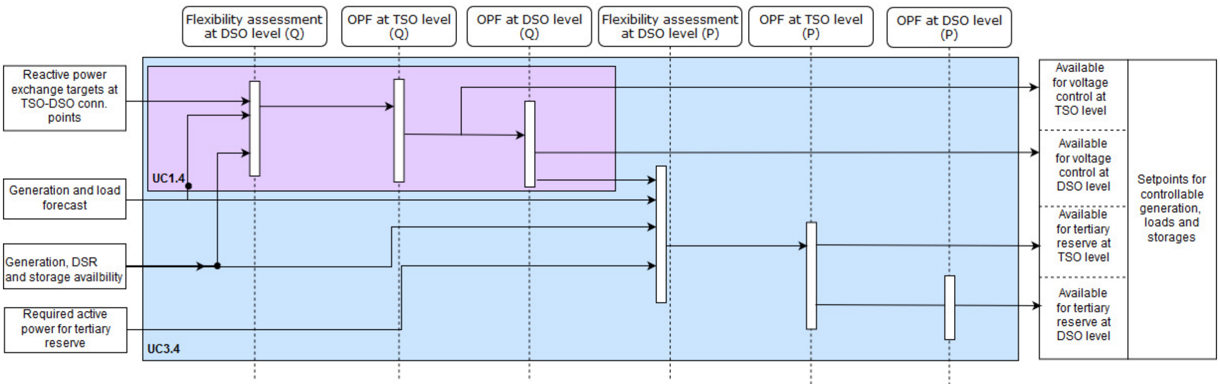


Figure 7: Sequence diagram of showcase 4

Power system components subject to operation planning
Even though both use cases are controlling the same variables of the same power system objects, conflicts between them do not occur since setpoints regarding tertiary control are not changed by power flow optimization process but they are used as one of the constraints.

Power system object	Rated power [MVA] / NC RfG group		Control variable	
	UC 3	***UC 1***	***UC 3***	***UC 1***
RES	B, C, D	B, C, D	Active power	Reactive power
DG	B	B	Active power	Reactive power
Synchronous gen-erators	C, D	C, D	Active power	Reactive power
Storage	>1 MW	>1 MW	Active power, SOC	Reactive power, SOC
EVs	>1 MW	>1 MW	Active power, SOC	Reactive power, SOC
Controllable load	>1 MW	-	Active power	-

KPI coverage by the showcase			
Planning Criteria		**KPI**	
ID	**Title**	**ID**	**Title**
1	Minimizing losses	1	Level of losses in transmission and distribution networks
		7	Power losses
2	Minimizing cost	19	Generating costs
3	Maximizing share of RES	17	RES curtailment
		27	Share of RES
4	Assuring voltage sta-bility	10	Voltage Quality: Voltage magnitude variations
		11	Number of tap position changes per time
		12	Quadratic deviation from global reactive power exchange target
		13	Mean quadratic deviations from voltage and reactive power targets at each connection point between TSO and DSO grids
		24	Reactive energy provided by RES and DG
6	Optimize TSO/DSO interaction	16	Transformer loading
		22	Quadratic deviation from global active power exchange tar-get
		23	Mean quadratic deviations from active power targets at TSO/DSO connection points
7	Maximize DG/DRES contribution to ancil-lary services	14	Level of DG / DRES utilization for ancillary services

6.5 Showcase 5

ID	SC5
Name	Optimal energy interruption management
Scope	Minimizing the energy interruption in the presence of a contingency event by re-scheduling the generators and controlling interruptible loads.
Description	The climate change impact and the unforeseen events have revitalized the importance of energy interruption planning. The grid of the future should be able to make smart choices by re-dispatching of available generation capacity and control of interruptible loads to ensure reliable supply to critical loads and minimize the total energy interrupted. The showcase demonstrates a tool that performs optimal energy interruption scheduling and generator dispatch while minimizing the total energy interrupted in the network. Grid congestion resulting from a contingency is an important consideration. The critical lines and buses are identified, and the sensitivity analysis is performed to prioritize resources that reduce the likelihood of grid congestion and voltage constraint violation.

Showcase beneficiaries	
Type	**What and how can be gained?**
TSO	TSO can use this tool to perform energy interruption planning to satisfy N-1 criterium by utilizing the flexibility offered by the generators and loads. The planning criteria combine minimization of the total energy interrupted and possible grid constraint violation.
DSO	DSO can use this tool to perform energy interruption planning to satisfy TSO requirements when asked, by dispatching the flexibility offered by the generators and loads. The planning criteria combine minimization of the total energy interrupted and possible grid constraint violations.

Showcase properties	
Scenario	INTERPLAN-2 Small and Local
Grid model	The grid model must contain a transmission system and distribution system. Detailed feeder models may not be required unless there is significant flexibility at LV level which can be remotely activated. The load flow of HV and MV levels shall be used to prepare the pre-contingency state of the network. Reliability data from lines, loads and transformers will be required to define a list of credible contingencies for which energy interruption planning is to be performed. The model should have controllable generators and interruptible loads at MV and HV levels. The network size should at least have 10 terminals (buses). This is a qualitative assessment, hence smaller model can be used to test the concept and larger will be beneficial to look in to scalability of the tool.

Simulation environment	DIgSILENT PowerFactory
Simulation type	Semi-dynamic

Time-series data		
Time frame	**Time resolution**	**Description**
24 hours	15 minutes	Real/synthetic profiles of loads, PVs and dispatchable generators will be required. The active and reactive power capability of the generators will be used in their dispatch. A list of credible contingencies will be modeled as events and the showcase will represent the corrective actions taken by a controller.

Sub use cases involved		
ID	**Use case name**	**Sub use case description**
7.4	Optimal energy interruption management	In this sub use case, optimal energy interruption management is performed by varying the energy interruption scheduling strategies. The objective is to minimize energy interruption costs and indirectly promoting the resources that are less likely to result congestion in the grid.

Sequence diagram

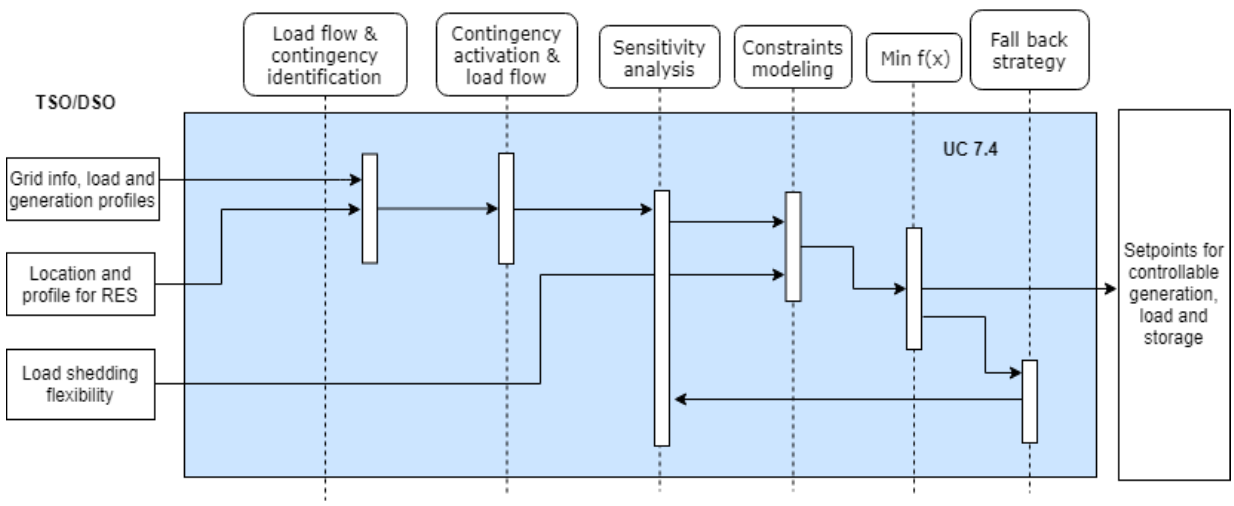


Figure 8: Sequence diagram of showcase 5

The showcase has two conceptual levels: contingency identification (load flow analysis, identification of critical lines, generators and loads) and energy interruption planning (activating the

contingency in the grid, performing sensitivity analysis, modeling the constraints, optimization). If the optimization fails, the fall back strategy is activated, and the process is repeated until the dispatch signals for the generators and interruptible loads are identified. The description of the individual actions is in the following: **Load flow and contingency identification** The user can be a TSO or a DSO who provides the grid information (network model) and load and generation forecasts. This action performs the loadflow to calculate the status of the grid. This information is used to identify the critical contingencies in the grid. The user (TSO/DSO) can also specify them. The list of credible contingencies is sent to next stage. **Contingency activation & load flow** This part activates one of the contingencies from the list and performs the load flow iteratively. **Sensitivity analysis** Here, the sensitivity of the critical lines and buses is calculated with respect to the buses having dispatchable generators and interruptible loads for the selected contingency. The sensitivity information is used to define the penalty cost terms that assign less penalty costs to the terminals whose control action can influence more the grid constraint violation. This information is communicated to the next stage of constraint modeling. **Constraints modeling** This action prepares the matrices for the constraints for the optimization process. The mathematical model of the problem is sent to the optimizer. **Min f(x)** Here, the optimization problem is solved, where its goal is the minimization of the energy interruption. If the optimization process succeeds and the generator & load set-points are dispatched. **Fall back strategy** If the optimization process is either unable to meet the demand due to lack of generation or there is a grid constraint violation, then the fall back or pre-defined backup strategy (pre- defined more load shedding by the DSOs) is selected. That could include allowing more load to be interrupted. **Output** This section receives the control signals from the optimizer and sends them to the respective generators and loads.

Power system components subject to operation planning		
Power system object	**Rated power / NC RfG group**	**Control variable**
	UC 7.4	**UC 7.4**
RES	A, B, C	Active and reactive power
DG	B, C	Active and reactive power
Synchronous generators	B, C, D	Active and reactive power
Storage	A, B	Active power
EVs	A	Active power

Controllable load	A, B, C, D	Active power

KPI coverage by the showcase			
Planning Criteria		KPI	
ID	Title	ID	Title
10	Minimizing energy interruptions	8	Energy not supplied
		3	SAIDI
		18	SAIFI
3	Maximizing share of RES	17	Share of RES
4	Assuring voltage stability	24	Reactive energy provided by RES and DG
		13	Mean quadratic deviations from voltage and reactive power targets at each connection point between TSO and DSO grids

7. Summary and outlook

In Task 5.,1 the concepts of "base showcase" and "showcase" were defined, which was the first step for defining and describing them.

The base showcase was defined as "*Presentation of base use case(s) with no planning criteria and no controllers for emerging technologies, such as RES, DG, demand response or storages in the frame of chosen scenario, simulation type, test model, and time-series data. The base showcase allows to analyze the operation challenges of the related use case(s) and improvements achieved through the application of planning criteria with related implementation of controllers in the associated showcase",* while the showcase was defined as *"Presentation of use case(s) in the frame of chosen scenario, simulation type, test model, time-series data and planning criteria".*

Based on those definitions and use cases developed in Task 3.2, five base showcases and five showcases have been developed:

- Low inertia systems
- Effective DER operation planning through active and reactive power control
- TSO-DSO power flow optimization
- Active and reactive power flow optimization at transmission and distribution networks
- Optimal energy interruption management

These showcases are aiming to achieve the following goals:

- Minimize losses
- Minimize costs
- Maximize share of RES
- Assure voltage stability
- Assure transient stability
- Optimize TSO/DSO interaction
- Maximize DG/RES contribution to ancillary services
- Assure frequency stability
- Minimize energy interruptions

The base showcases will be further utilized as a foundation for work to be conducted in Task 5.2, in which dynamic and semi-dynamic simulations of grid equivalents will be performed. Meanwhile, the showcases will serve as starting point in Task 5.3, where control system logic will be added to the base showcases, thereby simulation of the showcases will be possible. The outcome of those tasks will enable to study the impact of the proposed controllers, as for each pair of the proposed base showcase and showcase, the set of KPIs has been defined. Work conducted under Task 5.1 will be also used for further activities in Work Package 6: "INTERPLAN model validation and testing".

8. References

[1] INTERPLAN, "Deliverable D3.2 INTERPLAN scenarios and use cases", (Public report), October 2018.

[2] ENTSO-E, "The Network Code on Requirements for Generators," 2016. [Online]. Available: https://electricity.network-codes.eu/network_codes/rfg/. [Accessed 13 12 2018].

[3] R. Jankowski, A. Kąkol and J. Rychlak, "Wpływ kodeksów sieciowych na warunki pracy OSD przy uwzględnieniu OZE," *ENERGIA Elektryczna,* no. 8, pp. 20-23, 2018.

9. Annex

9.1 List of Figures

9.2 List of Tables

9.3 Glossary of terms and definitions

9.3.1 Definition of project general terms

Term	Definition
Use Case	The 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.
Sub Use Case	Description of a specific situation a use case is applied to. A Sub Use Case is always attributed to one (main) use case, but one use-case may have multiple sub use cases which detail the main use case in at least one aspect.
Base showcase	Presentation of base use case(s) with no planning criteria and no controllers for emerging technologies, such as RES, DG, demand response or storages in the frame of chosen scenario, simulation type, test model, and time-series data. The base showcase allows to analyze the operation challenges of the related use case(s) and improvements achieved through the application of planning criteria with related implementation of controllers in the associated showcase.
Showcase	Presentation of use case(s) in the frame of chosen scenario, simulation type, test model, time-series data and planning criteria
Scenario	Definition of a future situation applying to a well-defined time (most often year). A scenario can be fictional or predicted from the present situation. In INTERPLAN, scenarios describe the future situation of the European electric network, typically including grid topology, generation mix, loads and diffusion of EV, RES and storages.
Dynamic Simulation	A simulation experiment which considers the time dependent behaviour of a physical system, looking at events occurring in real-time operation, with a frequency of occurrence of less than one second of real time. The

	simulation may run faster or slower than real time, and may, despite the fast event frequency, span a total time interval of several hours real-time.
Semi-Dynamic Simulation (also: Quasi-Dynamic Simulation)	A medium- to long-term simulation experiment based on steady-state analysis, considering the state of a physical system at discrete steps of real time through user-defined time step sizes. The real time between the steps is at least one minute.
Grid Cluster	A group of grids and parts of grids with similar characteristics
Grid Equivalent	A simplified network model, which approximately behaves like an associated complex physical network or a group of physical networks. The grid equivalent thus is a representation of the physical network(s), which is typically used for a simulation experiment.
Controller	A device, which implements an algorithm or methodology that is used for real-time grid operation. A controller may influence the operation state of distributed generators, loads or grid assets (e.g. tap changer, power switch, FACTS) based on information from different sources.
Interface	A means of transmitting information between two or more controllers or actors. It usually includes a specification about which information is to be transmitted, how this information is represented by data elements, and defines a physical means for transmission of those data elements.
Cluster Controller	A controller having the aggregated behavior of individual controller characteristic in a larger grid.
Interface Controller	A controller, which is intended to be installed in a specific "home" cluster, and uses information received through an interface from at least one other cluster data source outside the home cluster. This data source could e.g. be another cluster, but also e.g. an external weather forecast provider using an interface
Local Controller	A controller which is associated with a single specific generator, load or grid asset and which operation does not rely on remotely received information originating from any remote source. i.e. the operation only relies on information available within the local area network of the local controller's installation site.
Co-simulation	A simulation which consists of different parts that form a coupled problem and are modelled and simulated in a distributed manner (cp. Wikipedia). The parts are called "Co-simulation subsystems" and are exchanging data during the simulation. Different models and simulation means can be used in different subsystems. The Co-simulation (in the ideal case) is carried out by running the subsystems, which were individually tested and validated beforehand, in a black-box manner. In INTERPLAN, the data exchange between subsystems is done by the OpSim platform.
Co-simulation sub-system / Co-	A part of a Co-simulation which is developed, modelled and validated individually, while at the same time able to be integrated into the Co-

simulation subcomponents	simulation platform. In INTERPLAN, a subsystem might represent e.g. a DSO or TSO operation centre, a controller, or even the real physical network model.
Data model	An abstract model that represents a real-world entity, and defines, organizes and standardizes the description of the data elements related with that entity. Since real-world entities are typically consisting of other entities (e.g. an electric grid consists of lines, transformers etc.), a data model typically is hierarchically structured and also allows to define interrelations between entities.
V2G and G2V	Vehicle-to-grid (V2G) describes a system in which *plug-in electric vehicles* communicate with the *power grid* to sell *demand response* services by either returning electricity to the grid or by throttling their charging rate. When an EV is being charged, it's called G2V (Grid to Vehicle).
Allocation	With reference to the grid operation planning phase, it is the process deciding, which are the most suitable resources to commit and dispatch among *n* operating resources for a specific objective and under specific constraints.
Placement and sizing	With reference to the grid planning, it is the process deciding the most proper location (bus) and the size of a resource (active power) for a specific objective and under specific constraints.
Energy Not Supplied	Energy Not Supplied is defined as the amount of energy that would have been supplied to the customer if there had been no interruption.
Energy spillage	Energy spillage is the production (from Solar and Wind) that is unable to be accommodated due to demand being lower than production.

9.3.2 Definition of actors

Term	Definition
TSO - Transmission System Operator	Natural or legal person responsible for operating, ensuring the maintenance of the transmission system and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the transmission of electricity. The term 'transmission' means the transport of electricity on the extra high-voltage and high-voltage interconnected system with a view to its delivery to final customers or to distributors, but does not include supply.
DSO - Distribution System Operator	A natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity. The term 'distribution' means the transport of electricity on high-voltage, medium-voltage and low-voltage distribution systems with a view to its delivery to customers, but does not include supply.

ESCO	Electricity supply company (sometimes also: Electricity service company). General term for a company which supplies end users with electric energy. An ESCO may offer additional services, e.g. electricity generation, metering or supply with non-electric energy.
Prosumer	Active energy consumer who consumes and produces electricity. Various types of prosumers exist: residential prosumers who produce electricity at home - mainly through rooftop PV, citizen-led energy cooperatives, commercial prosumers whose main business activity is not electricity production, and public institutions.
Generator	A device which produces electricity.
Load	A device which consumes electricity.
Producer	A natural or legal person generating electricity.
Consumer	A natural or legal person consuming electricity.
Distributed Energy Resource (DER)	A source or sink of electric power that is located on the distribution system, any subsystem thereof, or behind a customer meter. DER may include distributed generation, electric storage, electric vehicles and demand response.
Aggregator	Company who grouping distinct agents in a power system (i.e. consumers, producers, prosumers, or any mix thereof) to act as a single entity when engaging in power system markets (both wholesale and retail) or selling services to the system operator(s).
Distributed generation (DG) unit	Any source of electric power of limited capacity, directly connected to the power system distribution network. DG can be powered by photovoltaic system, micro-turbines, combustion engines, fuel cells, wind turbines, geothermal, etc.
Flexible Loads	A load which consumption can be influenced in terms of power, time, or total energy consumed while still serving its intended purpose. The influence may be exerted by manual means (e.g. switching the load on or off at arbitrary times) or automatic means (e.g. external control signal).