InterOPERA Stakeholder Committee - 1st technical workshop Summary report

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Inter OPERA

Enabling multi-vendor HVDC grids

ABOUT INTEROPERA:

The InterOPERA project will define technical frameworks and standards for electricity transmission and accelerate the integration of renewable energy. Ensuring that HVDC systems, HVDC transmission systems or HVDC components from different suppliers can work together – making them “interoperable”- is a top priority to accelerate Europe’s energy transition.

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1st technical workshop - summary report

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AUTHORS:
Alexandra Bonnet, Power System Engineer, RTE
Vincent Tackenberg, HVDC Grid Development Engineer, Tennet
Johannes Welsch, Electrical System Design, Tennet

REVIEWERS:
Riccardo Longo, Offshore Grid Manager, WindEurope
Nina Mavrogeorgou, Project Manager, WindEurope

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About the 1st technical workshop

1st technical workshop

On 14 March 2024 the first of a series of the InterOPERA technical workshops took place. This inaugural workshop, which focused on selected deliverables prepared by the experts of Work Package 1 (Development of standardised interaction study processes and interfaces) and Work Package 3 (Multi-vendor multi-terminal demonstrator project), was conducted fully online. It featured presentations from Réseau de Transport d'Électricité (RTE) and TenneT, as well as more than 30 professionals and experts from the Stakeholder Committee.

The Stakeholder Committee provided valuable feedback and inputs on the project deliverables, exchanged views on potential exploitation routes for the project demonstrator and engaged the keynote speakers with technical questions and observations.

The first part of the workshop, led by RTE, focused on defining standard interfaces and requirements for models, real-time systems, and simulation platforms. Specifically, it addressed:

- Requirements applying to the offline models (deliverable 1.1 – referred as D1.1).
- Requirements applying to the real-time systems (deliverable 1.1 – referred as D1.1).
- Requirements applying to the simulation platforms and system integrators (deliverable 1.2 – referred as D1.2).

This session was followed by a general discussion involving the Stakeholder Committee.

The second part of the workshop, focusing on demonstrator definition and system design studies (deliverable 3.1 – referred as D3.1), was led by TenneT. The main outcomes are:

- definition of the InterOPERA demonstrator;
- preliminary conceptual system design studies.

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1. Discussion summary

1.1 Definition of standard interface and requirements for models, real-time systems and simulation platforms

During the first Stakeholder Committee workshop, two hours have been dedicated to the definition of standard interface and requirements for models, real-time systems and simulation platforms. On top of the active discussions, some stakeholders shared documents and comments in the chat. These documents and comments will be reviewed to improve the quality of the deliverables D1.1 and D1.2, and the reference of the documents will be added as part of the reference used to prepare the deliverables.

For the sake of clarity, the feedback from the stakeholders is presented in this report by referring to the most relevant part to support the discussion, which is not necessary the part during which the feedback was provided.

1.1.1 Introduction

The presentation started with an introduction explaining why a new set of requirements was necessary for multi-vendor multi-terminal HVDC grids, connected to offshore wind farms. It is worth pointing out that the challenges are shared among the participants, who were eager to share their own experience and to know how we aimed to face these challenges. For example, how to use models over 20 years is also a concern for other transmission system operators (TSOs).

During this introduction, it has been clarified that:

- The models and real-time systems considered by the set of requirements, are the vendors' models and real-time systems (not generic ones), and are limited to HVDC converter station, DC switching station, DC Grid Controller, Power Plant Controller and offshore wind farms.
- The acronym TSO is often used in the presentation, but it can be any system owner, system operator or system integrator by reference to the READY4DC project's terminology.

The presentation (slides) is available on the project website here.

1.1.2 Requirements applying to the offline models

Slide 11: The choice of the frequency range, up to 2.5 kHz has been challenged: why not 3 kHz?

It has been clarified on this point that 2.5 kHz is based on the ENTSO-E Report.[1] This upper limit is defined for EMT models and corresponds to the 50th harmonic, which is generally the upper harmonic rank

[1] Final report from the expert group for interaction studies and 2253 simulation models (EG ISSM) at ENTSO-E level 2254
https://eepublicdownloads.blob.core.windows.net/public-cdn-2255 container/clean-2256 documents/network%20codes%20documents/gc%20esc/issm/eg_issm_final_re2257 port_211001.pdf

considered in Europe. But for impedance harmonic models, this ENTSO-E report offers the possibility to request for a model up to 9kHz. Regarding the upper limit for EMT models, other stakeholders also mentioned that, on the DC side, the DC cable would cut anyway the highest harmonics, and that it is hard to measure the highest harmonic ranks on the grids with actual measurement systems.

Regarding modelling recommendation, the stakeholder participants asked about the level of details to be included in the model for the grid-forming functions. It has been explained that in the deliverable D1.1, for the vendors' models, the requirements were written in a functional way, to be result-oriented. Hence, it is the duty of each vendor to define the appropriate level of details to demonstrate the grid-forming functions included in their models.

Slides 12 and 15: the stakeholders confirmed the importance of getting the measurements, as measured by the control system, and not the raw measurement coming from the simulation tool (using the standard library metering devices). This is in line with InterOPERA position, even though this method induces at least one step delay.

Slide 13: the Stakeholder Committee confirmed the importance of having the real code.

Slide 15: regarding the structure, a question has been raised by the Stakeholder Committee about the possibility to standardize the input/output signals' name and the circuit. In InterOPERA, the resources are limited and there is already a lot of work for the vendors to prepare tool- and compiler-independent DLL, which is the minimum requirement. Consequently, instead of an extensive standardization, it has been requested in InterOPERA to provide a clear documentation of the models, for the system integrators to know how to integrate the received models in the simulation tools to perform the studies. But it has been mentioned in InterOPERA that for commercial projects, TSOs could indeed want to standardize more the input/output signals' name and order.

Slide 16: this slide mentions, as an example, the request for multi-instances for simulations running in parallel on different cores. The stakeholder participants mentioned that multi-instances within one simulation shall also be considered, and that it could be better to speak of process instead of cores to be more generic. On the first point (multi-instances within one simulation), this is already written in the deliverable D1.1, the misunderstanding comes from the example given in the presentation. On the second point (replace cores by process), this improvement will be proposed to the WP1 participants in the deliverable D1.1

Besides, this slide introduces requirements related to the initialization of the models. The participants stressed that we had to be pay attention to the fact that there are some tricks in the models to speed up the energization, and therefore, that we had to be careful about drawing any conclusion during this period. This is indeed something that the InterOPERA participants have in mind.

The requirement related to the initialization of the models, also lead to discussion about the initialization of a system as a whole: how are we going to manage the fact that the models will disturb each other during the initialization? how are we going to have something stable? This process will be described in the deliverable D1.3 related to the interaction studies, and hence will be discussed during the 2nd Stakeholder Committee workshop. One solution, quickly discussed in the Work Package 1 while preparing D1.1, is to initialize each system on a separate circuit, and then connect to the whole circuit. During the workshop, another solution has been proposed: to request for a flat start possibility in the models and for a smooth transition between the flat start mode and the "normal" mode. This proposal will be investigated by the Work Package 1 participants.

Slide 15 and 17: as part of the documentation, it has been proposed to ask the vendors to demonstrate that the protections are operational in the model. This is indeed a sensitive point, anticipated in InterOPERA through 2 actions:

- As part of the documentation, as per D1.1, it is requested to mention which protections are included in the model or not.
- When a model is received, as per D1.3 (work is under progress), it is recommended for the system integrator to test and perform few faults to check that the protections are included as mentioned in the documentation.

Through experience sharing during the Stakeholder Committee workshop, it has been suggested by the participants to establish a certification process with a periodic accuracy check of the models, for example every four years. This is a solution to ensure that the models are still valid and that all the changes performed at site, influencing the behaviour for the studies, have been correctly reflected in the models. Omission can happen! This recommendation will be shared within Work Package 1.

1.1.3 Requirements applying to the real-time systems

Slide 26: one of the first question raised during the workshop, during the introduction, was related to the way to manage different interfaces between replicas and real-time simulators, and how to design them. The answer is finally provided in this slide: it is expected to rely on documented interfaces, in order to be able to configure correctly the real-time simulator and to have the correct implementation of the protocol(s) that are used.

The time step of 40 µs (as the main step for the real-time CPU) raised some concerns among the participants, as it reduces the accuracy and represents a risk of missing phenomena. Besides, there might be protections requiring a smaller time step to be fully operational. These limitations have been indeed discussed within WP1. It was agreed at that time in WP1, that the system integrator would not draw conclusion outside the validity domain of the simulation.

Participants agreed that adapting the real-time system to be robust across the entire time step range of the real-time simulator, for example by adjusting the filters, is a controversial topic: is it needed? Is it feasible? Is it acceptable? To which extent? There is no clear answer yet, this will be investigated in InterOPERA with the support of the manufacturers. Nonetheless, it is worth pointing out that in general, developing something new shall be avoided.

Slide 27: the participants recommended giving a clear definition of SIL in InterOPERA document, as there is no standard definition of SIL yet. In InterOPERA, SIL is used only in real-time, to describe any software that is not running on the real hardware.

In addition, the uses and advantages of SIL have been discussed. On top of facilitating the provision of other systems as SIL – such as the DC Grid Controller – for advanced Factory System Tests at a vendor's facility, SIL is an interesting solution to reduce the costs (providing SIL is less expensive than HIL), to speed up the process (for example, there are less constraints for delivery and installation of the system at the system integrator's lab and SIL can be provided earlier in a project than HIL), to limit the size of the simulation platform.

The last sentence of the slide: "Experience in preparing a tool-independent code for the tool-independent DLL can be re-used for the development of SIL solutions (but it is not sufficient)" lead to a misunderstanding among the participants because DLL is only for Windows. Therefore, it has been clarified that it is *the experience* to prepare tool-independent code, for tool-independent DLL, that can be re-used to prepare other types of compiled tool-independent code (such as .a or .so files) but not the DLL itself.

1.1.4 Requirements applying to the simulation platforms and system integrators

Slide 32 (EMT offline simulation tools requirements): as the recommendation for CIM compatibility in the EMT offline tools has been introduced to the committee, the participants questioned if InterOPERA anticipated receiving models directly based on CIM – CGMES standard. This could be indeed imagined on the long term; however, this is not planned in InterOPERA for several reasons:

- The newest versions of these standards have been recently published (February 2024), consequently the EMT tools are not ready yet to import and export models using these newest versions.
- It is not yet demonstrated that these newest versions are sufficient to be able to export or import any vendor's model[2]. In case extra-work would be necessary for the vendors to prepare their models using CIM-CGMES, this would not fit with InterOPERA initial workload.

Nonetheless, in InterOPERA, we will try to assess how far we are from this target, through a review of these standards. In addition, if the CIM-CGMES import and export functions are available in the simulation tools, some tests will be performed. The rough idea would be to combine CIM for the power part of the model, and as CIM also proposes to include DLL, IEEE/CIGRE DLL reference could be used for the control and protection part.

Slide 33 (EMT real-time simulation tools requirements): it has been clarified that the request for a coordinated trigger of the Transient Fault Recorders of all the vendors, will not lead to new developments in the real-time simulators. This can already be achieved with current real-time simulators. This point is just mentioned because it represents a new manner to use the real-time simulators compared to the manner they are used in single-vendor point-to-point projects.

Slide 34 (complementary tools requirements for higher efficiency): EMT simulation tool developers participating to the stakeholder committee workshop demonstrated interest in implementing the list of tests, once defined in InterOPERA, in the EMT simulation tools for automatic tests and performance checks.

1.1.5 General discussion

In addition to the initial scope of the first stakeholder committee workshop, participants demonstrated their interest in the following topics:

- How do we define the accuracy of the models? Currently, in the deliverable D1.1, "sufficient" accuracy is requested, but no strict values are given to quantify this accuracy. This is due to the lack of experience in multi-vendor multi-terminal HVDC grids and this point will have to be discussed at a later stage in InterOPERA.

[2] There is an ongoing work in the HVDC-WISE project on this topic with generic models, but not with vendors' models.

- How are the vendors going to test their offline models? and their real-time systems? This is discussed in other tasks or in other work packages, however some clues have been given to the participants. For offline, the idea, in InterOPERA, is to develop in task 2.5 a generic and public model of a grid, which can be used by the vendors to test their model against this benchmark. And performance tests will be proposed, at each sub-system level. One of the challenges, supported by all the participants, is to be able to define the requirements at each sub-system level while ensuring a satisfying behaviour of the whole system, because each vendor is only responsible for the performance at its sub-system level. If interactions are observed, even though the vendor is fulfilling all the requirements applying at its sub-system level, then it probably means that the requirements must be updated and strengthened. Work is ongoing in InterOPERA to define clear and verifiable requirements at the interfaces.
- With reference to slide 21: what is the protocol for the DC Grid Controller? In InterOPERA, the initial protocol chosen is the IEC 61850 MMS.
- With reference to slide 21: is there any direct communication between the converter stations, for example for the protections? Ideally, we would like to demonstrate in InterOPERA that no direct communication is necessary for the main functionalities. But indeed, we can imagine direct communication for the protections, using the IEC 61850 R-GOOSE. This is under discussion, we are open.
- With reference to slide 21: what is the architecture of the DC Grid Controller? It is currently designed as a central controller, in one block. But one could foresee different architectures.
- Will state-space models be provided in InterOPERA? In InterOPERA, only EMT models are requested as must-have, as per the consortium agreement. But it is true that state-space models represent a complementary approach, with the main advantage of providing participation factors. This will be investigated in InterOPERA, on a voluntary basis, as it is not part of the initial scope.
- What is the model delivery timeline? This will be defined in D1.3.

These questions promise fruitful discussions for the next Stakeholder Committee workshop, where we will enter the interaction studies process more into details.

1.2 Demonstrator definition & system design studies

During the first Stakeholder Committee workshop, one hour has been dedicated to the demonstrator definition and system design studies which represent the main outcomes of the InterOPERA Task 3.1 (T3.1) "Offshore HVDC grid system design – demonstrator definition". The following section summarizes the key takeaways and discussions on the two aforementioned topics. The discussion supports future deliverables in InterOPERA.

1.2.1 Introduction

The presentation started with an introduction explaining the main objectives of T3.1, namely the definition of the InterOPERA demonstrator topology and the execution of preliminary conceptual system design studies performed by the asset owner. It was also mentioned that T3.1 is already finished and that the deliverable is publicly available.

In due course of the meeting, the focus was on the two aforementioned core topics.

The presentation (slides) is available on the project website here.

1.2.2 Definition of the InterOPERA demonstrator

In the first part of the presentation, the topology of the InterOPERA demonstrator developed in T3.1 was presented and discussed.

The InterOPERA demonstrator enables the testing of key functionalities of multi-vendor HVDC systems. The full extent of the topology consists of five converter stations and five DC switching stations which ensures step-by-step verification process development of control and protection functions. Moreover, it enables extended testing procedures for advanced grid forming capabilities, a key outcome of the project. Via this topology, partial and full selective fault clearing strategies including DC-Fault Separation Devices (DC-FSD) in longitudinal couplings and on both DC line ends are covered. The AC connection of offshore converter stations connecting offshore wind farms using wind turbines from different Original Equipment Manufacturers (OEM) and onshore converter stations of different HVDC vendors in different synchronous areas enables the testing of interoperability of windfarms with HVDC converter stations and the testing of advanced grid forming capabilities.

To increase flexibility for offline and online testing purposes, the allocation of offshore and onshore converter stations can be adjusted accordingly leading to two variants of the InterOPERA demonstrator topology.

The first variant represents a meshed offshore grid for wind export and consists of three offshore converter stations, two onshore converter stations and five DC Switching Stations (DCSS) which enables testing scenarios for two offshore converter stations in close electrical vicinity.

The second variant represents a meshed multi-purpose hybrid interconnector and consists of two offshore converter stations, three onshore converter stations and five DC switching stations which enables e.g. the analysis of AC-side interactions between two onshore stations in close electrical vicinity.

The following questions were raised and discussed during the first part of the meeting:

- "Is an AC offshore interconnection (connection of two wind farms) possible?" With the demonstrator topology an interconnection of multiple wind farms is possible. The connection is indicated with a dotted line.
- "What does DC-FSD mean?" DC-FSD means "DC - fault separation device". It is a more general term compared to DC circuit breaker. DC-FSDs are illustrated with blue boxes.
- "In addition to DC circuit breakers, have you seen other means by which fault interruption is happening?" The term DC-FSD does also include functionalities like a DC fuse which is for now not being foreseen in InterOPERA but which could be possible;
- "What DC circuit breaker technologies are considered in the project?" We looked at technologies that (from an asset owner perspective) we think will get offered by the market. This includes power electronic based breakers, hybrid breakers and mechanical breakers.
- "Why are not all busbars sectionalized? What was the motivation behind this? For example: Why isn't a circuit breaker in the longitudinal coupling of the upper left DC switching station considered?" To enhance to flexibility and variety of the InterOPERA demonstrator, not all switching stations are equipped with circuit breakers as longitudinal couplers.
- "What protection is considered on the AC-side?" Each pole has its AC breaker illustrated with grey boxes in Figure 1 below.

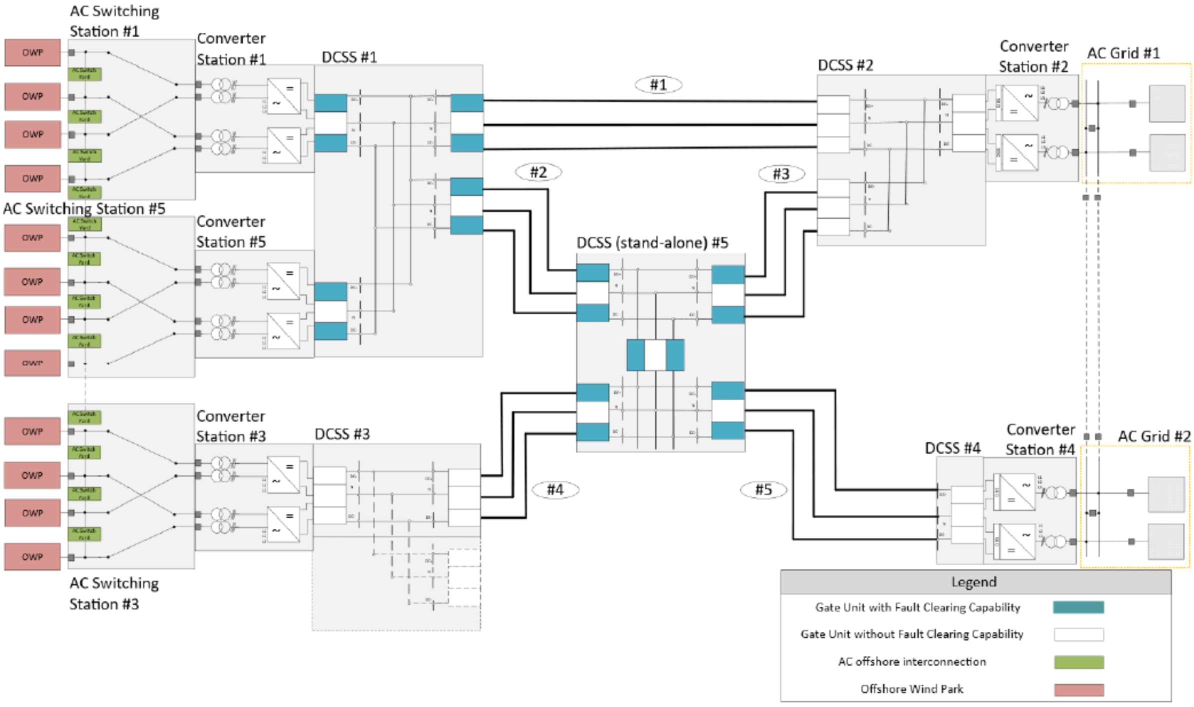

Figure 1 AC switching, converter and DCSS. The AC breaker is illustrated with grey boxes.

- "Are the poles of the onshore converter connected to different onshore grids (question related to split busbar)?" The demonstrator topology provides this option, but a split busbar operation was excluded for the studies conducted in T3.1.
- "The demonstrator topology consists of five terminals but there are only three HVDC vendors involved in the project. How does this fit together?" A distinction between an offline (five converter stations) and online (three converter stations) topology is foreseen. The allocation will be clarified in the due course of the project.

Regarding the design of the DC switching station, it was suggested to use sectionalized busbars for all switching stations since busbar faults could be very critical. Furthermore, it was mentioned that busbar protection is difficult, and it may be necessary to install sufficient reactance in the DC switching station to create a necessary discrimination.

To foster the discussions about the InterOPERA demonstrator, a survey was conducted to gather opinions of different stakeholders. The following question was discussed. The consortium's responses are listed as bullet points.

"What should be key characteristics of multi-terminal grids around the North Sea?"

- Flexibility and resilience;
- Voltage, ratings, distance, active power, losses, loss of infeed;
- Clear concept to limit impact on surrounding AC networks under all circumstances;
- Complex system;
- Bankable (After a discussion during the meeting it was clarified, "bankable" means that the responsibilities and performance requirements for each of the participants need to be clarified);

- Huge DC circuit breaker;
- Minimising loss of infeed to AC grid;
- Compliance with GB grid code;
- AC / DC grid interaction.

1.2.3 Preliminary conceptual system design studies

In the second part of the presentation, the results of preliminary conceptual system design studies for the demonstrator topology were presented and discussed.

The studies comprise a stationary, quasi-stationary and transient analysis and outline the approach from an asset owner which lead to the definition of DC voltage and DC current bands for the offshore and onshore converter stations. The results contribute to the selection of preliminary main circuit parameters. Besides that, general AC- and DC-system data as well as system- level concepts (e.g. protection design concepts, system states, and modes of operation) are defined to characterize the demonstrator grid design quantitatively.

The following questions were raised and discussed during the second part of the meeting:

- "What was the assumed length of the DC cables?" Different cable lengths between 50 km and 800 km were assumed for the five cable sections of the demonstrator topology. Instead varying the lengths, the values remained fixed for the studies.
- "Did you also look at a variation of the AC voltage profile?" Variation of the AC voltage wasn't considered for the studies conducted in T3.1.
- "The grounding has a significant impact on the transient stresses which is why this is a very important topic for such a study. What grounding scheme and grounding location was considered?" For T3.1 a low impedance grounding at the central DC switching station was assumed. Grounding scheme and location might change in the upcoming tasks when more detailed studies will be performed.
- "Do the DC circuit breakers have an inductance? If yes, how was the inductance sized?" Within T3.1, every circuit breaker has an inductance, and the value was varied.
- "What was the overall goal of the studies?" The overall goal was to enable a subsystem vendor to start their design. The studies provide a starting point at a system level to assess how the system should behave in each of these time domains. This was the first step of an iterative approach.
- "Are all DC faults assumed as permanent? Are overhead lines considered as well?" For the demonstrator topology only cables are considered, so in that case all faults would be considered as permanent for this time frame.

Regarding the transient analysis it was suggested to vary the grounding scheme and grounding location for the studies as this has a significant impact on the results. In addition, it was also recommended to consider more fault locations and fault types.

To foster the discussions about the preliminary conceptual system design studies, a survey was conducted to gather opinions of different stakeholders. The following question was discussed. The responses of the participants are listed as bullet points.

"What should be key outcomes of conceptual system level design studies performed by the asset owner?"

- Clearance of DC faults and impact on the AC system;

- Fault ride through of AC onshore faults – protection strategies (Comment from the presenters: AC faults were excluded in the studies of T3.1);
- How to meet everyone's grid code requirements at the same time, e.g. LFSM;
- Propagation of severe AC events through the DC network;
- Harmonics (AC and DC);
- Other resonances on AC-side (e.g. sub synchronous, power oscillations);
- Interactions of the DC grid with other PEIDs;
- Impact to the AC system;
- Interaction of AC and DC systems;
- Design for flexibility if characteristics of future wind farm additions are unknown.

Abbreviations and acronyms

	Text
AC	Alternating Current
CIM	Common Information Model
CGMES	Common Grid Model Exchange Standard
CPU	Central Processing Unit
DC	Direct Current
DC-FSD	DC-Fault Separation Devices
DCSS	DC switching stations
DLL	Dynamic Link Library
EMT	ElectroMagnetic Transient
HIL	Hardware In the Loop
HVDC	High Voltage Direct Current
OEM	Original Equipment Manufacturers
SC	Stakeholder Committee
SIL	Software In the Loop
TSO	Transmission System Operator
T3.1	Task 3.1 of the InterOPERA project