# SEVENTH FRAMEWORK PROGRAMME

## THEME [ENERGY.2011.7.2-1]

## [Innovative tools for the future coordinated and stable operation of the pan-European electricity transmission system]

**Project Deliverable**

***Deliverable D 1.1 "iTesla Cooperation"***

Project acronym: UMBRELLA

Project full title: **Toolbox for Common Forecasting, Risk assessment, and Operational Optimisation in Grid Security Cooperations of Transmission System Operators (TSOs)**

Grant agreement no.: *282775-2*

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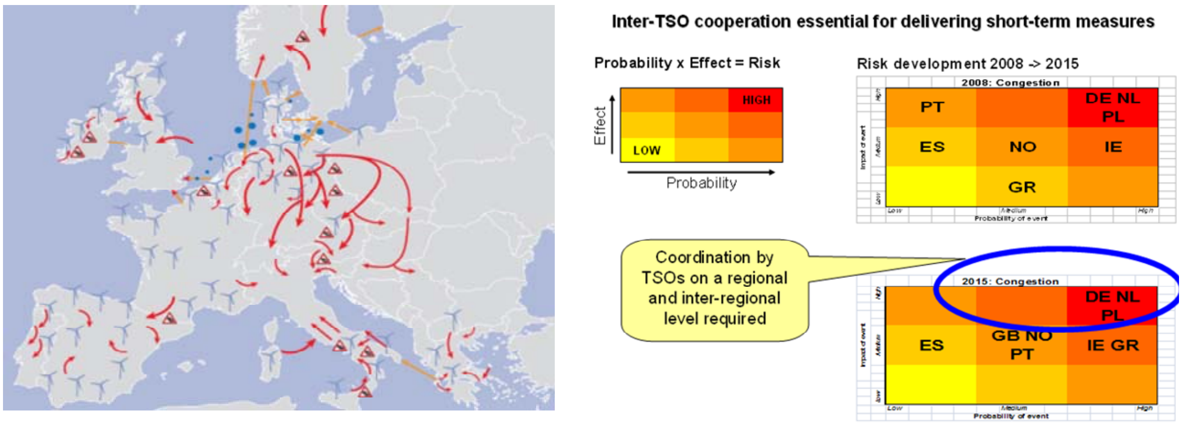
# 1 Introduction

The interconnected European electricity system has emerged from the interconnection of national grids that were designed for power transport from generation units to loads comparatively close to each other. Moreover, the power to be transported by the grid used to be rather predictable. Today, the situation has changed: interconnections between national grids are not only needed for mutual help in emergencies, but rather to enable a European-wide market for electricity, leading to significant cross-border flows. Another factor causing power transports over longer distances is the growing share of renewables often concentrated in areas far from load centres. Both aspects, the enhanced electricity trading activities and the growing infeed from renewable sources, furthermore produce significant uncertainties that network operators have to deal with.

Previous studies such as EWIS showed that in the mainland Europe synchronous area the difference between actual physical flows and the market exchanges can be very substantial in the area highlighted in UMBRELLA. TSOs are already experiencing issues due to these loop flows but analysis of the 2015 time horizon identified:

- High power flows starting in the areas with large wind power installations in Germany and directed to the remote load centres (higher than previous national studies had anticipated and existing planned reinforcements can accommodate).
- Substantial loop flows through Poland and the Czech Republic increasing flows significantly above those that are currently expected to result from market transactions.




Source: EWIS Study www.wind-integration.eu

Figure 1: Operational challenges in Central Europe

The main challenges currently reported by TSOs concerning system operation with a significant contribution from wind generation relate to:

- Coordinating the operation of flow controlling devices (such as phase shifting transformers, series compensation and HVDC links) across Europe.
- Coordinating system to generator and system to demand special protection arrangements to adjust power flows in the event of faults and other events.
- Developing and using dynamic equipment ratings reflecting ambient conditions, loading and conductor temperatures.
- Shared intelligence on developing generation and load conditions (including wind forecasts).
- Suitable monitoring and control facilities.
- Procedures for using enhanced operational measures so that maximum benefit is achieved across each region.

In the future, as the amount of wind generation increases, the challenges related to the variability and uncertainty of wind are expected to become more important. Improvements in forecasting and the use of flexible generation units are the principal mitigations at the national level that are currently perceived to address these challenges. As the parties responsible for ensuring the real-time matching of production and consumption in their control areas, TSOs are already active in developing and innovating this aspect of electricity system operation.

Throughout Europe there is a focus on improving intra-day and closer to real-time trading facilities which will provide market participants with opportunities to manage and evolve their positions. As participants in these markets, or as counter-parties in specialist mechanisms, TSOs are increasingly using these arrangements to procure the services they require and TSOs are already strengthening their networks by constructing new circuits, upgrading conductors on existing lines, installing reactive compensation devices to improve voltage performance, and installing devices such as phase-shifting transformers to control the sharing of power between circuits thereby making best use of existing circuits and reducing unwanted loop flows. TSOs are also implementing operational procedures and control systems that seek to maximise the usable capacity of existing assets

In the Continental Europe (formerly UCTE) system, there are both short-term mitigation action sand longer-term developments in progress. In the short-term, TSOs are seeking to manage power flows within the capability of existing networks by using available operational measures (such as network reconfiguration by switching and using flow control devices) and then notifying the resulting available transfer capacity to market participants.

In this project, a tool that optimizes preventive and curative actions in order to allow for maximum power transit and transport is to be developed. Decisions on remedial measures for relieving critical situations are today rather based on experience and are often not made in a coordinated way. This in many cases leads to suboptimal solutions. The tool to be developed is to make use of coordinated input data from several TSOs and to then find the economic optimum. It will thus provide for a solution which takes advantage of the given possibilities of the grid and therefore allow for better decisions.

The prototype will show a concept to exchange forecast information (e.g. load and generation pattern, renewable energies, intraday market) considering a risk based assessment.

## 2 Key challenges and data needs

Almost all major TSOs in continental Europe with large wind power installations and increasing solar power installations which are already experiencing huge difficulties to operate the network are part of the UMBRELLA project and will contribute their skills and experience regarding operational aspects of the project. As pointed out in the FP6 project EWIS, the difference between actual physical flows and the market exchanges can be very substantial (due to so called “loop flows”). This was particularly shown in the mainland Europe synchronous area under the high wind north snapshot. TSOs are already facing today operational challenges due to these loop flows but analysis of the 2015 snapshots identified high power flows starting in the areas with large wind power installations in Germany and directed to the remote load centres, substantial loop flows through Poland and the Czech Republic and increasing flows significantly above those that are currently expected to result from market transactions. Also high loop flows through Benelux countries with similarly increasing flows have been found. There is hence a substantial risk of cascade failures and disruption should a fault event occur. E.g. on the German-Czech Republic border, flows could exceed line capacities even with all circuits in service, risking network failure without an initiating fault event. On the German- Poland border, flows reach line limits with all circuits in service, risking network disruption in the event of a fault.

Beyond 2015, as the amount of wind generation increases, the challenges related to the variability and uncertainty of wind are expected to become even more important. Improvements in forecasting and the use of flexible generation units are the principal mitigations at the national level that are currently perceived to address these challenges. As the parties responsible for ensuring the real-time matching of production and consumption in their control areas, TSOs are already active in developing and innovating this aspect of electricity system operation. Throughout Europe there is a focus on improving intra-day and closer to real-time trading facilities which will provide market participants with opportunities to manage and evolve their positions. As participants in these markets, or as counter-parties in specialist mechanisms, TSOs are increasingly using these arrangements to procure the services they require. Also TSOs are already strengthening their networks by constructing new circuits, upgrading conductors on existing lines, installing reactive compensation devices to improve voltage performance, and installing devices such as phase-shifting transformers to control the sharing of power between circuits thereby making best use of existing circuits and reducing unwanted loop flows. TSOs are also implementing operational procedures and control systems that seek to maximise the usable capacity of existing assets.

In the Continental Europe system, there are both short-term mitigation actions and longer-term developments in progress. For the coming years, TSOs are seeking to manage power flows within the capability of existing networks by using available operational measures (such as network reconfiguration by switching and using flow control devices) and then notifying the resulting available transfer capacity to market participants.

For the success of such a research work for the development of a toolbox, the already gained experience of the TSOs involved with operational issues, the in-depth knowledge of day to day operational challenges, experience of effective Team work in setting new state of art while successfully integrating wind power in to European grid will be pivotal and decisive. Through their cooperation within ENTSO-E the TSOs will also ensure adequate coordination with other R&D projects concerning the planning and operation of the pan-European electricity transmission network. And they will ensure that the methods to be developed and implemented may be easily extended to further grid operators.

Umbrella as part of the ENTSO-E Research and Development Plan needs the ENTSO-E support for necessary historical data and information in order to obtain best results and to contribute to the R&D plan. Synergies between existing and on-going studies and data already available within ENTSO-E will be used by umbrella in order to optimize the timing, resources and budget of both projects.

# 3 Detailed description of information exchange and knowledge sharing between iTesla and umbrella

Innovative tools for the future coordinated and stable operation of the pan-European electricity system will be researched and developed by projects iTESLA and UMBRELLA that both responded to Topic ENERGY.2011.7.2.1 of the ENERGY-2011-1 Call and started their work in January 2012. The aim of both projects is to develop a simulation toolbox supporting future coordinated operations of the pan European electricity transmission network.

Besides the main developments undertaken by each consortium to reach the objectives of its own project, the two projects will cooperate and jointly develop recommendations to ENTSO-E regarding operational rules supporting the future coordinated operation of the pan-European electricity transmission network. To this end, both projects have agreed on a common procedure to use and exchange necessary data, information and knowledge to support the interaction between the two projects. iTesla and Umbrella have similar objectives. Both projects aim at developing new tools to meet the challenges of the future operation of the future coordinated pan-European power system. The geographical areas covered by the TSOs involved in iTesla and Umbrella represent a large part of the pan-European system including the mainland area with a high concentration of RES.

The TSOs involved in both consortia have agreed through a Memorandum of Understanding on the mechanisms of the interaction. According to the MoU already signed by both of the projects fine details of the interaction/cooperation between iTesla and

Umbrella have to be defined in an early stage of both projects (for iTesla, Deliverable D8.5 – for UMBRELLA D1.1). Besides the information exchange which will be specified more detailed in this document the cooperation of the two projects includes the following cornerstones:

- Three common workshops will be organized by iTesla and Umbrella:
  - Common open Workshop on innovative tools needed for the future and stable system operation to exchange information about respective project objectives, dissemination, key drivers, results of previous studies (knowledge sharing and information exchange)
    - Topic: Operational challenges seen by TSOs measures to mitigate the risks
    - When: June 2012, CW 25 (tbd)
    - Where: Brussels, ENTSO-E premises (tbd)
  - Workshop on intermediate results (M25) (exchange and present information about intermediate results and deliverables)
    - To be further developed
  - Workshop on final results (M46) (exchange and present information about final results).
    - To be further developed

In order to validate the simulation toolboxes developed in the framework of the iTESLA and UMBRELLA projects, the parties will exchange the following data in general:

- Data related to contingencies
- Data related to corrective actions to mitigate congestions
- Static system description/states (DACF, IDCF and snapshots files) if available
- General information and principles related to emergency controls and defence plans

In particular some data of the above list are already shared among TSOs in the framework of existing operational processes. Therefore each party authorizes the other Parties to use these data as well as the archives of these data in the respect of the confidentiality obligations set out in the MoU under Article 6. The following chapters will specify the details for the agreed information exchange.

In order to specify in more detail which data should be exchanged, the following questionnaire has been developed. The at hand questionnaire is divided into four parts. Part I inquires about the data availability for the individual control area/country necessary for the different tasks and Part II concentrates on the data currently exchanged (DACF, snapshots) as well as information on power plants. Part III focuses on dynamic data and finally, Part IV on time record of available measurements.

In order to understand the forecast process, not only information about the prediction and realization are needed, but also about the forecasting horizon and when this information becomes available. This is incorporated in the questionnaire as well. The subsequent example shows you how to complete these tables.

Example: When do you get the forecast at 6 p.m. for the entire next day, it is not updated during the forecast horizon and the time resolution is 15 minutes, your completion should look like the following table:

| | | **Day (d=day of delivery, d-1=day ahead, d+1=following day etc.)** | **Time* (please fill in)** |
|---|---|---|---|
| **Wind** | When do you get the day-ahead forecast? | *d-1* | *6 p.m.* |
| | When does the forecast period start? | *d* | *0 a.m.* |
| | When does the forecast period end? | *d* | *11:45 p.m.* |
| | How often is the forecast updated (if it is updated)? | *it is not* | |
| | What is the time resolution of the forecast? | *15 minutes* | |

If there are any questions regarding this questionnaire or any further comments or information you want to provide, please do not hesitate to contact University Duisburg-Essen and/or Jean-Baptiste Heyberger from RTE:

## 3.1 Part I: data availability for the individual control area/country

### 3.1.1 General expected level of description of electrical systems

#### *3.1.1.1 Voltage levels:*

What voltage levels can you provide in your electrical system files?

| | | yes | no | Not used |
|---|---|---|---|---|
| **Forecast system files** | 380kV (and above) | | | |
| | 220-230kV | | | |
| | 150kV | | | |
| | 110-100kV | | | |
| | 100-70kV | | | |
| | 70-50kV | | | |
| | 50-20kV | | | |
| | 20-10kV | | | |
| *Comments:* | | | | |
| **Snapshot** | 380kV (and above) | | | |
| | 220-230kV | | | |
| | 150kV | | | |
| | 110-100kV | | | |
| | 100-70kV | | | |
| | 70-50kV | | | |
| | 50-20kV | | | |
| | 20-10kV | | | |
| *Comments:* | | | | |

#### *3.1.1.2 Level of aggregation of generation:*

Given the voltage levels described above, how are modelled the generating units physically connected to the lower voltage levels that are not represented in your data files?

| | | yes | no |
|---|---|---|---|
| **Forecast system files** | aggregated Wind generation units separately from loads and other generating units | | |
| | aggregated PV generation units separately from loads and other generating units | | |
| | aggregated renewables separately from loads and other generating units | | |
| | Non aggregated machines over 100MW separately from any other injection | | |
| | Non aggregated machines over 20MW separately from any other injection | | |

Comments:

| | | | |
|---|---|---|---|
| Snapshot | aggregated Wind generation units separately from loads and other generating units | | |
| | aggregated PV generation units separately from loads and other generating units | | |
| | | | |
| | Non aggregated machines over 100MW separately from any other injection | | |
| | Non aggregated machines over 20MW separately from any other injection | | |

*Comments:*

#### *3.1.1.3 Level of aggregation of the load:*

Given the voltage levels described below, what level of detail of your load can you provide?

| | | yes | no |
|---|---|---|---|
| **Forecast system files** | The possibility to model several loads per bus | | |
| | Physical loads separated from flows of non described voltage levels | | |
| | Loads separated from distributed generation | | |

*Comments:*

| | | | |
|---|---|---|---|
| **Snapshot** | The possibility to model several loads per bus | | |
| | Physical loads separated from flows of non described voltage levels | | |
| | Loads separated from distributed generation | | |

*Comments:*

### 3.1.2 Integrating uncertainty in renewable power forecasts

If you do not have a relevant amount of renewable energy infeeds, go ahead in the questionnaire

#### *3.1.2.1 RES infeed forecasting and realized values*

| Can you provide us with | Yes | No | Time resolution if “Yes” (1/4 hourly, hourly, …) | Regional resolution if “Yes” |
|---|---|---|---|---|
| Actual wind infeeds (measured or extrapolated) | ☐ | ☐ | | |
| *Comments:* | | | | |
| Predicted wind infeeds | ☐ | ☐ | | |
| *Comments:* | | | | |
| Actual solar infeeds (measured or extrapolated) | ☐ | ☐ | | |
| *Comments:* | | | | |
| Predicted solar infeeds | ☐ | ☐ | | |
| *Comments:* | | | | |
| Installed wind generation capacity | ☐ | ☐ | | |
| *Comments:* | | | | |
| Installed solar generation capacity | ☐ | ☐ | | |
| *Comments:* | | | | |

For each “yes” answer, could you indicate in the “comment” box if this provided data is included in the existing DACF and snapshot files? Do you plan to include such data in future DACF and snapshots using the CIM format? If this is an additional data source, could you indicate the associated format?

#### *3.1.2.2 Procedure regarding RES forecasting*

For the most detailed forecast deliverable

| | Day (d=day of delivery, d-1=day ahead, d+1=following day etc.) | Time (please fill in) |
|---|---|---|

| | | | |
|---|---|---|---|
| **Wind** | When do you get the day-ahead forecast? | | |
| | When does the forecast period start? | | |
| | When does the forecast period end? | | |
| | How often is the forecast updated (if it is updated)? | | |
| | What is the time resolution of the forecast? | | |

*Comments:*

| | | | |
|---|---|---|---|
| **Solar** | When do you get the day-ahead forecast? | | |
| | When does the forecast period start? | | |
| | When does the forecast period end? | | |
| | How often is the forecast updated (if it is updated)? | | |
| | What is the time resolution of the forecast? | | |

*Comments:*

#### *3.1.2.3 Historical data availability*

| **Since when are this data available** | **Month** | **Year** |
|---|---|---|
| • Wind | | |
| • Solar | | |

*Comments:*

Could you please indicate in the comment box what is the data format associated with these historical data.

#### *3.1.2.4 Remedial Actions linked to renewable curtailment*

Taking into consideration that it is sometimes necessary to disconnect wind or solar generation parks from the grid (e.g. § 13(2) EnWG in Germany), the forecast error becomes biased due to such remedial actions. In order to account for this, we need the respective starting time, the duration and the respective disconnected power as a time series, which is requested in the subsequent table. Note that we assume that the spatial resolution (control area/postal code area/grid nodes) of the remedial actions coincides with the spatial resolution of the aforementioned RES infeeds.

| **Can you provide us with** | **Yes** | **No** |
|---|---|---|
| **Starting time, duration and disconnected power of the remedial actions undertaken to** | | |
| • wind parks | ☐ | ☐ |
| • solar parks | ☐ | ☐ |

*Comments:*

### 3.1.3 Integrating uncertainty in short-term trading

#### *3.1.3.1 Power delivery*

| Can you provide us with | Yes | No | Time resolution if "Yes" (1/4 hourly, hourly, …) | Regional resolution if "Yes" |
|---|---|---|---|---|
| **Realized power plant production** | ☐ | ☐ | | |
| *Comments:* | | | | |
| **Day-ahead power plant production schedules** | ☐ | ☐ | | |
| *Comments:* | | | | |
| **Intraday power plant production schedules** | ☐ | ☐ | | |
| *Comments:* | | | | |

For each "yes" answer, could you indicate in the "comment" box if this provided data is included in the existing DACF and snapshot files? Do you plan to include such data in future DACF and snapshots using the CIM format? If this is an additional data source, could you indicate the associated format?

#### *3.1.3.2 Procedure regarding power plant production schedules (if the schedules are available)*

| | | Day (d=day of delivery, d-1=day ahead, d+1=following day etc.) | Time (please fill in) |
|---|---|---|---|
| **Day-ahead** | When do you get the schedules? | | |
| | When does the schedule period start? | | |
| | When does the schedule period end? | | |
| | What is the time resolution of the schedules? | | |
| *Comments:* | | | |
| **Intraday** | When do you get the latest schedules? | | |
| | When does the schedule period start? | | |
| | When does the schedule period end? | | |
| | What is the time resolution of the schedules? | | |
| *Comments:* | | | |

#### *3.1.3.3 Historical data availability*

| Since when are this data available | Month | Year |
|---|---|---|
| • day-ahead production schedules | | |
| • intraday production schedules | | |

*Comments:*

Could you please indicate in the comment box what is the data format associated with these historical data.

#### *3.1.3.4 Trading schedules*

| Can you provide us with | Yes | No | Time resolution if "Yes" (1/4 hourly, hourly, …) |
|---|---|---|---|
| **Realized trading schedules between your area and neighboring control areas** | ☐ | ☐ | |
| *Comments:* | | | |
| **Day-ahead trading schedules between your area and neighboring control areas** | ☐ | ☐ | |
| *Comments:* | | | |
| **Intraday trading schedules between your area and neighboring control areas** | ☐ | ☐ | |
| *Comments:* | | | |

For each "yes" answer, could you indicate in the "comment" box if this provided data is included in the existing DACF and snapshot files? Do you plan to include such data in future DACF and snapshots using the CIM format? If this is a additional data source, could you indicate the associated format?

#### *3.1.3.5 Procedure regarding trading schedules (if the schedules are available)*

| | | Day (d=day of delivery, d-1=day ahead, d+1=following day etc.) | Time (please fill in) |
|---|---|---|---|
| **Day-ahead between control areas** | When do you get the schedules? | | |
| | When does the schedule period start? | | |
| | When does the schedule period end? | | |
| | How often is the schedule updated (if it is updated)? | | |
| | What is the time resolution of the schedules? | | |
| *Comments:* | | | |
| **Intraday** | When do you get the schedules at the latest? | | |
| | When does the schedule period start? | | |

| | | | |
|---|---|---|---|
| | When does the schedule period end? | | |
| | How often is the schedule updated (if it is updated)? | | |
| | What is the time resolution of the schedules? | | |

*Comments:*

### *3.1.3.6 Historical data availability*

| **Since when are this data available** | **Month** | **Year** |
|---|---|---|
| • day-ahead schedules between your area and neighboring control areas | | |
| • day-ahead schedules within you control area | | |
| • intraday between your area and neighboring control areas | | |
| • intraday within you control area | | |

*Comments:*

Could you please indicate in the comment box what is the data format associated with these historical data.

### 3.1.4 Integrating uncertainty in load forecasts and power plant outages

#### *3.1.4.1 Day-ahead load forecasting and realized values*

| Can you provide us with | Yes | No | Time resolution if "Yes" (1/4 hourly, hourly, …) | Regional resolution if "Yes" |
|---|---|---|---|---|
| **Realized total grid load (measured or extrapolated)** | ☐ | ☐ | | |
| *Comments:* | | | | |
| **Realized vertical grid load (measured flows between the DSO and the TSO)** | ☐ | ☐ | | |
| The vertical grid load is the sum of all electrical energy flowing from the transmission grid via directly connected transformers and lines to distribution networks and ultimate consumers. (Definition of German regulator BNetzA; transmission grid is assumed to be 380 kV and 220 kV level; pumps of pump storage plants and import/export to neighbouring TSOs are not considered – Please write a comment, if you have another definition.)<br>*Comments:* | | | | |
| **Predicted (day-ahead) total grid load** | ☐ | ☐ | | |
| *Comments:* | | | | |
| **Predicted (day-ahead) vertical grid load (flows between the DSO and the TSO)** | ☐ | ☐ | | |
| The vertical grid load is the sum of all electrical energy flowing from the transmission grid via directly connected transformers and lines to distribution networks and ultimate consumers. (Definition of German regulator BNetzA; transmission grid is assumed to be 380 kV and 220 kV level; pumps of pump storage plants and import/export to neighbouring TSOs are not considered – Please write a comment, if you have another definition.)<br>*Comments:* | | | | |

For each "yes" answer, could you indicate in the "comment" box if this provided data is included in the existing DACF and snapshot files? Do you plan to include such data in future DACF and snapshots using the CIM format? If this is an additional data source, could you indicate the associated format?

#### *3.1.4.2 Procedure regarding day-ahead load forecasting (if forecast data can be provided)*

For the most detailed forecast deliverable

| | | **Day (d=day of delivery, d-1=day ahead, d+1=following day etc.)** | **Time (please fill in)** |
|---|---|---|---|
| **Load** | When do you get the forecast? | | |
| | When does the forecast period start? | | |
| | When does the forecast period end? | | |
| | How often is the forecast updated (if it is updated)? | | |
| | What is the time resolution of the forecast? | | |

*Comments:*

#### *3.1.4.3 Historical data availability*

| **Since when are this data available** | **Month** | **Year** |
|---|---|---|
| • day-ahead loads | | |
| • forecast margin | | |

*Comments:*

Could you please indicate in the comment box what is the data format associated with these historical data.

#### *3.1.4.4 Unplanned power plant outages*

| **Can you provide the occurrence and duration of unplanned power plant outages** | **Yes** | **No** | **Technical resolution (for reach fuel type, for each generation unit, …)** |
|---|---|---|---|
| **In your control area** | ☐ | ☐ | |

*Comments:*

If “yes”, do this apply to all generating units of the controlled area or only to those above a given nominal power?
In this case, please indicate the nominal power: ____________.

#### *3.1.4.5 Unplanned power plant outages in subordinated grids*

| **Can you provide the outage data also for subordinated grids** | **Answer** |
|---|---|
| • yes, in the same temporal and spatial resolution as in our grid | ☐ |

| | |
|---|---|
| • yes, but with limitations (please use the comment line to put down the limitations) | ☐ |
| • No | ☐ |

*Comments:*

*3.1.4.6 Planned power plant unavailability*

| **Can you provide the occurrence and duration of planned power plant unavailability** | **Yes** | **No** | **Technical resolution (for reach fuel type, for each generation unit, …)** |
|---|---|---|---|
| **In your control area** | ☐ | ☐ | |

*Comments:*

### 3.1.5 Deriving forecast distributions for the system state

#### *3.1.5.1 System State Parameters (grid topology, voltage set points, tap positions)*

| Can you provide us with | Yes | No | Time resolution if "Yes" (1/4 hourly, hourly, …) |
|---|---|---|---|
| **Realized grid topology (switching operation)** | ☐ | ☐ | |
| **Planned grid topology (switching operations)** | ☐ | ☐ | |
| *Comments:* | | | |
| **Computed voltages of the realized system** | ☐ | ☐ | |
| **Voltage set points of the realized system** | ☐ | ☐ | |
| **Voltages set points of the forecasted system** | ☐ | ☐ | |
| **Computed voltages values of the forecasted system** | ☐ | ☐ | |
| *Comments:* | | | |
| **Computed phase angles of the realized system** | ☐ | ☐ | |
| **Computed phase angles of the forecasted system** | ☐ | ☐ | |
| *Comments:* | | | |
| **Realized/measured taps** | ☐ | ☐ | |
| **Predicted taps** | ☐ | ☐ | |
| *Comments:* | | | |

For each "yes" answer, could you indicate in the "comment" box if this provided data is included in the existing DACF and snapshot files? Do you plan to include such data in future DACF and snapshots using the CIM format?  If this is a additional data source, could you indicate the associated format?

Here you can make suggestions for other relevant system state parameters we should incorporate in our analysis:

*3.1.5.2 System state forecasting procedure (if forecast data can be provided)*

| | | Day (d=day of operation, d-1=day ahead, d+1=following day etc.) | Time (please fill in) |
|---|---|---|---|
| Grid topology | When do you get the plan? | | |
| | When does the planning period start? | | |
| | When does the planning period end? | | |
| | How often is the plan updated (if it is updated)? | | |
| | What is the time resolution of the plan? | | |

*Comments:*

| | | | |
|---|---|---|---|
| Voltage | When do you get the forecast? | | |
| | When does the forecast period start? | | |
| | When does the forecast period end? | | |
| | How often is the forecast updated (if it is updated)? | | |
| | What is the time resolution of the forecast? | | |

*Comments:*

*3.1.5.3 Historical data availability*

| Since when are this data available | Month | Year |
|---|---|---|
| • grid topology | | |
| • voltage set points | | |
| • computed voltage values | | |
| • computed phase angles | | |

*Comments:*

Could you please indicate in the comment box what is the data format associated with these historical data.

## 3.2 Part II: exchanged data

### 3.2.1 DACF

*Included Information*

| Is this information in your DACF data sets included | Yes | No |
|---|---|---|
| Scheduled active power exchange | ☐ | ☐ |
| Scheduled topology | ☐ | ☐ |
| Scheduled voltage set points | ☐ | ☐ |
| Scheduled tap positions | ☐ | ☐ |
| Scheduled active loads | ☐ | ☐ |
| Scheduled reactive loads | ☐ | ☐ |
| Scheduled generation schedules | ☐ | ☐ |
| Scheduled generation (P, Q) limits | ☐ | ☐ |
| Hourly data | ☐ | ☐ |
| • If you do not submit hourly values within your DACF data set, please indicate the number of submitted values a day | | |
| *Comments:* | | |

Can you provide us with the DACF historical data?
☐ Yes
☐ No

If yes, from which starting date?

### 3.2.2 Snapshots

Can you provide us with the snapshot historical data over the same period of time ?
☐ Yes
☐ No

### 3.2.3 Power plants

Having a list of the power plants (or if possible a list of individual generation units) in your control area, providing information on the plants connected to the grid nodes, would make our work easier. Thereby, a reference list with information about the fuel type, year of construction, nominal power and minimal power is sufficient. For that, please answer the subsequent questions.
Can you provide us with a list of power plants that inject directly into your grid?
☐ Yes, for the years ____________
☐ Yes, but only for power plants with a nominal power greater than ____________ MW.
☐ No
*Comments:*

### 3.2.4 Network security calculation

There are several degrees of freedom within the implementation of network security calculations. Especially the consideration of exceptional and out of range types of contingencies lies in the responsibility of TSOs. This paragraph faces questions regarding implementation and interpretation of network security calculations.

#### *3.2.4.1 Contingencies:*

What kinds of contingencies are taken into account within the network security calculation? (n-1) denominates the outage of a single element. (n-2) specifies a common mode failure or two independent outages.

| | **All** | **Only important elements** | **None** |
|---|---|---|---|
| (n-1) line 380 / 400 kV | ☐ | ☐ | ☐ |
| (n-1) double circuit line 380 / 400 kV | ☐ | ☐ | ☐ |
| (n-1) transformer 380 / 400 kV | ☐ | ☐ | ☐ |
| (n-1) DC Link 380 / 400 kV | ☐ | ☐ | ☐ |
| (n-1) generation unit 380 / 400 kV | ☐ | ☐ | ☐ |
| (n-2) generation unit 380 / 400 kV | ☐ | ☐ | ☐ |
| (n-1) busbar 380 / 400 kV | ☐ | ☐ | ☐ |
| (n-1) line ≤ 220 kV | ☐ | ☐ | ☐ |
| (n-1) double circuit line ≤ 220 kV | ☐ | ☐ | ☐ |
| (n-1) transformer ≤ 220 kV | ☐ | ☐ | ☐ |
| (n-1) generation unit ≤ 220 kV | ☐ | ☐ | ☐ |
| (n-2) generation unit ≤ 220 kV | ☐ | ☐ | ☐ |
| (n-1) busbar ≤ 220 kV | ☐ | ☐ | ☐ |
| (n-1) large voltage compensation installation | ☐ | ☐ | ☐ |
| Others: | ☐ | ☐ | ☐ |

Can you provide us with a list of exceptional type of contingencies?

☐ Yes
☐ No

Are you able to provide the additional information (if relevant) associated with your contingencies?

| | All | Only important elements | None |
|---|---|---|---|
| probabilities of occurrences | ☐ | ☐ | ☐ |

*3.2.4.2 Operating limits:*

Which operating limits are evaluated based on the quasi-stationary network security calculation? Please check “Voltage Stability” only if there is an additional criterion besides absolute voltage values to guarantee operation above critical voltage.

| | Evaluated in (n-1) | Evaluated in (n-0) | Not Evaluated |
|---|---|---|---|
| Thermal Limits | ☐ | ☐ | ☐ |
| Voltage Limits | ☐ | ☐ | ☐ |
| Short Circuit Currents | ☐ | ☐ | ☐ |
| Voltage Stability | ☐ | ☐ | ☐ |
| Voltage Phase Angle Difference | ☐ | ☐ | ☐ |
| If you run online dynamic simulations: Critical Fault Clearing Time | ☐ | ☐ | ☐ |
| Others: | ☐ | ☐ | ☐ |

Please use the comment box to precise if these limits are evaluated in “operational planning”, “near real time”, “real time”

Which of these operating limits are typically causing need for remedial actions?

| | Often | Rarely | Never |
|---|---|---|---|
| Thermal Limits | ☐ | ☐ | ☐ |
| Voltage Limits | ☐ | ☐ | ☐ |
| Short Circuit Currents | ☐ | ☐ | ☐ |
| Voltage Stability | ☐ | ☐ | ☐ |
| Voltage Phase Angle Difference | ☐ | ☐ | ☐ |
| If you run online dynamic simulations: Critical Fault Clearing Time | ☐ | ☐ | ☐ |
| Others: | ☐ | ☐ | ☐ |

#### 3.2.4.3 *TATL:*

The overloaded operation of equipment can be acceptable according to Temporary Admissible Transmission Loadings (TATL). Please provide typical values for TATL by utility type and overloading.

| TATL of current limits [minutes] | **5%** | **10%** | **20%** | **30%** |
|---|---|---|---|---|
| Overhead line | | | | |
| Transformer | | | | |

#### 3.2.4.4 *Voltage operating limits:*

The operational limits regarding voltage are dependent on type and age of equipment used. Please provide typical values for minimum and maximum voltage limits as well as for target voltage.

| Voltage [kV] | **Minimum** | **Target** | **Maximum** |
|---|---|---|---|
| (n-0) - busbar 380 / 400 kV | | | |
| (n-1) - busbar 380 / 400 kV | | / | |
| (n-0) - busbar ≤ 220 kV | | | |
| (n-1) - busbar ≤ 220 kV | | / | |

### 3.2.5 Topology description

#### 3.2.5.1 *Busbar configuration:*

The configuration of busbars and circuit breakers has significant influence on possible switching measures in network operation. Therefore it is important to identify frequently used busbar topologies for adequate modeling of topology modifications.

Which busbar topologies are currently used in your transmission network?

| 380/400 kV voltage level | **Frequently** | **Rarely** | **Not in use** |
|---|---|---|---|
| Single busbar | ☐ | ☐ | ☐ |
| Double busbar | ☐ | ☐ | ☐ |
| Triple busbar | ☐ | ☐ | ☐ |
| Ring bus | ☐ | ☐ | ☐ |
| Breaker and a half | ☐ | ☐ | ☐ |
| Others: | ☐ | ☐ | ☐ |

| ≤ 220 kV voltage level | Frequently | Rarely | Not in use |
| --- | --- | --- | --- |
| Single busbar | ☐ | ☐ | ☐ |
| Double busbar | ☐ | ☐ | ☐ |
| Triple busbar | ☐ | ☐ | ☐ |
| Ring bus | ☐ | ☐ | ☐ |
| Breaker and a half | ☐ | ☐ | ☐ |
| Others: | ☐ | ☐ | ☐ |

*3.2.5.2 “Bus branch” and “node breaker” topology description:*

What level of detail could you provide to describe the topology of your network?

| | Always | Sometimes | Never |
| --- | --- | --- | --- |
| Basic “Bus branch” description: no switches modelled between the buses | ☐ | ☐ | ☐ |
| More detailed “Bus branch” description: switches modelled between the buses | ☐ | ☐ | ☐ |
| “Node breaker” description (detailed topology) | ☐ | ☐ | ☐ |

In the case you are providing the “detailed Bus branch description” do you use the modeled switches to describe complex topological modifications (in a contingency context or in a remedial action context)?

☐ Yes
☐ No

In the case you are able to provide a “node breaker” description, in what format will you provide it?

_____________________.

### 3.2.6 Remedial actions

There are several remedial actions available to cope with contingencies in network operation. The selection of appropriate remedial measures is dependent on their availability, temporal constraints and costs. This paragraph faces the current use of remedial measures as well as their temporal and technical constraints.

Which remedial measures are currently used? How often are they applied?

| | **Often ~1/day** | **regularly ~1/week** | **Rarely ~1/month** | **Never < 1/year** |
|---|---|---|---|---|
| Topology modification | ☐ | ☐ | ☐ | ☐ |
| Redistribution of load/generation per busbar | ☐ | ☐ | ☐ | ☐ |
| Transformer tap position modification | ☐ | ☐ | ☐ | ☐ |
| PST tap position modification | ☐ | ☐ | ☐ | ☐ |
| Modification of the set point of a HVDC | ☐ | ☐ | ☐ | ☐ |
| Redispatching of generators | ☐ | ☐ | ☐ | ☐ |
| Redispatching of load | ☐ | ☐ | ☐ | ☐ |
| Counter trading | ☐ | ☐ | ☐ | ☐ |
| Others: | ☐ | ☐ | ☐ | ☐ |

Are the remedial measures applied in a preventive (anticipating a contingency) or curative (realized after the occurrence of a contingency) way?

| | **Preventive** | **Curative** | **Not in use** |
|---|---|---|---|
| Topology modification | ☐ | ☐ | ☐ |
| Redistribution of load/generation per busbar | ☐ | ☐ | ☐ |
| Transformer tap position modification | ☐ | ☐ | ☐ |
| PST tap position modification | ☐ | ☐ | ☐ |
| Modification of the set point of a HVDC | ☐ | ☐ | ☐ |
| Redispatching of generators | ☐ | ☐ | ☐ |
| Redispatching of load | ☐ | ☐ | ☐ |
| Others: | ☐ | ☐ | ☐ |

Please give an order of magnitude for temporal constraints in realization of remedial measures:

| [minutes] | Time to activation (while running) |
|---|---|
| Topology modification | |
| Redistribution of load/generation per busbar | |
| Transformer tap position modification | |
| PST tap position modification | |
| Modification of the set point of a HVDC | |

Please provide typical values of technical and temporal constraints of plants participating in redispatch:

| | Time to activation (from idle state) | Time to activation (while running) | Maximum power gradient | Minimum time of operation | Minimal power ( % / P_max ) | Not participating in redispatch |
|---|---|---|---|---|---|---|
| Nuclear | | | | | | |
| Lignite | | | | | | |
| Coal | | | | | | |
| Gas / Oil | / | / | / | / | / | / |
| -turbine | | | | | | |
| -steam turbine | | | | | | |
| -combined cycle | | | | | | |
| Industrial load | | | | | | |
| Others: | | | | | | |

Which cost components are currently included in costs of redispatching? Which cost components will be included in future scenarios?

| | Included | Not included |
|---|---|---|
| Startup costs | ☐ | ☐ |
| Power based cost component | ☐ | ☐ |
| Energy based cost component | ☐ | ☐ |
| Others: | ☐ | ☐ |

For some contingencies, can you provide a list of preventive actions?

☐ Yes
☐ No

If yes, what kind of additional information would be able to provide related to preventive actions?

| | yes | no |
|---|---|---|
| Level of priority | ☐ | ☐ |
| Scope of applicability: | ☐ | ☐ |

## 3.3 Part III: Sharing dynamic data:

### 3.3.1 Generalities: Detailed description of further information exchange and knowledgesharing among TSOs

Both of the projects have the need for dynamic data on global level and historical measurements/recordings of critical events which impact the entire synchronous area of Central Europe. In order to optimize the timing, resources and budget of both of the projects it was already agreed between both of the projects, synergies between existing and on-going studies and data already available within ENTSOE and among the TSOs in the ownership of previous TSO-studies related to this topic will be used.

The projects will provide simulation results for the validation of the Pan European model when build and used for dynamic risk assessment in the project based on agreed and collected synchronized measurements/recordings (WAMS/PMUs).

Specification of dynamic data required to TSOs/ENTSO-E

**Machines and equivalent generators**

All the machines connected to the 400kV and 225 kV network are represented individually. All the machines less than 100 MW are neglected unless their aggregate is over 100 MW. For aggregates over 100 MW see internal equivalent generator (IEG) below.

Two types of equivalent generators are required:

- **External Equivalent Generators** (EEG) for the surrounding systems of the global UCTE network: they are aggregates of the units connected to the transmission grid of the system which is not described in details in the UCTE model; each aggregate corresponds to a fuel type and is consistent with a type of regulation. Each aggregate is in the range of 100 MW – 2000 MW. Aggregates less than 100 MW are neglected. No aggregate is over 2000 MW (arbitrary limit). A too strong equivalent could indeed have a non realistic participation to oscillation modes. EEG are connected to equivalent step up transformers.

- **Internal Equivalent Generators** (IEG) represent units connected to lower voltage grid (110 kV and less) or to aggregates over 100 MW on the transmission grid. Each TSO should provide the appropriate representation bearing in mind that the size of the DRM cannot increase drastically. Therefore the equivalent under laying network should be as reduced as possible. All aggregates will be over 100 MW and consistent with a machine model and regulation type (wind aggregate, hydraulic aggregate,…).

All the equivalents generators have to be clearly identified as EEG (External Equivalent Generator) or IEG (Internal Equivalent Generator) in the data provided by the TSO’s. The behaviour of these equivalents as well as their contribution to the potential oscillation modes has indeed to be analyzed separately from those of the real machines.

**Block Transformer Data**

- Vector group (Yy,Yd,Dy,Dd,Y0)
- Classification figure (00,05,06,11)
- Nominal system voltage [kV]

- Rated apparent power [MVA]
- uRr [%] (uRr > 0)
- ukr [%] (ukr > uRr)
- Generator Connection Point
- Nominal system voltage [kV]

**Models of excitation, voltage regulation, turbine and speed control**

The simplest and most accepted way is to use well known IEEE-standard models. All IEEE standard models can be used. In the following those models are described in detail that satisfies the modeling needs in the most cases. If some specific models exist, for which it is not possible to work with IEEE-models, a detailed specific block diagram can be used.

For nominated data (per unit) the base for it (for example nominal apparent power, nominal voltage, no load generator field voltage on air gap line) is needed.

**Excitation system models and voltage regulation**

For modeling the excitation system including the voltage control it is recommended to use the IEEE standard models. For additional information on excitation systems refer to /1, 2/.
Each standard type is represented by a block diagram and the parameter.
When Power System Stabilizer (PSS) are used the block diagram and the Parameter for the PSS should be given.

/1/ IEEE Recommended Practice for Excitation System Models for Power System Stability Studies, IEEE Transactions on Power Apparatus and Systems, Vol. PAS-100, No. 2, February 1981

/2/ IEEE Recommended Practice for Excitation System Models for Power System Stability Studies, IEEE Std 421.5, August 1996

As example of the expected models, the following IEEE models are useful.

- IEEE Type DC 1
- IEEE Type AC 1
- IEEE Type ST 1

**IEEE Power System Stabilizer (PSS)**

**Turbine models, speed and power control**

The recommended simplified models for the turbine and turbine control are the IEEE standard model. If the model should prove insufficient to the behaviors in your power plants, please provide the real structure with their parameters. Please include the primary control ability in this part of the model.

For steam turbines, the recommended IEEE models are presented in /3/.

/3/ Working Group Report: Dynamic Models for Fossil Fuelled Steam Units, IEEE Transactions on Power Systems, Vol. 6, No. 2, May 91

For large hydro power plants, it is recommended to use IEEE methods /4/ for simplified modeling the turbine and the controller taking into account the static head deviation.

/4/ IEEE Working Group Report: Hydraulic Turbine and Turbine Control Models for System Dynamic Studies: Transactions on Power Systems Vol.7, No.1; February 1992

For gas turbines and combined cycles, the recommended IEEE models are presented in /5/

/5/ IEEE Working Group Report: Dynamic Models for Combined Cycle Plants in Power System Studies. Transactions on Power Systems Vol.9, No.3, August 1994

**Load models**

The load characteristic is described by load parameters according to following equations:

$P_0$ = nominal active power of load,

$Q_0$ = nominal reactive power of load,

$V_0$ = nominal bus voltage,

$f_0$ = nominal frequency

The voltage and frequency dependences of the load are described by the exponent parameters α, β, γ and δ :

$$P = P_0\,(\Delta V/V_0)^{\alpha}\,(\Delta f/f_0)^{\gamma}$$

$$Q = Q_0\,(\Delta V/V_0)^{\beta}\,(\Delta f/f_0)^{\delta}$$

The typical parameters for the average system load are 0, 1 or 2. If no data are available in the dynamic analysis standard values will be assumed and validated by the recordings from WAMS.

Further details will be specified in a separate questionnaire for dynamic data for an ENTSO-E request.

### 3.3.2 Dynamic data

#### *3.3.2.1 Tools:*

What tools are you using for your own dynamic studies?

| | |
|---|---|
| PSS/E | ☐ |
| Netomac | ☐ |

| | |
|---|---|
| Digsilent | ☐ |
| EUROSTAG | ☐ |
| Other | ☐ |

*3.3.2.2 Available data formats:*

Can you provide the data used for these dynamic simulations (dynamic files and regulations) in the format associated with one of these tools:

| | **Dynamic files** | **Regulations** |
|---|---|---|
| PSS/E | ☐ | ☐ |
| Netomac: | ☐ | ☐ |
| Digsilent | ☐ | ☐ |
| EUROSTAG | ☐ | ☐ |
| Other | ☐ | ☐ |

*3.3.2.3 DRM data:*

In addition, do you accept that both projects use data contained in the DRM?

☐ yes ☐ No

If you can only provide DRM data, could you explain if the differences are important between the data contained in the DRM and the data you are currently using for your own dynamic simulations?

## 3.4 Part IV: time records:

### 3.4.1 Available measurements:

Can you provide us with the synchrophasor measurements available in your network?

☐ All ☐ Some ☐ None

Can you list the measurements you can provide on your network? (PMUs, WAMS)

| Name | Location | Measured variables | Frequency |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |