European Network of
Transmission System Operators
for Electricity

Task Force Code – System Dynamic Issues for the synchronous zone of Continental Europe

- Final -

RG-CE System Protection & Dynamics Sub Group

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1. Introduction

The sub group System Protection and Dynamics (SG SPD) is dealing with operational issues related to dynamic stability of the synchronous zone of Continental Europe, including topics such as defence plans and system protection issues. For the network code implementation, SG SPD executed various studies in order to provide guidance on specific issues related to the network codes. The main focus is put on dynamic system aspects related to Continental Europe, but the methodologies might also be relevant for other synchronous zones.

The current document provides a brief overview on how the different dynamic aspects were analysed as well as references to the detailed reports delivered by specific task forces. All reports are published on the ENTSO-E webpage, see /4-7/:

Initially, the identification of the specific tasks was performed by scanning the following codes with respect to system dynamic aspects, namely:

a. Guideline for System Operation /1/
b. Requirement for Generators /2/
c. Demand Connection Code /3/
d. Emergency and Restoration Code (will follow as soon as the code is ready)

For this activity the following background reports are available from SG SPD:

- Inertia Report /4/
- Critical Fault Clearing Time (CFCT) /5/
- Dynamic Security Analysis (DSA) /6/
- Overfrequency Control Schemes (OFCS) /7/

2. Inertia report /4/

One of the future challenges will be the significant increase of rate of change of frequency in the case of events causing a sudden power imbalance. This is due to the substitution of synchronous generation by inertia-less generation connected through a power-electronic interface. For the normal interconnected operation the available amount of inertia is sufficient so far, considering the normative loss of 3000 MW in the CE power system. The most critical situations will instead occur if the system encounters a system split during high power exchange conditions possibly triggered by poorly damped system oscillations. A guidance for minimum inertia calculation is given in /4/.

3. Critical Fault Clearing Time /5/

/1/ requires the TSOs to check the protection setttings against generator critical fault clearing time. /5/ is intended to provide a common understanding of the impacting factors related to the calculation of Critical Fault Clearing Time and specify a methodology for the calculation. The report focuses on synchronous generation and does not address issues related to asynchronous generators or generators with a converter-based interface.

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4. Dynamic Security Analysis (DSA) /6/

Among others, /1/ requires that the dynamic security assessment shall be executed within the scope of daily operational processes if dynamic limits of the grid are met before its steady state limits. This dynamic assessment shall capture the relevant dynamic issues related to the generation mix and commercial exchanges based on /4-6/. The current status of dynamic security assessment within CE as well as future recommended approaches are documented in /6/.

5. Overfrequency Control Schemes (OFCS) /7/

This report /7/ addresses requirements to the Limited Frequency Sentive Mode for overfrequency (LFSM-O) to be implemented in power generating modules and in HVDC links to prevent the creation of an overfrequency island due to black out after a system split. The idea is to use LFSM-O to reduce the power injection and thus match the load of the island. The report addresses the recommended settings related to droop settings and reaction speed considering the maximum rate of change of frequency.

6. Other aspects related to system dynamics and codes implementation

The following sections highlights other aspects related to system dynamics to dealt with in the implementation of network codes. Due to the fundamental changes in the operational aspects of the European power system it is necessary to put high emphasis on the dynamic issues to guarantee the security of supply. The system stability is becoming more dependent on new active and passive devices whose dynamic behaviour will have to be carefully analysed.

Dynamic stability models

Model requirements are highly dependent on the dynamic phenomena which are involved in a specific study. One of the main challenges is determining the appropriate level of simplification to ensure sufficient model accuracy, performance and numerical robustness.

Depending on the need and nature of stability model calculations, the individual dynamic models differs with respect to the exact time domain and the required level of detail. Ensuring the right balance between complexity, robustness and effort for model calibration and maintenance is permanently required. However, due to interoperability reasons the use of standard models instead of specific user-defined models is recommended.

In order to analyse the dynamic stability of the power system all TSOs have to set up dynamic models of their systems. These models are in use in the time frame of system planning, system extension studies or detailed event analysis.

Besides the exchange of detailed system dynamic data between neighbouring TSOs, a dynamic model of the CE power system is available for third-parties and will be updated on a regular basis, see /8/. The corresponding model is tailored in such a way that it could be used by all interested and affected players as e.g. TSOs, DSOs, GenCos, manufacturers, consultants and academia.

The system load itself is also undergoing a significant change with respect to dynamic response due to increased usage of power-electronic connected load. This aspect will have to be increasingly taken into consideration as well as the mix of distributed generation and load on lower voltage levels. This implies consideration of related modelling needs and related connection and disconnection behaviour during large voltage or frequency disturbances. How loads might help to stabilise the system and protect it from a blackout is described in /11/.

Dynamic model validation

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In order to assess the dynamic power system performance. accurate measurements of voltage, power or frequency shall be available. Transient recorders or PMU-based measurement systems deliver the required time synchronised measurements which are a pre-requisite for analysing time sequences of measurements collected from different locations of the interconnected system. However, as no common standards for calculating the rate of change of the frequency are yet available, this will have to be specified in the future. In addition, the data exchange formats, acquisition rate and measurements accuracy will have to be commonly agreed. For electromechanical transients, a sampling rate of 100 ms was found to be adequate.

Detection of poorly damped oscillations

During the the last years several events with poorly-damped inter-area oscillations were recorded e.g. /9, 10/. These oscillations were detected by the existing CE WAM systems and subsequently analysed by experts. The conclusions and recommendations gained are in line with the efforts to ensure enough system damping by proper tuning of all relevant power plant controllers as well as by active damping devices close to system loads including the ability of HVDC links to also contribute to the overall system damping.

Detection could be managed:

1. In real time, mainly thanks to algorithms implemented in WAMS (Power Oscillation Monitoring, Modal Analysis tools); in some cases, TSOs have decided visualize alarms in Control Room /10/
2. In DSA /6/ systems, in real time or off line, by detecting a significant decrease of damping in simulations.

Minimum inertia

One of the future challenges is the significant increase of rate of change of the frequency in the case of events causing a sudden power imbalance. This is due to the substitution of synchronous generation by inertia-less generation connected through a power-electronic interface.

For the normal interconnected operation, the inertia is sufficient considering the normative loss of 3000 MW in the CE power system. The most critical situations will instead be if the system undergoes a system split during high power exchange conditions possibly triggered by poorly damped system oscillations. A guidance for minimum inertia calculation is given in /4/.

7. Outlook

The most important dynamic aspects for Continental Europe related to codes implementation are addressed in the references to this "umbrella" paper.

However, for some specific issues more detailed guidance and support will have to be futher developed. The following issues are subject to future activities

- Recommnedations for measurement of rate of change of frequency for different applications.
- PMU data exchange formats, acquisition rate and measurements accuracy
- Dynamic load models considering power-electronics
- Compliance testing. Based on the fact that the number of providers for various system services is increasing, the exact, transparent and detail-related quality requirements will have to be defined. Based on these requirements dedicated tests for prequalification to deliver ancillary services or simple compliance testing with respect to dynamic capabilities will have to be developed.

8. References

[1] Guideline for System Operation
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1485&from=EN

[2] Requirements for Generators
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0631&from=EN

[3] Demand Connection Code
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R1388&from=EN

[4] Inertia Report
https://www.entsoe.eu/Documents/SOC%20documents/RGCE_SPD_frequency_stability_criteria_v10.pdf

[5] Critical Fault Clearing Time Report
https://www.entsoe.eu/Documents/SOC%20documents/Regional_Groups_Continental_Europe/2017/SPD_FCT-BestPractices_website.pdf

[6] Dynamic Security Analysis Report –
https://www.entsoe.eu/Documents/SOC%20documents/Regional_Groups_Continental_Europe/2017/DSA_REPORT_Public.pdf

[7] Overfrequency Control Scheme Report
https://www.entsoe.eu/Documents/SOC%20documents/Regional_Groups_Continental_Europe/2017/170926_RG_CE_TOP_08.1_D.2_SPD_Codes_TF_v6_Overfrequency_Control_Schemes.pdf

[8] Dynamic Data Model
https://www.entsoe.eu/publications/system-operations-reports/continental-europe/Initial-Dynamic-Model/Pages/default.aspx

[9] Italy Oscillation
https://www.entsoe.eu/fileadmin/user_upload/_library/publications/entsoe/RG_SOC_CE/Top7_110913_CE_inter-area-oscil_feb_19th_24th_final.pdf

[10] Iberian Oscillation
https://www.entsoe.eu/Documents/SOC%20documents/Regional_Groups_Continental_Europe/2017/CE_inter-area_oscillations_Dec_1st_2016_PUBLIC_V7.pdf

[11] Requirements for UFLS settings
- https://www.entsoe.eu/Documents/Publications/SOC/Continental_Europe/141215_Technical_background_for_LFDD.pdf

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