4th SO ESC meeting
Ljubljana | 12 June 2018
Dynamic Stability Assessment / Minimum Inertia

Knud Johansen

12 June 2018

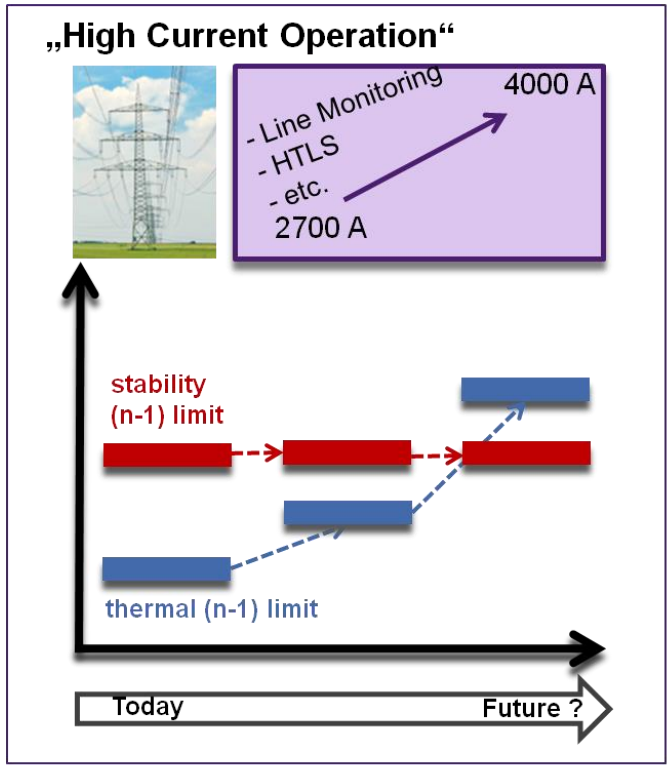
AGENDA

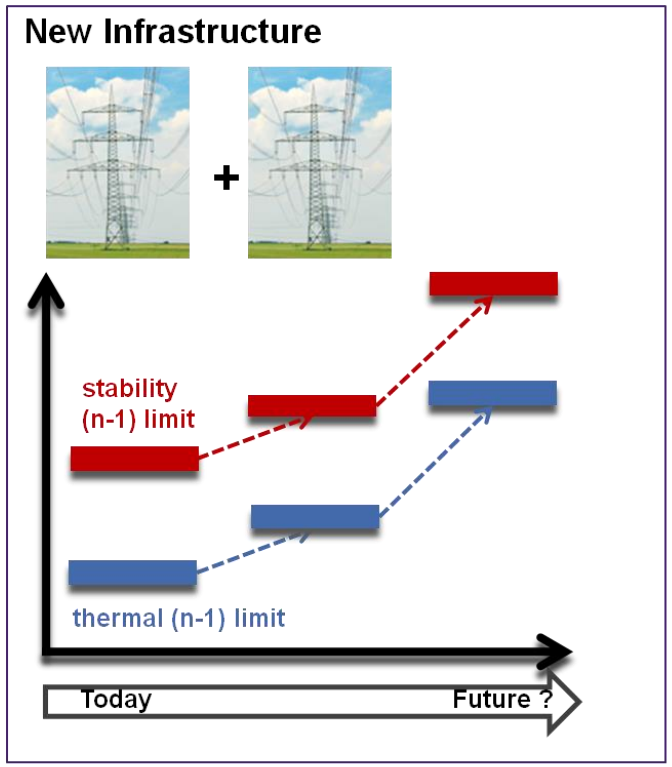
1. Activities in ENTSO-E on DSA & Minimum Inertia
2. Current practice in RG CE, RG Nordic, RG GB, RG IE/NI, RG Baltic
3. Conclusions and wrap up of stakeholder workshop
4. Road map proposal

Activities organized by ENTSO-E

- In May 2017 the DSA Project was established with the main objective to coordinate activities on fulfillment of SO GL requirements.
- Coordination until now has mainly been facilitated through ENTSO-E TSO workshops
- Two ENTSO-E - TSO workshops have been performed:
  - November 2017.
  - April 2018.
- Goals of the TSO workshops:
  - to acquaint TSO experts with the SO GL requirements
  - To gather and exchange information on current practices
  - To discuss how coordination at regional levels can be secured
- 3rd TSO workshop will be organized for Sep 18th, 2018
- Stakeholder workshops:
  - 1st DSA stakeholder workshop took place on May 23rd, 2018.
  - 2nd DSA stakeholder workshop will be organized for Oct 30th, 2018.

Why DSA



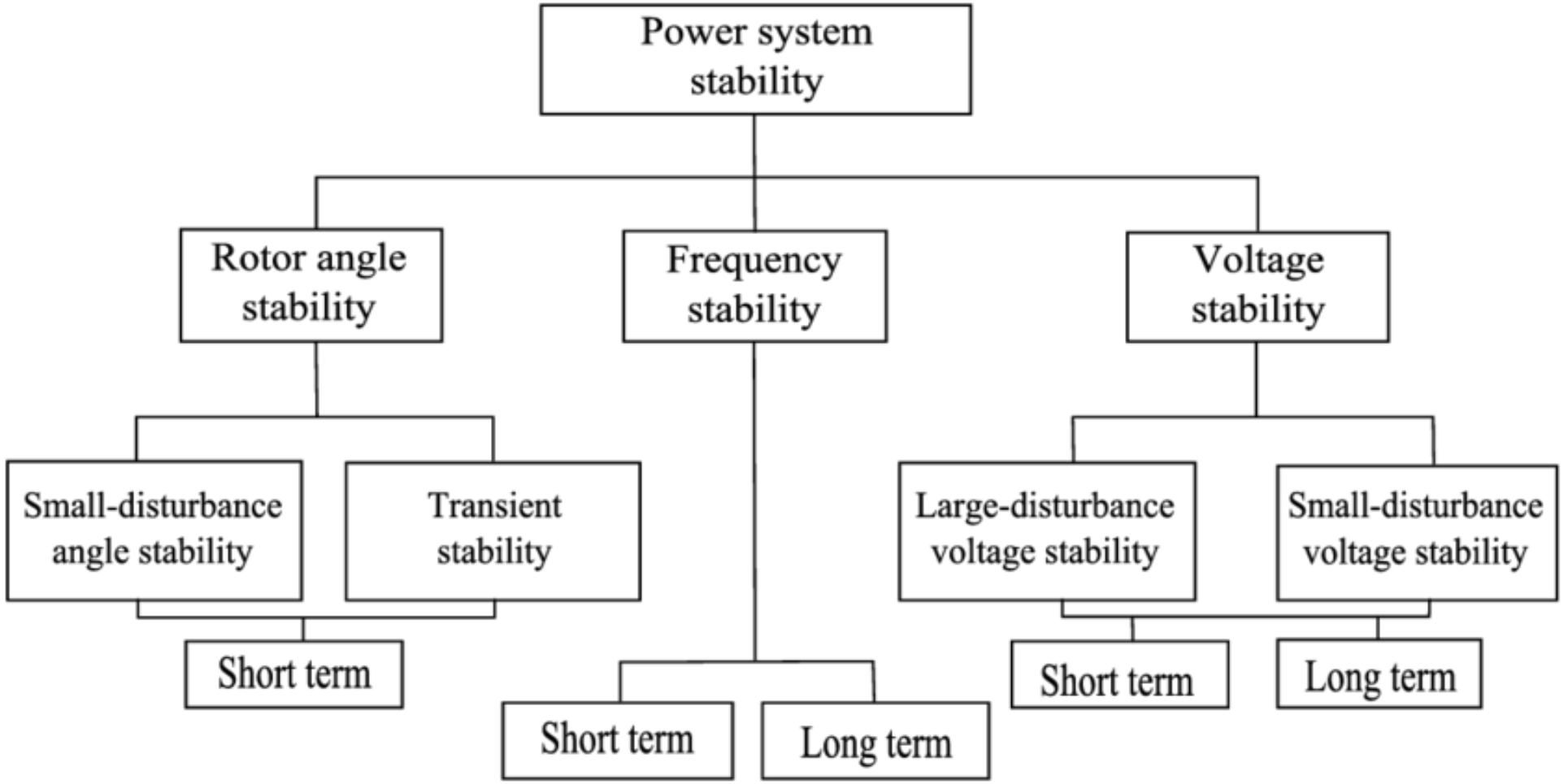


Country	Mean duration to build new lines
Austria	3
Belgium	5
Danmark	2,5
Finland	5
France	6,5
Germany	10
Greece	6
Poland	4
Portugal	2
Sweden	7

- (n-1) contingency analysis is not enough!
- Additional calculations are required

Source SPD WS 10. Nov. 2010, Brussels

What is DSA concerned about?



Definition and classification of power system stability IEEE/CIGRE joint task force on stability terms and definitions, IEEE Transactions on Power Systems, Aug. 2004

RG CE - conclusion

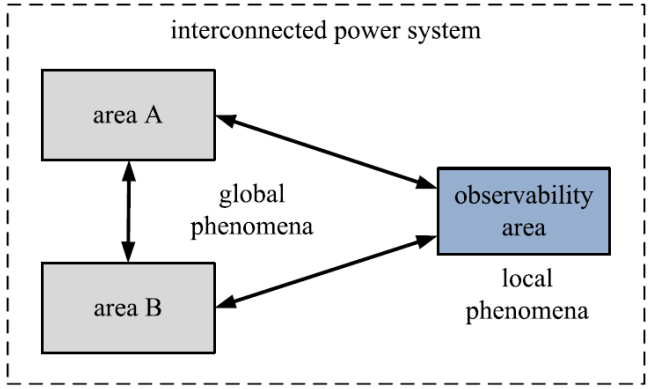
Article 38 (No deadline in SO GL but "*..some feedback on yearly DSA and coordination should arrive in the beginning of 2019*")

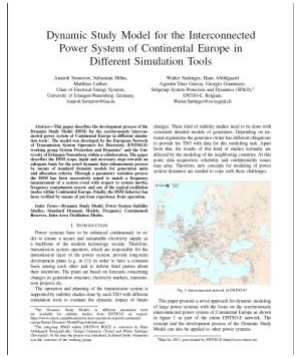
- Dynamic models will be available for TSOs to execute DSA studies

Article 39 (Deadline SO GL EIF 14/9/2017+2 years)

- Ready for Continental Europe
- Short report consolidating existing results ~ Q2 2019

- For RG CE dynamic analysis at operational timescales is carried out at TSO level for rotor angle and voltage stability issues where applicable
- For RG CE frequency system stability is not an issue in normal and alert state. For now definition of a minimum inertia tipping point for interconnected operation is not required
- In case of system split, various scenarios have been investigated (for emergency state). The methodology for establishing such scenarios is still subject for discussion.
- RG CE expert group for system stability (SPD group) will continuously monitor system disturbances (in particular inter area oscillations), propose mitigation measures and validate dynamic system models.




Dynamic Study Model for the Interconnected Power System of Continental Europe in Different Simulation Tools

Dynamic Study Model for the Interconnected Power System of Continental Europe in Different Simulation Tools. PowerTech, 2015 EES, SPD.

RG CE - Further reading

System Dynamic Issues for the synchronous zone of Continental Europe

- https://docstore.entsoe.eu/Documents/SOC%20documents/Regional_Groups_Continental_Europe/2017/170926_RG_CE_TOP_08_1_D_1_SPD_Codes_TF_v5_System_Dynamic_Issues_for_CE.pdf

Frequency stability evaluation criteria (Inertia Report)

- https://www.entsoe.eu/Documents/SOC%20documents/RGCE_SPD_frequency_stability_criteria_v10.pdf

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

Critical Fault Clearing Time Report

- https://www.entsoe.eu/Documents/SOC%20documents/Regional_Groups_Continental_Europe/2017/SPD_FCT-BestPractices_website.pdf

Dynamic Security Analysis Report

- https://www.entsoe.eu/Documents/SOC%20documents/Regional_Groups_Continental_Europe/2017/DSA_REPORT_Public.pdf

Initial Dynamic Model

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

Frequency measurement requirements and usage

- https://docstore.entsoe.eu/Documents/SOC%20documents/Regional_Groups_Continental_Europe/2018/TF_Freq_Meas_v7.pdf

Requirements for UFLS settings

- https://www.entsoe.eu/Documents/Publications/SOC/Continental_Europe/141215_Technical_background_for_LFDD.pdf

RG NORDIC - performing DSA

Off-line studies already possible:

- Nordic planning model (PSS/E) – N, S, FI for DSA
- Svk and SN use also Aristo for DSA
- Energinet is using DigSilent PowerFactory for DSA

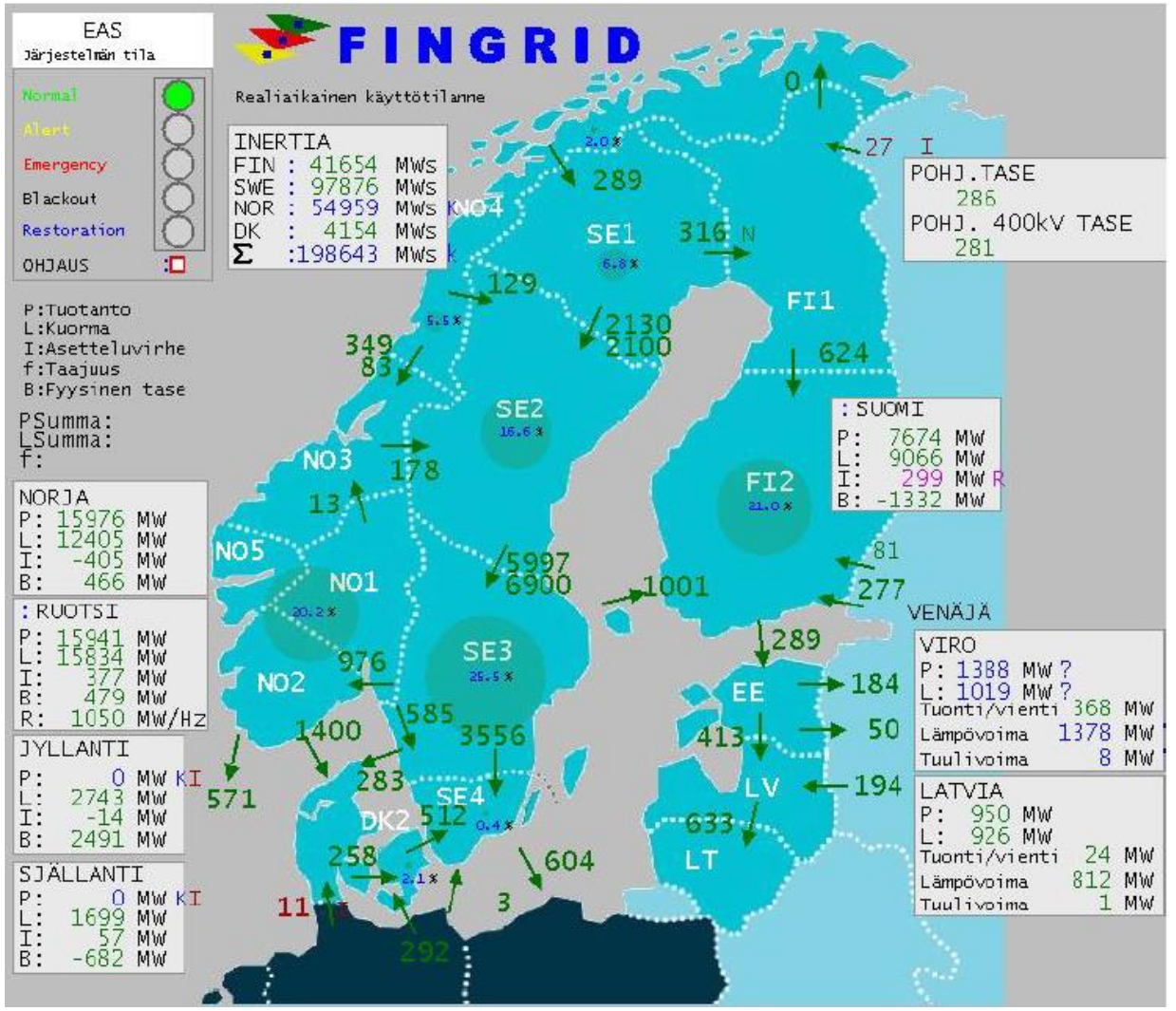
In future nearly real-time DSA becomes possible:

- Common grid model will include dynamic models
- Many of the dynamic models in Nordic planning model will need to be revised in order to suit CGMES-standard

Inertia monitoring

- Tool developed to monitor system inertia at real time level in the Nordic region
- Bottom-up approach
  - Based on breaker state and power measurements
- Visualized in each Nordic control room
- Further reading see:

[Nordic report Future system inertia]



RG NORDIC - Handling low inertia situations

Several measures for handling low inertia cases have been identified to be further investigated:

- synthetic inertia
- hydro power plants running at minimum active power or as synchronous compensators
- reducing the size of the dimensioning incident
- adjustable parameters for power plants contributing to FCR

Suitable measures will be agreed on in Nordic System Operation Agreement

RG GB - Dynamic stability monitoring and assessment (Art.38)

SOGL Article number	Current approach in GB
38.1 and 38.2	Dynamic assessment is already carried out
38.3 and 38.4	NGET is sole entity with SO responsibility for coordinated dynamic stability in GB synchronous area
38.5	Not relevant for GB synchronous area as transmission system is not AC-interconnected
38.6	Dynamic assessment rules specific to GB synchronous area

RG GB - Dynamic stability management (Art.39)

Article number	NGET compliance
39.1	In the case of violation of stability limits, NGET has a process to carry out remedial actions
39.2	Process for clearing faults in time is calculated through dynamic system assessment
39.3	Current studies are based on reduction of largest loss, there is no set minimum inertia. - Minimum inertia study is not yet carried out

NG proposes maintaining dynamic stability requirements at a synchronous level in accordance with the existing approach

RG IE / NI - Implementation of Article 38 (Dynamic Stability Monitoring and Assessment)

Wind Dynamic Security Assessment Tool (WSAT) automatically runs every 5 minutes (24/7 – 365) in both Ireland (IE) and Northern Ireland (NE) Electricity Control Centers

WSAT provides Grid Controllers with a real-time information and advice on operational security of the Grid

This goes even beyond the most strict requirement of Article 38 – paragraph 38(6)(c)

Conlcusion: for RG IE/NI the requirements of Article 38 are fully fulfilled

RG IE / NI - Implementation of Article 39 (Dynamic Stability Management - paragraphs 1 and 2)

When WSAT indicates violation of stability limits, it also suggests remedial actions. These are performed by Grid Controllers using approved steps:

- Likelihood of the insecure scenario
- Severity of possible consequences
- Other factors (e.g. weather warnings, existence of substantial outages etc.)
- Action (as recommended by WSAT or/and from previous experience)

Critical Fault Clearance Time (CCT) and Fault-Ride-Through (FRT) requirements are indirect criteria of transient stability. These are to be met at planning stage before generator can be connected to the grid.

WSAT assesses transient stability directly – by running time-domain analysis of system every 5 minutes for the current system state.

Conclusion: for RG IE/NI the requirements of Article 39(1) and Article 39(2) are fully fulfilled

RG Baltic - Brell system

RG Baltic-conclusion

Because of strong connections with Russia dynamic security assesment is not a critical issue.

Currently no issues with minimium inertia criteria have been identified under normal operating conditions.

Main operational security assesments:

- N-1 calculations day ahead and real time.
- Transmission capacity monitoring
- Ensuring baltic area hourly power balance
- FRR activation

DSA stakeholder WS 2018.05.23 – summary & conclusions

1. Participants acknowledged the need for monitoring the system inertia in all synchronous areas for normal and alert operation.
2. Stakeholders suggestion to extend the DSA coordination on agreeing among TSOs on the assumptions on the system split scenarios, including stakeholder's participation.
3. Stakeholders expectation on exchanging information on DSA assessment and management. Workshop concept seems to be an efficient solution.
4. Expectations form stakeholder on establishing a set of clear definitions/requirements on the algorithms/assumptions related to frequency stability aspects (synthetic inertia, fast frequency response functions) in order to enable industry/vendors to provide services.
5. The participants agreed that quality of models used for calculations is a key element for obtaining proper quality of results.
6. Suggestion from stakeholder for the TSOs to take the lead on the RoCoF studies / requirements.
7. Distinction between „network design" and "system design" were proposed as essential in the system stability discussions. The terms could be defined as follows:
   a. "Network design" shall define the dimensioning of the transmission (and distribution) grid infrastructure. One relevant criterion for network design is robustness/resilience against normal and a number of exceptional contingencies (e.g. common mode failures).
   b. "System design" shall define the robustness/resilience of the transmission (and distribution) system against more severe contingencies, which are beyond network design, e.g. exceptional contingencies without a common cause or out-of-range contingencies like system splits. These incidents shall be mitigated by system defense plans, to which all system users shall contribute through their system-supportive behavior, e.g. by contributing to system inertia.
8. ACER requested a pan-European harmonization on scenario assumption and boundary condition for the DSA studies. Eventually a set of reference scenarios as used by EirGrid
9. Special Protection Schemes is considered in the scenarios simulated and presented at the workshop.
10. Investigation of the catalogue of "normative incidents" needs to be reviewed and whether a set reference incidents can be established needs to be discussed at ENTSO-E level. A more detailed look on the definitions on what is normal and what is exceptional must be included in the review.

Roadmap – Dynamic Stability Assessment

1st TSO DSA WS
- Current status of DSA in each region

2nd TSO DSA WS
- Coordination of DSA activities in each region

1st Stkhld WS
- Current status of DSA in the regions

3rd TSO WS
- Coordination of DSA activities and *commonly agreed scenarios*

2nd Stkhld WS
- Further development on DSA – response to pending issues

Additional slides

SO GL art. 38 Dynamic stability monitoring and assessment

1. *Each TSO shall monitor the dynamic stability of the transmission system by studies conducted offline in accordance with paragraph 6. Each TSO shall exchange the relevant data for monitoring the dynamic stability of the transmission system with the other TSOs of its synchronous area.*
2. *Each TSO shall perform a dynamic stability assessment at least once a year to identify the stability limits and possible stability problems in its transmission system. All TSOs of each synchronous area shall coordinate the dynamic stability assessments, which shall cover all or parts of the synchronous area.*
3. *When performing coordinated dynamic stability assessments, concerned TSOs shall determine:*
   a) *the scope of the coordinated dynamic stability assessment, at least in terms of a common grid model;*
   b) *the set of data to be exchanged between concerned TSOs in order to perform the coordinated dynamic stability assessment;*
   c) *a list of commonly agreed scenarios concerning the coordinated dynamic stability assessment; and*
   d) *a list of commonly agreed contingencies or disturbances whose impact shall be assessed through the coordinated dynamic stability assessment.*
4. *In case of stability problems due to poorly damped inter-area oscillations affecting several TSOs within a synchronous area, each TSO shall participate in a coordinated dynamic stability assessment at the synchronous area level as soon as practicable and provide the data necessary for that assessment. Such assessment shall be initiated and conducted by the concerned TSOs or by ENTSO for Electricity.*
5. *When a TSO identifies a potential influence on voltage, rotor angle or frequency stability in relation with other interconnected transmission systems, the TSOs concerned shall coordinate the methods used in the dynamic stability assessment, providing the necessary data, planning of joint remedial actions aiming at improving the stability, including the cooperation procedures between the TSOs.*
6. *In deciding the methods used in the dynamic stability assessment, each TSO shall apply the following rules:*
   a) *if, with respect to the contingency list, steady-state limits are reached before stability limits, the TSO shall base the dynamic stability assessment only on the offline stability studies carried out in the longer term operational planning phase;*
   b) *if, under planned outage conditions, with respect to the contingency list, steady-state limits and stability limits are close to each other or stability limits are reached before steady-state limits, the TSO shall perform a dynamic stability assessment in the day-ahead operational planning phase while those conditions remain. The TSO shall plan remedial actions to be used in real-time operation if necessary; and*
   c) *if the transmission system is in the N-situation with respect to the contingency list and stability limits are reached before steady-state limits, the TSO shall perform a dynamic stability assessment in all phases of operational planning and re-assess the stability limits as soon as possible after a significant change in the N-situation is detected.*

SO GL art. 39 Dynamic stability management

1. *Where the dynamic stability assessment indicates that there is a violation of stability limits, the TSOs in whose control area the violation has appeared shall design, prepare and activate remedial actions to keep the transmission system stable. Those remedial actions may involve SGUs.*
2. *Each TSO shall ensure that the fault clearing times for faults that may lead to wide area state transmission system instability are shorter than the critical fault clearing time calculated by the TSO in its dynamic stability assessment carried out in accordance with Article 38.*
3. *In relation to the requirements on minimum inertia which are relevant for frequency stability at the synchronous area level:*
   a. *all TSOs of that synchronous area shall conduct, not later than 2 years after entry into force of this Regulation, a common study per synchronous area to identify whether the minimum required inertia needs to be established, taking into account the costs and benefits as well as potential alternatives. All TSOs shall notify their studies to their regulatory authorities. All TSOs shall conduct a periodic review and shall update those studies every 2 years;*
   b. *where the studies referred to in point (a) demonstrate the need to define minimum required inertia, all TSOs from the concerned synchronous area shall jointly develop a methodology for the definition of minimum inertia required to maintain operational security and to prevent violation of stability limits. That methodology shall respect the principles of efficiency and proportionality, be developed within 6 months after the completion of the studies referred to in point (a) and shall be updated within 6 months after the studies are updated and become available; and*
   c. *each TSO shall deploy in real-time operation the minimum inertia in its own control area, according to the methodology defined and the results obtained in accordance with paragraph (b).*