System inertia considerations at ENTSO-E

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General observations on system inertia

- It is recognized that system inertia is an essential feature of frequency stability, which is inherently provided mainly through the kinetic energy of rotating masses of synchronous power generating modules
- The increasing displacement of synchronous power generating modules by power generating units connected through power electronics (e.g. wind or PV) reduces system inertia considerably, resulting in higher frequency sensitivity in case of load imbalances
- Depending on the size/characteristics of a synchronous area, frequency stability becomes a major concern under “normal” operating conditions considering single contingencies (e.g. IE or GB) or on case of larger system disturbances (e.g. CE) already nowadays with an increasing tendency
- A measure to mitigate this development is to emulate the transient behavior of synchronous power generating modules (determined by their inherent inertia), i.e. the immediate response to load imbalances through charging or discharging kinetic energy, by a comparable response of other system users
- Since other users cannot provide such response inherently, they need to be technically designed accordingly

ENTSO-E approach and stakeholder interaction

- Because of its character, the topic of system inertia and related issues on stability (frequency, but also voltage phase angle and where applicable voltage stability aspects) are dealt with by ENTSO-E in a coordinated way pursuing a holistic approach
- The fundamental engineering and research work is coordinated by dedicated expert group
- The legislative obligations are analyzed and coordinated by ENTSO-E including:
  - Obligations from Grid Connection Codes & Guidelines
  - Obligations from System Operation Guideline
- Equal information shall be provided to the European Stakeholder Committees through regular reporting of actual development and relevant findings, whereas depending on each Committee, emphasis is put on a given area:
  - Grid connection
  - System Operation
  - Market (whilst no legal obligations, still market considerations because of future services …)

Inertia in context of connection network codes (CNCs) - I

- One objective of connection network codes is to define, that system users are equipped with technical capabilities to ensure adequate performance under normal and disturbed operating conditions to contribute to maintain and restore system security
- The relevant technical capabilities to be established by connection requirements are
  - RfG: synthetic inertia of power park modules
  - DCC: very fast active power control through demand response
  - HVDC: Synthetic inertia of HVDC systems
- All CNC requirements related to synthetic inertia / very fast active power response
  - are non-mandatory at European level and can be made mandatory at national level, if required by the relevant TSO
  - are non-exhaustive requirements, which introduce the capability as such, but would need further specifications at national level
- The coordinated TSO decision-making on introduction of these requirements would be based on a prospect of the longer-term dynamic system performance with focus in frequency sensitivity / stability
- The detailed technical specifications are still subject to research studies to analyse improvements on system stability, but also to identify possible drawbacks because of dynamic interactions
- In order to guide the national decision-making and its preparation, WG CNC has released a series of Implementation Guidance documents (IGDs)

Inertia in context of connection network codes (CNCs) - II

- IGD on High Penetration of Power Electronics Interfaced Power Systems (HPoPEIPS)

Adobe Acrobat Document

- IGD on Need for Synthetic Inertia

Adobe Acrobat Document

- IGD on RoCoF Withstand Capability

Adobe Acrobat Document

- IGD on Fast Fault Current Injection

Adobe Acrobat Document

Inertia studies in context of system design

- Long-term studies on evolution of intrinsic system inertia
- Analysis based on hourly market simulations of all TYNDP scenarios at synchronous area level and for each Member State
- Demonstrating the continuous decrease of intrinsic system inertia over the next years/decades and explanation of the associated challenges and system needs.
- The objective is to state the facts, the associated challenges and the possible solutions in a systematic manner
- These studies do not identify tipping points / reference incidents, for which system stability shall be maintained
- With tipping points / reference incidents to be provided by other workstreams on inertia:
  - Further cost and benefit analysis can be envisaged for identifying measures to preserve a minimum system inertia vs. constraints on instantaneous penetration of non-synchronous power generating modules
- Calculations to be systematically performed by a dedicated team
- Current studies shall inform the TYNDP
- Study results are intended to be published in the context of the TYNDP
- Studies on system inertia development together with knowledge about tipping points / reference incidents provide guidance to TSOs at national / synchronous area level on the urgency to implement the non-mandatory CNC requirements on synthetic inertia / very fast active power response

Inertia & stability in system operation I/IV

- Legal obligations related to stability and inertia in the narrow scope of system operation are defined in SO GL Articles 38-42
  - Art. 38 defines the setup and obligations for stability studies, taking into account priorities and respective treatment, depending on prevailing steady-state or stability limits; moreover, the Art. 38(4) calls for common synchronous-area wide stability assessment in synchronous area in case of stability problems especially due to poorly damped inter-area oscillations
  - Art. 39(3)(a) calls all TSOs of a synchronous area to conduct a study on minimum inertia at latest two years after SO GL EIF for identification of minimum inertia (➔ focus on frequency stability); where applicable, Art. 39(3)(b)-(c).
  - Art. 41(4)(a)(i) requests each TSO to exchange forecast data including the total inertia of its own part of the same synchronous area.
  - Art. 127(8)(a)(i) requests all TSOs to include the inertia of the synchronous area if they change the values for frequency quality specified in the SO GL;
  - Art. 141(1)(a) request all TSOs of each synchronous area shall take into account at least the following criteria: (a) the size and the total inertia, including synthetic inertia, of the synchronous area;
  - Art 153(2)(c) requests all TSOs of the synchronous area shall have the right to define a probabilistic dimensioning approach for FCR taking into account the pattern of load, generation and inertia, including synthetic inertia as well as the available means to deploy minimum inertia in real-time.

Inertia & stability in system operation II/IV

- The annual dynamic stability assessment (as a minimum condition) is already now performed by each European TSO
- The inertia studies at synchronous area level are anticipated to be completed in June/July 2019, which is two years after SO GL EIF and the respective results will be made available both to the TSOs (for their decision on dealing with minimum inertia, if applicable) and to the public via the ENTSO-E
- Inertia studies shall be reviewed periodically and be updated every 2 years
- Besides delivering the criteria for dealing with inertia (i.e. a need for minimum inertia per TSOs of each synchronous area), the study, to be updated bi-annually in the future, will serve as a indicator of the overall system stability development in relation to the continued “disappearance” of rotating masses from the system – i.e. synchronous generators and rotating loads
- The implementation of the system operation framework (SO GL) is hence satisfied with the study and follow-up method for inertia, whereas further implementation and details in relation to the required grid users’ capability might result and demand for consideration in the scope of grid connection codes

Inertia & stability in system operation III/IV

- for RG CE the subgroup System Protection and Dynamics (SPD) is analysing various aspects:
  - System inertia:
    - frequency sensitivity assessments in terms of frequency stability under both normal and exceptional system operating conditions, i.e. system splits with huge load imbalances and low inertia
    - definition of principles to define system user withstand capabilities, e.g. for RoCoF /1/
  - Frequency measurement
    - System requirements to frequency measurement and RoCoF calculation
  - OFCS (overfrequency control schemes) /2/:
    - Approaches for on active power response at high frequency (LFSM-O) and low frequency (LFSM-U)
  - System dynamic security
    - The future role of DSA tools
    - Wide area measurement for real time application
    - System studies on enhanced dynamic model of the synchronous area of continental Europe
- The SPD delivered important information for CNC implementation, in particular for recommendations on non-exhaustive requirements for frequency stability

References:

/1/ Frequency Stability Evaluation Criteria for the Synchronous Zone of Continental Europe, ENTSO-E, March 2016, https://www.entsoe.eu/Documents/SOC%20documents/RGCE_SPD_frequency_stability_criteria_v10.pdf

/2/ Task Force Overfrequency Control Schemes - Recommendations for the Synchronous Area of Continental Europe 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

Inertia & stability in system operation IV/IV

- for RG Nordic the Nordic Analysis Group (NAG) is analysing the minimum inertia aspects:
  - TF Future System Inertia:
    - frequency sensitivity assessments in terms of frequency stability under both normal and exceptional system operating conditions, i.e. large dimensioning faults and low inertia (/1/, /2/)
    - definition of principles to define a minimum inertia /2/
  - Future system inertia:
    - A project group has been established to address the requirements in the SO GL art. 39. A continuation of the analyse results in /2/.
    - First step will be to get proper monitoring of stability margins implemented in the TSO SCADA systems, with corresponding triggering of manual remedial actions.

References:

/1/ ENTSO-E report: Future System Inertia, 2016 - https://www.entsoe.eu/Documents/Publications/SOC/Nordic/Nordic_report_Future_System_Inertia.pdf

/2/ ENTSO-E report: Future System Inertia 2_Vfinal, 2017- *to be published*

Inertia studies in context of market integration

- ENTSO-E internal considerations on inertia as an ancillary service
- main subject under consideration:
  - can (virtual) inertia be procured market-based
  - can it be considered a cross-border market issue
  - what are technical limitations to a market approach

Interrelation of ENTSO-E considerations on inertia

To … / From …	Connection Codes	System design analysis	System Operation Guideline	System stability analysis	Market issues
	Requirements for synthetic inertia / very fast active power response	*Long-term studies on development of inertia per synchronous area / country*	*Studies on system stability (each TSO, annually) and minimum inertia (synchronous area, bi-annually*	*Studies on frequency stability to identify reference cases / tipping points for each synchronous area*	*Identification/definition of frequency-related ancillary services*
Connection Codes		Technical capabilities of system users	Technical capabilities of system users	Technical capabilities of system users	Performance criteria for market products
System design analysis	Need/urgency to define requirements		Awareness for operational challenges	Awareness for operational challenges	Need/urgency to define market products
System Operation Guideline	Criteria to specify requirement details			Triggering further stability analysis	Need/urgency to procure market products
System stability analysis	Criteria to specify requirement details	System design / planning criteria	Criteria to identify critical situations		Need/urgency to procure market products
Market issues			Market products performance	Market products performance	

ENTSO-E deliverables on system inertia I/V

Perspective:	Connection Codes	
Responsible Entity:	WG CNC	
Deliverable(s):	Implementation Guidance on frequency stability requirements	
Format of deliverable(s):	Implementation Guidance Document(s)	
Motivation:	Legal obligation for each Connection Code	
Publication:	√	
Level of coverage:	Pan European	√
	Synchronous Area	√
	Country	
Timing of final deliverable(s):	01/2018	
Source of input:	System stability analysis	
Type of input:	Recommendation on system user parameters for reference cases to be withstood	

ENTSO-E deliverables on system inertia II/V

Perspective:	System design analysis	
Responsible Entity:	WG SDS / DT PS	
Deliverable(s):	Estimation of future system inertia, analysis framework, associated challenges and range of mitigation measures.	
Format of deliverable(s):	TYNDP reports	
Motivation:	Further improve the inclusion of system stability issues in ENTSO-E long term planning analysis. Provide clear and comprehensive approach to better inform on long-term system challenges and needs.	
Publication:	√	
Level of coverage:	Pan European	√
	Synchronous Area	√
	Country	√
Timing of final deliverable(s):	Q1/2018; Q4/2018	
Source of input:	TYNDP scenarios; TF System Indicators	
Type of input:	Market simulations as a basis for calculations	

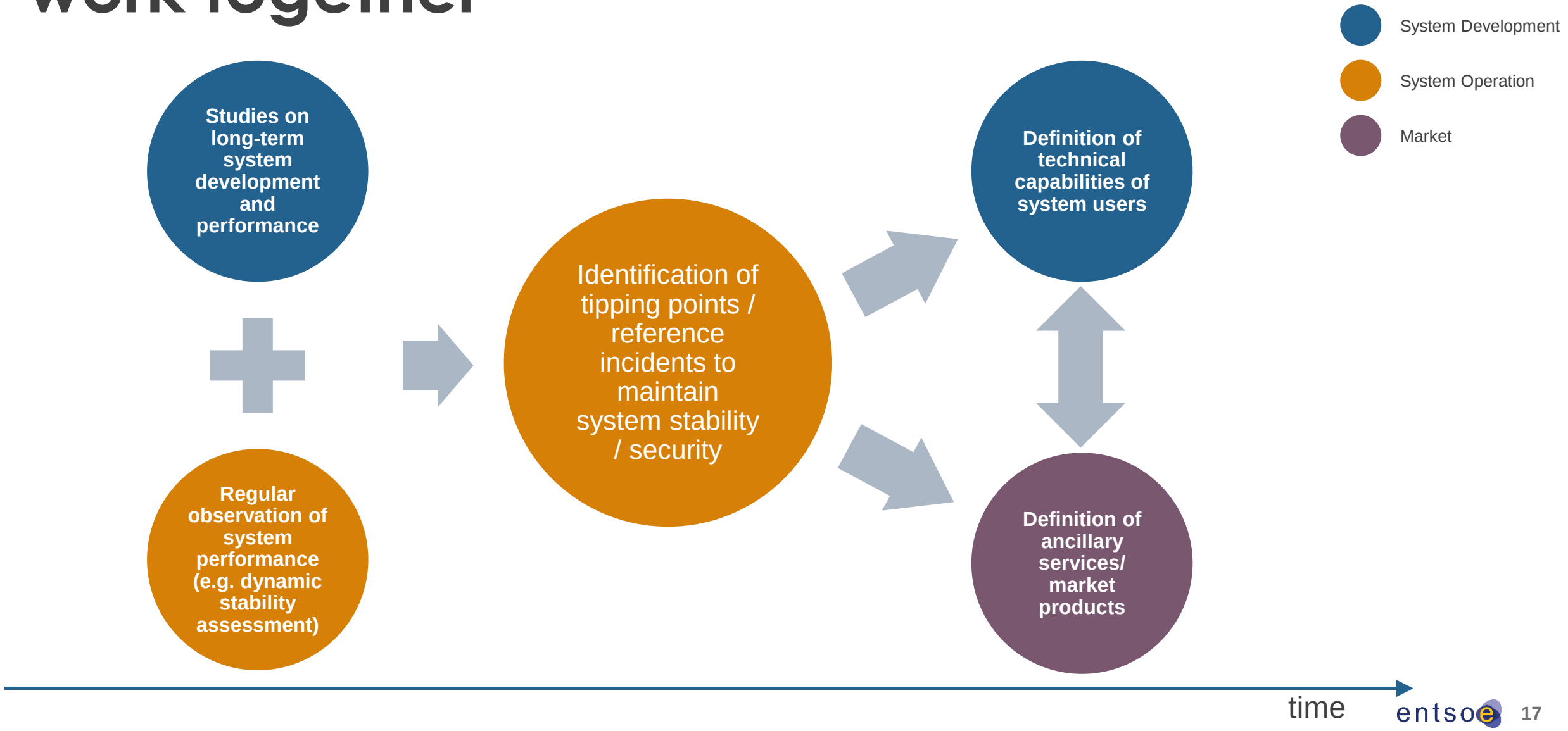
ENTSO-E deliverables on system inertia III/IV

Perspective:	Dynamic Stability Monitoring and Assessment	
Responsible Entity:	StG OF / Coordination Team under SOC	
Deliverable(s):	Regular workshops on dynamic stability assessment practice, guidelines for conducting dynamic studies,	
Format of deliverable(s):	reports on essential findings and case studies of common interest	
Motivation:	Fulfilment of requirements of SO GL art. 38	
Publication:	Reports on current practices, results from regular workshop	
Level of coverage:	Pan European	
	Synchronous Area	√ (reports, studies)
	Country	√ (reports, studies)
Timing of final deliverable(s):	Q3.2019 - periodic reviews and updates every year	
Source of input:	Current practices, workshop(s) conclusions	
Type of input:	Dynamic Stability Assessment (DSA) results and system simulations	

ENTSO-E deliverables on system inertia IV/IV

Perspective:	Dynamic stability management / Minimum inertia	
Responsible Entity:	StG OF / Coordination Team under SOC	
Deliverable(s):	Regular workshops on minimum inertia assessment practice, review of methodology for calculation of minimum inertia. Reports on essential findings and case studies of common interest.	
Format of deliverable(s):	As the case may be: studies, reports and a methodology on defining minimum inertia	
Motivation:	Fulfilment of requirements of SO GL art. 39	
Publication:	Reports on current practices, results from workshops	
Level of coverage:	Pan European	
	Synchronous Area	√ (reports, studies)
	Country	√ (reports, studies)
Timing of final deliverable(s):	Q3/2019 - periodic reviews and updates every 2 years	
Source of input:	Current practices, workshop conclusions	
Type of input:	DSA results and system simulations	

How ENTSO-E considerations on inertia work together



Road map - proposal

2nd TSO DSA WS
Feb 18

Input to NC RfG implementation
Mar/Apr 18

Stakeholder WS
May 18

Regular stability & inertia analysis