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 behaviour 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 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 specialist 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 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)

- IGD on Need for Synthetic Inertia

- IGD on RoCoF Withstand Cpability

- IGD on Fast Fault Current Injection

Inertia studies in context of system design

- Long-term studies on development of system inertia
- Analysis based on TYNDP scenarios at synchronous area level and for each Member State
- Calculations to be systematically performed by a dedicated team
- Demonstrating the continuous decrease of system inertia over the next years/decades
- 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
- 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/III

- Legal obligations related to stability and inertia in the narrow scope of system operation are defined in SO GL Articles 38-39
  - 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 requests each TSO to exchange forecast data including the total inertia of its own part of the same synchronous area and Art. 42 requests each TSO to exchange real-time data.
- The mentioned experts group of ENTSO-E analyses in turn the key elements in relation to inertia impact on frequency in emergency system states, including reference cases for withstanding capabilities like e.g. RoCoF; this group deals also with the overfrequency control schemes

Inertia & stability in system operation II/III

- The annual dynamic stability assessment (as a minimum condition) is already now performed by each TSO
- The bi-annual inertia study is anticipated 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 ENTSO-E
- Besides delivering the criteria for dealing with inertia (i.e. a need for minimum inertia per TSOs of each synchronous area – as the basis for the ENTSO-E wide criteria for minimum inertia), the study, to be updated every two years in the future, will serve as an indicator of the overall system stability development in relation to the continued “disappearance” of rotating masses from the system
- 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/III

- For CE the Regional Group Continental Europe (RGCE) System Protection & Dynamics (SPD) is analysing two aspects:
  - TF 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 (see reference /1/)
  - TF OFCS (overfrequency control schemes):
    - Approaches for on active power response at high frequency (LFSM-O) and low frequency (LFSM-U)
- Both TFs would deliver important information for CNC implementation, in particular for recommendations on non-exhaustive requirements for frequency stability

Reference:

/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

Inertia studies in context of market integration

- ENTSO-E internal considerations on inertia as an ancillary service
- Main subject under investigation:
  - can (virtual) inertia be procured market-based
  - can it be considered a cross-border market issue
  - what are the technical limitations to a market approach
- TSO survey planned, but not issued yet
- Studies/survey was originally considered for internal use only, but could be made public depending on WG decision

Interrelation of ENTSO-E considerations on inertia (I)

From … \ To …	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	

How ENTSO-E considerations on inertia work together