ENTSO-E workshops on Connection Network Code Amendments on (RoCoF and Grid Forming) & Stability Management

ENTSO Public Workshop, 23rd November 2022.

entsoe
Reliable Sustainable Connected

Moderated by Adrian Gonzalez

Agenda

09:00-09:10	Introduction (10min) - Adrian Gonzalez
09:10-09:40	**Proposal of NC RfG amendment with regard to Grid Forming capability (30min) - Mario Ndreko**
09:40-10:30	**Open discussion on GFC and feedback from stakeholders on ENTSO-E proposal (50min)**
10:30-11:00	**Proposal of of NC RfG amendment with regard to RoCoF withstand capability (30min) - Hans Abele**
11:00-11:50	**Open discussion on RoCoF and feedback from stakeholders on ENTSO-E proposal (50min)**
11:50-12:00	Summary and conclusions (10min)

Join also the session 2 (13:00-15:00): “Stability Management in Power Electronics Dominated Systems” focusing on Research, Development and Innovation Challenges

ENTSO-E amendment proposal for NC RfG: on Grid Forming Capability

ENTSO Public Workshop, 23rd November 2022. 09:10-09:40

Presented on behalf of ENTSO-E by Mario Ndreko

entsoe
Reliable Sustainable Connected

Power Park Module (PPM) capabilities in NC RfG

- Frequency ranges
- Voltage ranges
- Reactive power capability
- FRT
- Fast Fault current injection

- FSM
- LFSM-O / U
- Power quality
- Voltage control – steady state
- Voltage control – dynamics
- Power Oscillations Damping

Towards RfG 2.0

- NC RfG 2.0 need to include all the needed capabilities to **safeguard an energy transition under high penetration of RES while ensuring stable and reliable power system.**

- Grid forming capabilities for power park modules (PPMs) are required to ensure stable operation with the high penetration of non-synchronous generation in a 2030-2040 horizon.

NC RfG 2.0 / Grid forming new Article

- ENTSO-E recommends to add a new provision in the NC RfG for grid forming capability followed by a provision for fast frequency control.

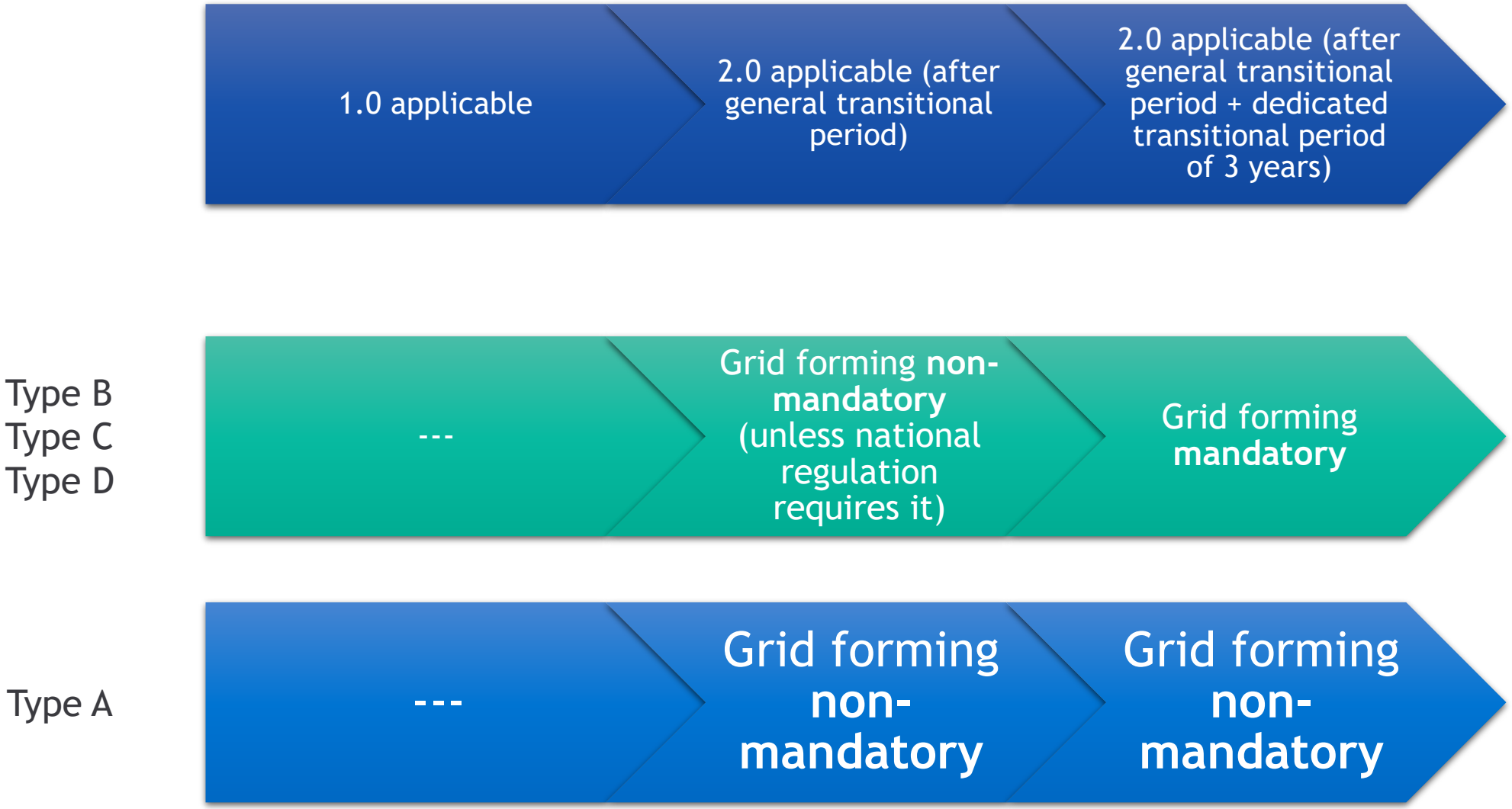
- ENTSO-E recommends this requirement to **be non-mandatory for type B, C, and D PPMs including Electricity Storage Module (ESM) and non exhaustive for a dedicated transitional period for Grid Forming of 3 years**.

  - The transitional period defines the longest period that the requirement will stay as non-mandatory requirement.

  - ENTSO-E recommends that on a member state level, a NRA may make the transitional period shorter based on the urgency and system needs.

- **ENTSO-E recommends this requirement to be mandatory for type B, C, and D PPMs including Electricity Storage Module (ESM) and non exhaustive after dedicated transitional period for Grid Forming.**

NC RfG 2.0 / Grid forming new Article



NC RfG 2.0 / Grid forming new Article / Legal Text

Article Y
(new article, to be placed before current Article 20):

Requirements for type A power park modules

[…]

6. The relevant TSO shall have the right to request grid forming capability from type A PPM at its connection point as defined by the following paragraphs:

a. Within the power park module current limits, the power park module shall be capable of behaving at its connection point as a voltage source behind an internal impedance (Thevenin source), during the normal operating conditions (non-disturbed grid conditions) and quasi immediately after a grid disturbance (including voltage, frequency and voltage phase angle disturbance). The Thevenin source is characterized by its voltage amplitude, voltage phase angle, frequency and internal impedance.

NC RfG 2.0 / Grid forming new Article / Legal Text

Article Y (new article, to be placed before current Article 20)

Requirements for type A power park modules

[…]

b. During the first instant following a grid disturbance and while the power park module capabilities and current limits are not exceeded:

(i) the instantaneous AC voltage characteristics of the Thevenin source according to paragraph (a) shall be capable of not changing its amplitude and voltage phase angle while voltage phase angle steps or voltage magnitude steps (in positive and in negative sequence) are occurring at the connection point (grid side). The positive and the negative sequence current exchanged between the power park module (power park module side) at the connection and AC grid shall flow naturally according to grid and converter impedances.

(ii) The relevant system operator shall specify a minimum time dependent current profile for which the grid forming capability of the power park module is required.

NC RfG 2.0 / Grid forming new Article / Legal Text

Article Y (new article, to be placed before current Article 20)

Requirements for type A power park modules

[…]

c. During the disturbance period (voltage magnitude, frequency and voltage phase angle disturbance) and after the first instant,

(i) The internal voltage magnitude and voltage phase angle of the power park module shall be adapted according to a predefined dynamic performance.

(ii) The power park module active and reactive current adjustment shall always respect the minimum and maximum power park module capability and current limits.

(iii) The TSO may specify additional requirements in the case that current limitation is necessary.

(iv) The power park module shall be capable of stable and smooth transition when reaching the power park module current limits, without interruption, in a continuous manner and returning to the behaviour described in paragraph (b)(ii) as soon as the limitations are no more active.

NC RfG 2.0 / Grid forming new Article / Legal Text

Article Y (new article, to be placed before current Article 20)

Requirements for type A power park modules

[…]

d. The required energy to deliver the minimum capability in paragraph (a) to (b) shall be ensured through the whole active power operating range of power park module.

e. The required dynamic performance of the power park module for the paragraphs (a) to (d) and its associated performance parameters shall be specified by the relevant TSO.

NC RfG 2.0 / Grid forming new Article / Legal Text

Article 20

Requirements for type B power park modules

4. The relevant TSO shall have the right to request grid forming capability at its connection point from type B PPM as listed in Article Y. After a transitional period of maximum 3 years after entering into force, a type B PPM shall be capable of providing grid forming capability requirements at its connection point listed in Article Y. Member states shall have the right to shorten this transitional period based on system needs and urgency.

NC RfG 2.0 / Grid forming new Article / Legal Text

Article 21

Requirements for type C power park modules

[…]
5. A type C PPM may be capable of providing grid forming capability at its connection point as listed in Article Y. After a transitional period of maximum 3 years after entering into force, a type C PPM shall be capable of providing grid forming capability at its connection point. Member states shall have the right to shorten this transitional period based on system needs and urgency. Type C PPMs shall fulfil the following additional requirements in relation to grid forming capability:

a) If applicable according to Article 15.4.(b), the power park module shall be capable of supporting system survival by means of stable and smooth transition towards and from island mode of system operation (islanding), without interruption, in a continuous manner performing the needed active and reactive power adjustments.

NC RfG 2.0 / Grid forming new Article / Legal Text

Article 21
Requirements for type C power park modules

5. [..]

b) The relevant system operator may specify that a study is required (including its scope) in order to ensure that no adverse control interactions occur during the normal operating conditions (non-disturbed grid conditions), quasi immediately after a grid disturbance, during grid fault conditions and during the post fault operation where voltage and frequency profiles have returned to normal operating conditions.

c) If grid forming capability as prescribed in Article Y is requested and if specified by the relevant system operator, in coordination with the relevant TSO, the power park module shall be capable of limiting the transient frequency deviation both in low and/or high frequency regimes. In that case the relevant TSO shall specify the contribution to inertia in Article (Y) paragraph (6)(e).

NC RfG 2.0 / Grid forming new Article / Legal Text

Article 21
Requirements for type C power park modules

5. [..]

d) During the transitional period of maximum 3 years after entering into force and if specified by the relevant system operator, in coordination with the relevant TSO, the power park module shall be capable of limiting the transient frequency deviation both in low and/or high frequency regimes. The following shall apply:

1. The power park module shall be capable of rapidly adjusting the active power injected to or withdrawn from AC grid within its rated power, the contribution is limited only by the maximum energy content of the electricity storage module or primary energy source of the power-generating module. This active power adjustment shall be performed proportional to the measured RoCoF.
2. When the frequency has recovered, the operating point of the power park module shall return to its pre-disturbance active power value.

Coherent requirements in NC HVDC

Towards HVDC 2.0

- In coherence with evolution of RfG towards RfG 2.0, ENTSO-E believes that NC HVDC should also evolve towards HVDC 2.0.
- NC HVDC 2.0 need to include all the needed capabilities to **safeguard an energy transition under high penetration of RES while ensuring stable and reliable power system.**
- Grid forming capabilities for HVDC Systems and DC-connected PPMs are required to ensure stable operation with the high penetration of non-synchronous generation in a 2030-2040 horizon.

09:40-10:30

Open discussion on Grid Forming capability and feedback from stakeholders on ENTSO-E proposal

ENTSO-E amendment proposal for NC RfG: on Rate-of-Change-of-Frequency withstand capability

ENTSO Public Workshop, 23rd November 2022. 10:30-11:00

Presented on behalf of ENTSO-E by Hans Abele

entsoe
Reliable Sustainable Connected

In which situations a Rate of Change of Frequency (RoCoF) appears?

If the balance of load and generation is suddenly disturbed

Disturbances leading to relatively small RoCoF values:

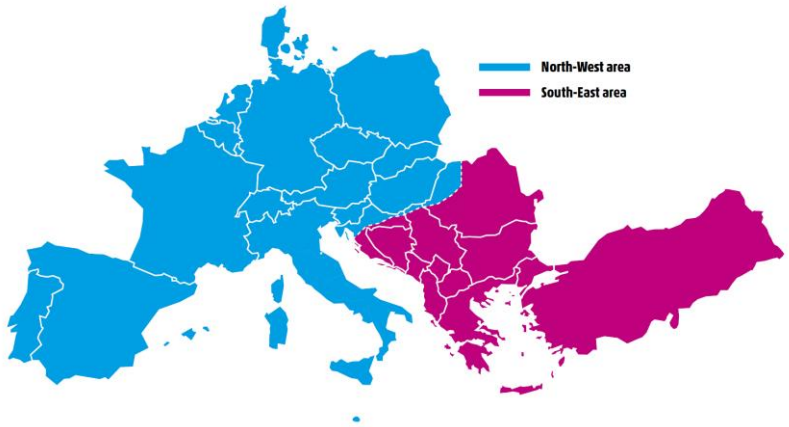
- Loss of load, generation or HVDC links to other synchrous areas
- Causes higher RoCoF values in smaller systems than in larger systems

Disturbances leading to high RoCoF values:

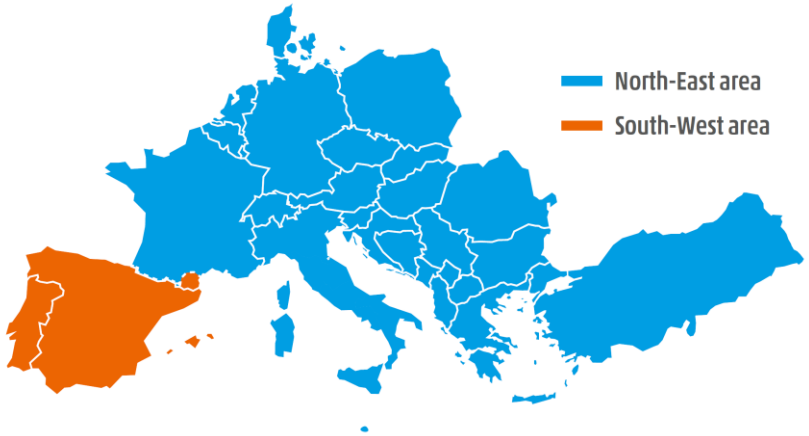
- System Splits

Proposed RoCoF requirement is targeting system splits

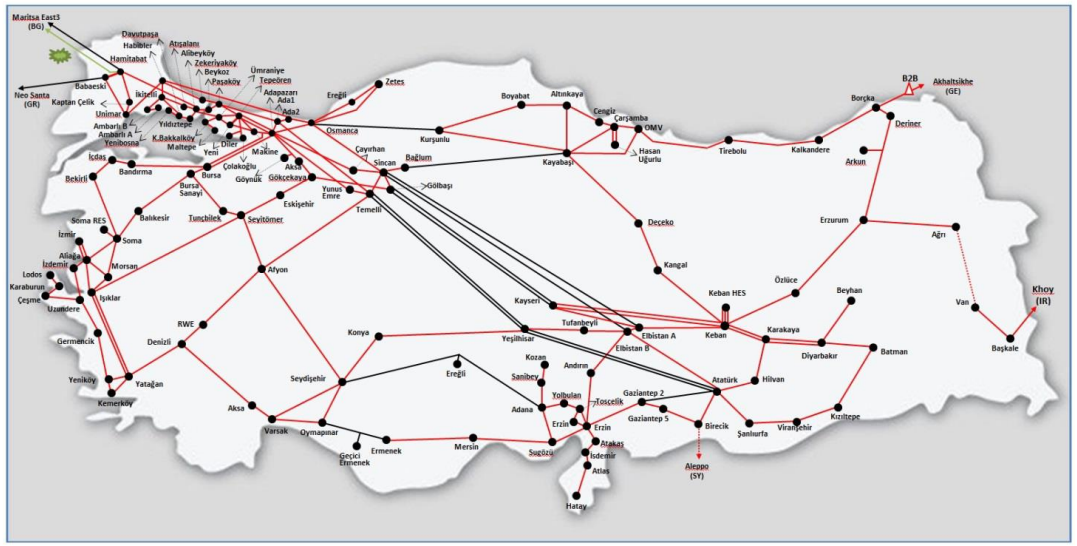
System Splits – are they real?



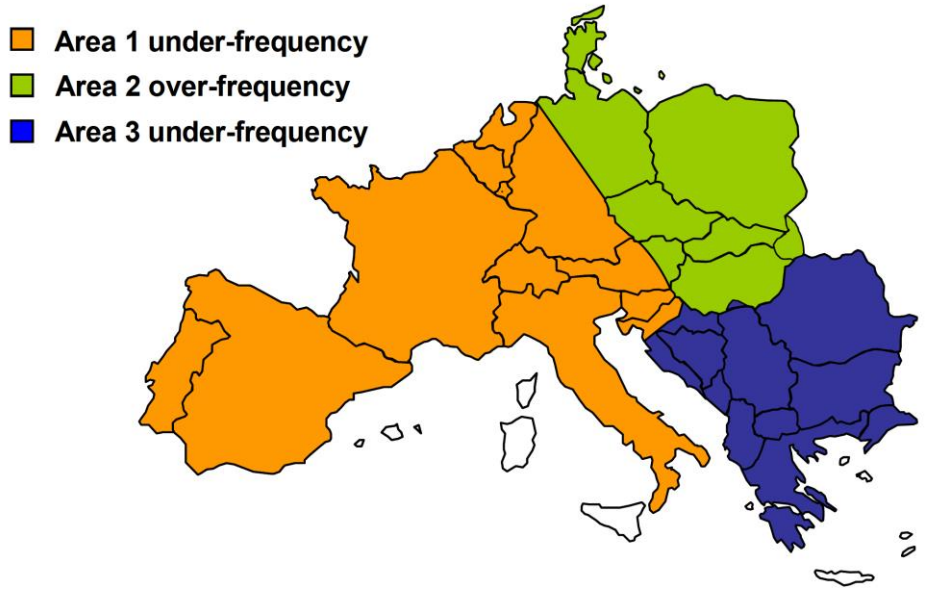
ENTSO-E, "Continental Europe Synchronous Area Separation on 08 January 2021 " Final Report 2022.



ENTSO-E, "Continental Europe Synchronous Area Separation on 24 July 2021 " Final Report "," 2022.



ENTSO-E, "Report on Blackout in Turkey on 31st March 2015, 21 September 2015



UCTE "System Disturbance on 4 November 2006" Final report

RoCoF values of the real system splits

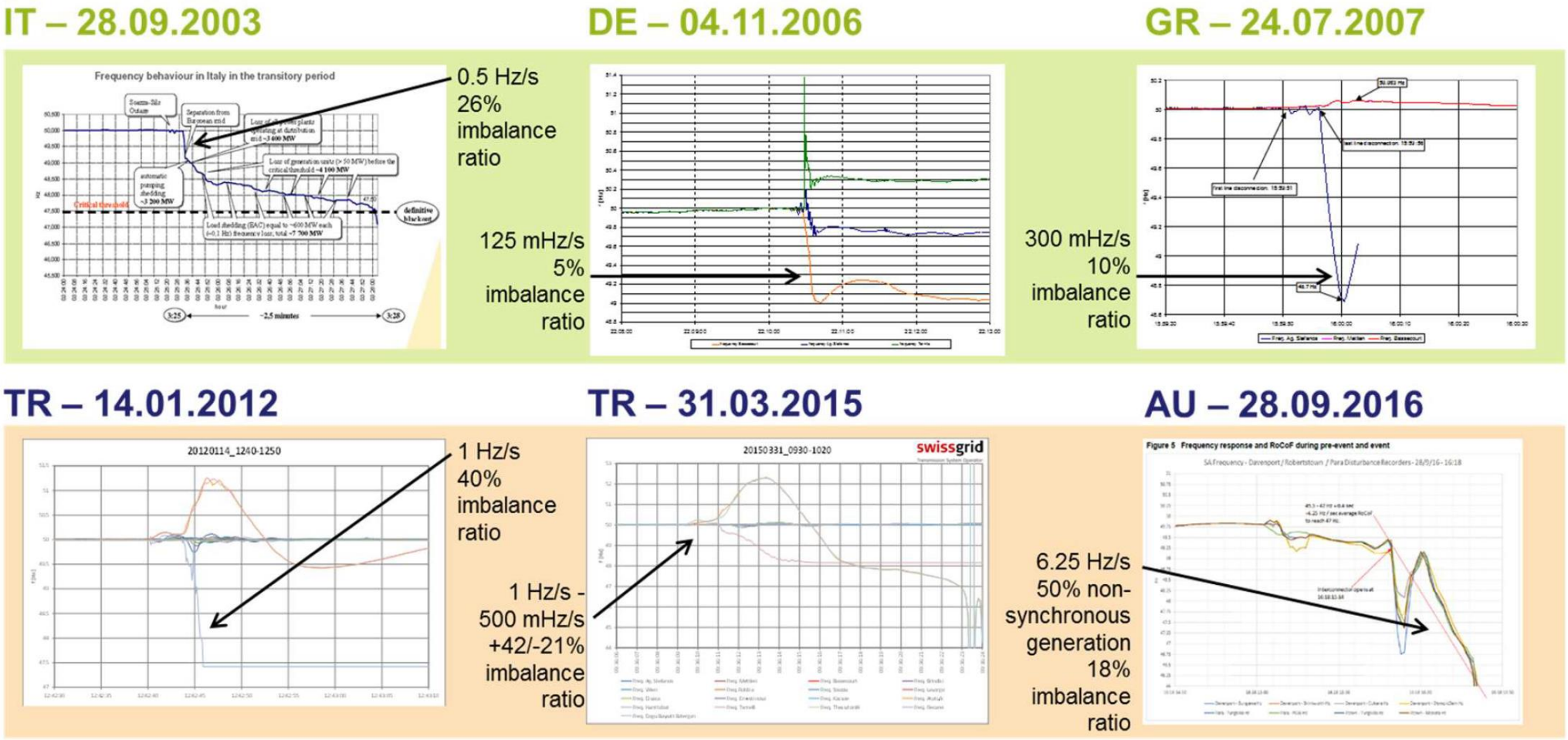
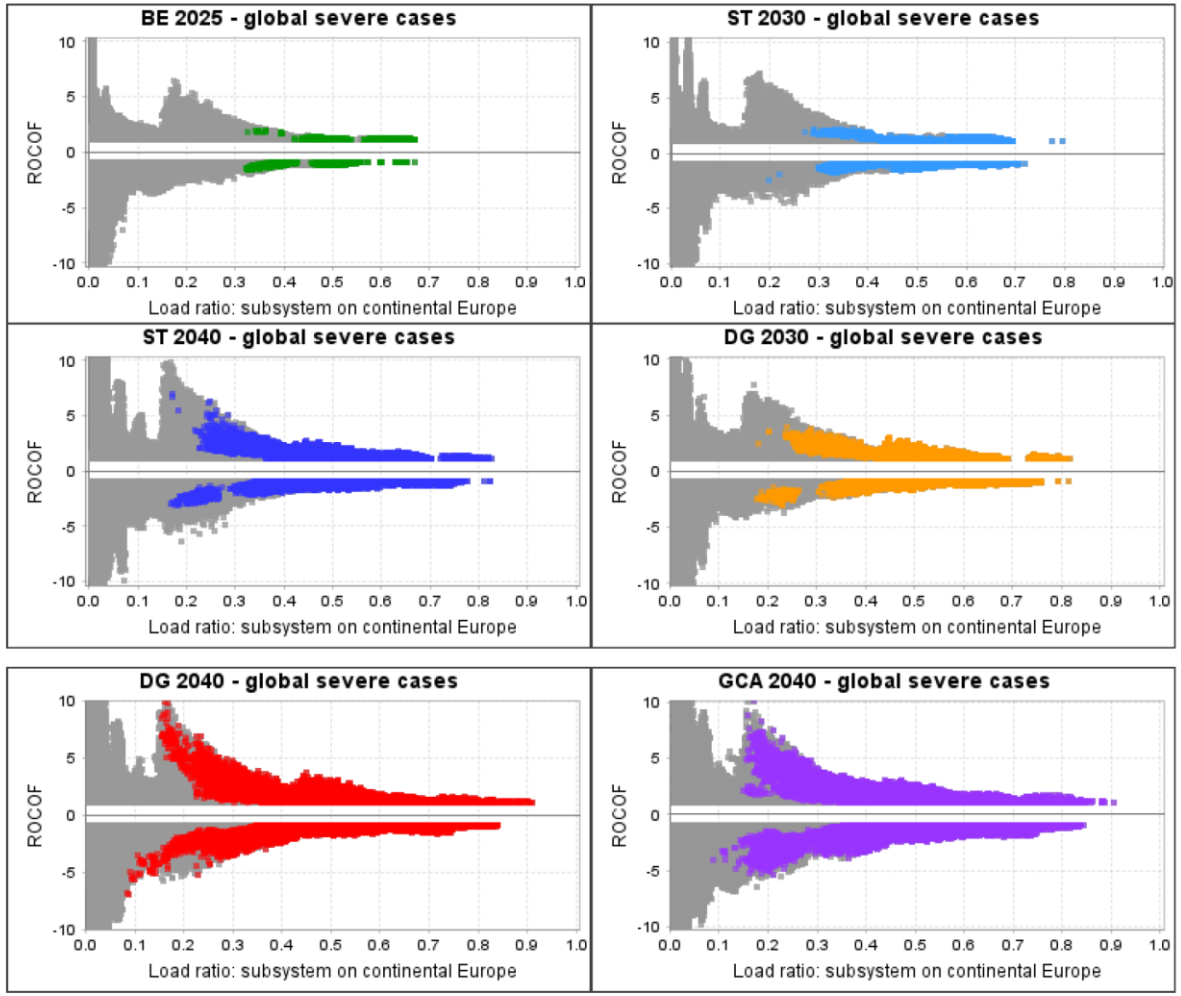


Figure 24 – Worldwide serious events

Will it become better in future?

- In the case of a system split, high RoCoF values anticipated in future (all dots)
- Even high RoCoF values in both islands after the system split (coloured dots)
  - Risk of both islands blacking out
  - Makes the restoration process difficult
  - → Global severe system splits



ENTSO-E, "Frequency Stability in Long Term Scenarios and relevant Requirements", 3 December 2021

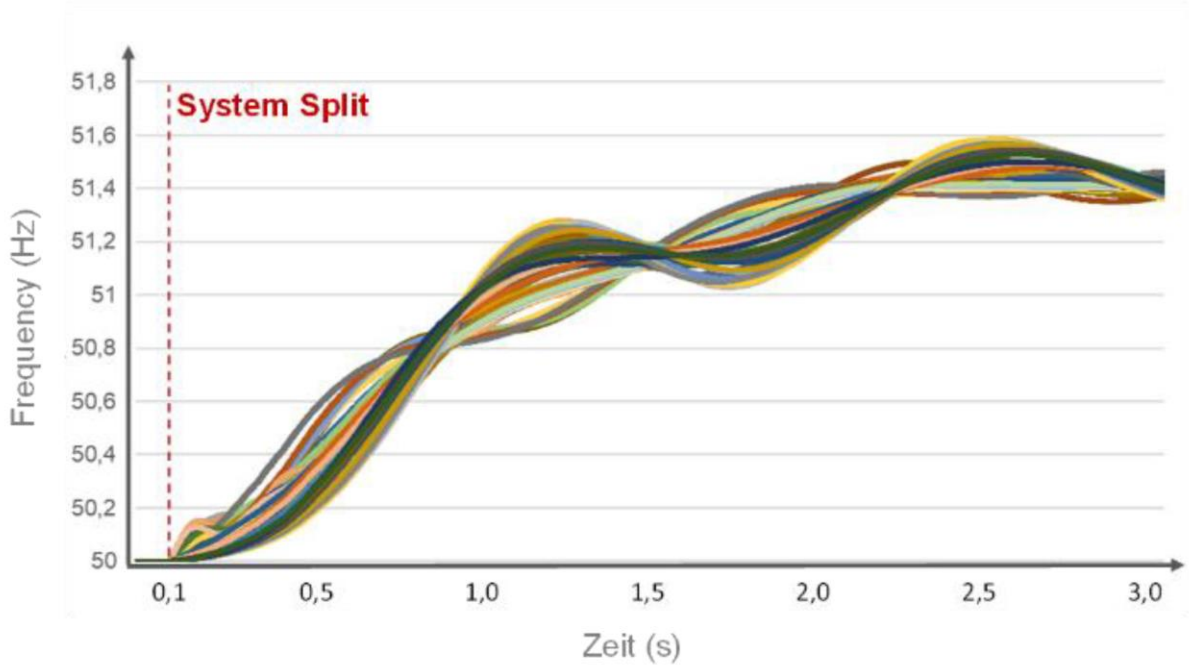
How to cope with the problem?

Make sure that for „normal“ system splits, a maximum RoCoF is not exceeded

- ENTSO-E: Maximum RoCoF for system design: 1 Hz/s (meanvalue centre of inertia)

Make the grid users robust against this RoCoF

- RoCoF requirement in the RfG
- Consider local higher RoCoF values



Christoph Strunk et al. “Correlation between global and local RoCoFs and their relevance for robustness requirements of generation units” WIW 5 September 2022

ENTSO-E proposal

Article 13. 1

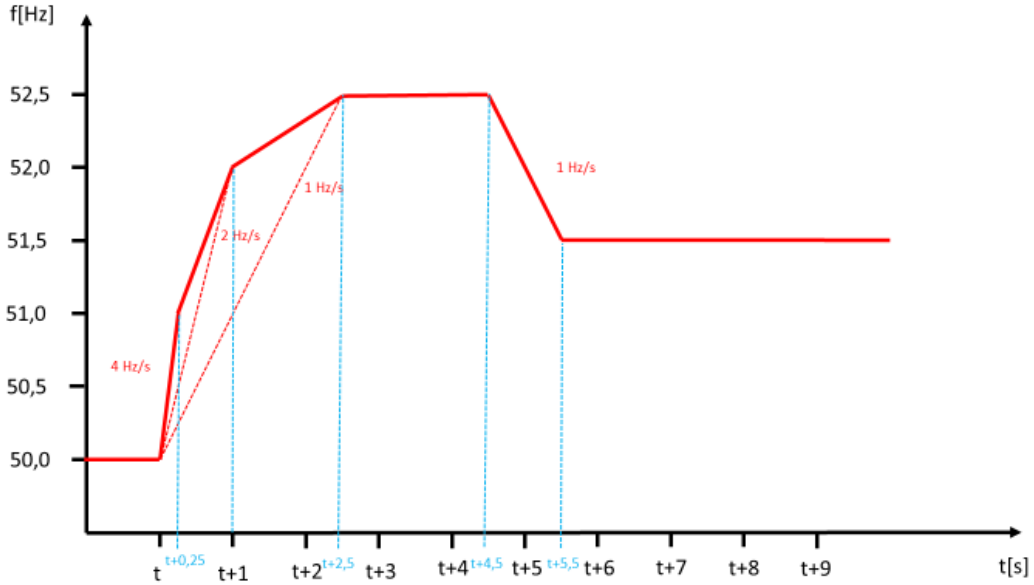
(b) With regard to the rate of change of frequency withstand capability,

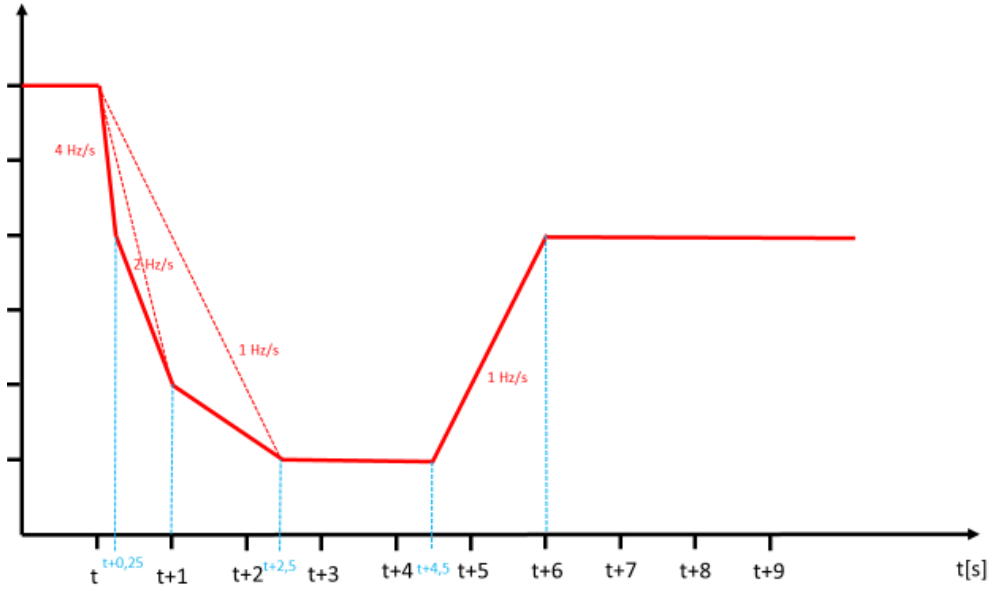
(i) a power-generating module shall be capable of staying connected to the network and operate at rates of change of frequency up to the following values:

- ±4,0 Hz/s over a period of 0,25 s
- ±2,0 Hz/s over a period of 0,5 s
- ±1,5 Hz/s over a period of 1 s
- ±1,25 Hz/s over a period of 2 s

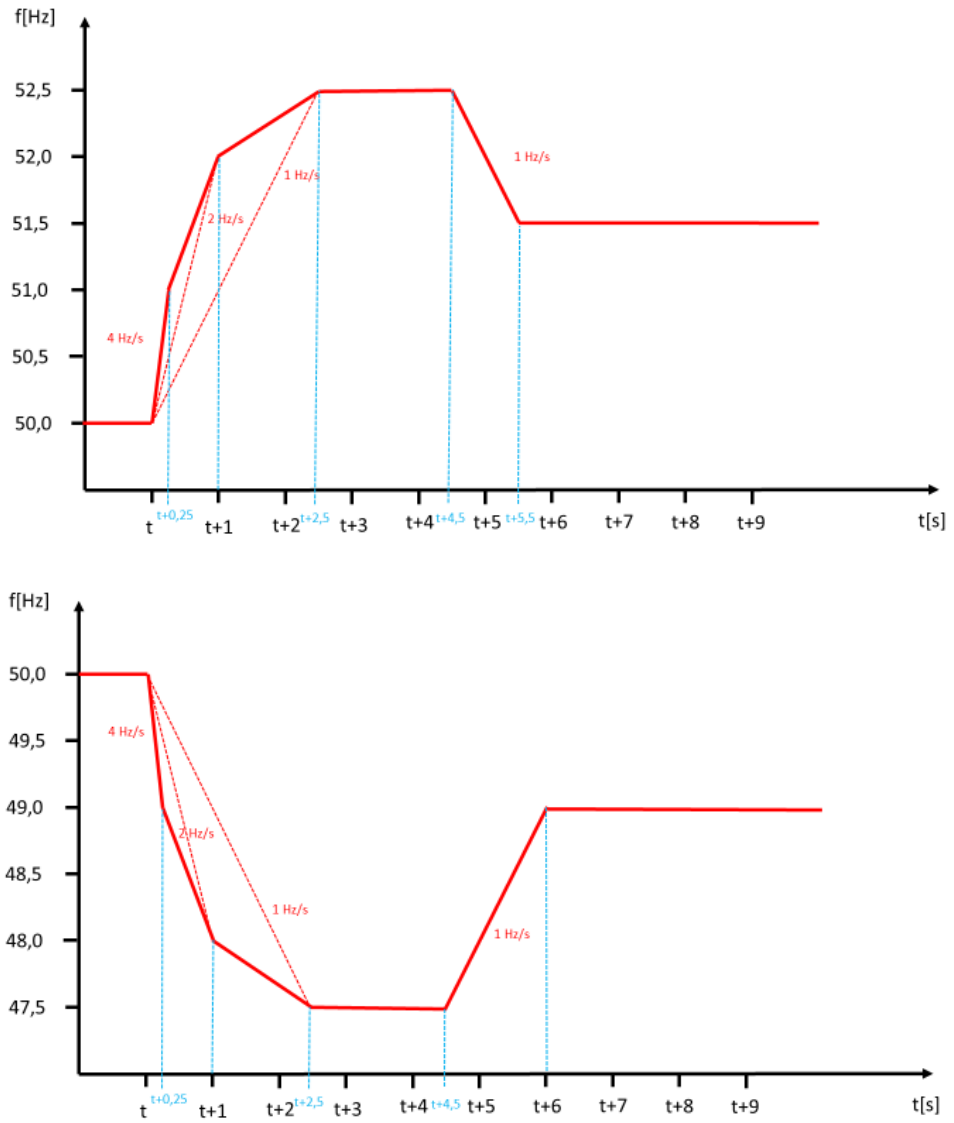
ENTSO-E proposal

(ii) Without prejudice to Article 13.a.i, power-generating module shall be capable of staying connected to the network and operate at the sequence of rates of change of frequencies which are defined considering the overfrequency against time profiles given in figure XX.a and the underfrequency against time profiles given in figure XX.b





ENTSO-E proposal



- Frequency against time profile as acceptance criterion
- Is based on 1 Hz/s (meanvalue centre of inertia) as system design criteria
- Reflects a typical frequency course during a system split near the split line
- Foresees higher RoCoF values at the beginning for local effects
- Foresees a transient in overfrequency up to 52,5 Hz in order to allow LFSM-O an overshoot without disconnection
  → increase the chances of a successful islanding
- Gets rid of the measurement windows
  - No filtering as part of the requirement
  - The frequency ride through profile is the acceptance criteria
  - Post mortem compliance check in case of a real event is not possible only based on this requirement. For this, a measurement window would have to be defined additionally

ENTSO-E proposal

(iii) If rate-of-change-of-frequency (RoCoF) is used for loss of mains protection, the rate-of-change of frequency threshold shall be set at an higher value than the ones defined in paragraph 13(1)(b).

(iv) The power-generating module shall be capable of remaining connected to the network and continuing to operate stably when the network frequency remains within the frequency range specified in Table 2. The protection schemes shall not jeopardise frequency-ride-through performance specified in Art. 13.2.b;

Functionalities checked by this requirement

PGM in general:

- No protection setting leading to trip

PPM grid following:

- Proper behaviour of the PLL and the control, not leading to instability

PPM grid forming:

- Stability of control
- No loss of synchronism

SPGM:

- Cope with fast rotor speed changes
- Loss of synchronism
  - Due to stakeholder reaction, this seems to pose a problem
  - Further discussion is needed

11:00-11:50

Open discussion on RoCoF withstand capability and feedback from stakeholders on ENTSO-E proposal

Thank you very much for your attention

Our values define who we are, what we stand for and how we behave.
We all play a part in bringing them to life.

EXCELLENCE

We deliver to the highest standardss. We provide an environment in which people can develop to their full potential.

TRUST

We trust each other, we are transparent and we empower people. We respect diversity.

INTEGRITY

We act in the interest of ENTSO-E

TEAM

We care about people. We work transversal and we support each other. We celebrate success.

FUTURE THINKING

We are a learning organisation. We explore new paths and solutions.

We are ENTSO-E