EUTurbines – ROCOF Position

GC ESC 15 June 2023

Stakeholder supporting this presentation

RoCoF, where are we?

- Technology physical constrains for big units have been studied extensively by EUTurbines and discussed with ENTSO-E and other stakeholders in several meetings. The conclusions are recognized by all stakeholders.

- Based on these studies, EUTurbines concludes that a RoCoF local withstand capability of 1Hz/s during 500ms (maximal duration, not rolling window) could be an achievable requirement for these units, which is consistent with values indicated by ENTSO-E for system stability and already adopted in numerous countries (UK, Ireland, France,…); the finding are also in line with the conclusion of the KEMA-DNV report "RoCoF An independent analysis on the ability of Generators to ride through Rate of Change of Frequency values up to 2Hz/s"

- ENTSO-E provided a reference information for a grid and a table with different RoCoF values to be evaluated

- ACER organized a RoCoF dedicated meeting, occurred in Ljubljana on 10th of May 2023 where position of different stakeholders has been presented

- Expected follow up discussion with ENTSO-E and stakeholder in the coming weeks

What is ROCOF requirements?

- EUTurbines highlights that assessing the capability of real generating units to withstand without any damage and/or trip RoCoF values/profiles above 1Hz/s means not only electrical simulations, but involves
  - extended design engineering activities on multiple elements of complex units
  - A detailed understanding of the phenomena to be studied and correspondent simulation set-up (system frequency deviation, system splits, which can be totally different phenomena to be simulated)
  - Inertia threshold criteria might not be sufficient to assess capabilities, other parameters need to be evaluated

- RoCoF requirements are expected to be different for specific units and technologies and it should be the outcome of detailed investigation

- **This activity requires significant effort and it could be carried out only with extensive collaboration between manufacturers and system operators**

- It is difficult to estimate the risks and consequences of the frequency excursions and RoCoF values proposed by ENTSO-E.

EUTurbines notes on boundary conditions for ROCOF simulations provided by ENTSO-E

Example of preliminary analysis

Short circuit ratio: $S_{k\ (connection\ point)}''/P_{r(generator)}=6$
X/R ratio= 10
PSS: Off
Voltage: $U=U_r$
Operating point:
$P=P_{max}$,

- Q/P_{max}=0,33 (underexcited) **at the connection point** (with a realistic transformer).
- Q/P_{max} =0 (neutral) at the generator **at the connection point** (with a realistic transformer).

	Q/Pmax= 0%																
H	4Hz/s 250ms	4Hz/s 150ms	2Hz/s 250ms	2Hz/s 500ms	1,5Hz/s 250ms	1,5Hz/s 1s	1,5Hz/s 500ms	1,5Hz/s 250ms	1,25Hz/s 2s	1,25Hz/s 1s	1,25Hz/s 500ms	1,25Hz/s 250ms	1Hz/s 2s	1Hz/s 1,5s	1Hz/s 1s	1Hz/s 500ms	1Hz/s 250ms
8																	
7	NO			NO		NO			NO						OK		
6																	
5																	

Completed above are preliminary results of rotor angle stability studies for a typical 1800 MW nuclear shaftline.

(Reference: EUTurbines presentation of 30 January 2023 for ENTSOE Webinar on RoCoF amendment - SPGMs constraints).

EUTurbines position on ROCOF and Frequency Limits

EUTurbines position on ROCOF:

- **to use the 1Hz/s, 500ms value as target value,** as indicated by ENTSO-E upper limit for system stability and in line with DNV KEMA study
- **to not exceed present frequency limits,** new values as defined in the last proposal can have major impact on design and goes beyond existing technical standards and requirements.
- to define targets for RoCoF and frequency values that do not lead to risks of damage to generating units;
- To consider existing units to define appropriate RoCoF targets
- RoCoF requirement should also be used as target reference for defining local/global minimum grid inertia requirement

EUTurbines position on ROCOF and Frequency Limits

- **Assessing the real capabilities** to cope with the RoCoF and frequency limits values presented, represents a real challenge that is not easy to answer even in the future **for all grid users** and not only for the technologies represented by EUTurbines.

- EUTurbines considers that it is already a task of TSOs to define contermeasures to keep inertia and associated RoCoF in line with expected grid users capability and that various technical solutions are available to foster this accomplishment, like but not limited to:
  - synchronous condensers / fly wheels,
  - contribution from Grid Forming Converters ('synthetic inertia'),
  - define RoCoF values compatible with existing units (likely ~1Hz/s for big synchronous units)

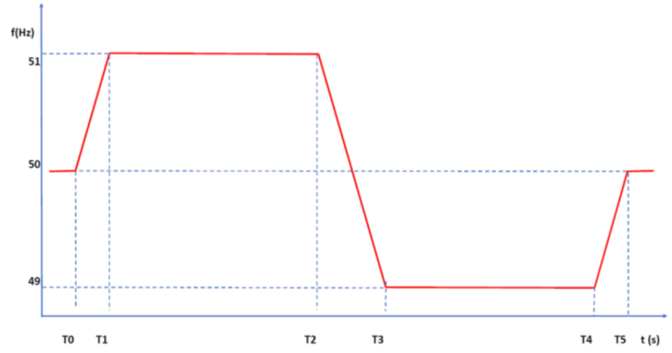
- This task is already indicated in the existing regulations (RfG (recital 25) and SOGL art 38 and art 39), and it is consistent with strategies already in place in countries adopting contermeasures to compensate for the erosion of grid inertia due to high RES penetration (eg Ireland and UK)

EUTurbines possible compromise

- A possible and reasonable compromise could be consider a RoCoF requirement of 1Hz/s, 500ms for all Type D units (no Pmax Threshold)

- EUTurbines could recommend for Type A, B and C to be evaluated among stakeholders and grid users the proposal/feasibility of adopting a requirement of 2Hz/s on 500ms (corresponding to 1Hz/s, 500ms global ROCOF):
  - This would be in line with ENTSO-E document (e.g. frequency stability in long-term scenarios and relevant requirements),
  - This would be in line with present requirements in most of European Countries,
  - This would be in line with CENELEC std EN 50549 -1 and -2,
  - This would not exceed the frequency limits threshold of 51.5 Hz Continental Europe and 52 Hz Uk.

RoCoF profile could be as described in EN 50549-10:



EUTurbines possible compromise for discussion

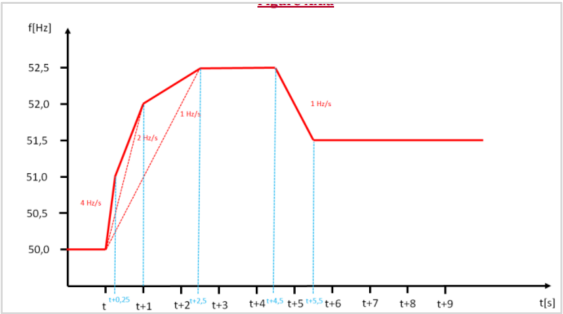
Type A, B and C SPGM and Type A, B, C and D PPM	Type D SPGM
2Hz/s, 500ms	1Hz/s, 500ms

- Type C unit however has not been completely investigated (e.g. for generating unit in the range of 40 MW); the result of the investigation could be that in some grid conditions also such units can accept only up to 1Hz/s, 500ms ROCOF as proposed for Type D; in such a case appropriate wording shall be considered in the RfG 2.0 to cover such point.

On ACER back-up solution and RoCoF profile

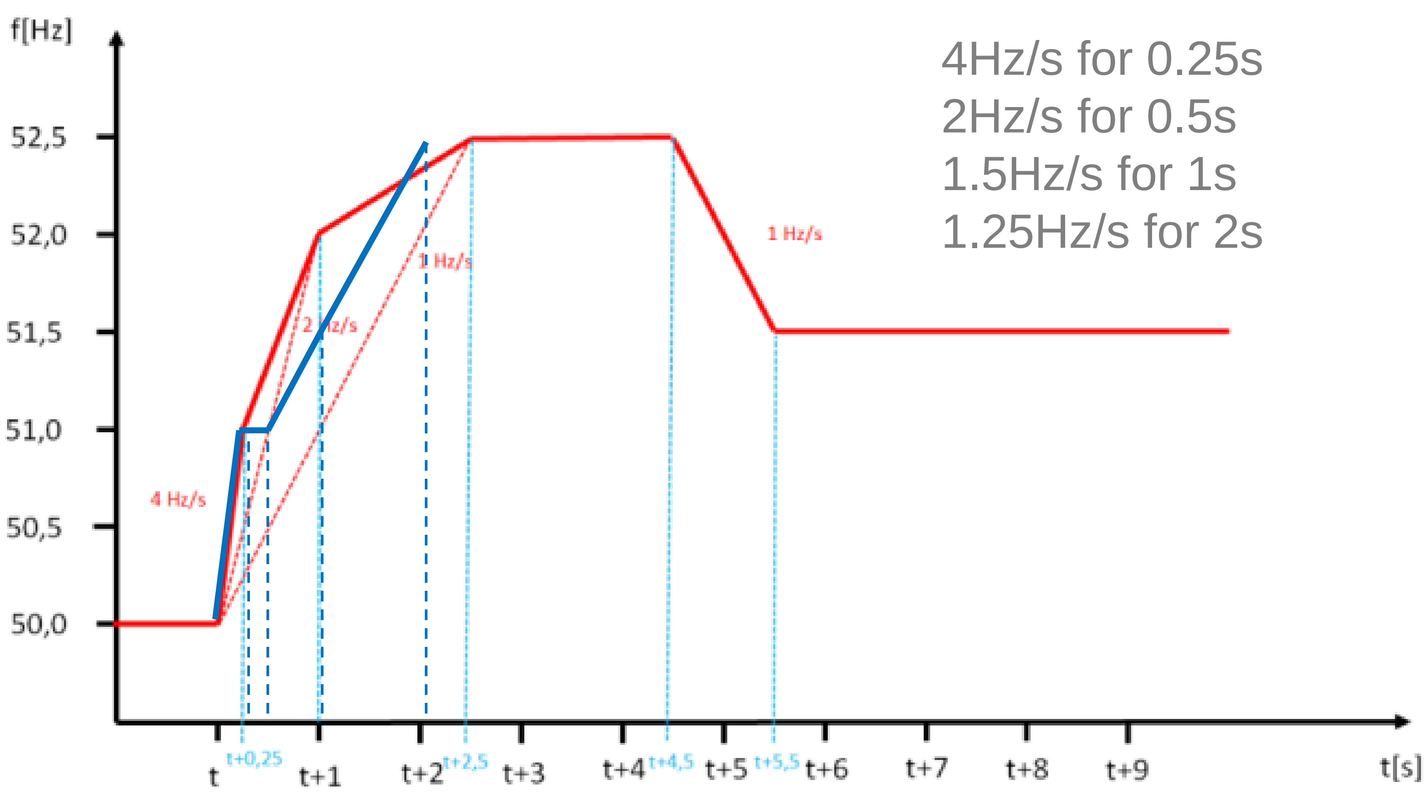
- During the 10th of May meeting ACER proposed a simplified solution
- We have issues with the proposed RoCoF requirements taken from ENTSO-E proposal
- We discovered during the meeting that the RoCoF values proposed are separate different requirements
  - 4Hz/s for 0.25s
  - 2Hz/s for 0.5s
  - 1.5Hz/s for 1s
  - 1.25Hz/s for 2s

Different/separate requirements from



- This was not as it was understood before when only the profile has been considered
- The above values (and the profiles) can lead to systematic misinterpretation **and need a revision**

EUTurbines comments on new profile



4Hz/s for 0.25s
2Hz/s for 0.5s
1.5Hz/s for 1s
1.25Hz/s for 2s

Real RoCoF on 500ms = 3Hz/s

Beyond ENTSO-E stated system limits in case of grid splitting of 1Hz/s 500ms global RoCoF and 2-2,5 Hz/s local RoCoF on 500ms (*)

Beyond the ratio local/global RoCoF of 1.8 for 500ms as defined in presented studies German TSOs (**)

In general not in line with present National requirements and European standards

(*) FREQUENCY STABILITY IN LONG-TERM SCENARIOS AND RELEVANT REQUIREMENTS, 3 Dec 2021
(**) LoGlo Abschlusspresentation – Ruhr GmbH – 29.10.2021

EUTurbines

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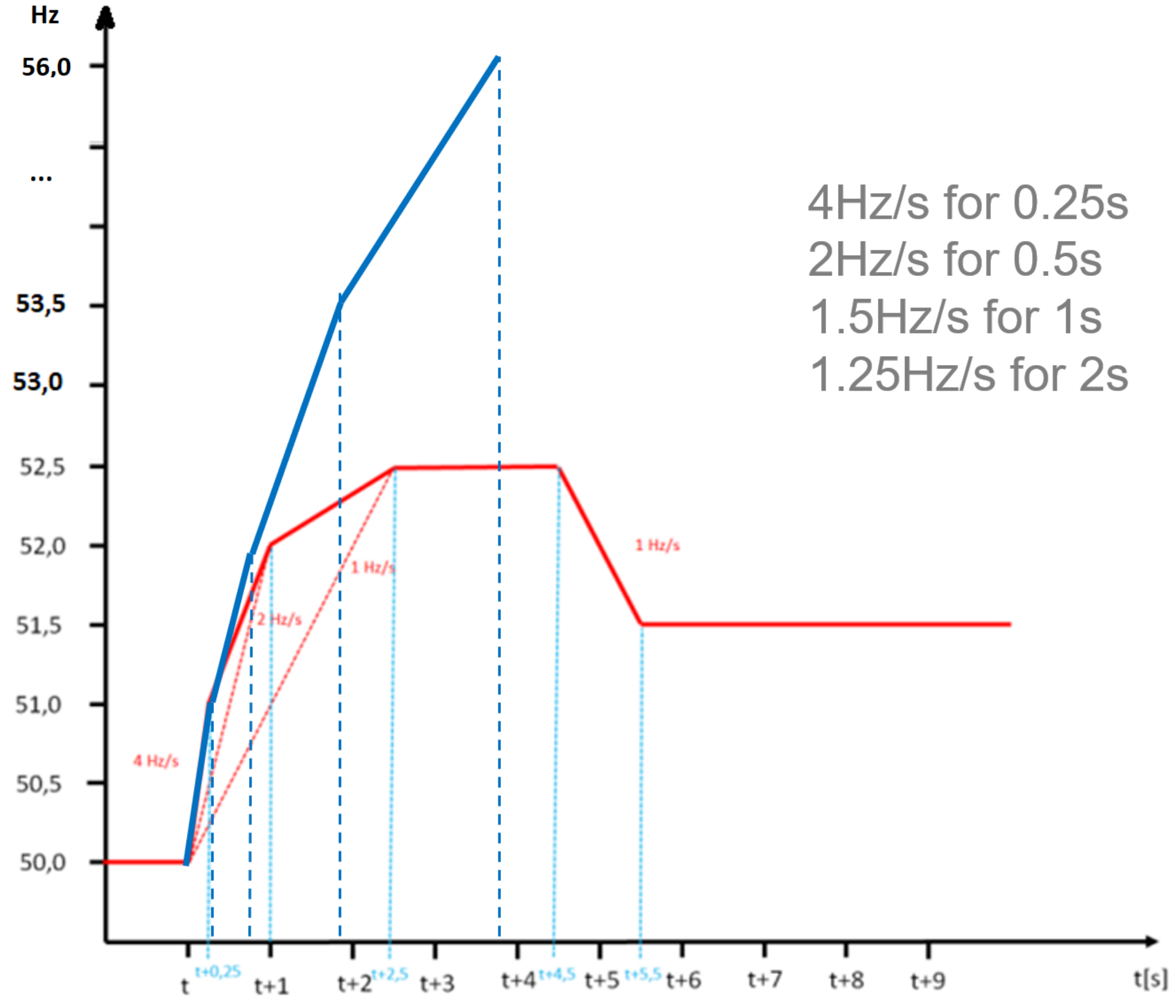

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Thank You!

Backup Slides / Inertia Constant H(s)

References for the definition of H constant from National Grid (UK) and IEC:

The maths behind inertia

$$H = \frac{\frac{1}{2} J \omega^2}{MVA}$$

H = Inertia constant in MWs / MVA
J = Moment of inertia in kgm^2 of the rotating mass
ω = nominal speed of rotation in rad/s
MVA = MVA rating of the machine

Typical H for a synchronous generator can range from 2 to 9 seconds (MWs/MVA)

$$\frac{\partial f}{\partial t} = \frac{\Delta P}{2H}$$

∂f/∂t = Rate of change of frequency
ΔP = MW of load or generation lost
2H = Two times the system inertia in MWs / MVA

nationalgrid
The power of action

Abstract from IEC 60034-4 (2008) (replaced by IEC 60034-4-1 (2018)):

7.25 Valeur assignée des constantes de temps d'accélération et d'énergie cinétique réduite

7.25.1 A partir de l'essai d'oscillation du rotor suspendu

Les constantes de temps d'accélération et d'énergie cinétique réduite obtenues à partir de l'essai d'oscillation du rotor suspendu (voir 6.30) sont calculées en utilisant les formules suivantes:

$$\tau_J = \frac{J\omega_N^2}{P_N} \cdot 10^{-3} \quad ; \quad H = \frac{J\omega_N^2}{2S_N} \cdot 10^{-3}$$

avec les unités conventionnelles suivantes:

J	est le moment d'inertie, en kg·m²;
$\omega_N = \pi n_N/30$	est la vitesse angulaire assignée, en rad/s;
n_N	est la vitesse de rotation assignée, en tours par minute;
P_N, S_N	sont en kW ou kVA, respectivement.

Backup Slides / Gas turbine specific risks

Electrical Risks

- Loss of generator stability
- Power oscillations (initially Pmax & leading PF)
- Trip generator protections
- Impact on auxiliaries power supply
- Voltage oscillations due to interactions with PSS

Same risks as for large synchronous nuclear generators

Control Risks

- Combustion instability Loss of flame
- Compressor instability
- Load rejection to House Load
- Instrumentation “default”
- Reverse power (at Pmin)

Mechanical Integrity Risks

- Torsion fatigue
- Compressor/Turbine blade excitation

Same risks as for large synchronous nuclear generators

- Hot gas temperature out of tolerance

<u>CONCLUSION OF THE STUDY FOR CCGTs:</u>

High Rocof values may lead to hardware damage and further long period plant outage

Backup Slides / Ongoing simulations with New ENTSOE Boundary conditions / Preliminary results under review

			Typical 'big' EPR nuclear turbogenerator	Typical SMR 300MW range	Virtual SMR H=4s 300MW range
Total Turbogenerator Inertia Moment	**J**	**kg.m2**	**1205470**	**60000**	**28500**
Turbogenerator speed	**n**	**rpm**	**1500**	**3000**	**3000**
Total stored kinetic energy	**E**	**MWs**	**14857**	**2958**	**1405**
Turbogenerator apparent power	S	MVA	2094,1	350	350
Turbogenerator Inertia constant	**H**	**s**	**7,09**	**8,45**	**4,01**
Rotor angle stability with SCP=6*Pmax for the 2Hz/s IGD profile			**No**	**No (prel. results to be confirmed)**	**No (prel. results to be confirmed)**