EUTurbines – ACER Workshop on rate of change of frequency and grid forming capabilities

10 May 2023

EUTurbines understanding from last developments

- 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.

- Generator electrical stability simulation studies show that the 2Hz/s profile proposed in the IGD cannot be applied to big thermal units due their inertia (high risks of trip of the units due to loss of synchronism). In addition, high RoCoF values may lead to severe hardware damages on gas turbines.

- Studies performed by EUTurbines provide conclusions in line with Kema’s well recognized report (considered by Eirgrid to define the 1Hz/s value for Ireland).

- 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,…).

EUTurbines understanding from last developments

- Generator electrical stability simulation studies based on new proposed RoCoF profiles and information provided by System Operators and ENTSO-E had been carried out by EUTurbines and are ongoing.
- RoCoF requirements is expected to be different for specific units and technologies and it should be the outcome of detailed investigation.
- The RoCoF requirement should also be used as target reference for defining local/global minimum grid inertia requirement.

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

- A set of information and possible RoCoF values have been provided by ENTSO-E on 25th of April. The information is under scrutiny and first feedback has been provided to ENTSO-E by EUTurbines.

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

- Some values shown in the table might lead to **damage and/or trip** for some generating units (not just a mere capability to ride through or not).

- In the table are indicated inertia constant values (H). EUTurbines recommend to have a **proper definition of the H constant** and further elaboration to confirm that (H) is the most and only appropriate parameter to be used as threshold for all technologies and plant configurations (e.g. gas turbines, CCGT, nuclear, hydro, CHP, single-shaft/multi- shaft, indirect/direct coupled (no gearbox),...).

- Many existing units will not be able to comply to the 2Hz/s IGD profile and many of these new RoCoF/SCP conditions. It is understood they will not need to comply with new requirements. EUTurbines highlights that even in case of significant modernization the expectation is that they will not be able to comply.

Reference to EUTurbines presentation of 30 January 2023 for ENTSOE Webinar on RoCoF amendment - SPGMs constraints

EUTurbines position on ROCOF and Frequency Limits

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

Hence, we keep recommending as our preferred approach:

- to **use the 1Hz/s, 500ms value as target value,** as indicated by ENTSO-E for system stability,
- 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.

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

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 under control (definition of local minimum grid inertia) 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).

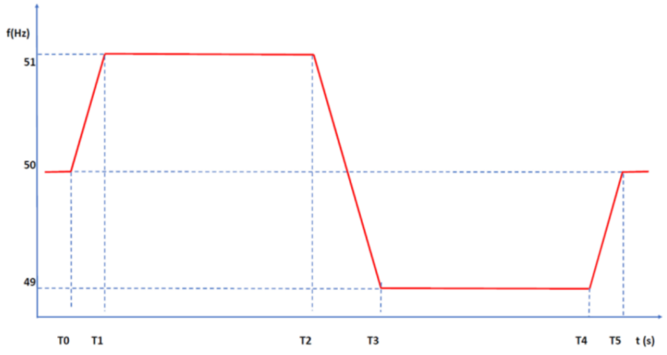
- This task is already indicated in the existing regulations (RfG and SOGL art 38 and art 39), and it is consistent with strategies already in place in countries adopting contermeasures to compensate for the erosion of grid inertia due to high RES penetration.

EUTurbines possible compromise

- A possible compromise that seems to be reasonable could be to 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 evaluate among stakeholders and grid users the proposal/feasibility of adopting a «single value» 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:



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 kgm² 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

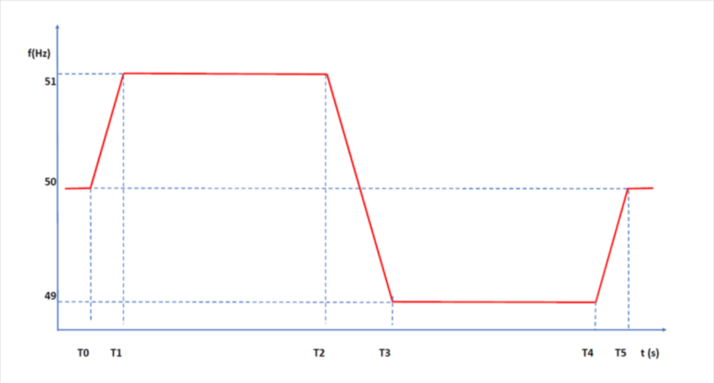
CONCLUSION OF THE STUDY FOR CCGTs:

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

Backup Slides / EUTurbines suggestion for discussion

Type A, B, C, SPGM &
Type A, B, C and D PPM

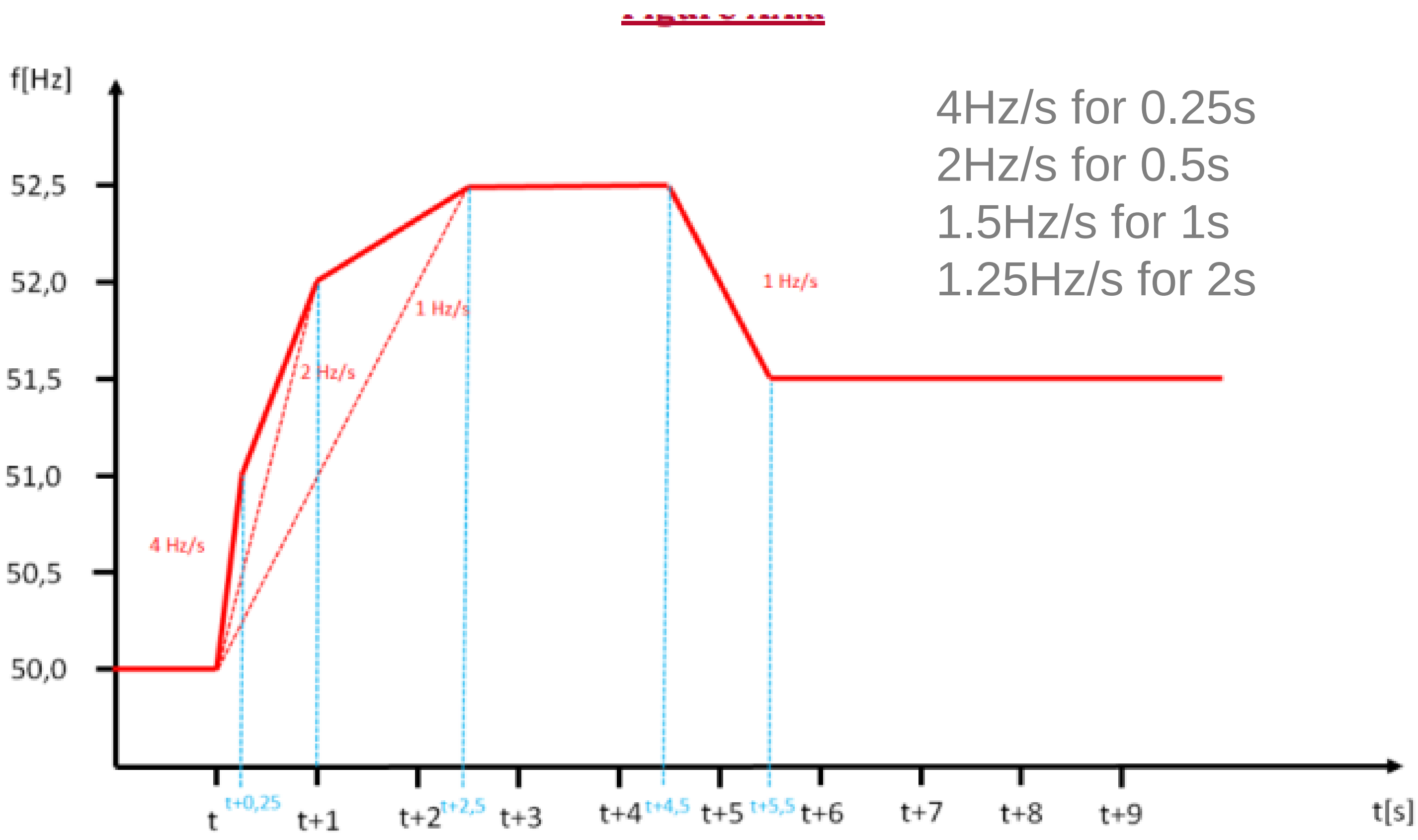
2Hz/s, 500ms



Type D SPGM

1Hz/s, 500ms

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 ENTSOE 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 std

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

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)**