February 2022

EUTurbines position paper on RoCoF related questions

EUTurbines welcomes with much interest the discussion over Rate of Change of Frequency (RoCoF), as initiated by ENTSO-E, with the event “stakeholders' webinar on RoCoF related consideration” on 1 February 2022.

The intent of this paper is to address several points raised in this discussion, providing background information and recommendations from the gas and steam turbine manufacturers perspective.

Local versus global RoCoF

While the average frequency on a synchronous power system is the same in all its location, it may not be the same when considering very short-term transients. This effect is due to inter-area oscillation, where a mean RoCoF will be observed at the center of inertia of the grid, while other locations may see higher RoCoF. That effect is also commonly called mass/spring effect, where the masses are the spinning rotors connected to the grid (i.e., synchronous rotor of generation, demand, or synchronous condensers), and the springs are the electro-magnetic links between those.

Such phenomenon has been studied by Eirgrid in 2012 in its “summary of Studies on Rate of Change of Frequency event on the All-Island System”. A graphical example can be found below.

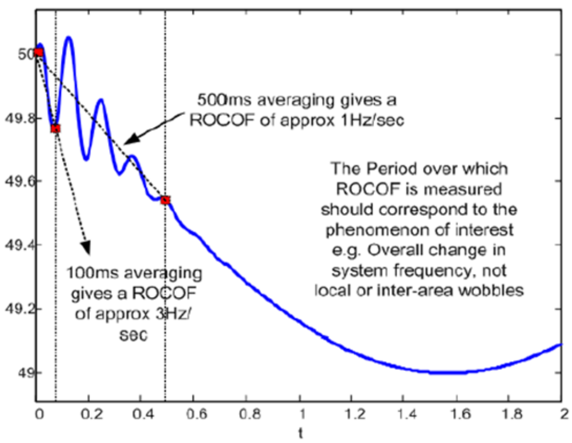

Figure 1 - Figure 3 Illustration of frequency change and the effect of using different measuring windows [1]

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The previous studies and events have shown that most of the power systems will see such oscillations disappear in 500 ms or less after the event, leading to same frequency and RoCoF values at different location of the grid after this point. The below figure shows the RoCoF measurements printed by the frequency measurement systems on various locations of the grid, considering an interval measurement time of 100 ms, and 500 ms after the event.

Bus	T = 100 ms	T = 500 ms
AA	0.23	0.41
AD	1.07	0.41
CF	1.34	0.42
LOU	2.09	0.43
CKM	1.91	0.43
GI	1.56	0.42
BALLY	1.55	0.43
PB	2.71	0.53
AVG	**1.59**	**0.43**

Figure 2 - Maximum RoCoF measurements at each measurement bus for different time windows, on several locations of the Irish grid, following a grid event [2]

What is observed is a convergence of the measurement based on a 500 ms interval measurement time. Considering the 100 ms interval measurement time, the measurements differ, and inter-area oscillation are incriminated as the prime contributors. It may also be worth to note that dynamic accuracy of the frequency measurement system may not be perfect, and that the algorithm to calculate frequency may differ among stations. This was not studied in this paper, but can also explain the relative gap, as a second-order contributor.

Considering synchronous generating units, their rotor will follow the electrical (stator) frequency, while also experiencing a phase offset (also known as load angle), which itself will vary and wobble while tracking the electrical frequency. If the unit does not slip poles, the 500-ms RoCoF value the rotor undergoes will be the same as the 500-ms RoCoF value of the grid.

Also, in terms of semantics, what is considered here is in reality the “interval measurement time”, meaning the RoCoF calculated via considering two frequency measurements at different times. This is often improperly called “average”.

Conclusion: following the first demonstration on the Irish grid, is recommended NOT to consider the need to define both a local transient (sub-500 ms) and a global RoCoF, but to retain only the definition of a global RoCoF, off 500 ms interval measurement time or more.

Impact on gas and steam turbines

Gas and steam turbines convert power through synchronous generators. As mentioned above, their rotor frequency may differ from the grid frequency during rapid change of the load angle. That change may be experienced during short circuit and fault ride through, which leads the unit to accelerate on a very short timeframe. In the best case, the fault will clear before the unit slip poles (also known as critical clearing time), and the rotor frequency will progressively converge with the stator frequency.

During fault right through events, the unit may therefore experience acceleration well in excess of 2 Hz/s, considered in a 100 ms interval measurement time.

The manufacturers of gas and steam turbines therefore consider that any maintenance consideration of RoCoF in less than 500 ms average measurement time is covered through the relevant fault ride through studies.

Considering now a definition of RoCoF equal or more than 500 ms interval measurement time, several items are at stake, namely controls and electrical behaviours (e.g., governor response, I&C systems…), technological process stability (compressor/turbine stall and surge margin, steam turbine stability, generator stability), and life consumption/maintenance action for the plant owner. Also, some units provide heat or steam to a dedicated process, which will be upset by the reaction to the RoCoF event.

Furthermore, it must be noted that the power plant's ability to ride through RoCoF will be limited to the ability of the auxiliary systems to properly feed it during the event. To properly study these, a frequency versus time profile must be included in the proper simulation tool. As such, EUTurbines recognises and recommends continuing the use of the profiles listed in the RoCoF Implementation Document, as follows:

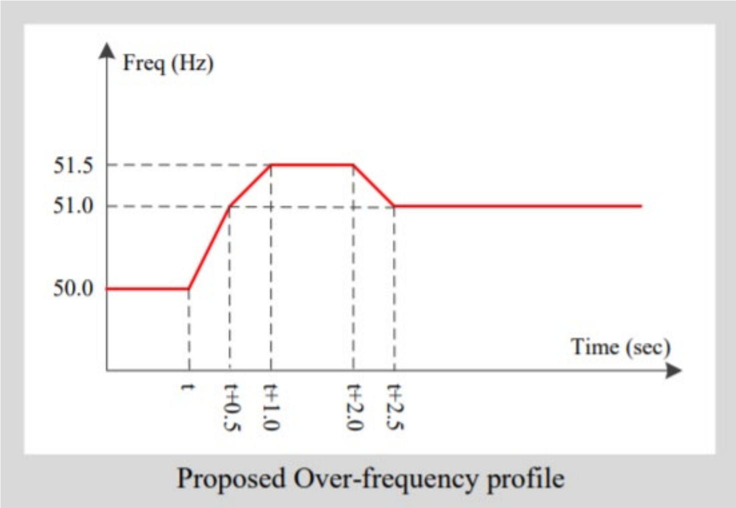

Figure 3 - RoCoF profile as depicted in the 2018 Rate of Change of Frequency IGD

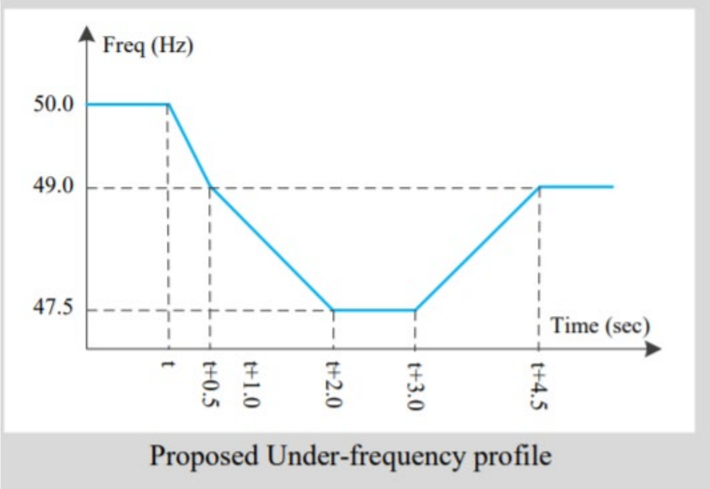

Figure 4 - RoCoF profile as depicted in the 2018 Rate of Change of Frequency IGD

Credible event definition

It must be also recognised that RoCoF events are considered rare by nature (e.g., typically associated with grid split at national interconnectors, as reminded by the grid operators on 2nd Feb 2022). Also, grid operators on islands, such as Eirgrid, Soni or National Grid concluded that despite their non-interconnected situation, low inertia target with the advent of renewable, and high potential imbalances, they would not need to rule more than a ±1 Hz/s, 500 ms interval measurement time requirement.

The difficulty to study RoCoF withstand capability increases exponentially with RoCoF amplitude, while real-scale site testing is not practically possible – making more difficult the fine-tuning of turbines. Also, the current installed fleet was not manufactured with RoCoF withstand as a design criterion, which means that its capability is currently mostly unknown and shall be assessed.

The cost of those studies, or mitigation plan to comply with the most onerous requirements, may lead to up to 5% of the plant CAPEX. As a side note, one may refer to the effort led in the UK to evaluate the impact of ±1 Hz/s on the generating units, which required substantial public funding [4].

As inverter-based resources increases, current grid short-circuit levels will decrease. RoCoF withstand capability for synchronous machines from a transient stability perspective is impacted by grid short-circuit levels. Hence, RoCoF studies need to take account of this grid system's characteristic.

The question is therefore raised to the continental Europe stakeholder on how to keep maximum RoCoF as a target of the power systems, and contain inertia, and not consider RoCoF as the inevitable consequence of some actions done without precaution or countermeasures. RoCoF is considered a direct consequence of the decreasing inertia in the electrical system and it belongs to dynamic stability management. Therefore, the definition of a minimum inertia and associated countermeasures to maintain such minimum value are already part of the tasks of TSOs as indicated in Commission Regulation (EU) 2017/1485 Art 39. The expectation is that studies and processes to put in place necessary and credible countermeasures will start as soon as possible.

Conclusion: Based on the information provided above, it is considered that the RoCoF requirements/expected deviations shall not be extended to more than ±1 Hz/s 500 ms or ± 2 Hz/s 500 ms interval measurement time, also considering technology-dependent configuration of the power plant.

References:

[1]http://www.soni.ltd.uk/media/documents/Archive/RoCoF%20Modification%20Proposal%20TSOs%20Opinion.pdf
[2]http://www.easyres-project.eu/wp-content/uploads/2019/02/Rate-of-Change-of-Frequency-events-on-the-All-Island-System.pdf
[3]https://eepublicdownloads.entsoe.eu/clean-documents/Network%20codes%20documents/NC%20RfG/IGD_RoCoF_withstand_capability_final.pdf
[4]https://www.enwl.co.uk/get-connected/network-information/accelerated-loss-of-mains-change-programme/#:~:text=The%20Accelerated%20Loss%20of%20Mains,any%20new%20generation%20connecting%20to

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