Eurelectric approach to Rocof withstand capability

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A strong focus was put on Rocof withstand capability of PGMs rather than Rocof management (i.e avoid high Rocofs)

- **Recital 25 of existing RfG network code**

  Synchronous power-generating modules have an inherent capability to resist or slow down frequency deviations, a characteristic which many RES technologies do not have. Therefore countermeasures should be adopted, to avoid a larger rate of change of frequency during high RES production. Synthetic inertia could facilitate further expansion of RES, which do not naturally contribute to inertia.

- **Eurelectric considers that other means (e.g synchronous condenser) shall be used to mitigate the occurrence of high Rocofs, as well as the natural inertia of synchronous power plants. Their connection rules should be described in the future version of RfG network code.**

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Rocof withstand requirements studies

- **Ireland**
  - The now well-known DNV-KEMA study for Eirgrid shows that most synchronous production means with high inertie are physically unable to bear high Rocofs.

Generation Units Result Summary					1 Hz total frequency drop			
Generator Set	Unit Size	Inertia Constant H	Xd	Terminal Voltage	Stable	during	RoCoF	
[name]	[MW]	[Sec.]	[p.u.]	[kV]	[@ 0.5 Hz/s]	[@ 1.0 Hz/s]	[@ 1.5 Hz/s]	[@ 2.0Hz/s]
CCGT Single-shaft	400	5.5	1.9	20	Y	Y*	Y*	N
CCGT Dual-Shaft	260	6	2.3	17	Y	N	N	N
CCGT Dual-Shaft	140	9	2.1	17	Y	N	N	N
Steam Thermal (Reheat)	300	5	1.7	17	Y	Y*	Y*	N**
Steam Thermal (Once Through)	250	4.5	2.3	20	Y*	Y*	N	N
Steam Thermal (Fluidized bed peat)	150	8	2.2	11	Y*	N	N	N
OCGT	50	1.5	2.9	11	Y*	Y*	Y*	Y*
Salient-pole Hydro	30	2.7	1.4	11	Y	Y	Y	Y

The tables give a general overview of the findings where:
Y is used to indicate stable operation
Y* is used where a pole slip is only observed for a 0.93 leading power factor operation mode;
N is used when a pole slip is also observed for power factors of 1 unity or/and 0.85 lag;
N** is used when no pole slip is observed for power factors of 1 unity or/and 0.85 lag but negative power generation is detected.

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(ii) remain synchronised to the **Transmission System** for a **Rate of Change of Frequency** up to and including 1 Hz per second as measured over a rolling 500 milliseconds period. **Voltage** dips may cause localised **Rate of Change of Frequency** values in excess of 1 Hz per second for short periods, and in these cases, the **Fault-Ride Through** clause CC.7.3.1.1(y) supersedes this clause (CC.7.3.1.1(d)). For the avoidance of doubt, this requirement relates to the capabilities of **Generating Units** only and does not impose the need for **Rate of Change of Frequency** protection nor does it impose a specific setting for anti-islanding or loss-of-mains protection relays;

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Rocof withstand requirements in different places

- **Saudi Arabia**
  - The Saudi network code considers a 1 Hz/s during 500 ms as a relevant value to ask synchronous generators to withstand.
  - https://www.se.com.sa/en-us/Pages/SaudiArabianGridCodeGuide.aspx

Chapter 2 - Connection Code

2.5.5.4 All Synchronous Generating Units shall be capable of withstanding any rate of change of frequency up to 1Hz/s without disconnection from the network other than triggered by loss of mains protection. The rate of change of frequency shall be measured over a sliding 500ms time period.

All Power Park Modules shall be capable of withstanding any rate of change of frequency up to 2.5Hz/s without disconnection from the network other than triggered by loss of mains protection. The rate of change of frequency shall be measured over a sliding 500ms time period.

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Rocof withstand requirements in different places

- **France**
  - The same criterion for synchronous machines is also used in France (« Documentation Technique de Référence »).
  - Stronger requirements apply for PPMs.
  - Synchronous machines

Cahier des charges des Capacités Constructives Unité Synchrone Conditions Générales

3.9 Capacité à supporter des vitesses de variation de la fréquence

Condition d'application : types B, C, D

L'unité de production doit rester connectée et continuer à fonctionner tant que la fréquence du réseau varie à une vitesse inférieure ou égale à :

+/– 1 Hz/s en moyenne sur une fenêtre glissante de 500 ms.

Toute précision de la mesure de variation de fréquence supérieure à ± 1 mHz/s sur une fenêtre glissante de 500 ms devra être justifiée par des éléments techniques. Cette exigence doit être, à minima, validée pour le point de fonctionnement suivant : P=Pmax, Q=0MVAr et U = 1 pu.

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PPMs

Cahier des charges des capacités constructives
Conditions générales
Parc non synchrone de générateurs

3.9 Capacité à supporter des vitesses de variation de la fréquence

L'unité de production doit rester connectée et continuer à fonctionner tant que la fréquence du réseau varie à une vitesse inférieure ou égale à :

+/– 2 Hz/s en moyenne sur une fenêtre glissante de 500 ms.

Et

+/– 1.5 Hz/s en moyenne sur une fenêtre glissante de 1000 ms.

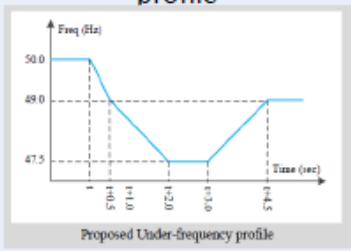
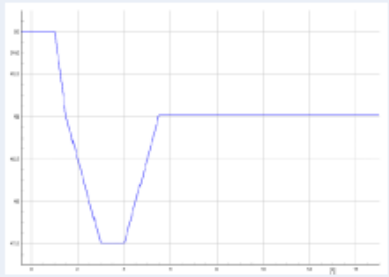
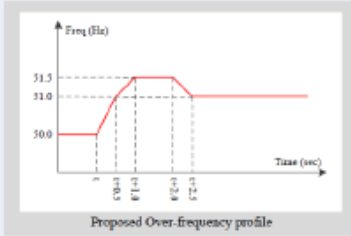
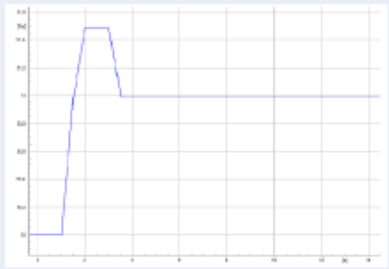
Et

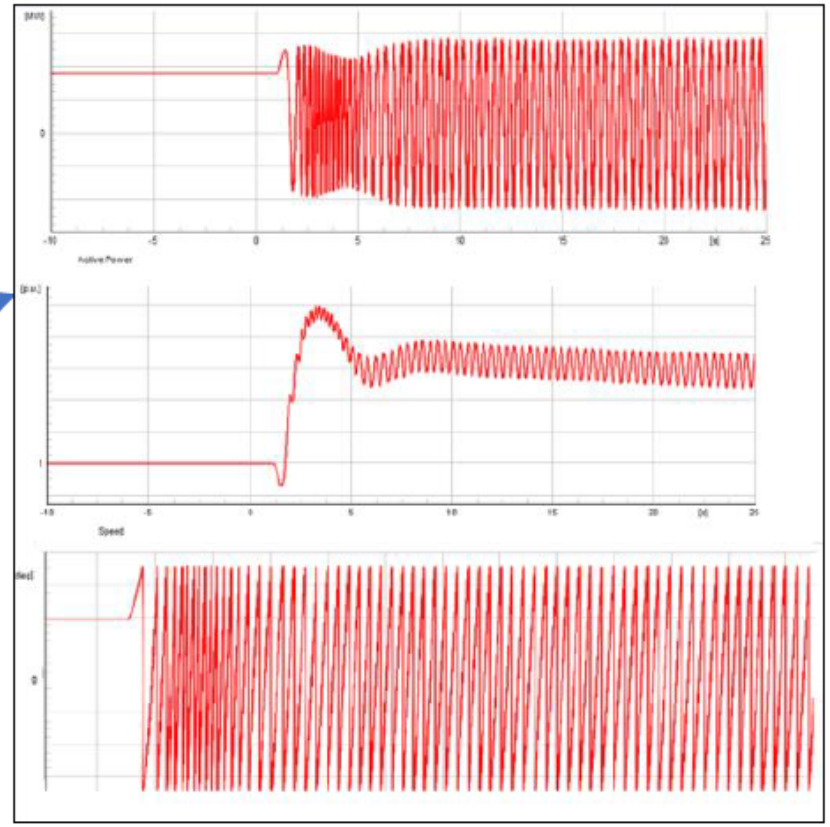
+/– 1.25 Hz/s en moyenne sur une fenêtre glissante de 2000 ms.

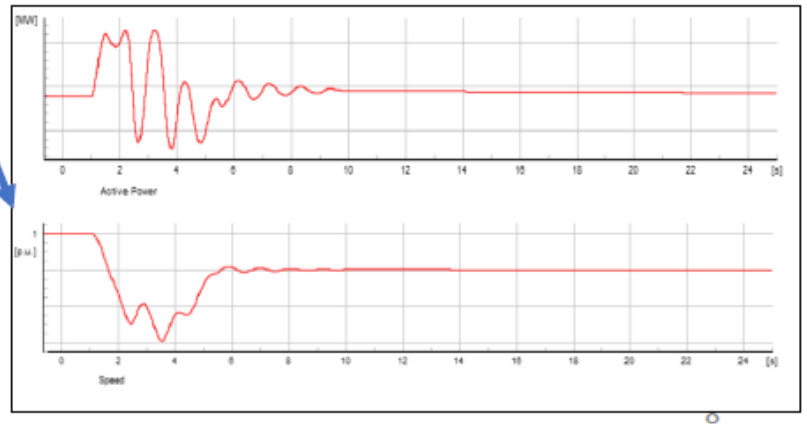
Toute précision de la mesure de variation de fréquence supérieure à +/- 1 mHz/s sur une fenêtre glissante de 500 ms devra être justifiée par des éléments techniques. Cette exigence doit être, à minima, validée pour le point de fonctionnement suivant : P=Pmax, Q=0MVAr et U = 1 pu.

Additional simulations confirm this point (courtesy EDF)

Results for new nuclear power plants with ENTSOE profiles (Digsilent Powerfactory)

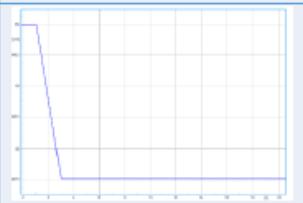
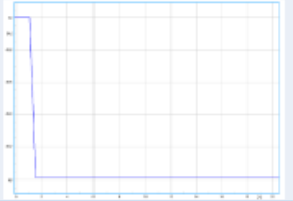
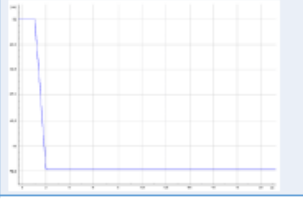
RoCoF		Q generator	Xcc line	Stable operation
ENTSOE under-frequency profile  Proposed Under-frequency profile		Max lagging	21%	N
		0Mvar	5%	Y
		Max leading	5%	N
		Max lagging	15%	Y
		0Mvar	15%	N
ENTSOE over-frequency  Proposed Over-frequency profile		Max leading	21%	Y
		Max leading	5%	Y

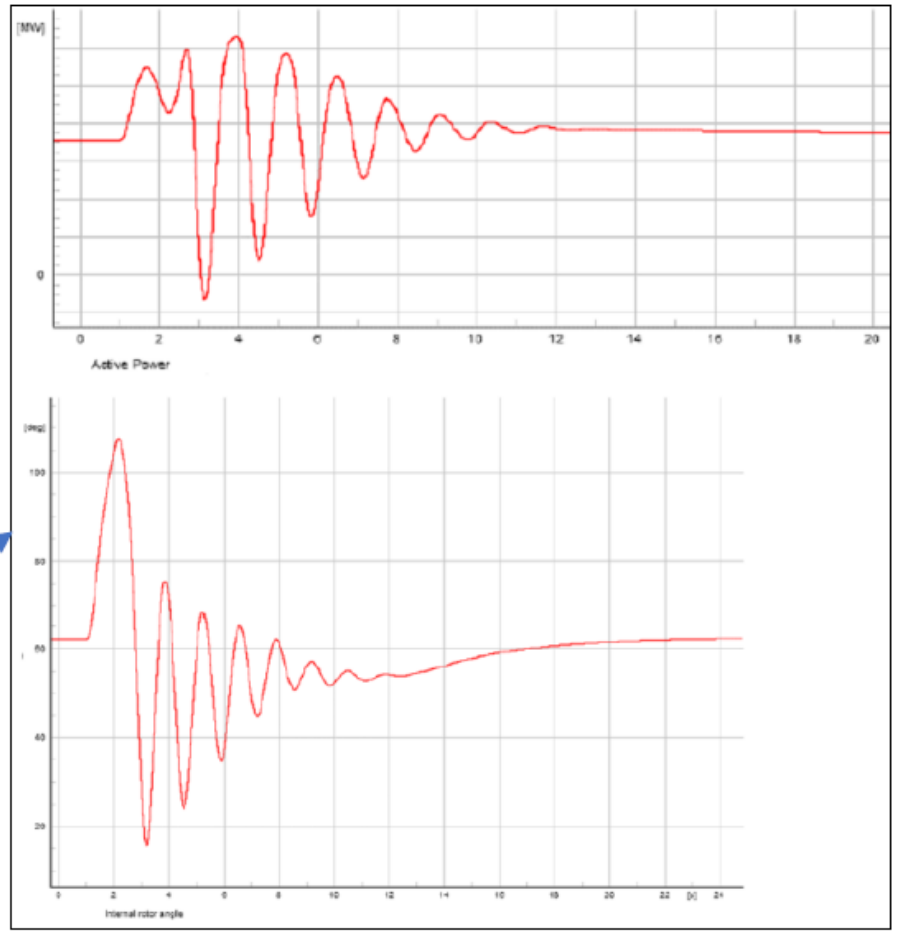




Additional simulations confirm this point (courtesy EDF)

Results for new nuclear power plants with single rate of change (Digsilent Powerfactory)

RoCoF		Q generator	Xcc line	Stable operation
ENTSOE RoCoF criteria 1.5Hz/s for 1s		Max lagging	21%	Y*
		0Mvar	21%	N
ENTSOE RoCoF criteria 1.25Hz/s for 2s		Max lagging	21%	Y*
		0Mvar	21%	N
ENTSOE RoCoF criteria 2Hz/s for 500ms		Max lagging	21%	Y*
		0Mvar	21%	N
RoCoF 1,2Hz/s for 1s		0Mvar	21%	Y**



*Entsoe criteria are borne only in the specific case of maximum lagging
** The result is very slightly positive, however it is only because the hypotheses used (Xcc and Q) are quite favourable.

Synchronous power plants remain key actors to provide the grid with inertia, but cannot physically bear all Rocof values mentionned.

- **Simulations carried with different electro-magnetic transient tools lead to the same conclusion.**

- **Important parameters for Rocof withstand are:**
  - **Reactive power operating point: high leading condition is unfavorable to Rocof withstand**
  - **Grid-short circuit power: low Pcc is unfavorable to Rocof withstand**
  - **Inertia constant of the power plant**

- **A criterion of 1 Hz/s on a 500 ms sliding window appears to be relevant.**

- **High inertia synchronous generators are essential actors to prevent the appearance of high Rocofs in the grid, but their physical capacity does not allow them to resist any imposed Rocof.**

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