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Study Committee C4

Power System Technical Performance

Paper 682_2022

IMPACT OF AGGREGATED ASSETS IN THE POWER SYSTEM

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Motivation

- As distributed energy resources (DERs) are aggregated into cloud business models, cyber-security risks increase.
- The volume of DERs in Europe, such as PV and EVs, already exceeds the procured primary frequency reserves.
- Simultaneous and massive disconnection/reconnection of these devices may endanger system frequency stability.

Objects of investigation

- To get insights about the frequency stability impact on the Continental European Power System by the malfunction/sudden loss of a large pool of OEMs assets.
- To examine the need for a revision of actual primary frequency reserves to cover the current and future conditions of the system.

Method/Approach

- The initial dynamic model of Continental Europe (IDMCE), developed by ENTSO-E, is used for simulation studies.
- Failure/non-intentional control of cloud-based assets is emulated through the disconnection/reconnection of a collective power accommodated in a decentralized way.
- A set of test cases under current and future scenarios are defined in terms of equivalent system inertia.

CE power system overview

- An amount of only 3 GW is procured across Europe for Frequency Containment Reserve (FCR).
- There are currently about 100 GW of PV power installed in CE.
- A growing number of EVs are being connected to the grid (more than 1 million plug-in EVs registered in Europe).
- Over 30% of all PV inverters and most charging stations are now connected to cloud systems.
- The control of the pool through the cloud could fail or be hacked and misused by hackers.

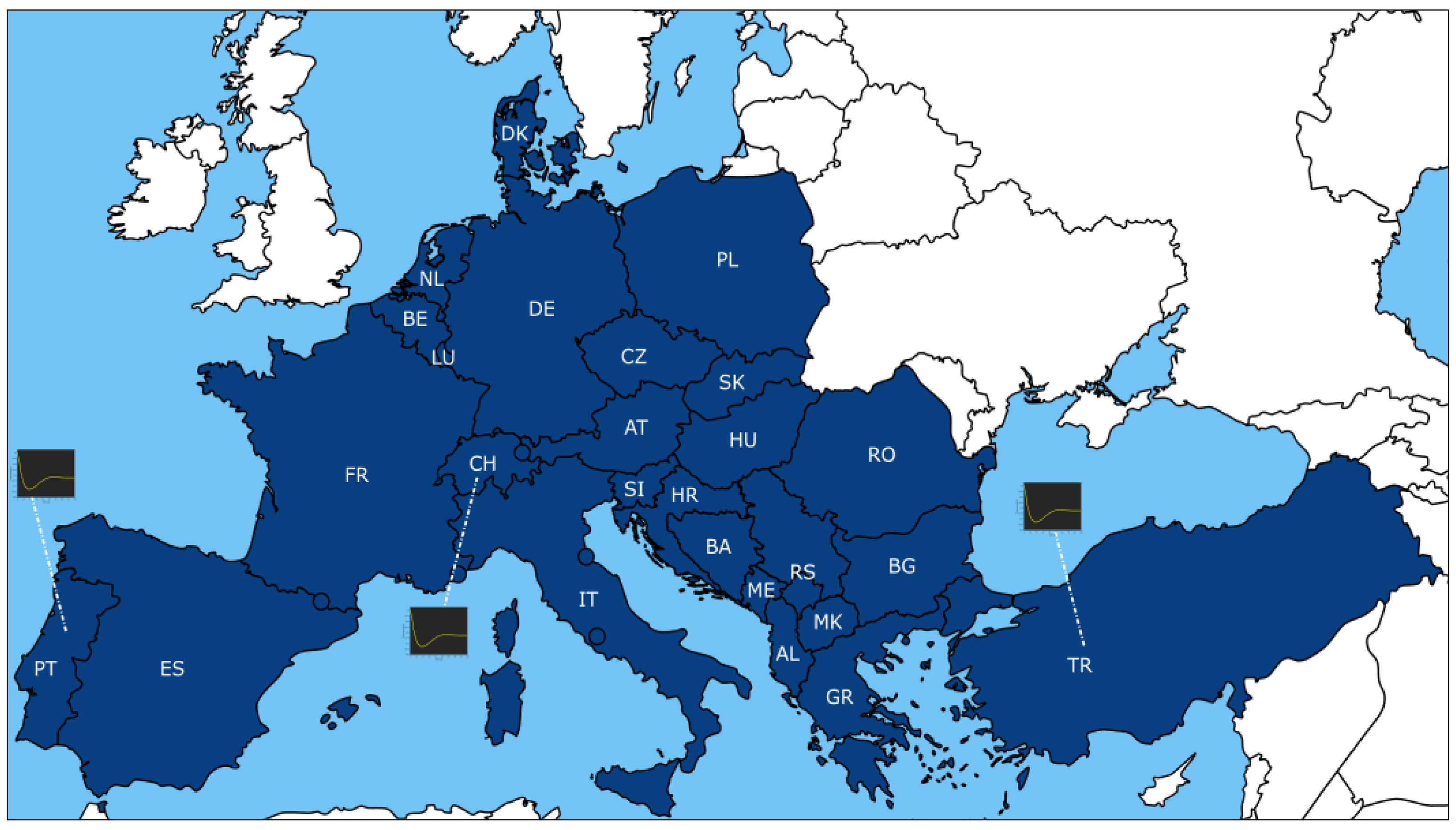

Figure 1: Representation of the countries covered by the IDMCE

- The IDMCE is a very large-scale dynamic model (approx. 23000 buses, 6000 generating units, 7000 loads, 18000 lines, and 9000 transformers).
- The model approximates over-all dynamics in terms of system inertia, FCR and dominant inter-area oscillations.

Asset aggregation and malfunction

- Asset aggregation was carried out by desired collective power, which was proportionally accommodated across the system by the random selection of loads/generators.
- Here, malfunction of large asset pools considers the unintentional control of these assets mainly leading to frequency declines due to a shortfall of power.
- Most important frequency dynamics of an interconnected power system can be approximated by:

$$\frac{2HS_B}{\omega_0}\frac{d\omega}{dt} = P_{gen} - P_{load}$$

- Then, initial RoCoF after a generation loss can be estimated according to:

$$\frac{df}{dt} = \frac{P_{gen} - P_{load}}{S_B}\frac{f_0}{2H}$$

- Large values of P_{gen}-P_{load} clearly influence initial RoCoF, which is especially high in regions with a small total H.

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Simulation results

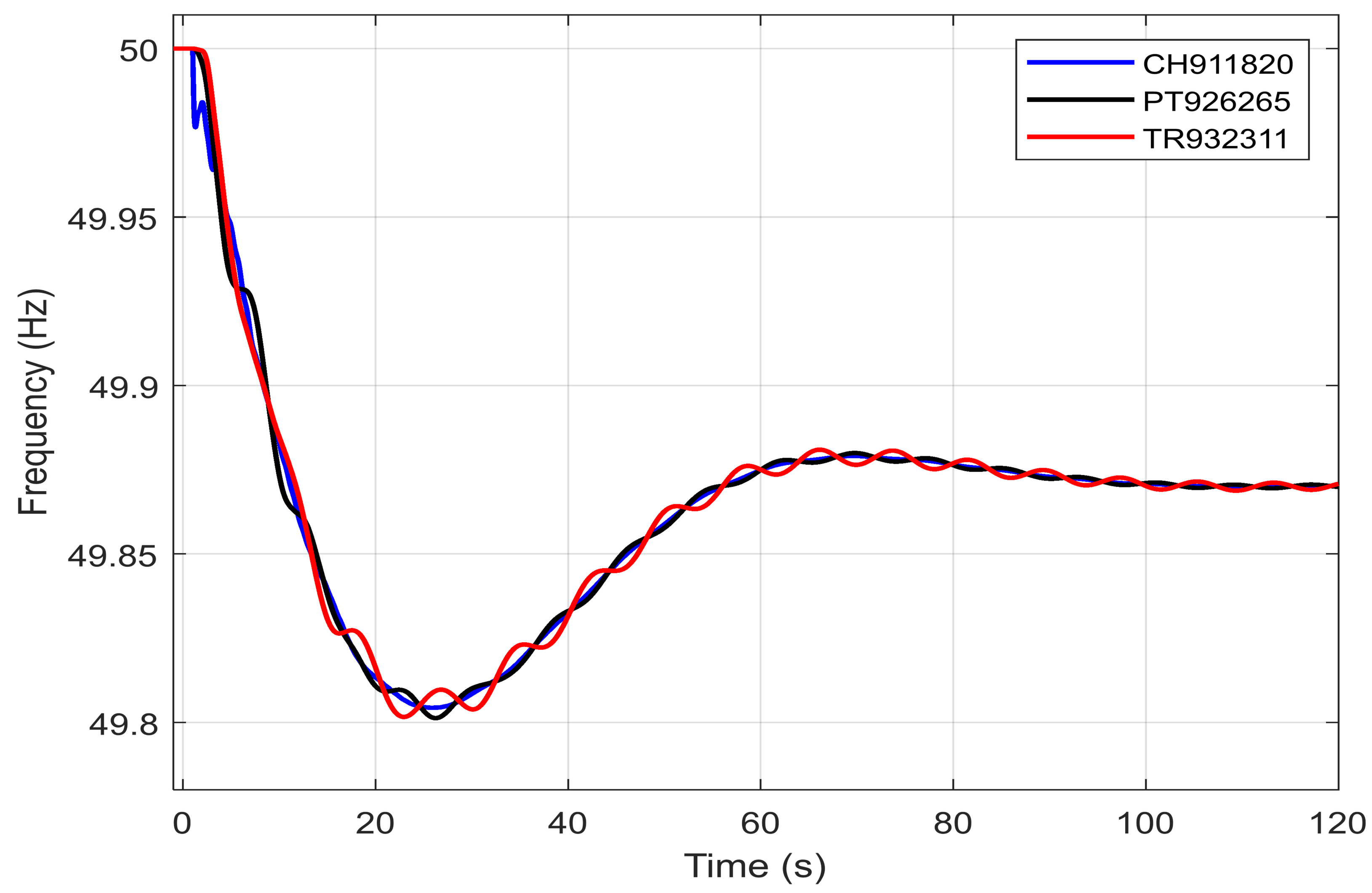

Figure 2: Generation loss of 2.6 GW and reserves limited to 3 GW

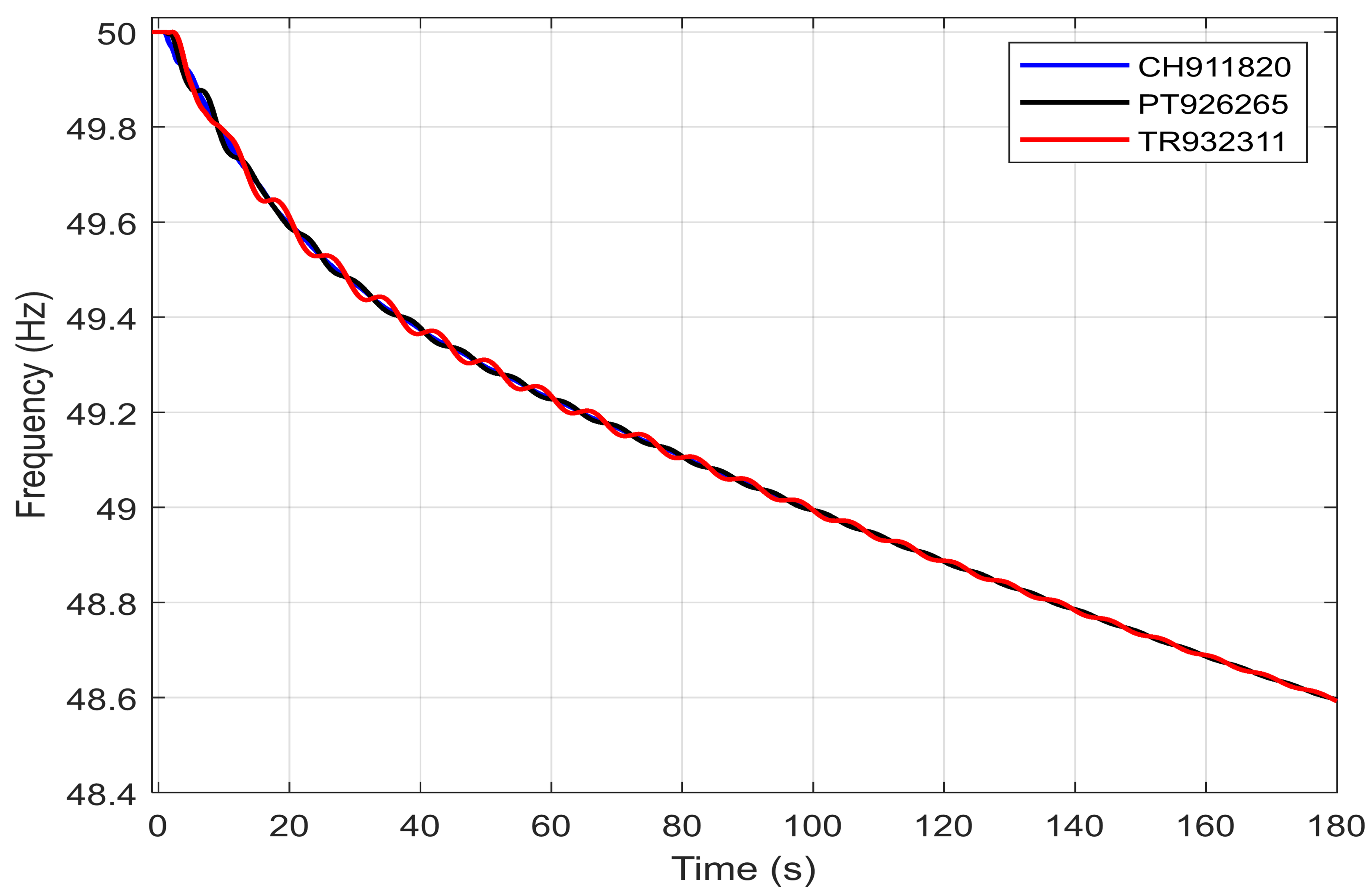

Figure 3: Generation loss of 4.1 GW and reserves limited to 3 GW

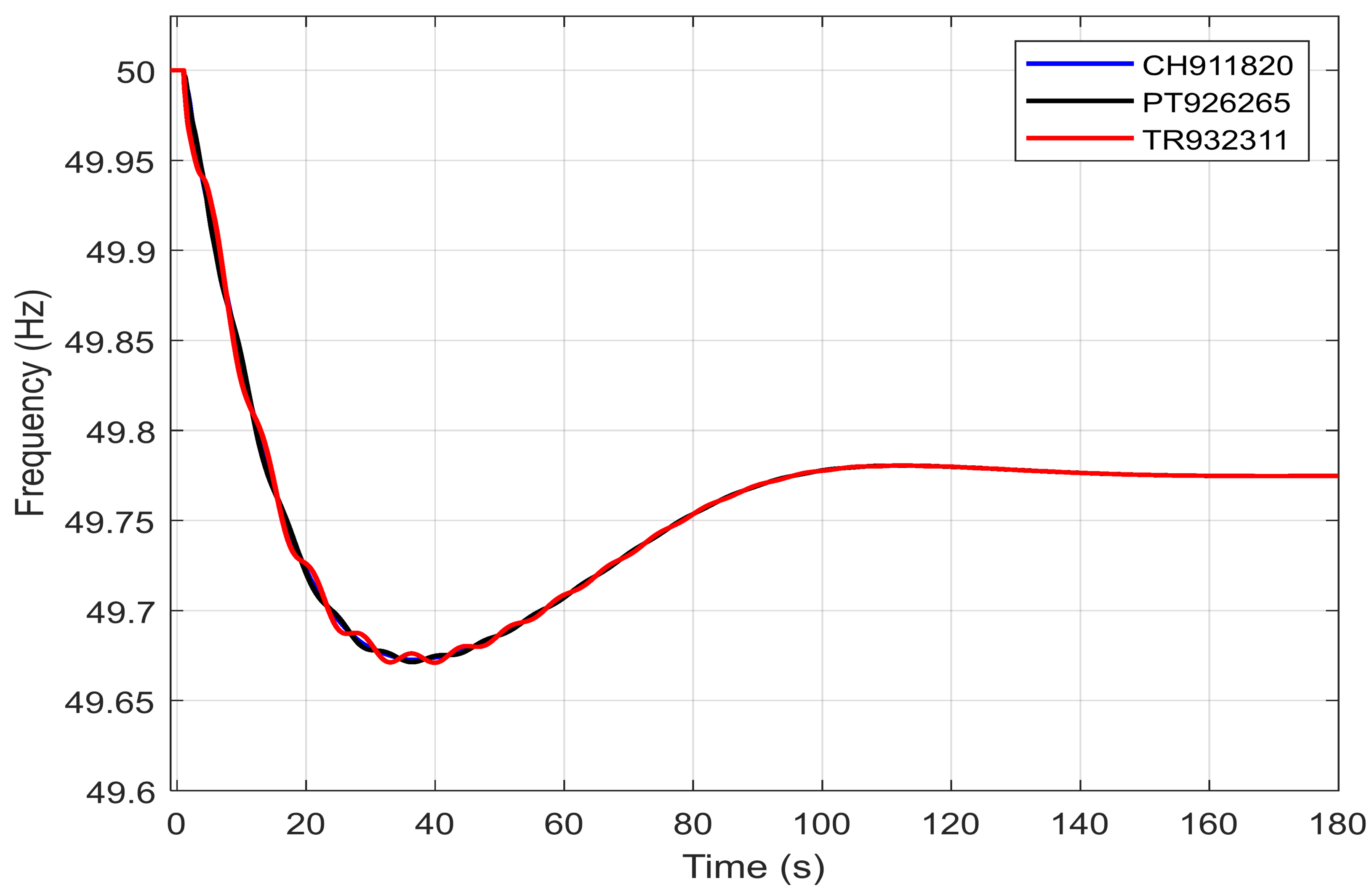

Figure 4: Load step increase of 3 GW and reserves limited to 3 GW

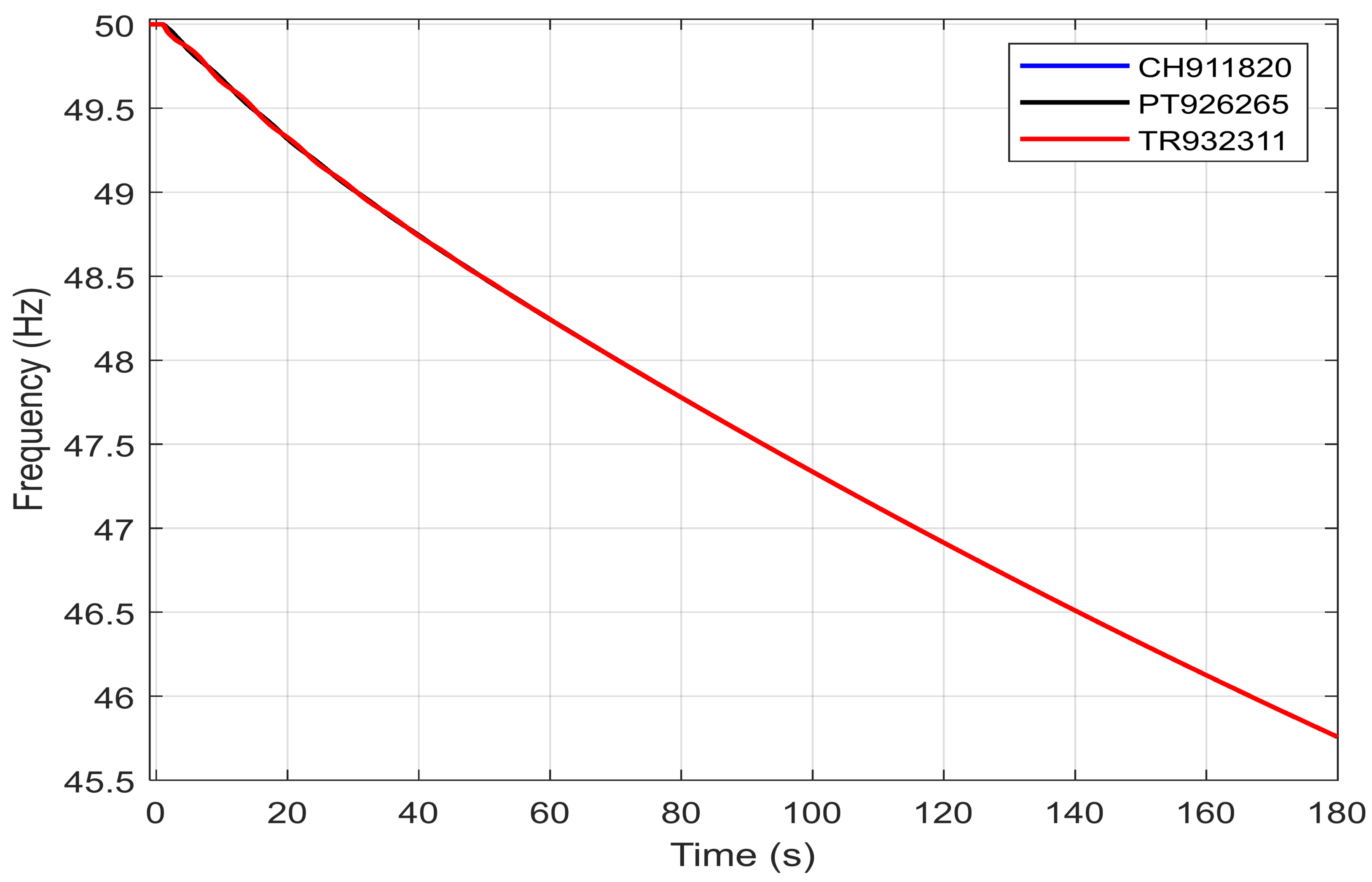

Figure 5: Load step increase of 6 GW and reserves limited to 3 GW

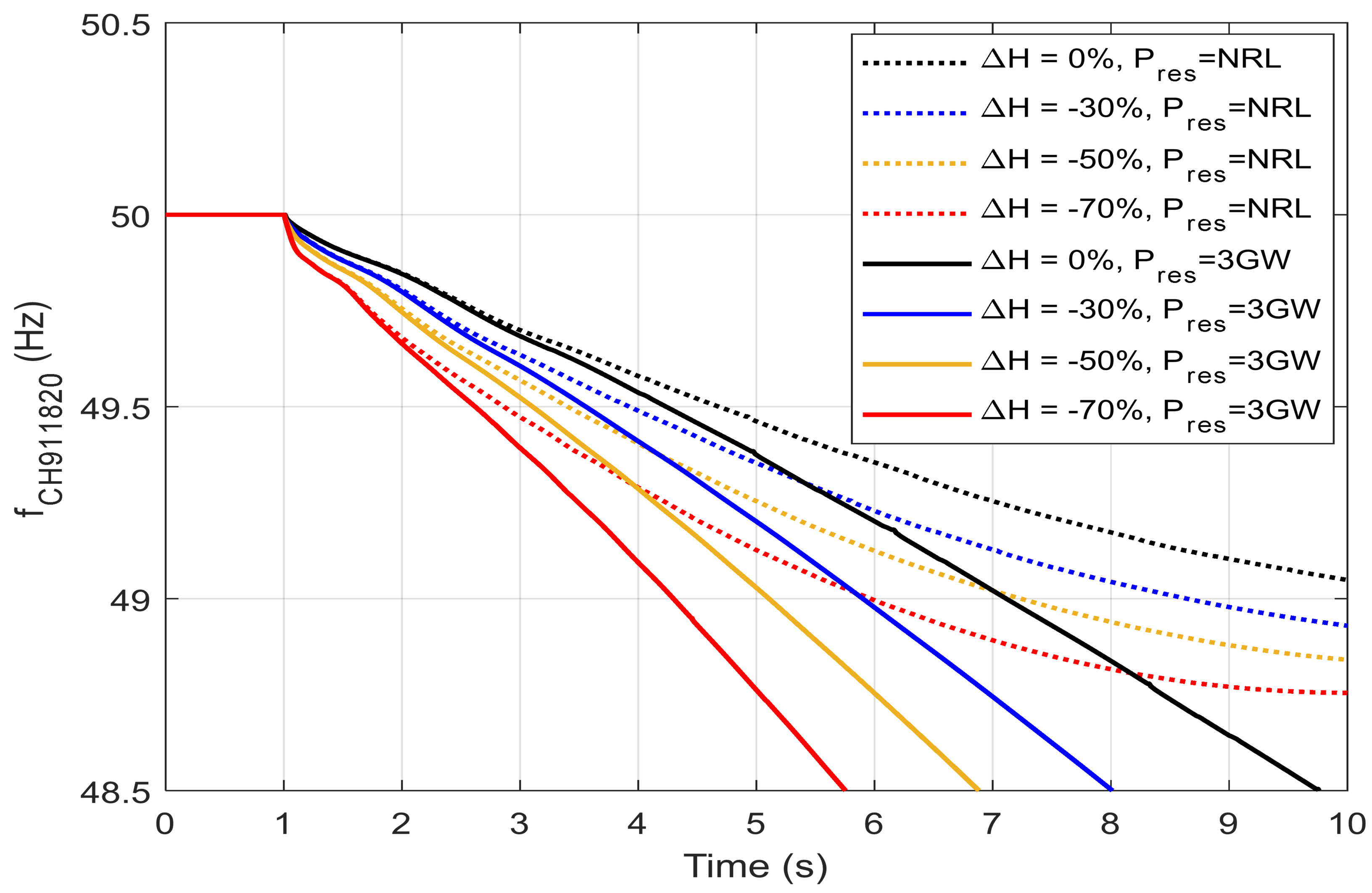

Figure 6: ΔP_{load}=24 GW with several ΔH (NRL=no reserve limitation)

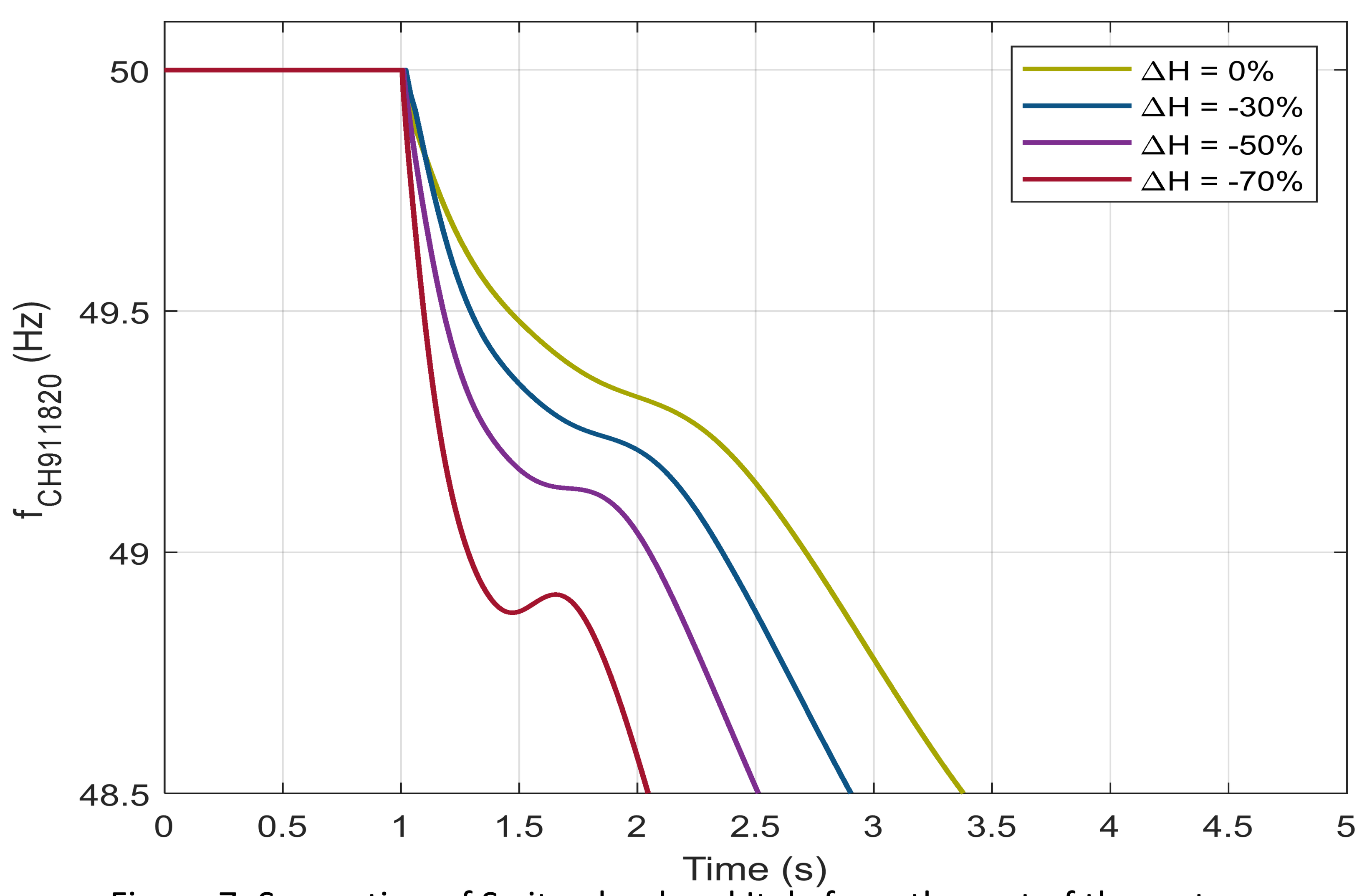

Figure 7: Separation of Switzerland and Italy from the rest of the system

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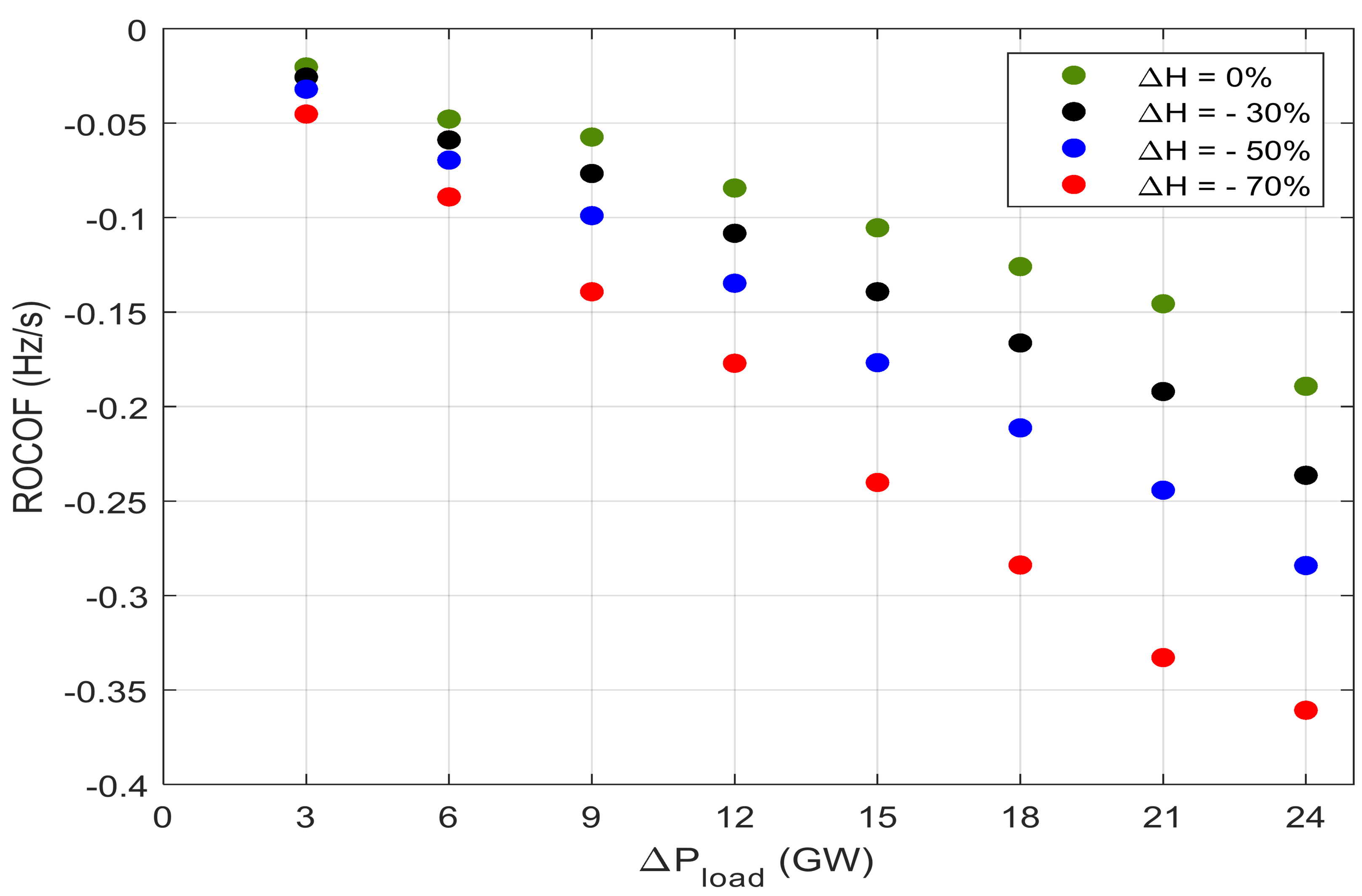

Figure 8: RoCoF with active power reserves as originally included in IDMCE

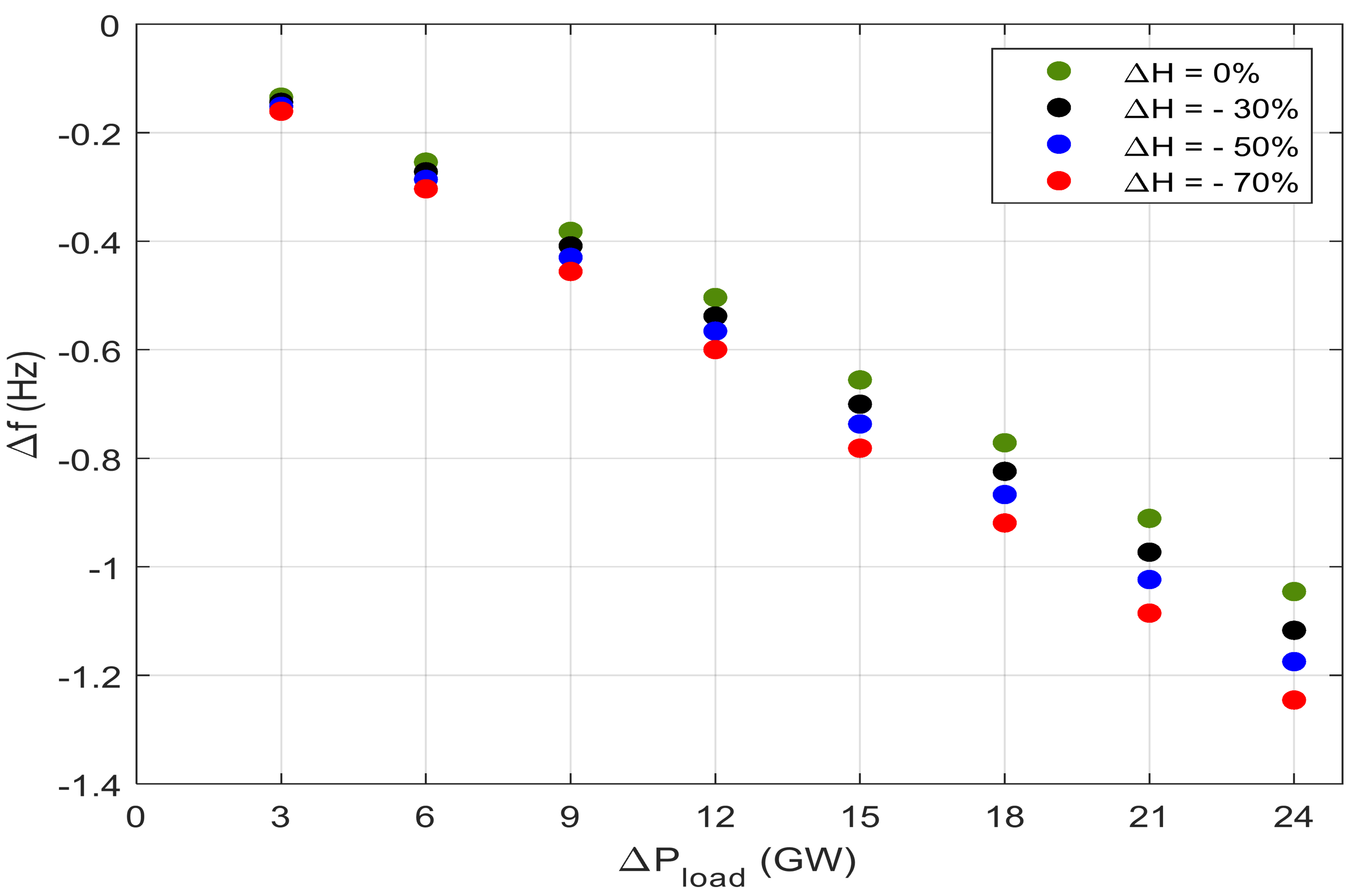

Figure 9: Δf at nadir with active power reserves as originally included in the IDMCE

Table I: RoCoF for interconnected operation

ΔP_{load} (MW)	Limited reserves	RoCoF (Hz/s) at 500 ms			
		ΔH=0%	ΔH=-30%	ΔH=-50%	ΔH=-70%
3	No	0.020	0.025	0.032	0.045
	Yes	0.020	0.025	0.032	0.045
6	No	0.047	0.058	0.069	0.089
	Yes	0.047	0.059	0.070	0.089
12	No	0.084	0.108	0.134	0.177
	Yes	0.084	0.109	0.136	0.178
18	No	0.125	0.166	0.211	0.283
	Yes	0.126	0.168	0.214	0.286
24	No	0.189	0.236	0.284	0.360
	Yes	0.189	0.238	0.287	0.365

Table II: RoCoF in the islanded system consisting of CH & IT

RoCoF at 500 ms (Hz/s)			
ΔH=0%	ΔH=-30%	ΔH=-50%	ΔH=-70%
-1.042	-1.301	-1.656	-2.246

Conclusion

- During interconnected operation, RoCoFs are small for different power imbalances under system inertia variations.
- However, active power deficits exceeding actual FCR may endanger containment of Δf and trigger UFLS protection.
- Split scenarios showed RoCoFs higher than 1 Hz/s, with more critical values as equivalent inertia is reduced.
- Cloud aggregated assets raise the potential incidence of more severe active power imbalances.
- A review of the FCR in CE is recommended to take into account the malfunction of large OEM asset pools.
- Cyber security aspects should be addressed with a reliable cloud risk assessment model