International Workshop on
Dynamic Stability Challenges of the Future Power Grids

Power System Stability during Energy Transition

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Germany

Tuesday, September 9th 2025, Rome, Italy

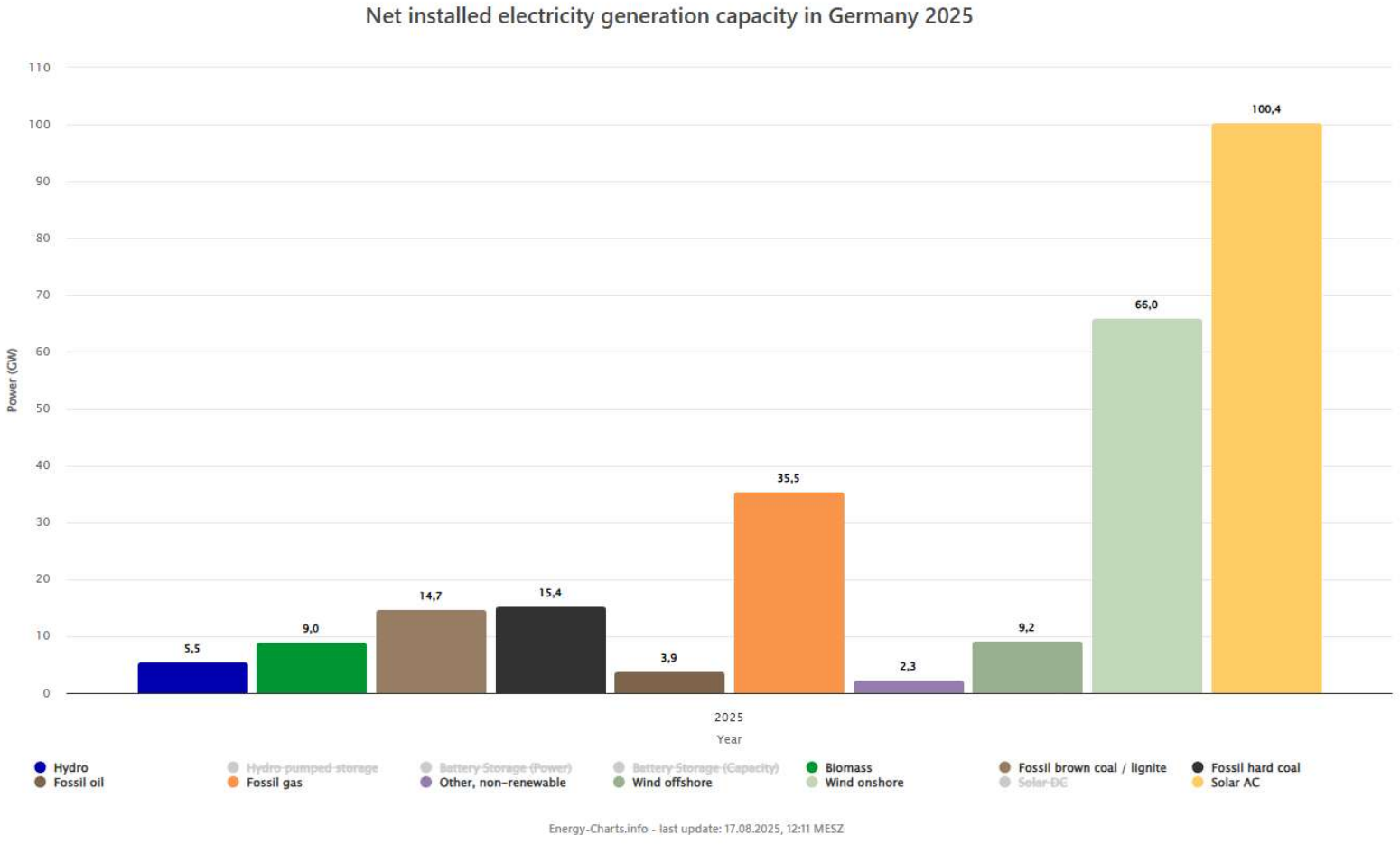
Agenda

- Main Challenges
- Recent Observations
- Required Actions
- Conclusions

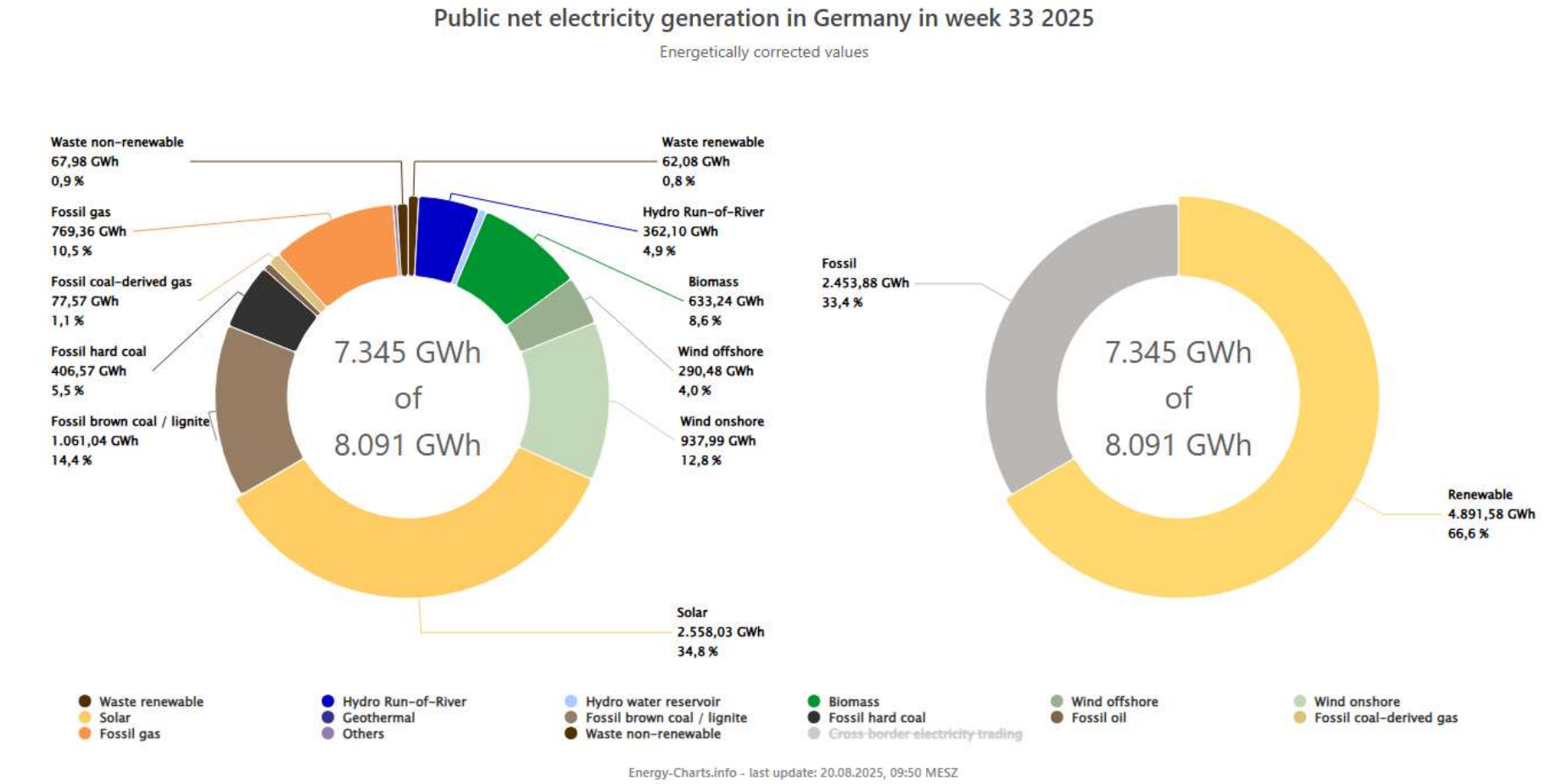
500 MW, Núñez, Spain

1218 MW, Hornsea 2, United-Kingdom

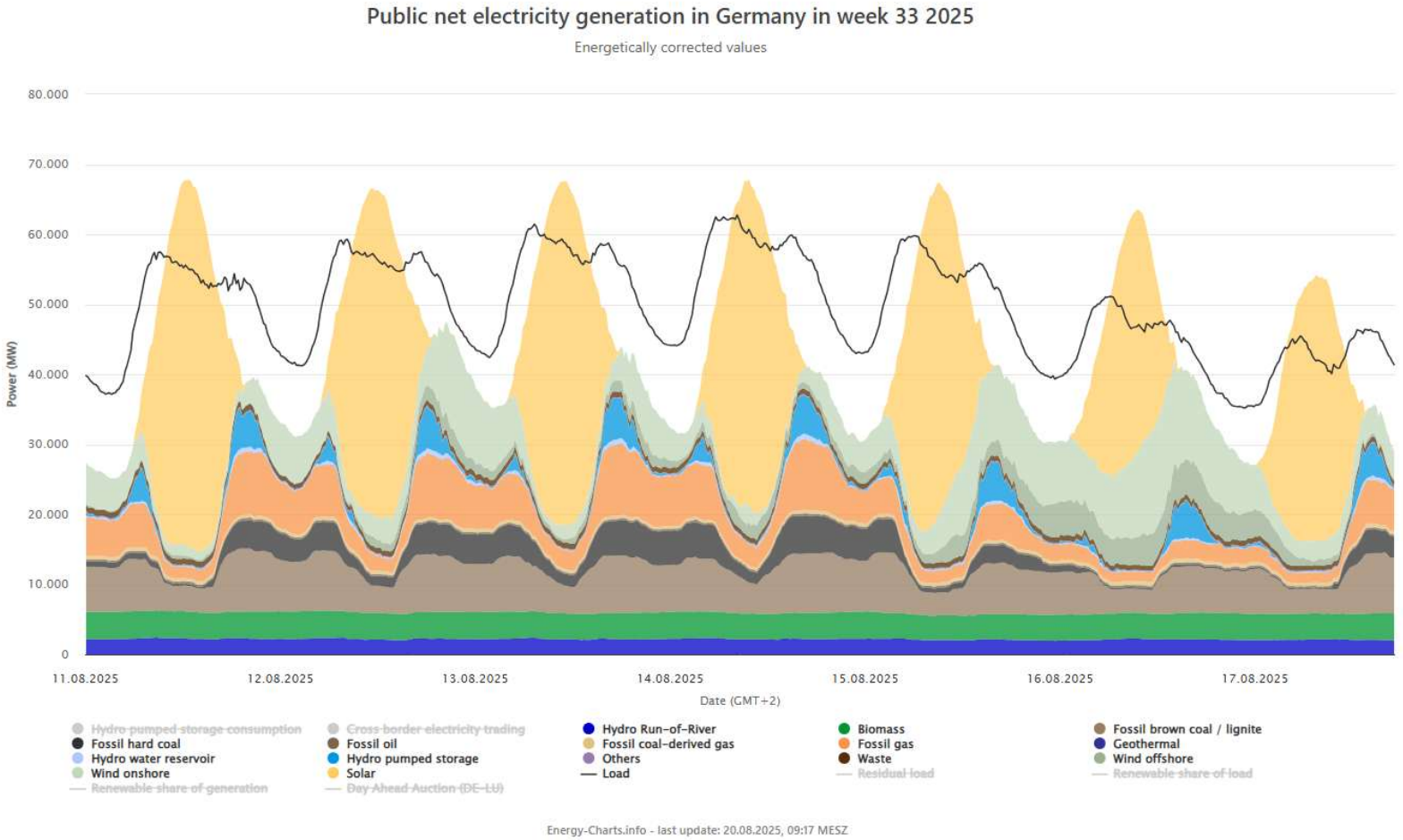
Installed Power in Germany



Energy Sources in Germany

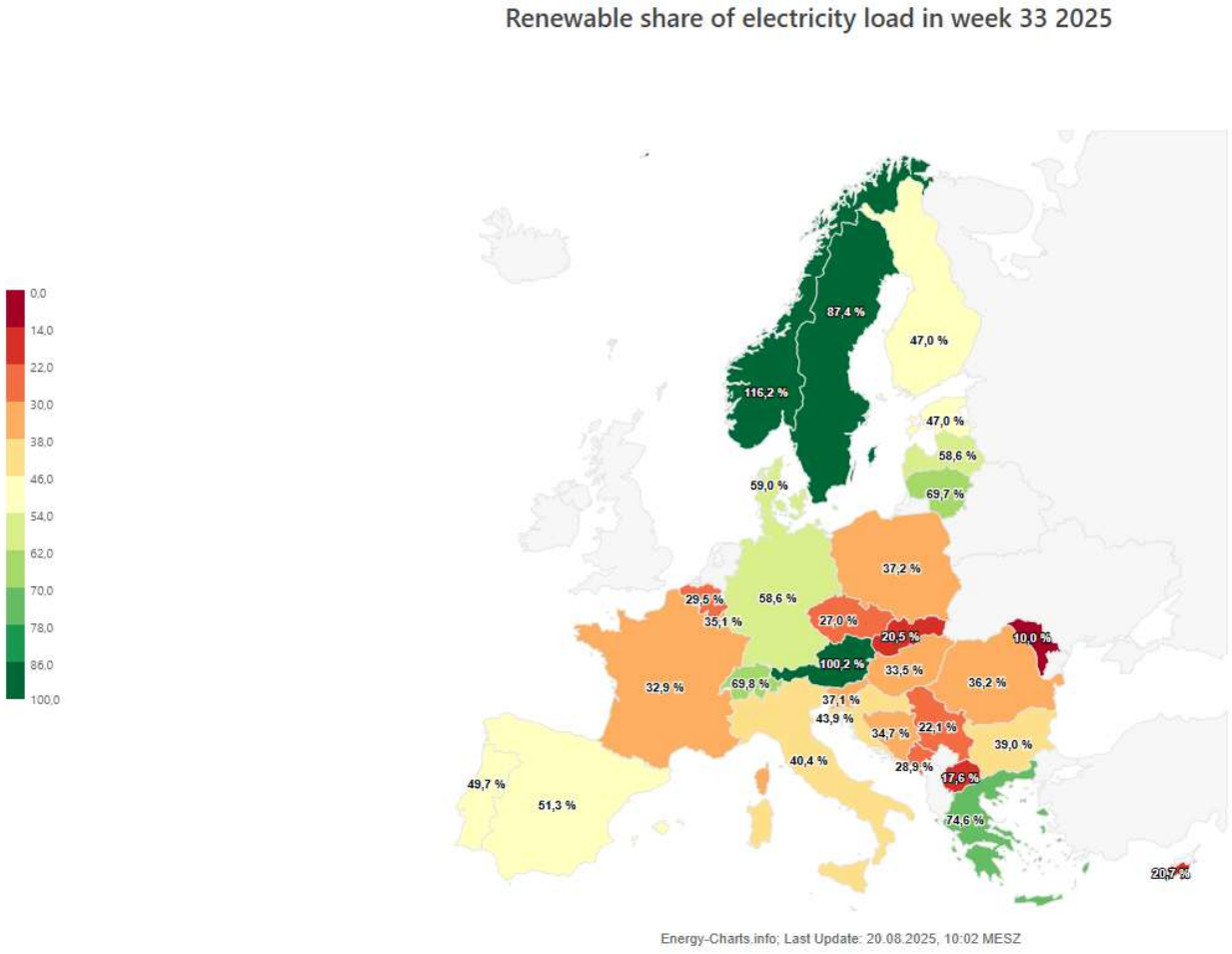


Active Power in Germany

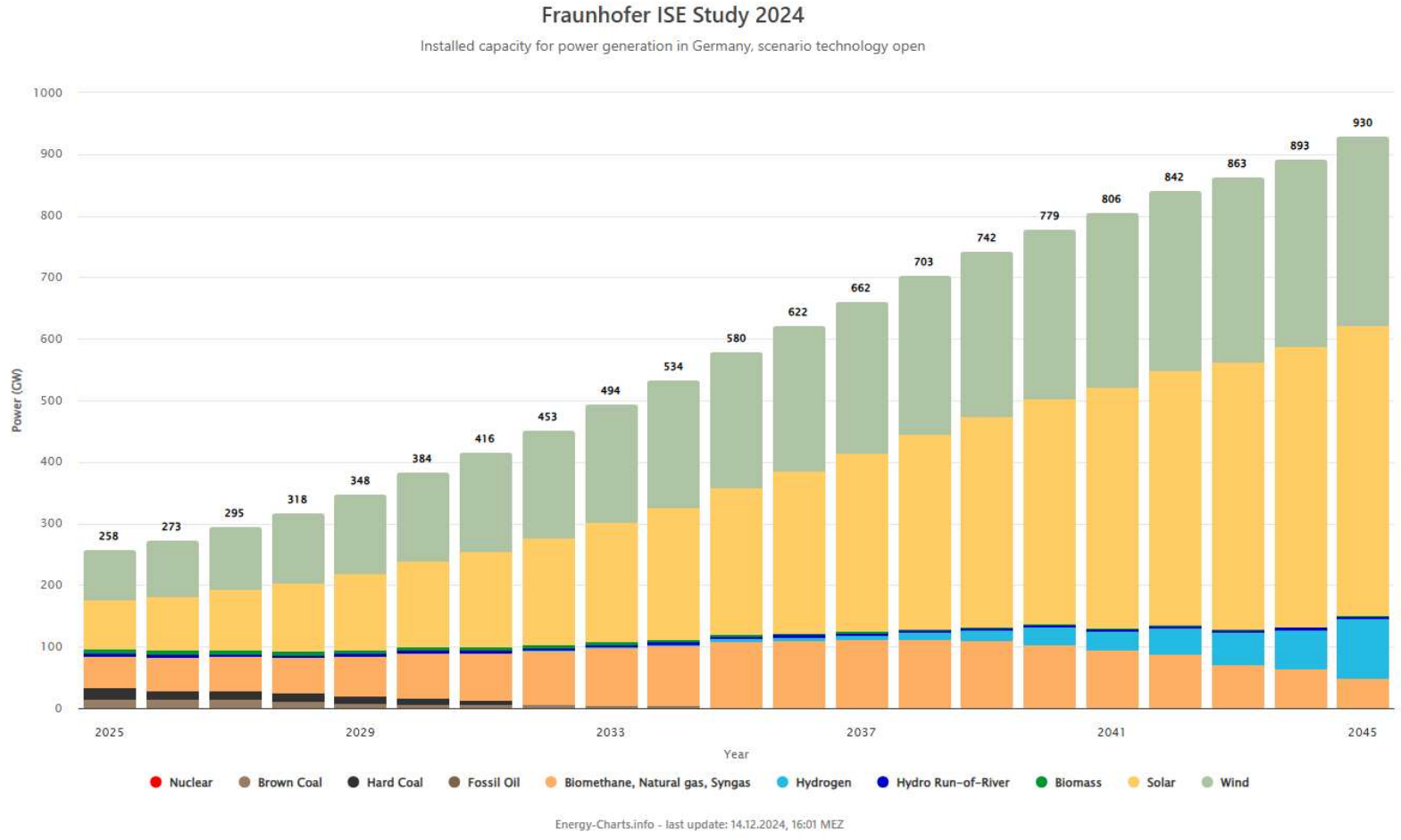


Spot Market Prices in Germany

Shares of Renewables in Europe



Development of Installed Power in Germany



Main Changes for System Loads

- Electromobility – Car batteries charging -> AC/DC converter
- Air condition load – Induction machine load (compressor)
- Heat pumps – Induction machine load (compressor)
- Dramatic increase of power-electronic connected loads – industrial & domestic loads

System Inertia – 24 July 2021 CE Event

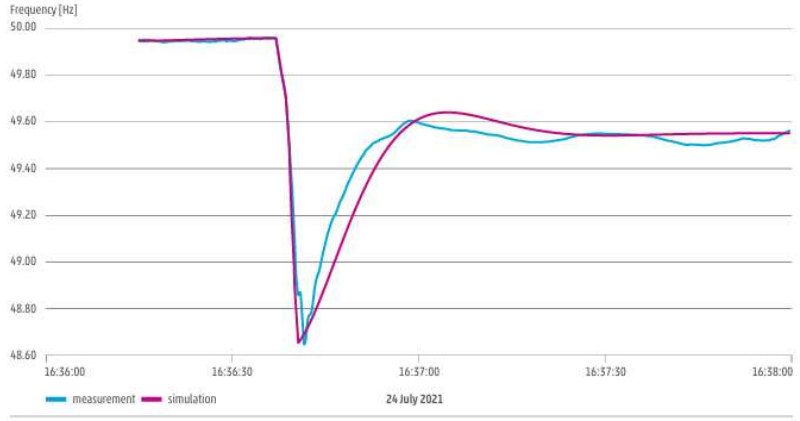


Figure 23: Simulation results (frequency) of the single busbar model and comparison with real PMU measured value (La Cereal).

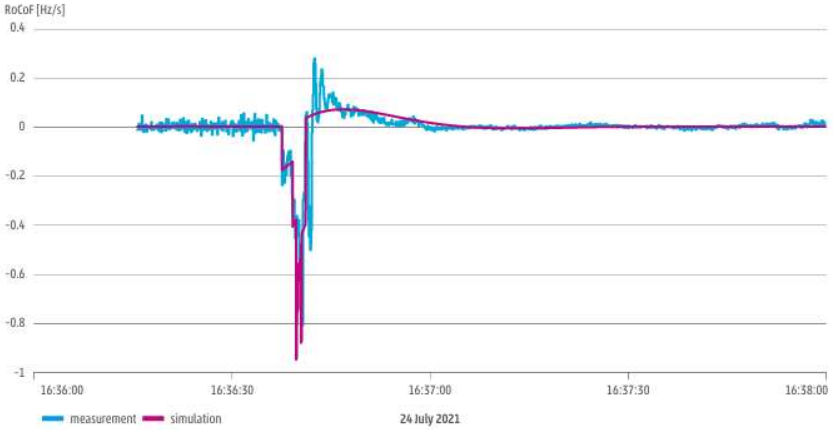
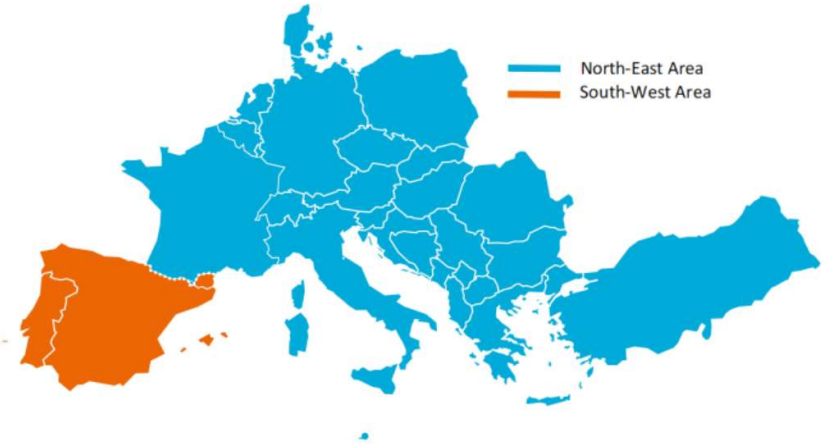


Figure 24: Simulation results (ROCOF) of the single busbar model and comparison with real PMU measured value (La Cereal).



Parameter	Value
System load	35.4 GW
Active power deficit	1,000 MW (at 16:36:37.1)
	1,500 MW (at 16:36:38.7)
System inertia constant (H)	4 s
Self-regulating effect of loads	2%/Hz

Table 18: Main parameters for the single busbar model.

Source: Continental Europe Synchronous Area Separation on 24 July 2021, Technical Report, ENTSO-E, 12. November 2021

System Inertia – 28 April 2025 CE Event

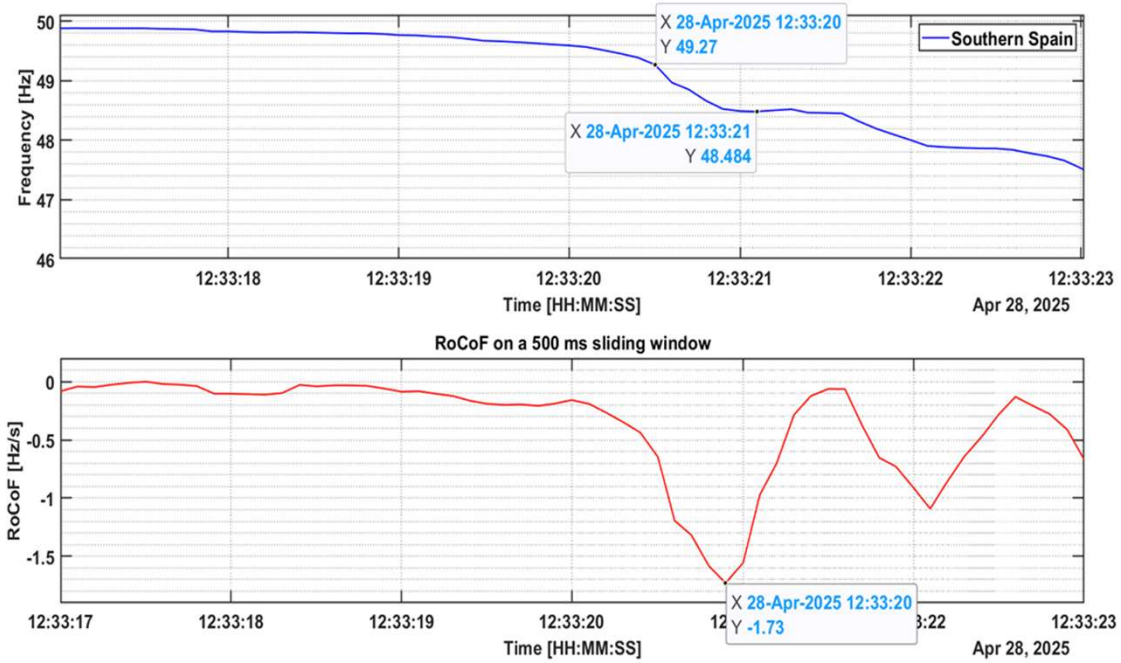


Figure 15 - Evolution of the frequency and RoCoF in the seconds before the blackout (source : PMU data from Red Eléctrica)

Source: 28. April 2025 Blackout, ENTSO-E Website, 19. August 2025

Voltage Quality – 24 July CE 2021 Event

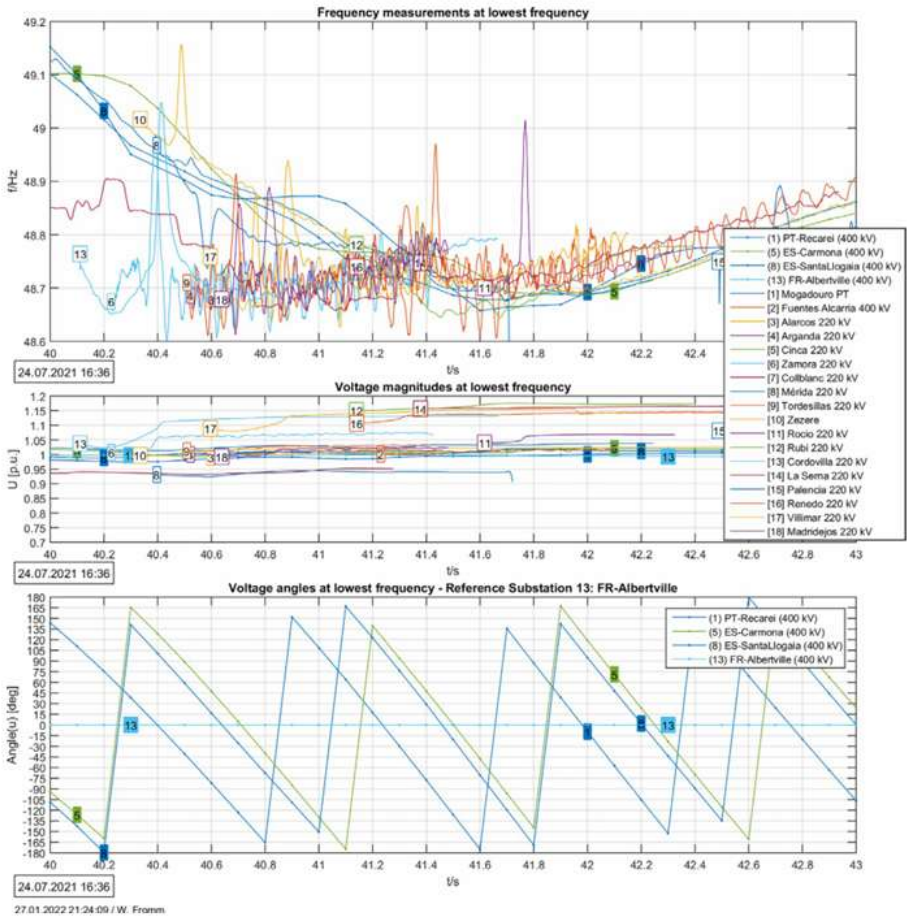
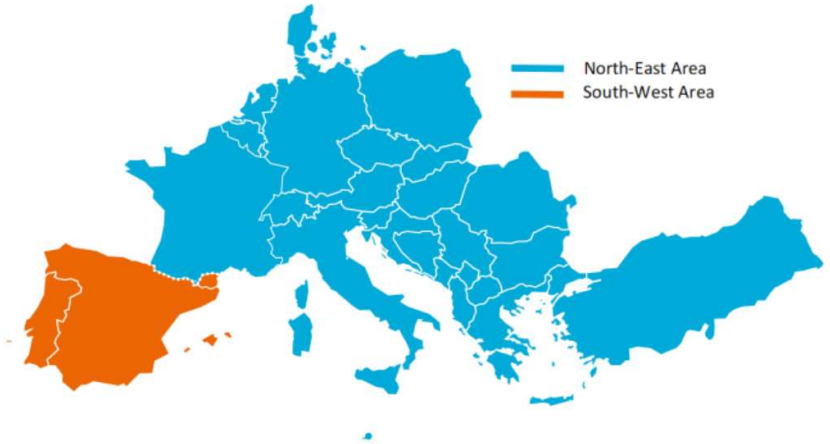


Figure 99: Overlapped measurements at the lowest frequency



Source: Continental Europe Synchronous Area Separation on 24 July 2021, Final Main Report, ENTSO-E, 25. March 2022

Voltage Quality – 28 April 2025 CE Event

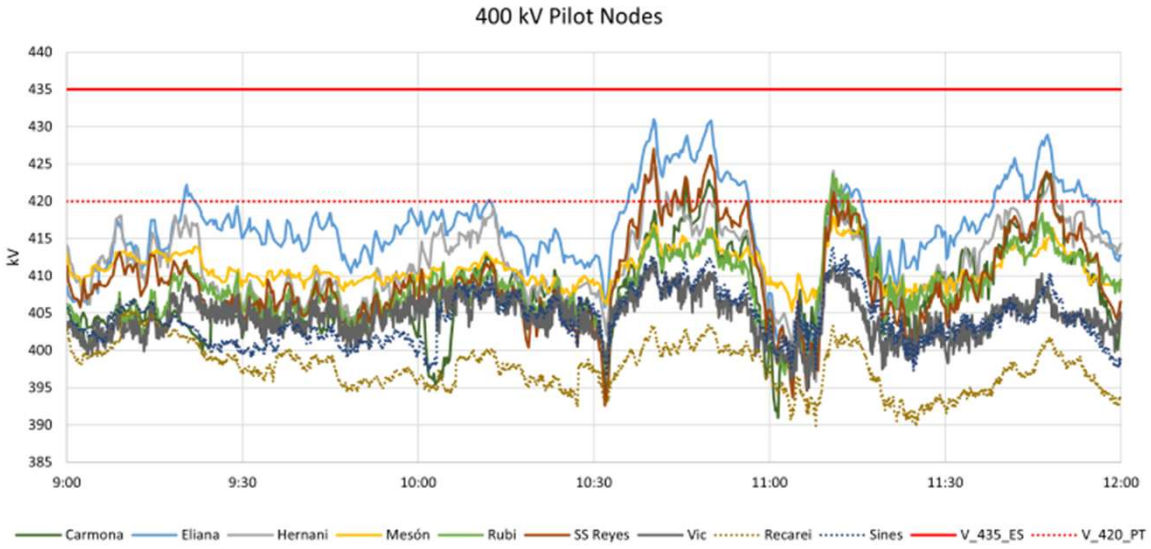


Figure 2a - Voltage evolution from 9:00 to 12:00 CEST in the main 400 kV transmission substations in Spain and Portugal.
[source: Telemeasures every 4'' from Red Electrica and REN]

Source: 28. April 2025 Blackout, ENTSO-E Website, 19. August 2025

Voltage Quality – 28 April 2025 CE Event

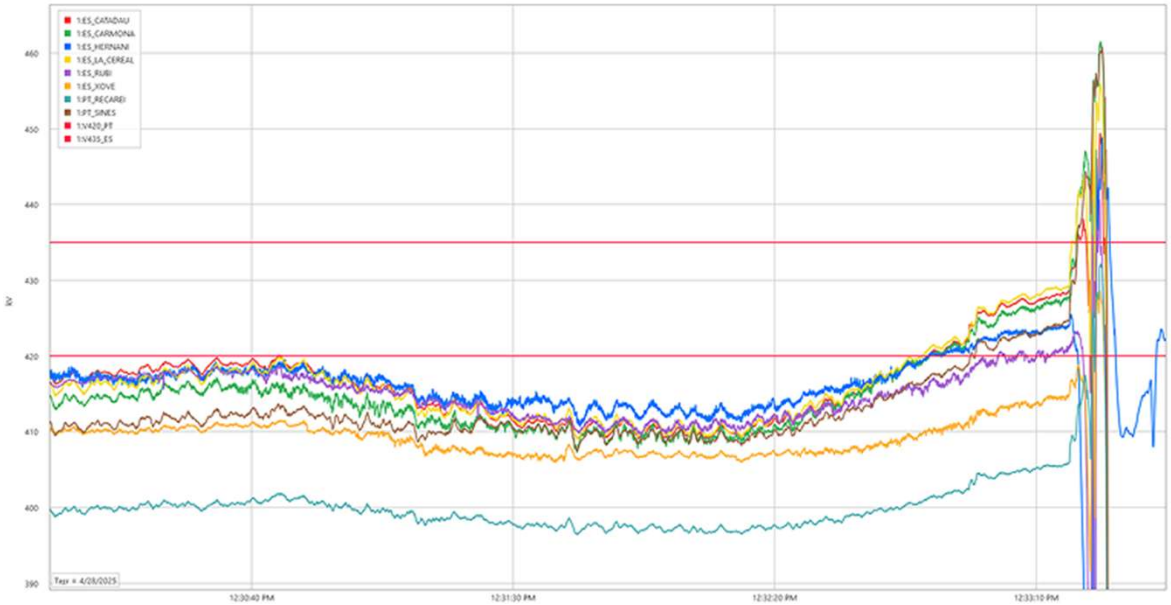


Figure 13a - Voltage evolution after 12:30 CEST in the main 400 kV transmission substations in Spain and Portugal.
[source: PMU data from Red Eléctrica and REN]

Source: 28. April 2025 Blackout, ENTSO-E Website, 19. August 2025

Required Actions

- Increase of system inertia -> synchronous condenser with flywheels
- Impose participation on voltage control to new renewable installations
- Introduce a certain percentage of grid forming converters, carefully observe their behaviour in the interconnected power system -> pilot projects; fine-tune and coordinate their control loops

Conclusions

- Improve collaboration between all involved/affected players:
  - GenCos
  - DSOs
  - TSOs
  - Regulatory Autonomies
  - Energy Ministries
  - Politics
  - Academia
  - Manufacturers
  - Consultants

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