COORDINADOR ELÉCTRICO NACIONAL

SERVIMOS A CHILE CON ENERGÍA

Chilean Grid Blackout of February 2025: Causes and Lessons

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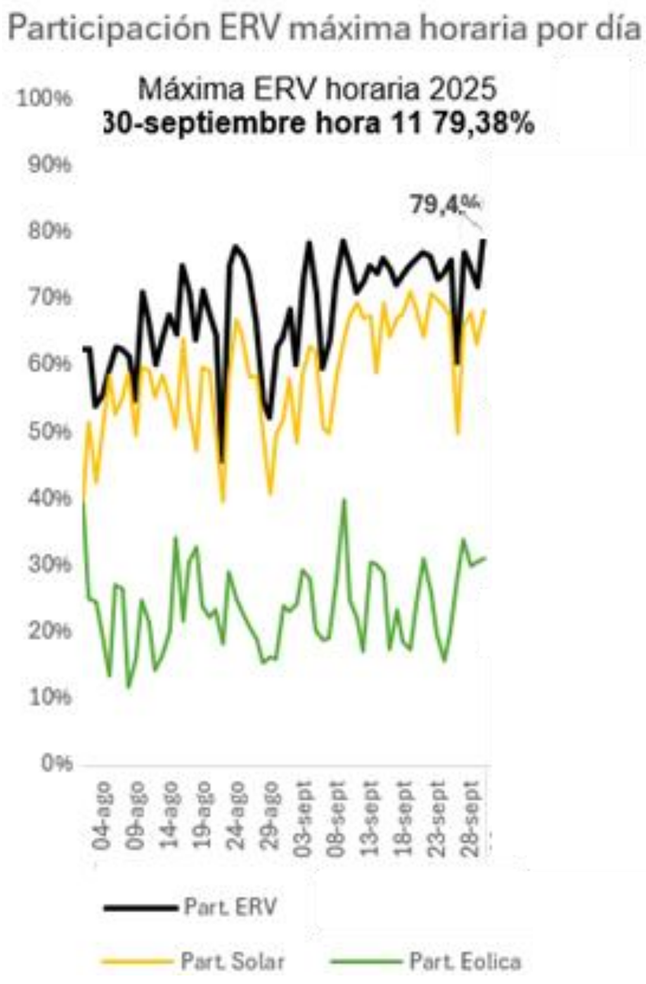
Chilean Power System Overview

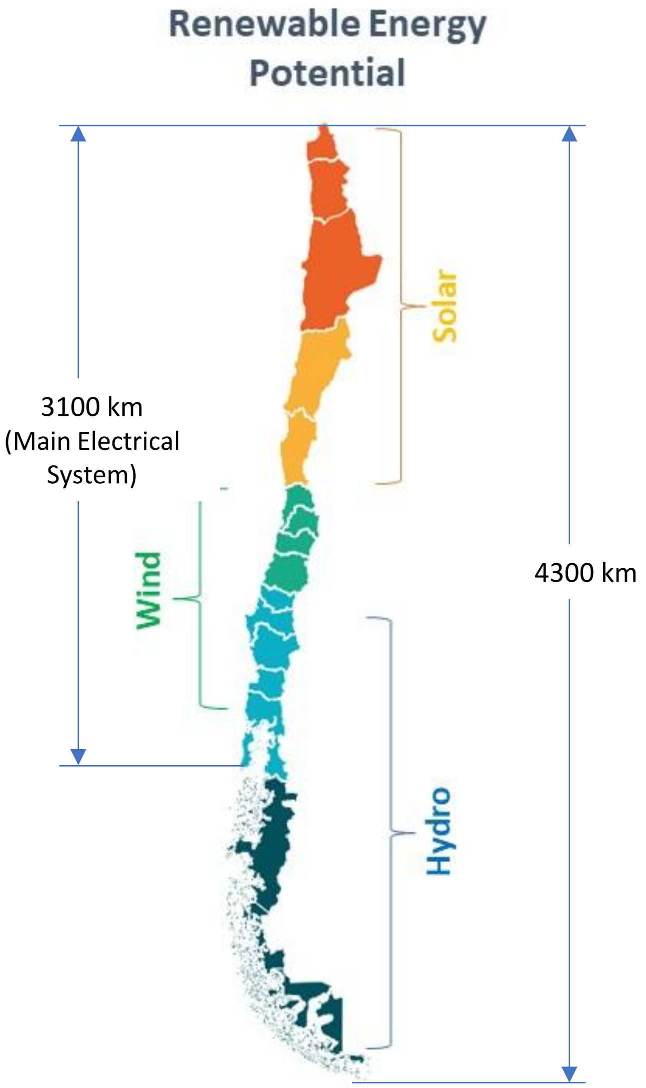
Facts 2025

- ✓ Energy: 85.5 TWh
- ✓ Capacity: 38.3 GW
- ✓ **Peak load: 12.9 GW**
- ✓ **VRE (Wind/Solar): 33%**
- ✓ **VRE Peak: 79,38%**
- ✓ DER: 3.4 GW

Long-term RE Goals:

- ✓ Carbon Neutrality by 2050
- ✓ Decarbonization by 2035
- ✓ 100% RE by 2030 (85% VRE)





The situation before the blackout

The Electric System operated in an interconnected and stable condition.

Generation

11.657 MW

Energy Flow

1,800 MW N→S 2x500 kV NMA- NPA line. **90% of the line's capacity.**

The **northern part** mainly transmitted **solar and wind** (IBR-GFL).

The **southern region** relied on energy **from the north, local solar and wind, hydro, thermal power, and DER.**

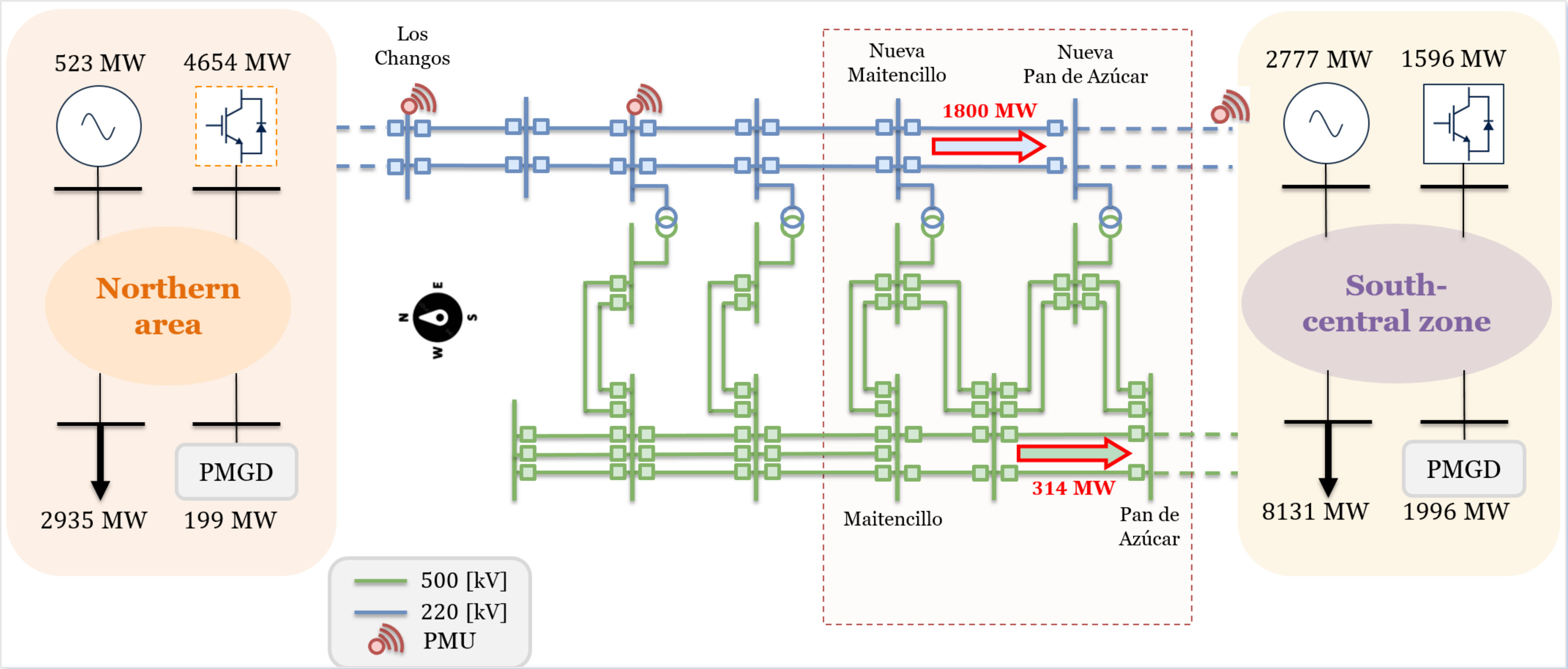
Stable Operation

The system operated with **N-1 safety criteria**.

The situation before the blackout

Generation: 11.7 GW
VRE share: 72 %
Total N-S Power Flow: 2,114 MW

The Electric System operated in an interconnected and stable condition.



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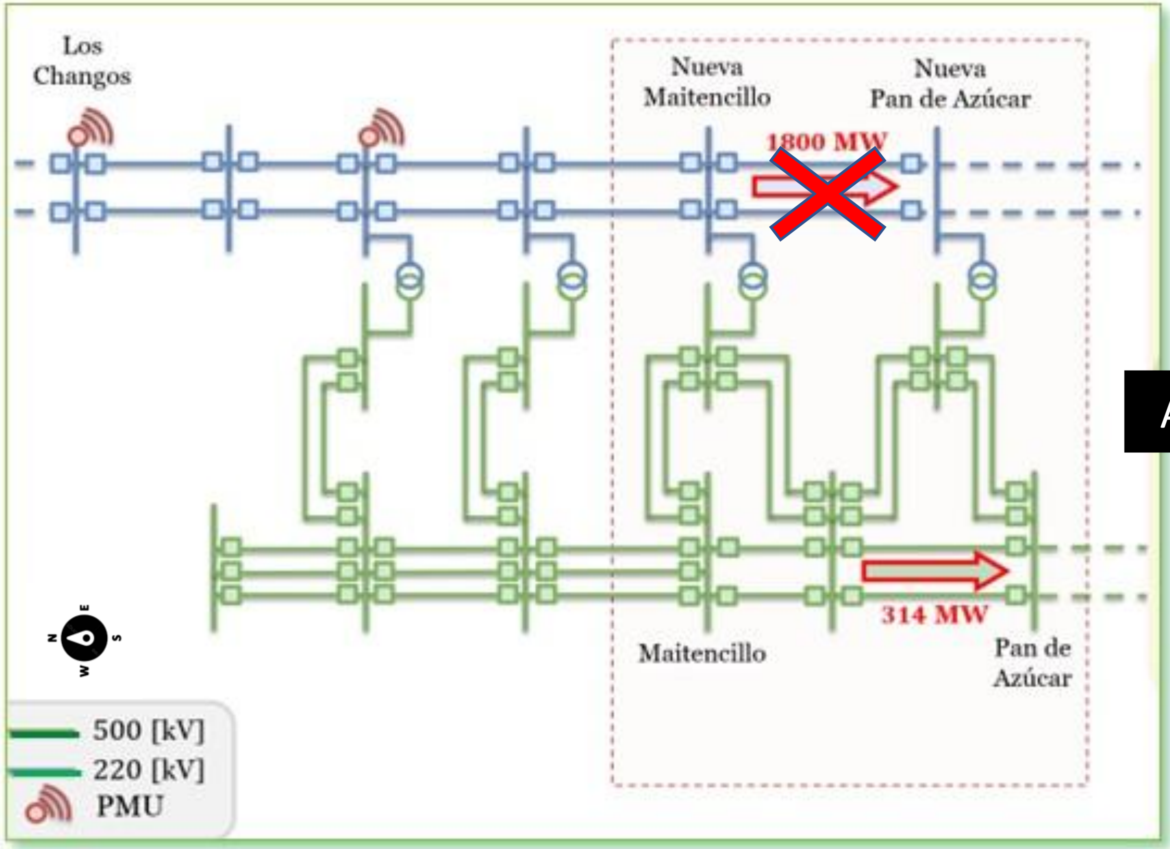
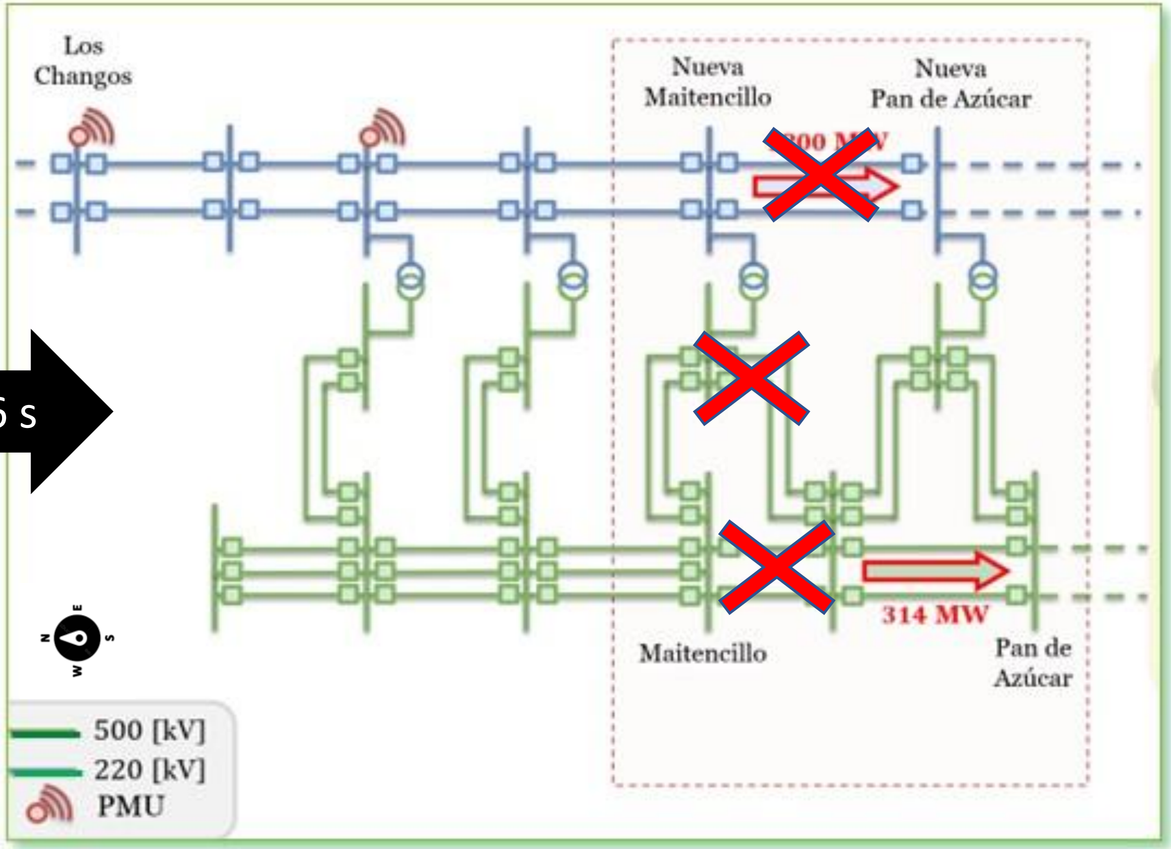
Initial fault root cause: what happened?

- Manual intervention to resync the telecom module of 87L protection caused the **unexpected trip of the two circuits** in one of the main 500 kV lines.
- The system remained interconnected through a weak 220kV link, and **after 1.6s, it separated into two islands**: North (30%) and Center-South (70%).



After 1.6 s



System separation & fault propagation

Initial Impact

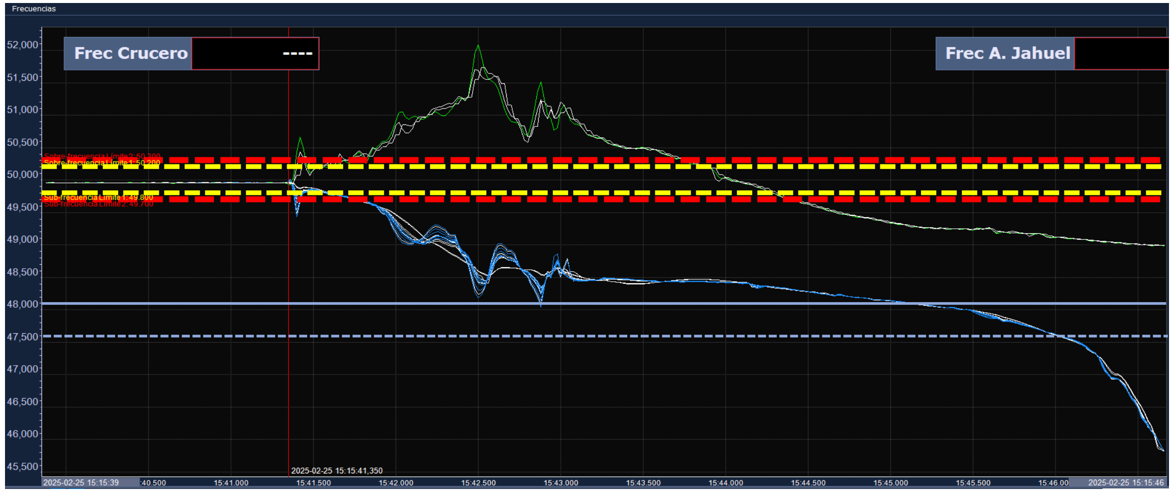
- 1.6 s delay triggered **severe power and voltage oscillations**, tripping OFLS and UFLS resources.

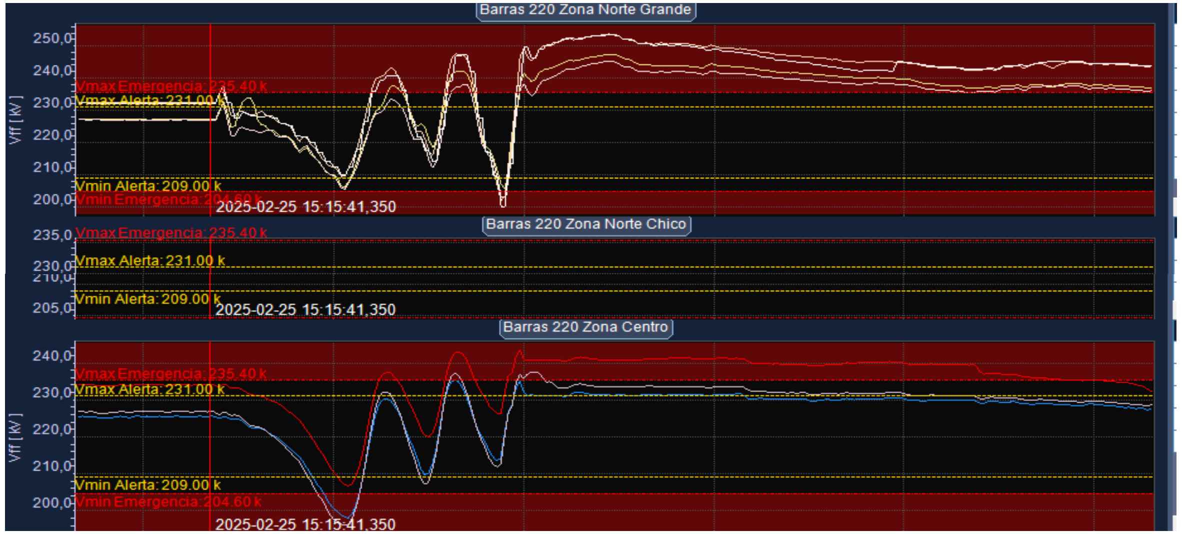
Northern Island

- **Remained stable for ~4 min**, then collapsed due to low frequency.
- Generators tripped from overvoltages before and after separation.

Central-South Island

- **Collapsed in ~4 s** from low frequency, following multiple generator trips and partial UFLS (DER) failure.

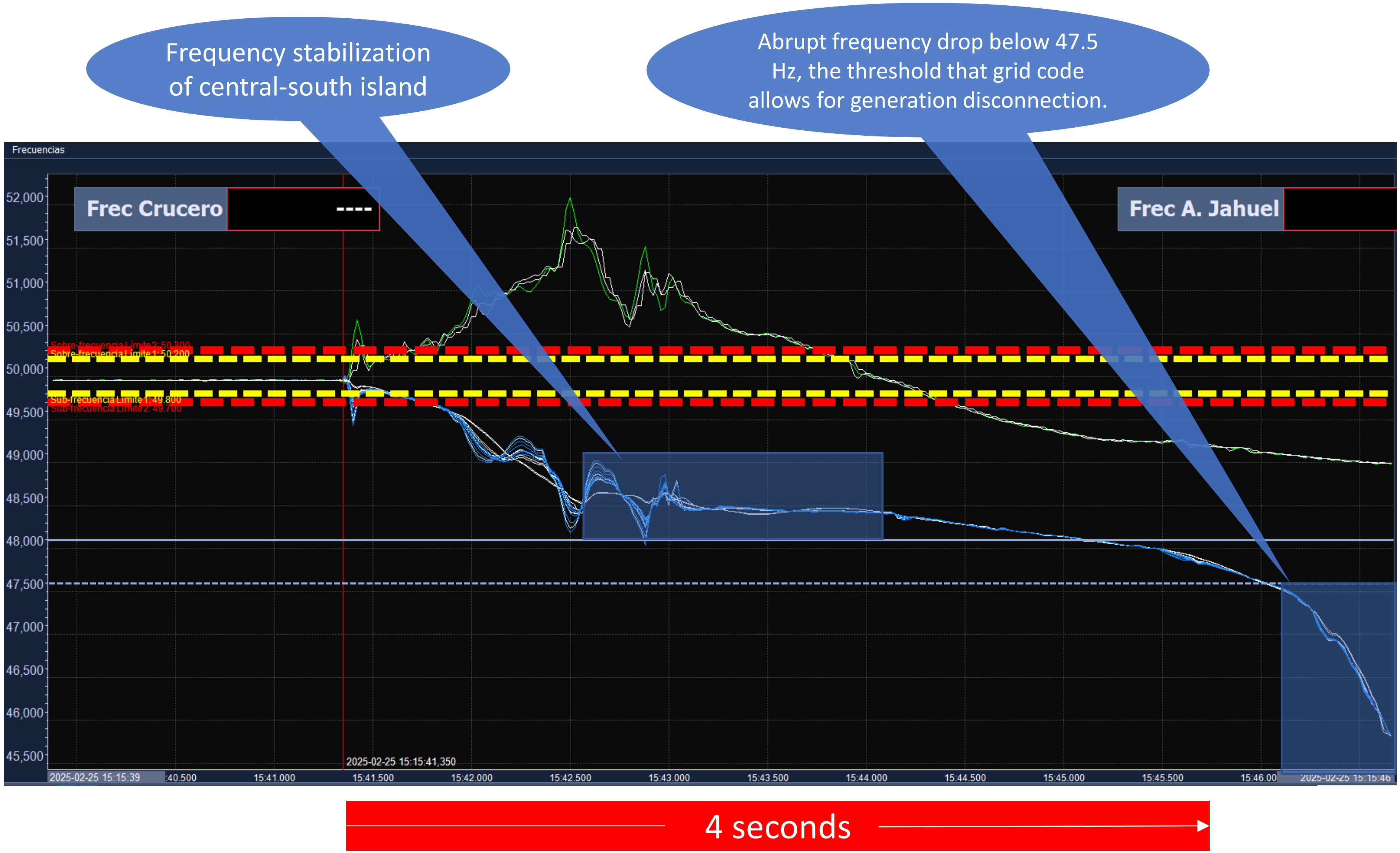




Frequency evolution Center-South Island

Sequence

- Rapid frequency decline driven by poor contingency response and generation behavior.
- Temporary stabilization at 48.5 Hz, then gradual fall to 47.5 Hz (≈ –0.3 Hz/s).
- Crossing 47.5 Hz triggered additional trips, leading to total loss of supply



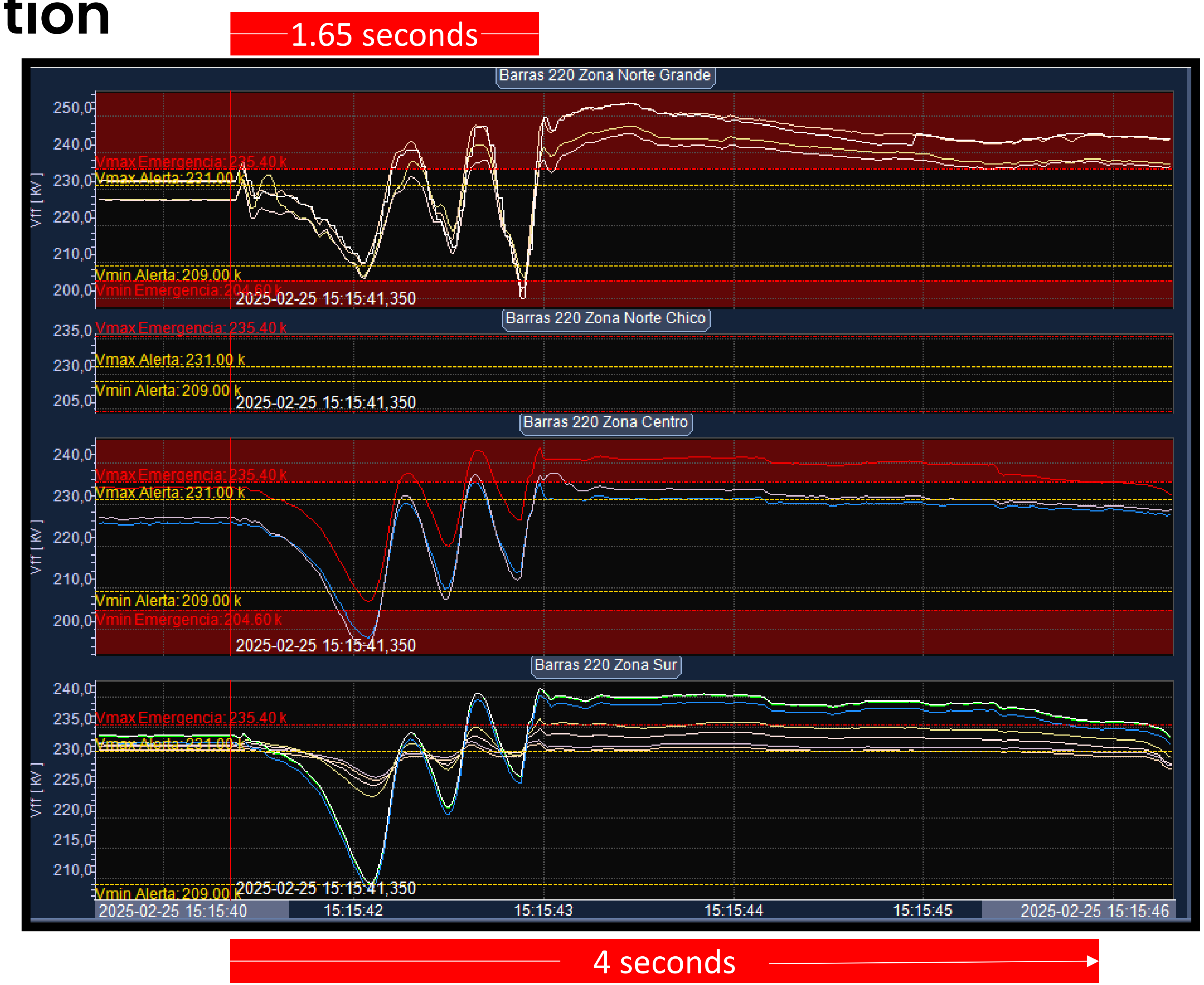
Voltage evolution

Northern Zone

- Voltage rise caused by lack of voltage control in VRE plants and loss of reactive compensation.
- Rapid increase observed within **1.6 s**, remaining above alert thresholds.

Central-South Zone

- Moderate voltage rise following system separation.
- Increase less pronounced but persistent during the event.



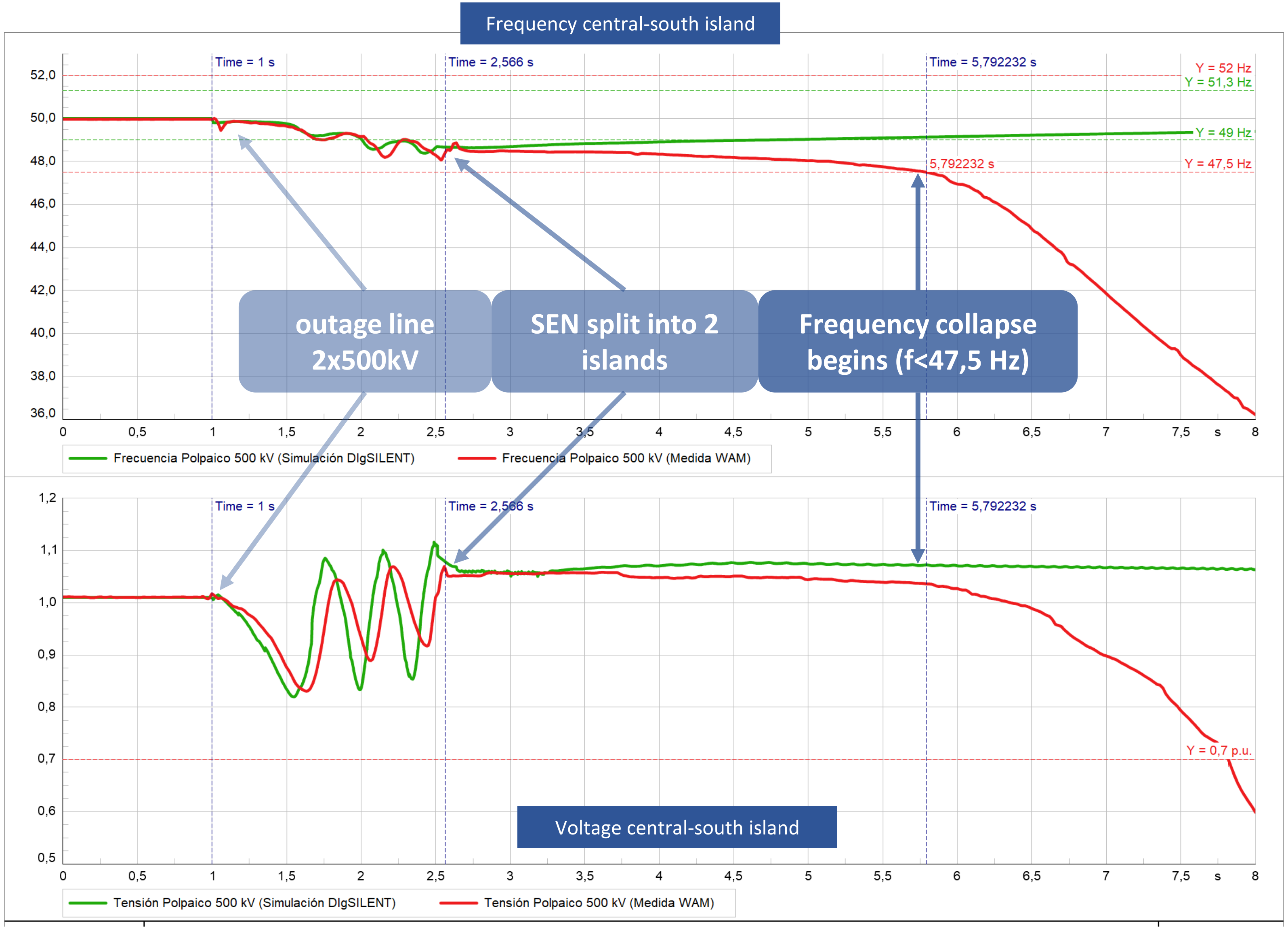
Real vs Expected Behavior of Central-South Island

Real behavior (PMUs – Red line)

- **1,450 MW** generation disconnected earlier than expected.
- **UFLS** malfunctioned or misoperated due to **DERs**.

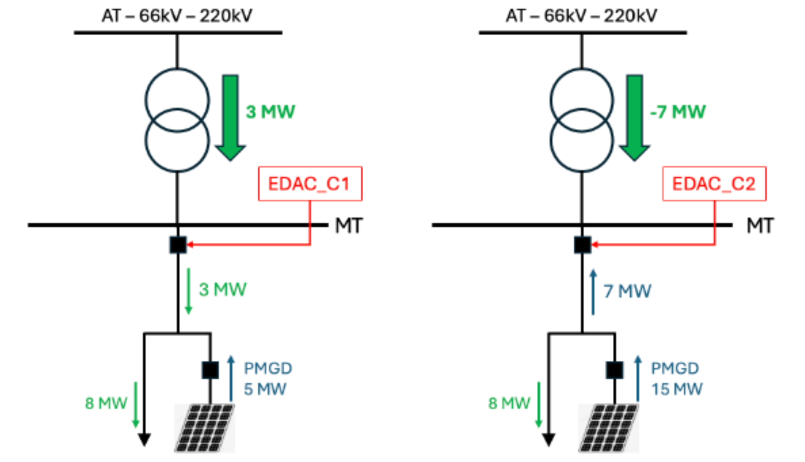
Expected behavior (Simulations – Green line)

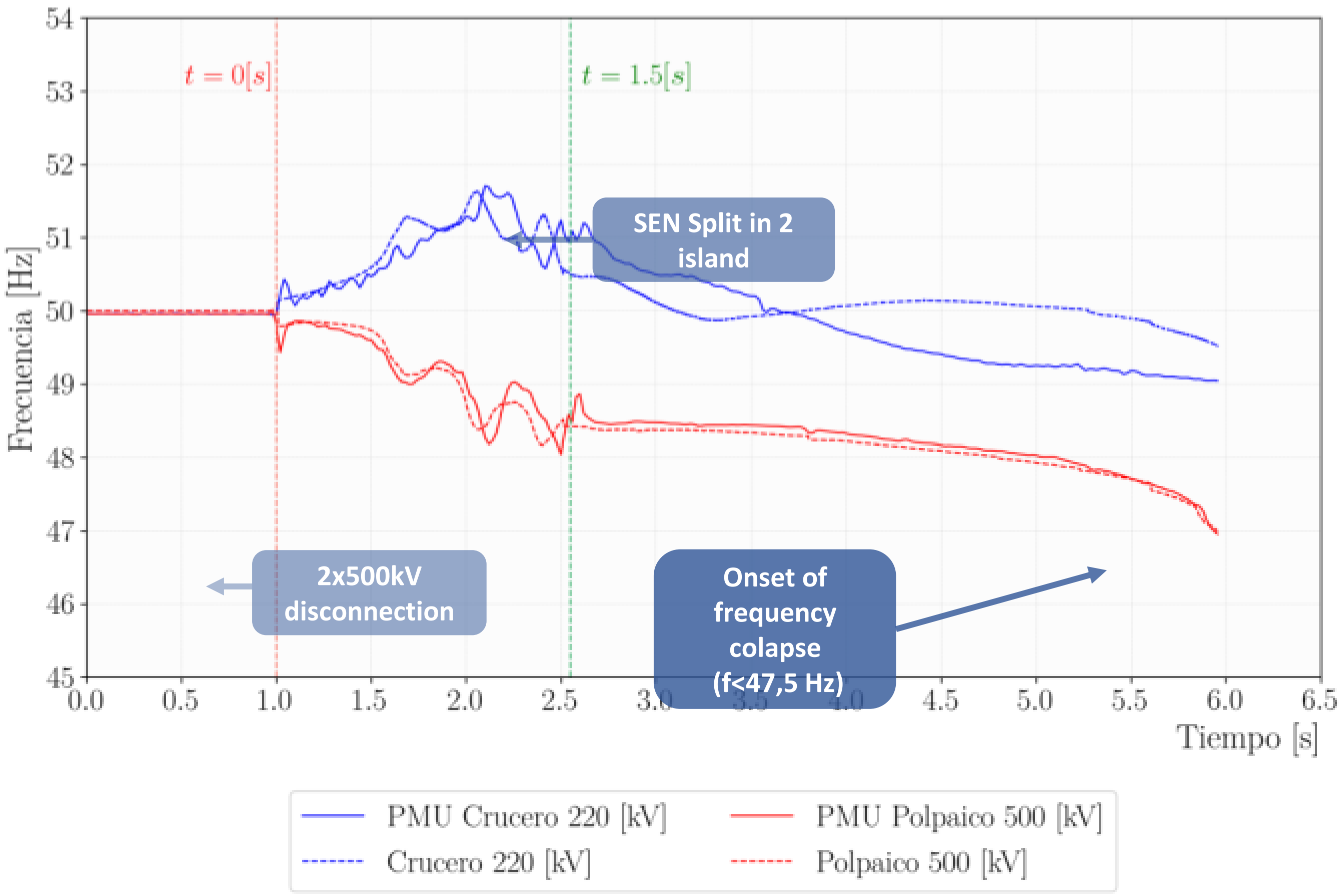
- If all protections had correctly worked, frequency and voltage would have remained stable.
- The central-south island **should have remain stable**, avoiding the blackout.



Simulations by Chilean Universities

- **Blue line:** simulated (dotted line) vs recorded (PMU) frequency response in the **northern island**.
- **Red line:** simulated (dotted line) vs recorded (PMU) frequency response in the **center-south island**.
- **Blackout could have been avoided** with compliance with the grid code by all generating units, and with **properly functioning UFLS schemes (with associated DER)**

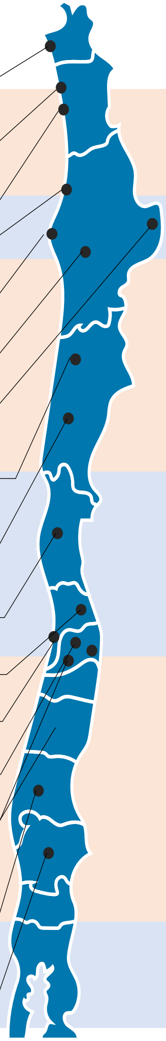




Source: https://www.coordinador.cl/wp-content/uploads/2025/08/InformeCEN_FINAL.pdf

System recovery

- Several **black-start facilities failed to synchronize to the grid, delaying the recovery process.**
- Several **SCADA systems** in charge of the COR (Regional Restoration Operation Centers) function **failed, causing the loss of visibility and controllability** of the black-start situation and transmission facilities status.
- One of the largest transmission companies lost its SCADA for three hours, delaying the recovery process.
- **90% of regulated demand was restored in 9 hrs.** Total demand recovered within in 24 hrs.



Area	COR	Black-start Capacity
Arica	Engie	15 MW
Iquique	Engie	
Tarapacá	Transelec	20 W
Centro	Engie	623 MW
Capricornio	Engie	
O'Higgins	Enel	
Cordillera	AES Andes	
Diego de Almagro	Transelec	181 MW
Cardones	Transelec	
Pan de Azúcar	Transelec	
Quinta Valle	Chilquinta	1.728 MW
Quinta Costa	Chilquinta	
Cerro Navia	Transelec	
Alto Jahuel	Transelec	
Itahue	Transelec	
Biobío	Transelec	1.672 MW
Araucanía	Transelec	

Short Term Actions Taken / Instructions Issued

- **Instruct** asset owners to correct generation settings that caused unexpected trips.
- **Conduct** technical inspections and normalize protection schemes, replacing failed comm modules.
- **Direct** DER plants to verify and adjust protection settings per grid code.
- **Request** UFLS data and normalization of DER configurations.
- **Submit** fault report and report all grid code non-compliances.

- **Instruct** to modify communication scheme design to meet independence and redundancy requirements.
- **Propose** regulatory updates for GFM/GFL inverter requirements and **new DER visibility and controllability standards.**
- **Initiate** technical audit of TO protection SCADA and communication systems.
- **Start** review of methodologies and resource adequacy for load-shedding, RAS, and system recovery plans.

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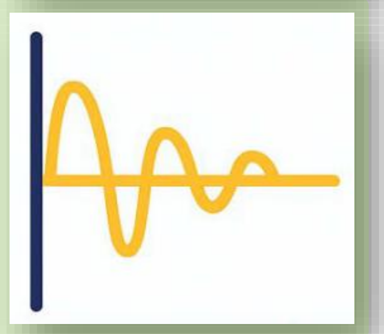
Mid and Long Term Iniciatives

- **Enhance** operator training programs and recovery plan testing.
- **Integrate** dynamic voltage control from GFL VRE and BESS plants.
- **Review** RAS schemes to include fast voltage control using GFM technologies.
- **Update** RMS models and **accelerate** EMT model delivery for IBR facilities.
- **Incorporate** advanced DSA platforms and tools into control room operations



Final remarks

Key Lessons

The blackout revealed **a series of non-compliances** by asset owners in design, procedures, and operations (Generation trips, RAS, UFLS, etc.).

It is critical **to ensure strict compliance with the technical standards and grid code.**

IBRs must play a central role in strengthening system reliability and resilience to prevent blackouts and speed recovery.

THE END