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April 28, 2025 Iberian Grid Blackout

Technical Summary – Based on REE's Live Briefing and possible Trigger explanations

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🕒 Event Timeline

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- 12:33 CET – Sudden defect (cause unknown).
- Immediate disconnection of a major power plant in SW Spain.
- 1,5 seconds later – A second major plant disconnects in the same area.
- Followed by:
  - PV generation tripping off
  - Disconnection from France
  - Cascading failure and partial blackout

What could triggered the First Plant Trip?

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- Likely cause: sudden defect, that triggered Solar PV or Nuclear, not yet known.
- Plant protection relays triggered automatic disconnection.
- Protection logic designed to avoid damage from unstable grid conditions.
- Consistent with grid disturbance behavior and historical events.

⏱️ What Triggered the Second Trip (1.5s Later)?

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- Out-of-step detection is a key suspect:
- - Phase angle between buses became unsustainable.

- System may have lost local synchronism.

- Could also be a cascading voltage instability after first trip.

Role of Grid Protections

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- Automatic undervoltage protection triggered second trip, after first trip of first power plant.
- Plants are not designed to 'ride through' deep undervoltages.
- No LVRT-like function in old nuclear or large thermal units.
- Coordinated tripping is a defensive mechanism to prevent damage.

⚠️ Loss of Synchronism and Phase Shift

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- If angle difference between zones exceeds safe limits, synchronism is lost.
- Out-of-step protections isolate affected units.
- Prevents equipment damage, but deepens instability if multiple units trip.

Why BESS and Grid-Forming Inverters Matter

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- BESS can absorb/extract power instantly to stabilize frequency.
- Grid-Forming inverters help sustain voltage references.
- Without these, grid collapses cascade quickly from N-1 to N-2.
- Spain and Portugal needs fast-acting, distributed stability assets.

☢ Nuclear Plants Behavior

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- Spanish nuclear plants automatically disconnect on severe voltage swings.
- Nuclear power in Spain probably would not comply with LVRT (Low Voltage Ride Through), according to Commission Regulation (EU) 2016/631
- Safety-first logic: Protect reactor integrity over grid continuity.
- Aligned with international nuclear safety protocols.

🔄 Spinning Reserve in Spain

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- Must-run generation required by the TSO in Spain is more than 3 GW.
  - In the moment of the event, synchronous generation was much bigger than that.
- Always synchronized with the grid.
- If the running generation is lower than 3 GW then a blackout is likely probable to happen.
- Happens regardless of energy source (solar, wind, thermal, etc.).

🧠 Summary of Trigger Hypothesis

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- First trip: sudden defect → protection trip.
- Second trip: out-of-step event or local voltage collapse.
- Followed by:
- - Solar tripping (weak voltage support).
- - Disconnection from France.
- - System-wide collapse due to N-2 condition.

🧠 Key Lessons

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- The system is designed to withstand the loss of the biggest online generator. But yesterday's events probably were more severe than design criteria
- The system wasn't designed to withstand N-2 events.
- Grid-forming inverters must be properly integrated and tuned.
- BESS is crucial for modern grid resilience.
- LVRT must de installed in old CCGT, because it's not possible to install LVRT in the old Spanish Nuclear Power plants, due to the design of the same
- Spain and other grids need:
  - Virtual inertia
  - Fast digital control systems
  - Distributed, responsive reserve mechanisms

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