

# Expert Panel Final Report

## 28 April 2025 Blackout in Spain and Portugal

20 March 2026 – Media Briefing



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# 1. Introduction



# 1.1 Purpose and scope of the Final Report

- The purpose of this report is to provide concrete technical analyses of the sequence of events leading to the blackout and the measures taken to restore its operation, in order to identify and understand its root causes.
- It aims to support transparency, learning and continuous improvement of the power system across Europe.
- The report provides recommendations to improve power system security, improve coordination and reinforce security of supply across the European power system, underlining the need for close cooperation among all relevant power system actors.
- This report is not intended to allocate or imply any liability or responsibility to any party, as this will be the responsibility of the competent authorities in the respective countries.

*The report has been prepared and agreed by the Expert Panel established in accordance with the applicable legislation. The analyses, findings, and recommendations contained herein reflect the Expert Panel's technical assessment as at the date of issuance and are without prejudice to any investigation or supervisory action that may be undertaken by the competent authorities. The data presented in the report and in this PowerPoint are based on most reliable data made available to the Expert Panel. Given that the data originates from a wide range of providers, no representation or warranty, whether express or implied, is made as to the accuracy, completeness, fairness, or correctness of the information and opinions contained in this report and the accompanying PowerPoint presentation.*

## 1.2 Expert Panel: role and composition

- The Expert Panel is a body legally mandated by the applicable legislation to investigate, from a technical perspective, any major grid incidents (Scale 2 and 3).
- The composition of the Expert Panel is determined in accordance with the applicable legislation.
- The Expert Panel for the 28 April 2025 incident is co-led by Klaus Kaschnitz (APG, Austria) and Richárd Balog (MAVIR, Hungary).



The Expert Panel includes **49 members** from:

### Transmission System Operators (TSOs) and Regional Coordination Centres (RCCs) of:

Belgium  
Denmark  
France  
Germany  
Greece  
Hungary  
Ireland  
Italy  
Poland  
Portugal  
Romania  
Spain  
Switzerland

### ENTSO-E

### ACER

### National Regulatory Authorities of:

Belgium  
Czech Republic  
France  
Germany  
Hungary  
Italy  
Poland  
Portugal  
Romania  
Spain  
Sweden  
Switzerland

## 1.3 Significance of the incident

- On 28 April 2025, at 12:33 CEST, continental Spain and Portugal suffered a blackout.
- A small area in the South of France (at the border with Spain) was also affected during a very short period of time.
- The rest of the European power system did not experience any disturbance resulting from the incident.
- **This was the most severe blackout on the European power system in over 20 years, and the first ever of its kind (overvoltage).**
- It had major repercussions for citizens and society.

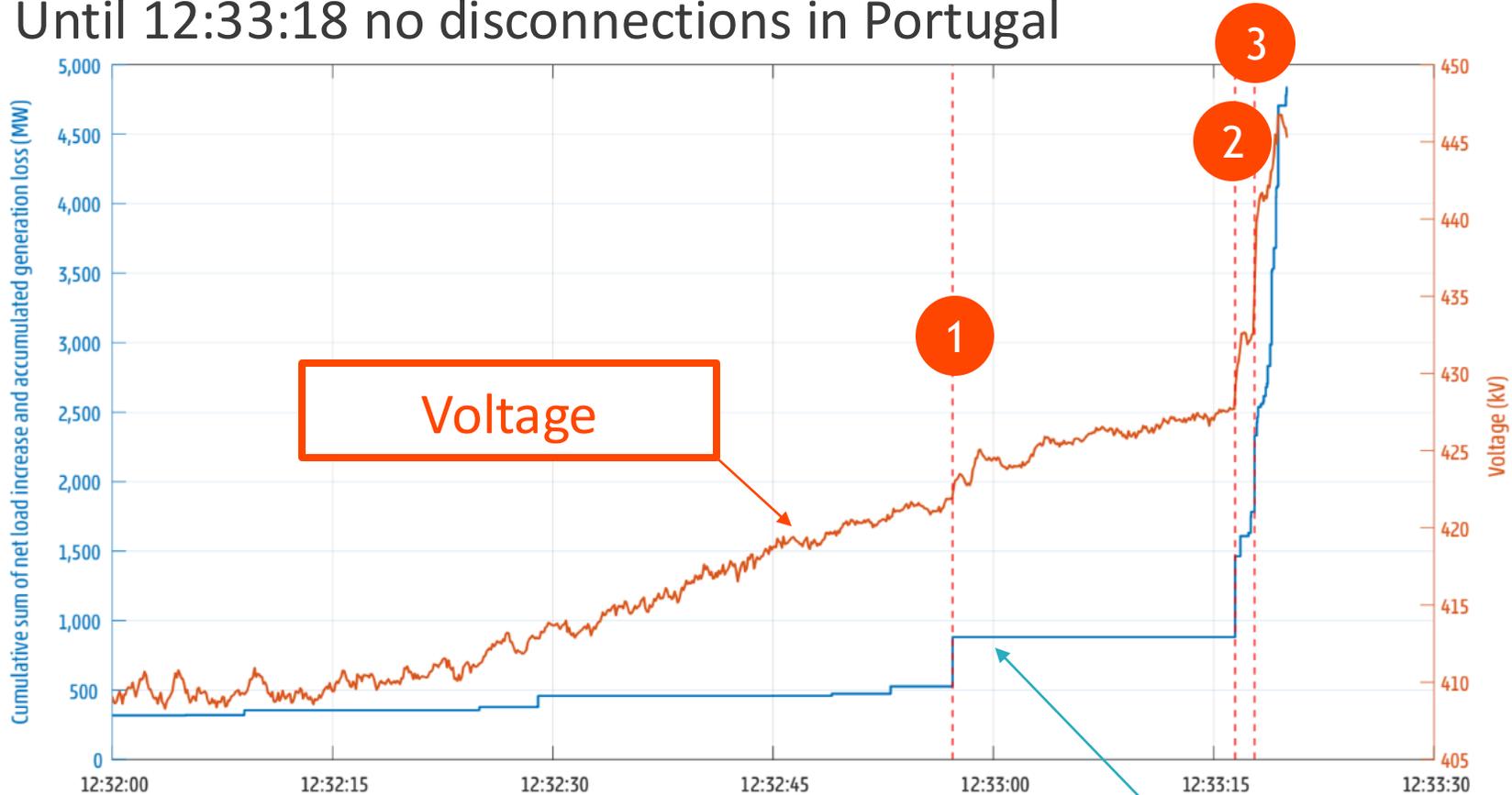


## 2. Final sequence of the blackout



## 2.1 Three major tripping events in South-West Spain

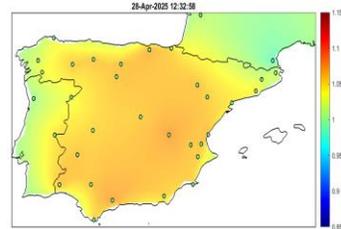
Evolution of cascade of overvoltage disconnections of generators  
Until 12:33:18 no disconnections in Portugal



12:32:57

1

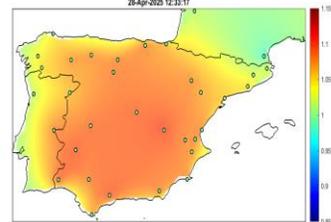
**355 MW** in  
Granada (Wind,  
PV, Thermo-Solar)



12:33:16

2

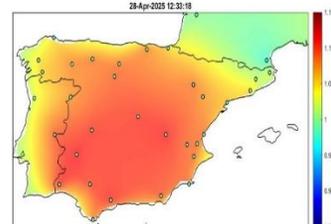
**727 MW** in  
Badajoz (PV,  
Thermo-Solar)



12:33:17

3

**928 MW** in  
Segovia, Huelva,  
Badajoz, Sevilla  
and Caceres (PV,  
Wind)



Disconnection of generators, reduction  
of infeed, increase of load

Loss of generation

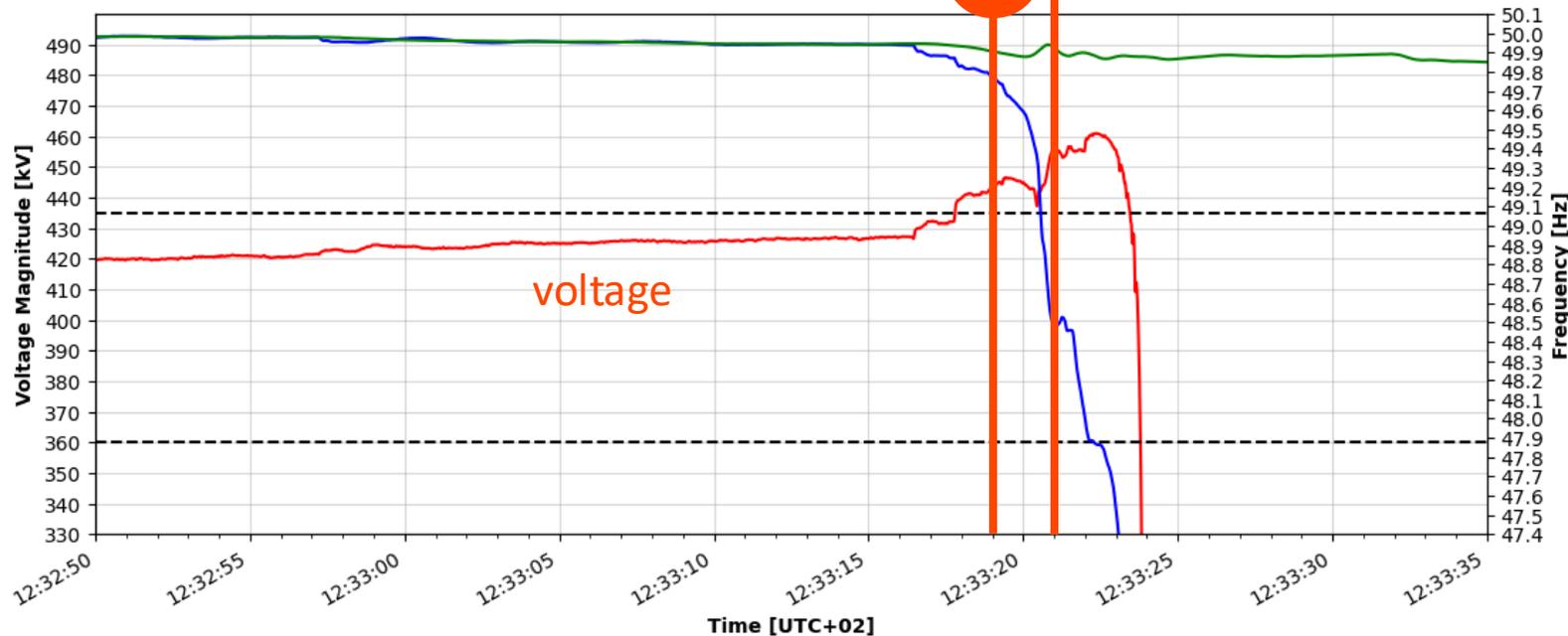
## 2.2 Voltage and frequency evolution during the incident

12:33:19

4

- Decrease of **frequency on Iberian Peninsula** and loss of synchronism with **rest of Continental Europe**

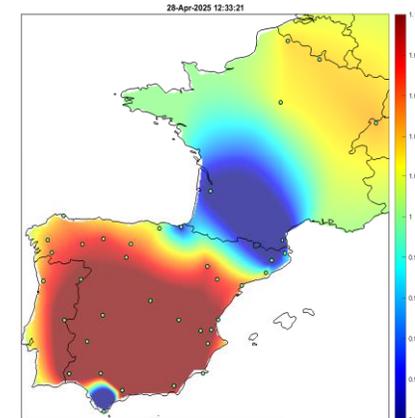
- System Defence Plans (automatic load shedding) were activated in Spain and Portugal but unable to stop the blackout due to its overvoltage nature



12:33:21

5

- Disconnection of all AC-lines from Spain to Morocco and France



### 3. Analysis of factors that caused the blackout



# 3.1 Full Root Cause Tree

## Root cause tree

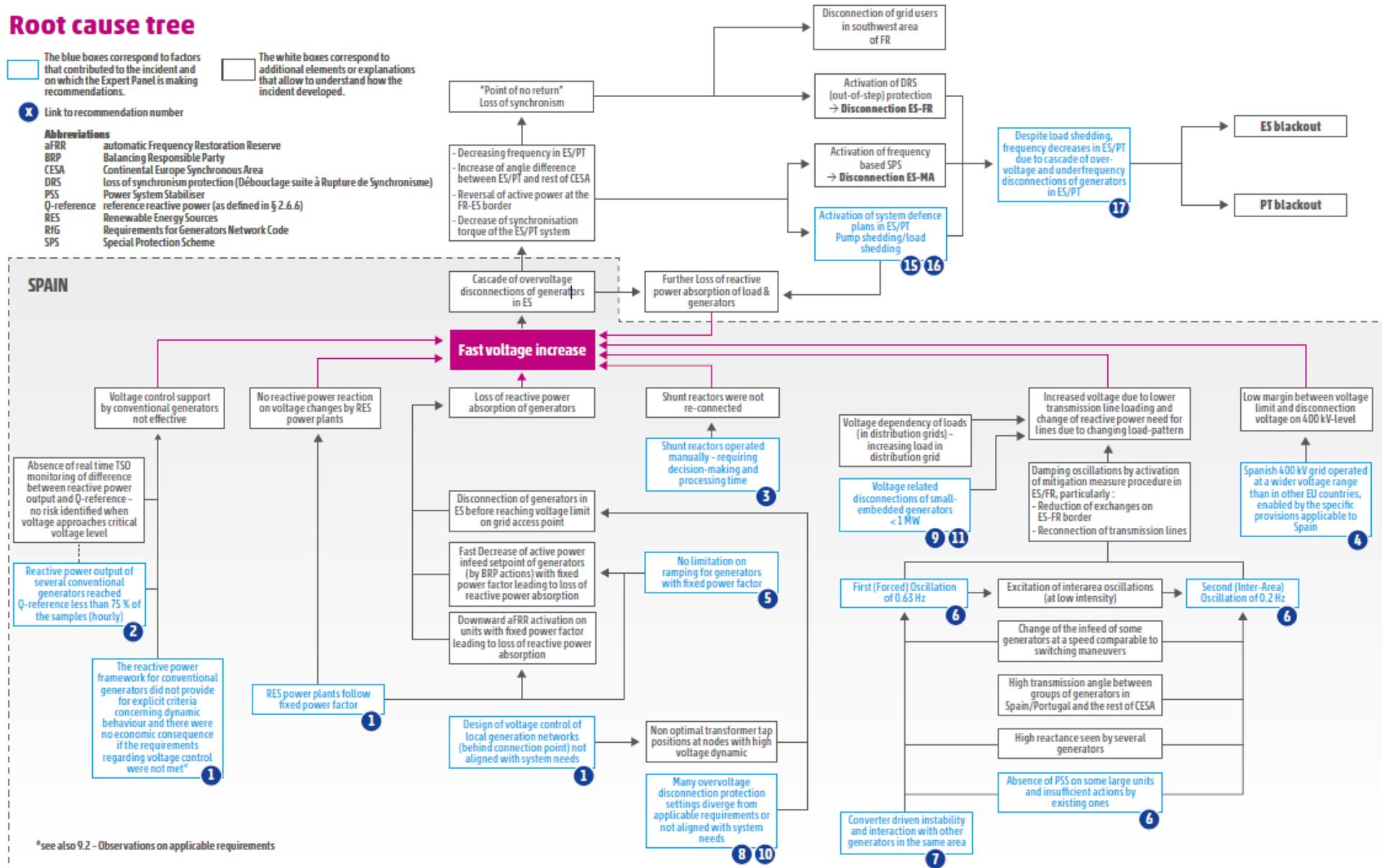
The blue boxes correspond to factors that contributed to the incident and on which the Expert Panel is making recommendations.

The white boxes correspond to additional elements or explanations that allow to understand how the incident developed.

Link to recommendation number

### Abbreviations

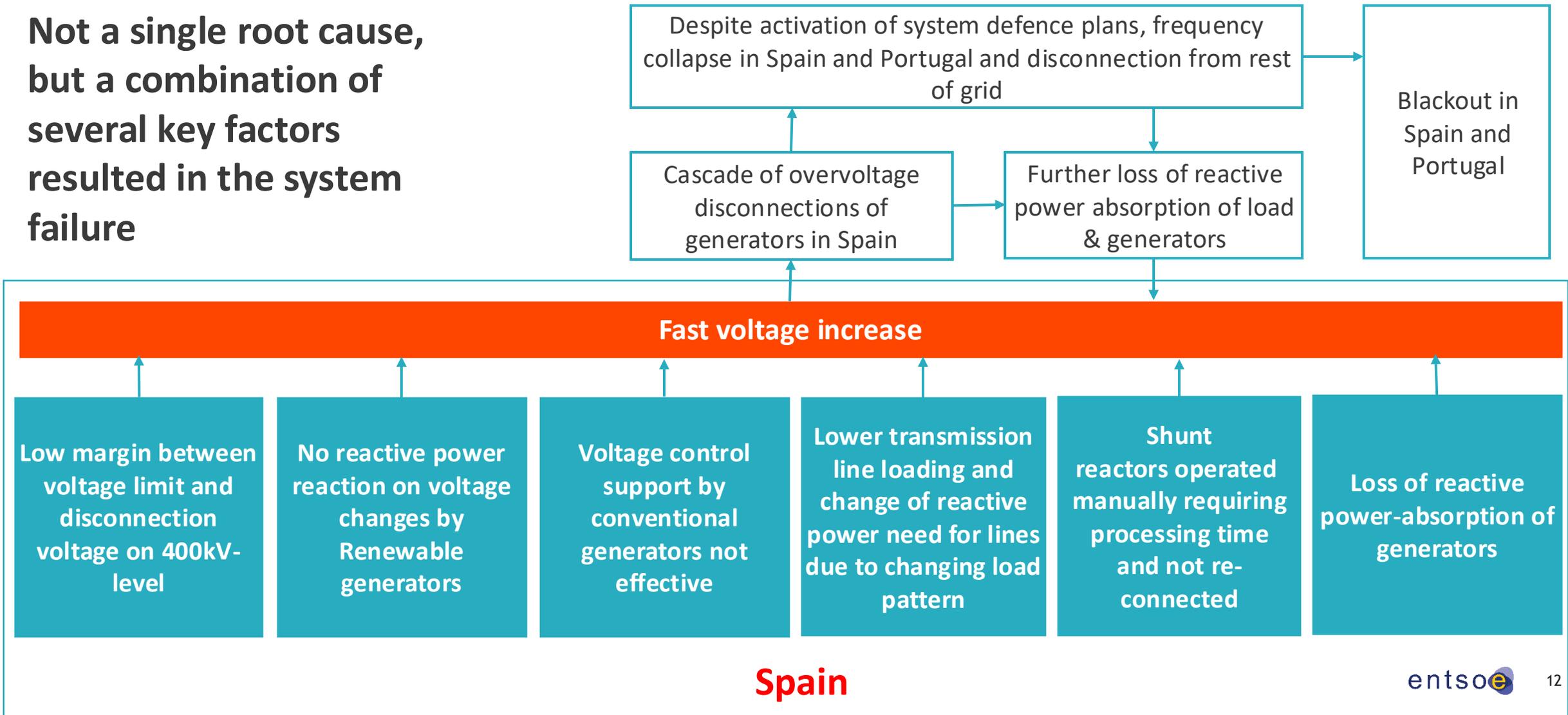
aFRR	automatic Frequency Restoration Reserve
BRP	Balancing Responsible Party
CESA	Continental Europe Synchronous Area
DRS	loss of synchronism protection (Débouclage suite à Rupture de Synchronisme)
PSS	Power System Stabiliser
Q-reference	reference reactive power (as defined in § 2.6.6)
RES	Renewable Energy Sources
RfG	Requirements for Generators Network Code
SPS	Special Protection Scheme



\*see also 9.2 - Observations on applicable requirements

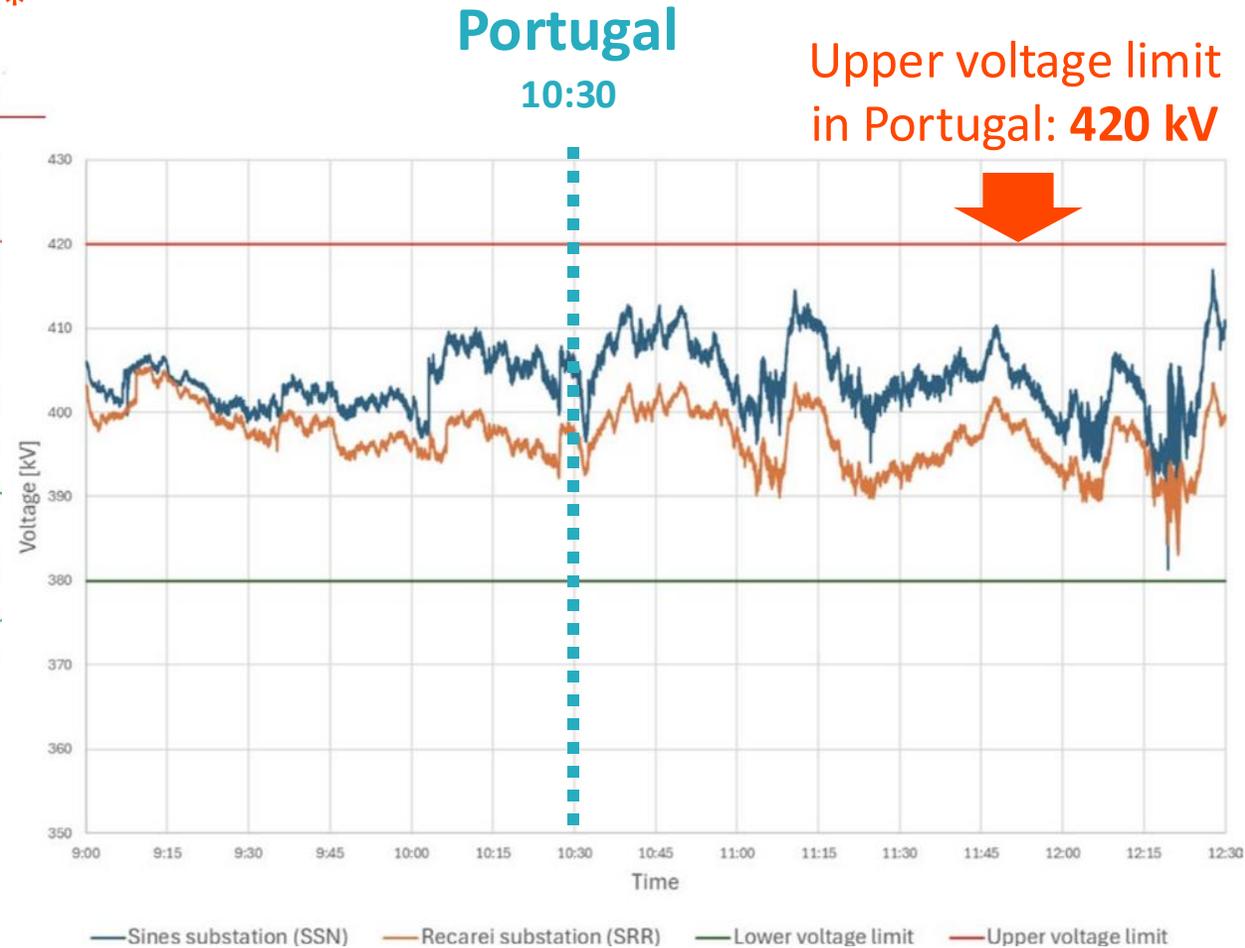
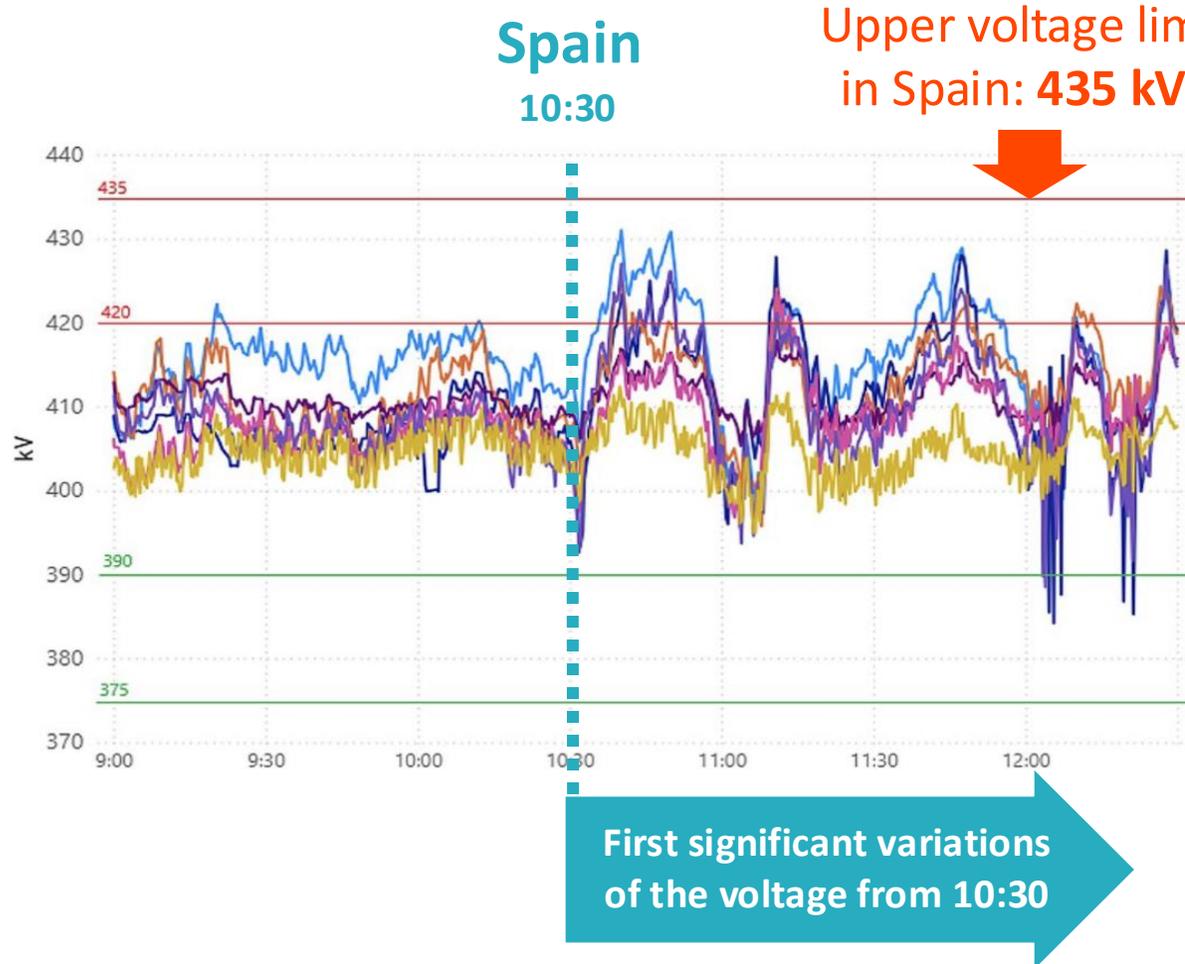
## 3.2 Simplified Root Cause Tree

**Not a single root cause, but a combination of several key factors resulted in the system failure**





# 3.3 Low margin between voltage limit and disconnection voltage on 400 kV level in Spain



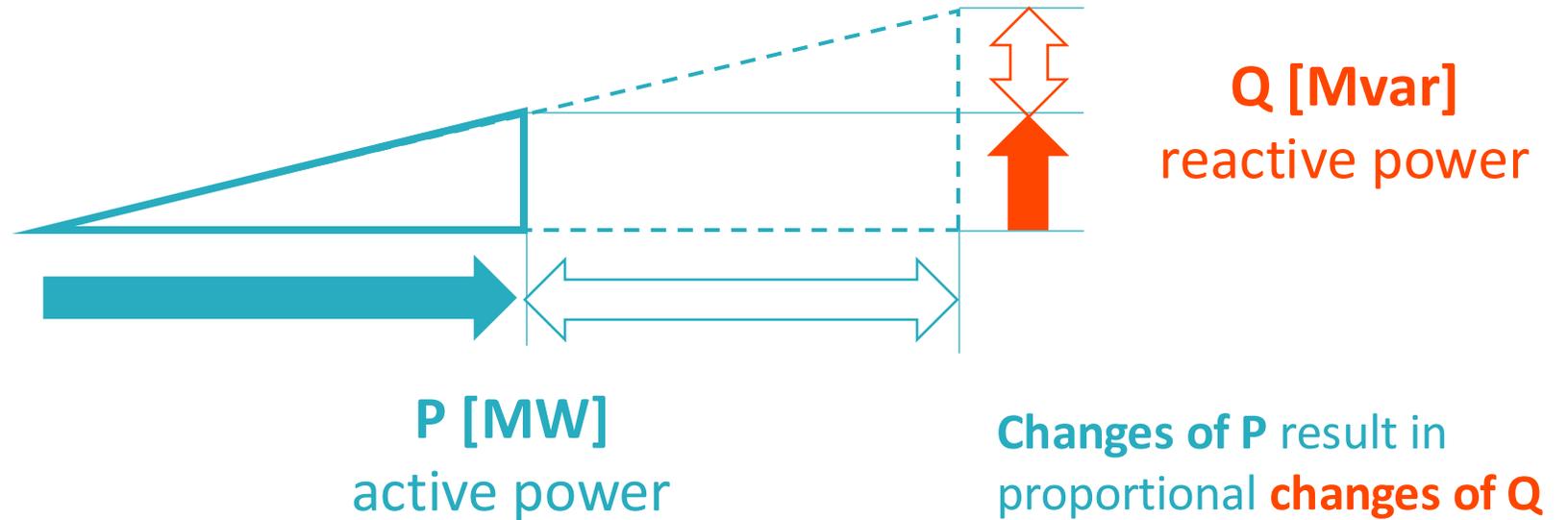
\* These values may occur on occasion at the 400 kV level (confirmed by CNMC, Spanish regulator)



# 3.4 No reactive power reaction on voltage changes by Renewable generators in Spain

Renewables with fixed power factor:

P and Q are always in the same ratio to each other

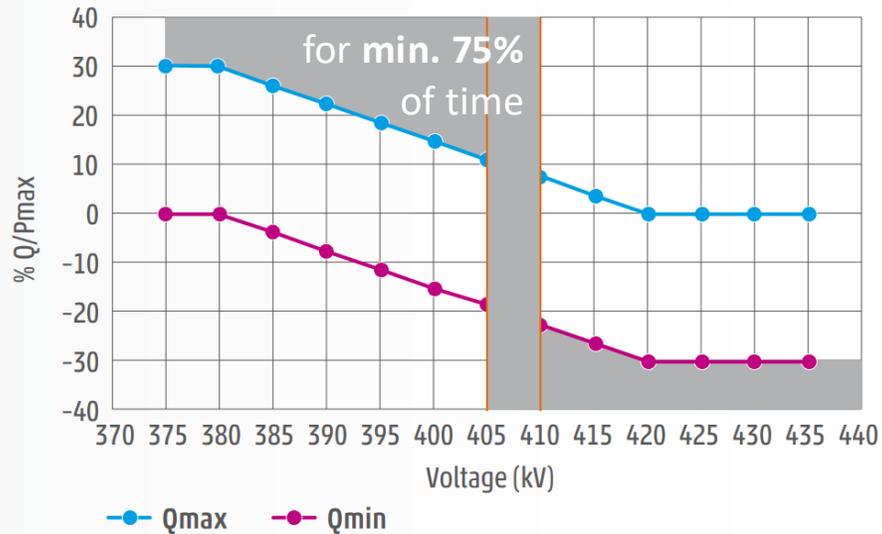


No dynamic voltage control by Renewables with fixed power factor, as Q absorption is dependent on P, but not voltage



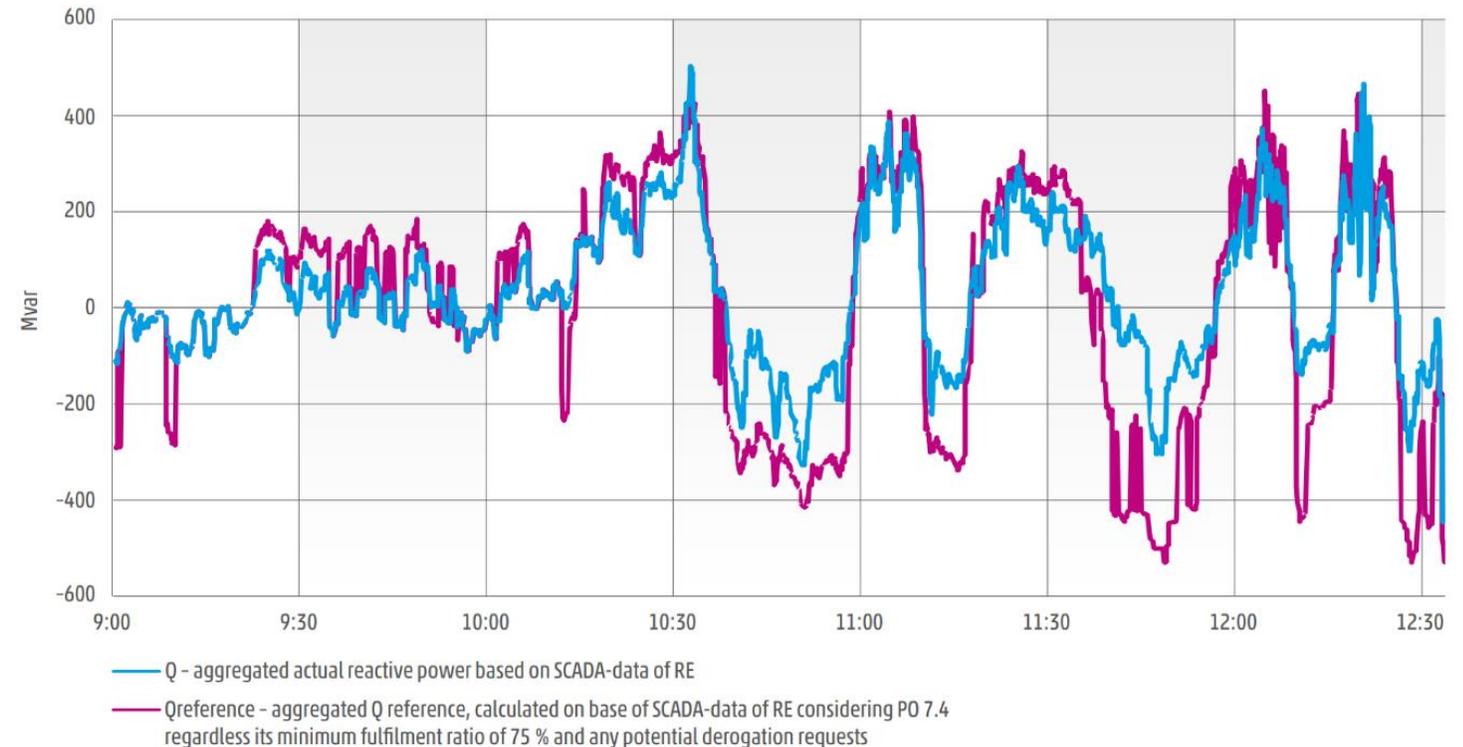
## 3.5 Voltage control support by conventional generators not effective in Spain

Q-area defined by PO 7.4



The **requirements** applicable to the conventional generators' Q output **do not include specifications for dynamic behaviour** and there is **no economic consequence** if Q output is not aligned with the 75% rule

Some generators diverged from the applicable requirements for 75% alignment of actual Q with Q reference, **without prejudice to any potential derogations** from these requirements



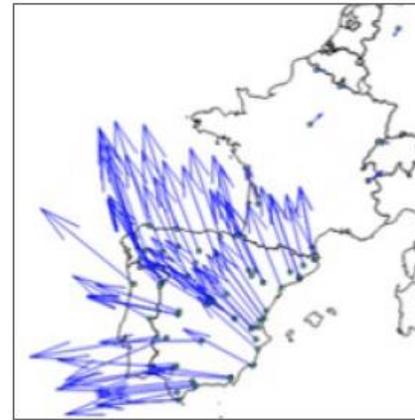
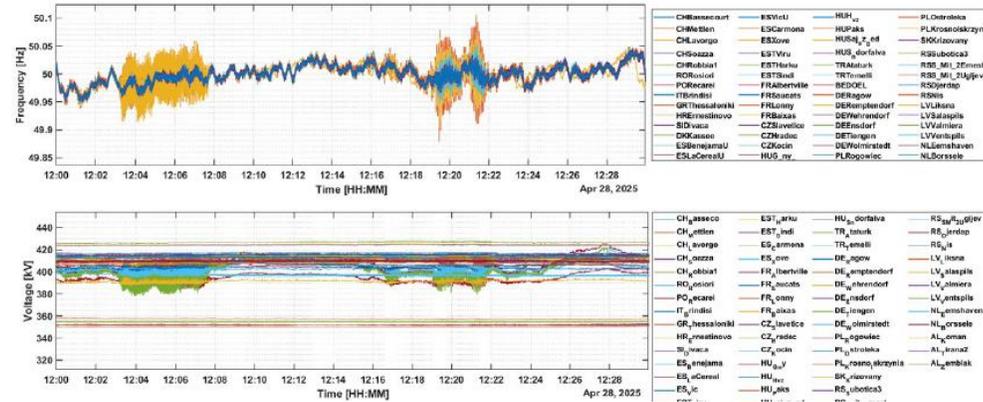
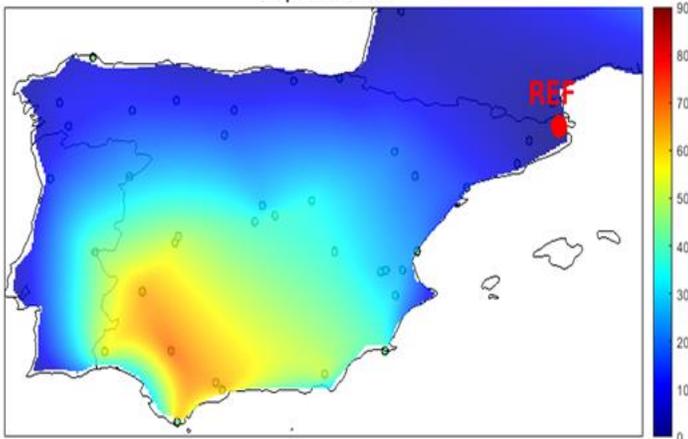


# 3.6 Lower transmission line loading after mitigating oscillations

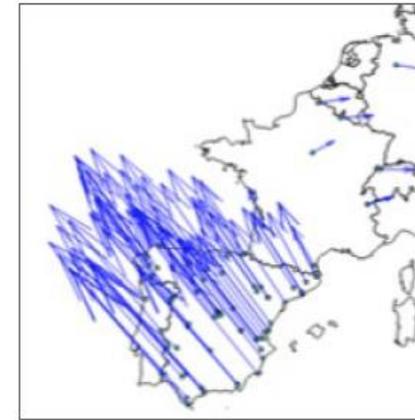
## High Renewables infeed in Southwest of Spain

Heatmap of angular displacement at 12:00

28-Apr-2025 12:00:00



Local oscillation by 0.63 Hz



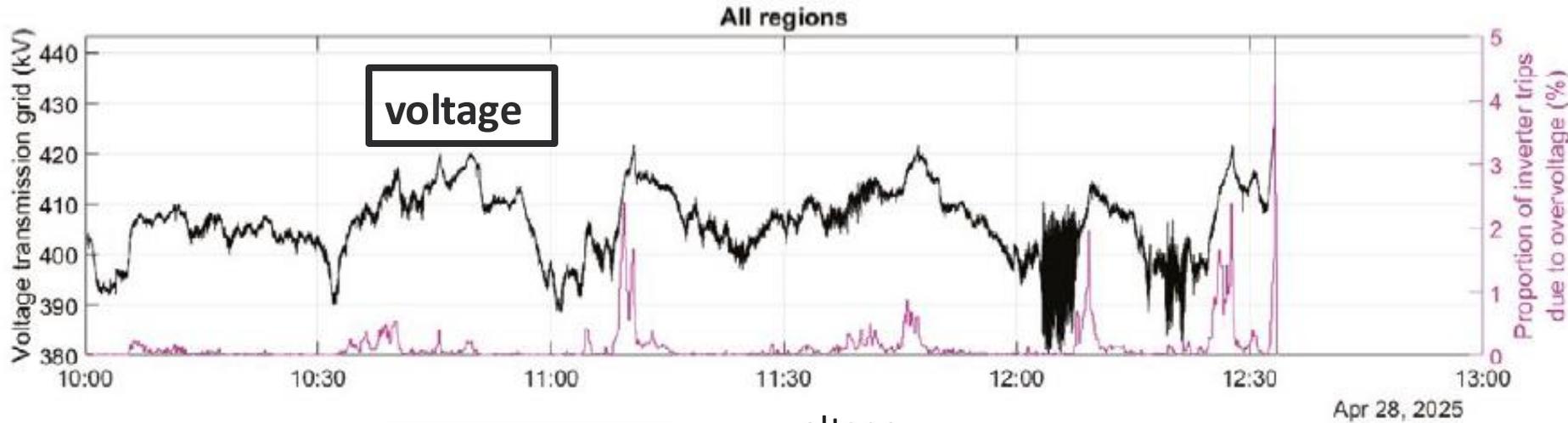
Inter-area oscillation by 0.2 Hz

Mitigation measures according to common protocol of French and Spanish TSOs

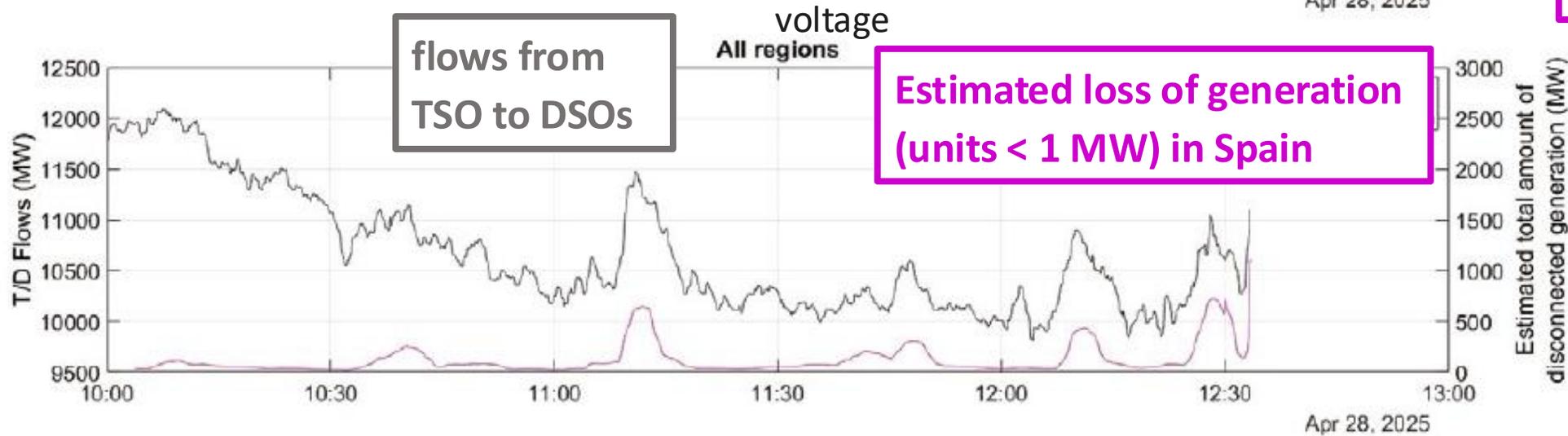
- successful in damping the oscillations
- naturally leading to **voltage increase** (still within operational range)



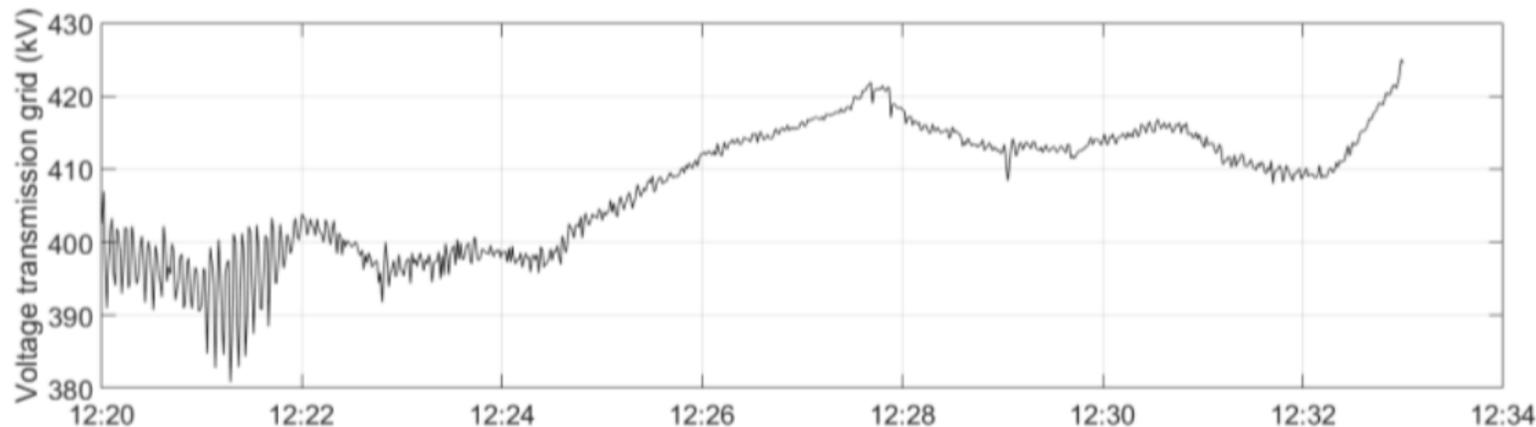
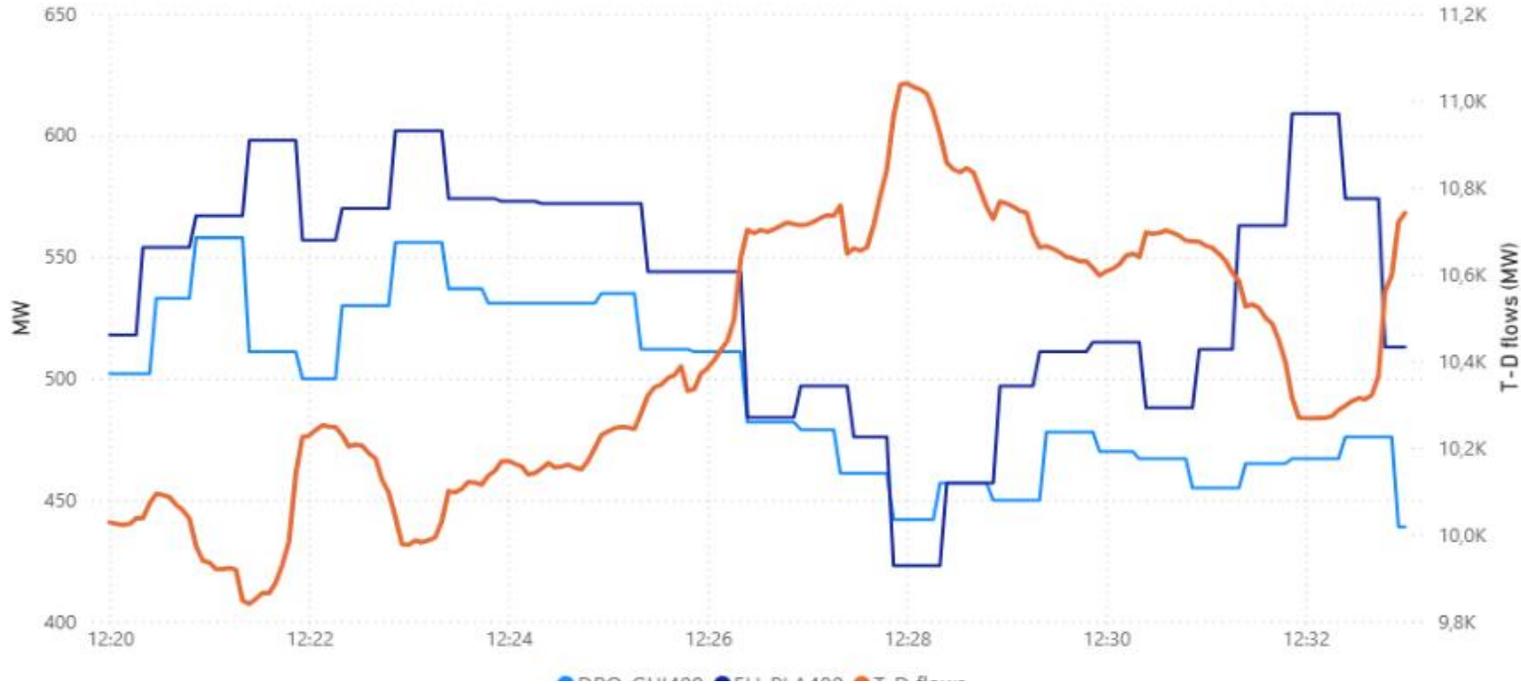
# 3.7 Loss of small embedded generators and increase of flow from TSO to DSO grids in Spain



Tripping of small embedded generators < 1 MW (e.g. PV-household) reported by one inverter company



## 3.8 Lower transmission line loading due to increase of flow from TSO to DSO grids in Spain



### Root Cause Tree



Loss of active power infeed plus increase of load due to higher voltage leads to **higher flows from TSO to DSOs**

This results in **lower line loading** in some parts of the grid

Lower line loading results in **voltage increase**



# 3.9 Shunt reactors operated manually - requiring processing time - and not re-connected

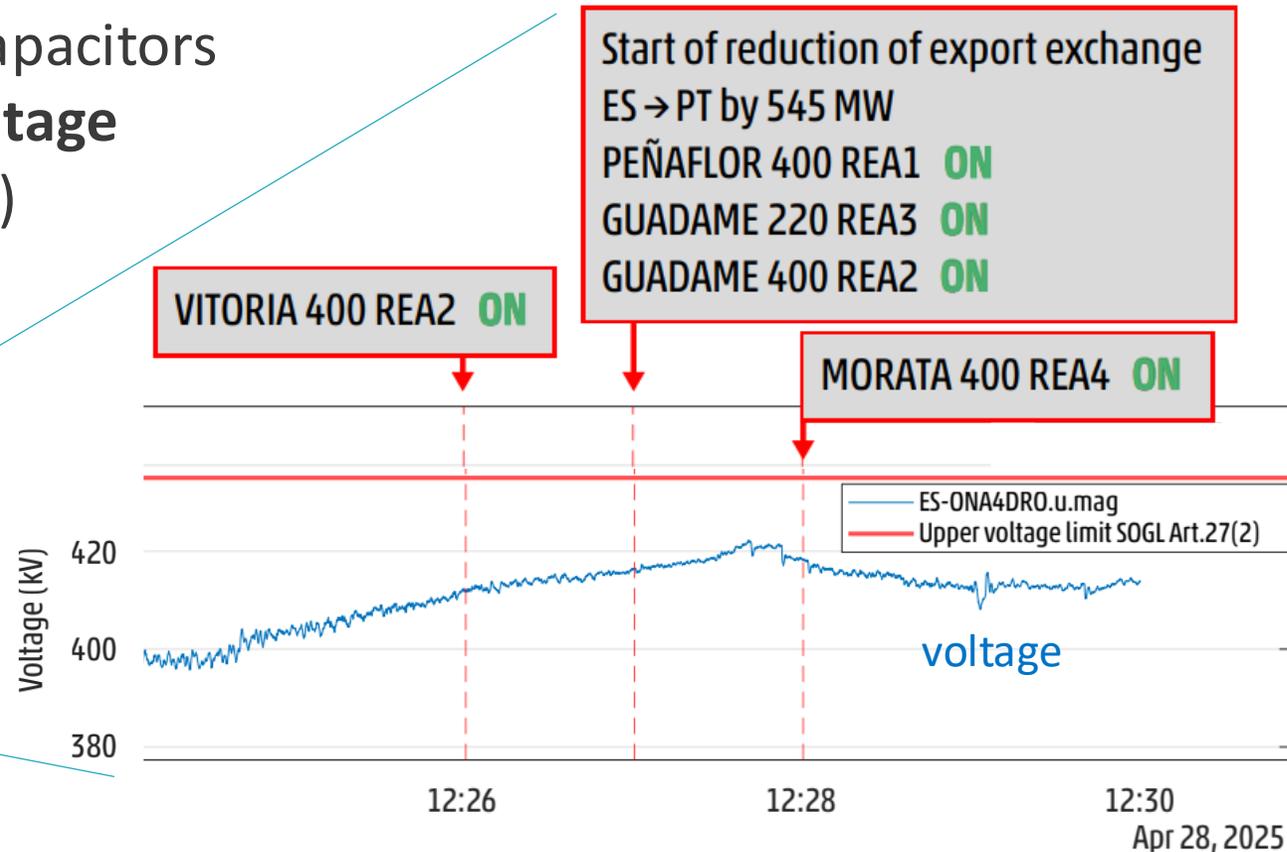
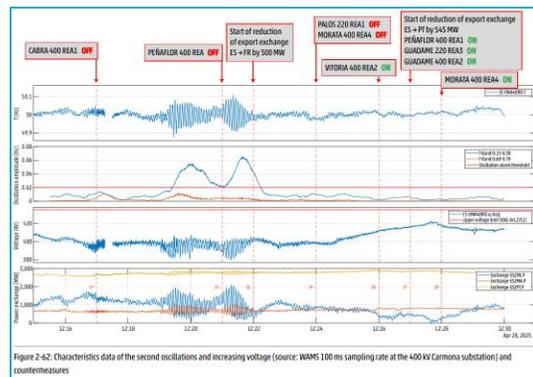
Low voltage during oscillation episodes required shunt reactor disconnection

Shunt reactors and capacitors are used for static voltage control in Spain, (dis-) connected manually

Connecting shunt reactors contributed to voltage stabilisation until 12:32

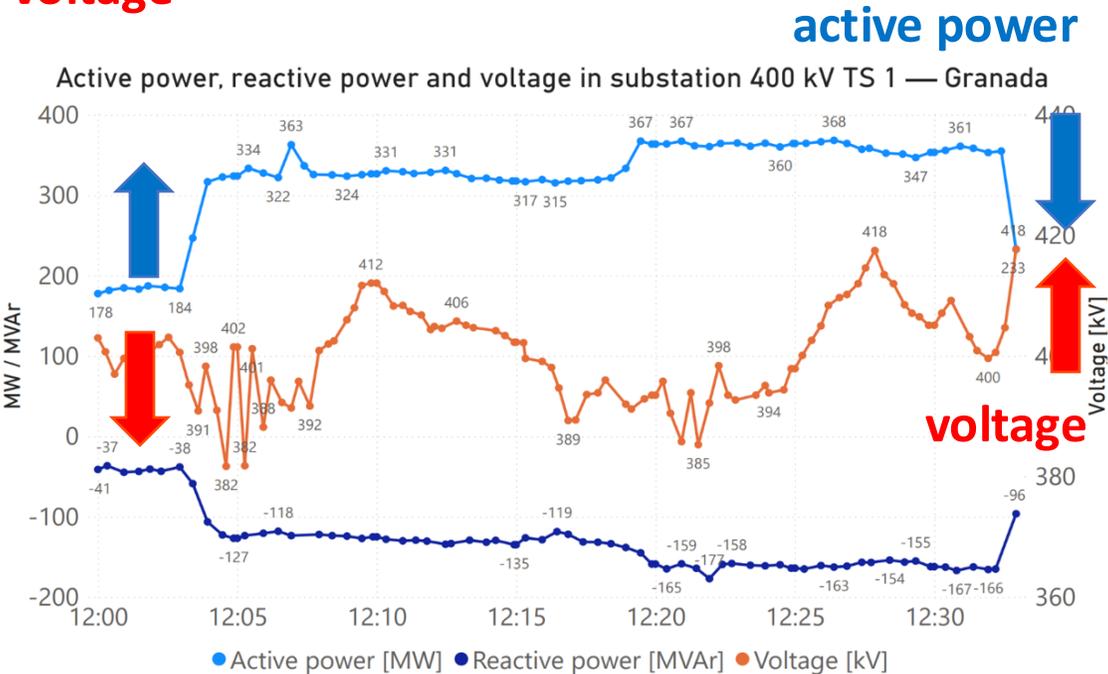
At 12:32 about 58% of reactive power capacity of Spanish shunt reactors were connected

Remaining capacities could not be connected in time due to needed processing time for manual switching



# 3.10 Loss of reactive power absorption of generators in Spain

Fast changes of infeed setpoints of generators with fixed power factor result in **fast changes of voltage**

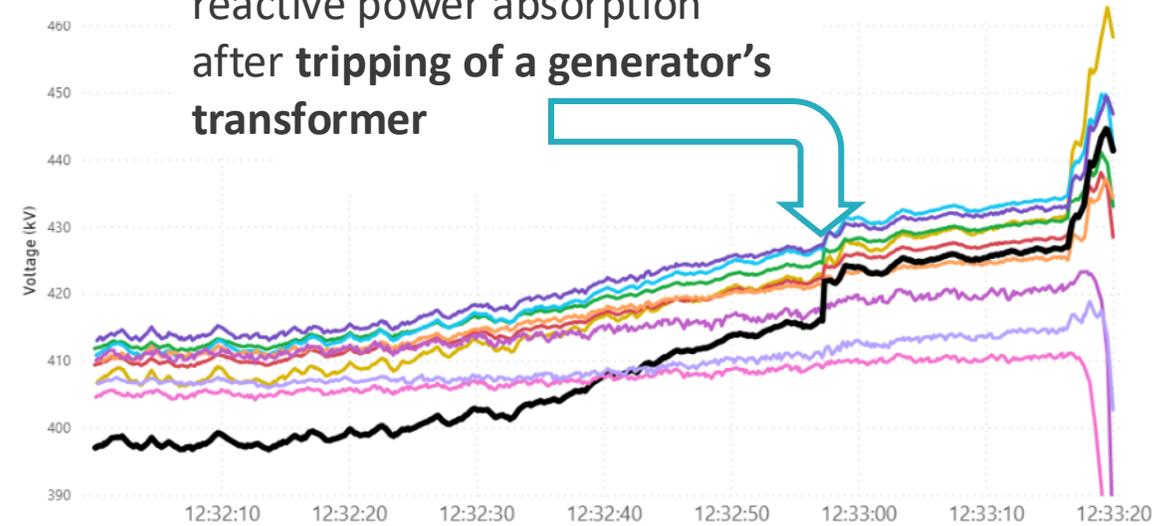


Rate of infeed change sometimes (in case of generators without ramping limitations) comparable with switching events



12:32:57

Voltage increase due to loss of reactive power absorption after tripping of a generator's transformer



Many protection settings diverged from applicable requirements or were **not aligned with system needs**

Design of voltage control of some local generation networks (behind connection point) **not aligned with system needs**

## 4. Key recommendations and observations



## 4. Key recommendations and observations

1

### Voltage Control

Voltage range, control mode and behavior of generators, dynamic voltage control capabilities

2

### Oscillations

Damping, modelling, monitoring and detection.

3

### Disconnections

Protection settings (generators, evacuation grids, embedded units)

4

### System Defense Plan

Modernization to integrate fast voltage variations

5

### Restoration

Black start capability, testing, communication, reconnection

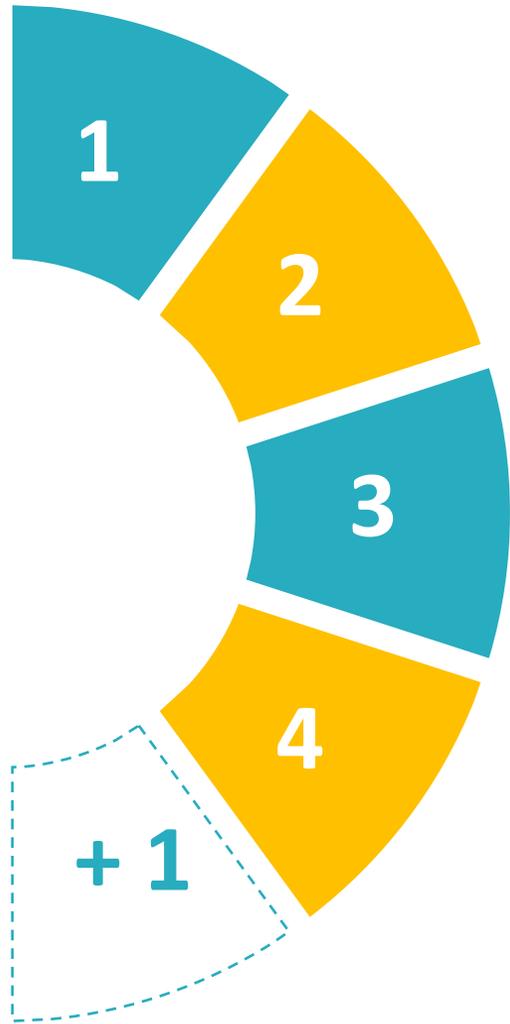
### Observation on Regulatory Frameworks

The investigation shows the need for regulatory frameworks to adapt to implement these recommendations in line with the evolving nature of the power system.

## 5. Concluding remarks



## 5.1 Key Takeaways from the blackout



1

### **A first-of-its-kind blackout**

With valuable learnings to prevent similar incidents in the future.

2

### **No single cause, clear recommendations**

Multiple interacting factors, with solutions already technically feasible.

3

### **Complex interactions between active system participants**

Need to strengthen coordination between all Generators, DSOs and TSOs.

4

### **A local issue that escalated very quickly**

Knowledge and action at both Local and European levels are essential.

### **The Power System is governed by Physics**

The fundamental physical limits must be considered for all market mechanisms, regulatory frameworks and energy policies.

# Q&A

