Stability Management in Power Electronics Dominated Systems

A public stakeholders webinar

Focusing on Research, Development and Innovation Challenges

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#StabilityM

Online, 23 November 2022

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Reliable Sustainable Connected

Agenda

	Agenda item	Presenter	Min	Time
	(Q&A INCORPORATED IN EACH ITEM)			
	Moderator: Íris Baldursdóttir, ENTSO-E			
1	Welcome, introduction	Håkon Borgen, RDIC Chair	10	13:00-13:10
2	Tackling System Stability - A Prerequisite to the Success of the Energy Transition	Knut Hornnes, Stability Management Workstream convener	30	13:10-13:40
3	Learnings from Project Inertia and next steps	Joao Moreira, Project manager	20	13:40-14:00
4	New demand units and advanced capabilities	Mario Ndreko, StG CNC convener	15	14:00-14:15
5	6x5min national examples of stability related challenges and events • Statnett (Nordic examples) • GB Transmission System • Continental Europe • Energinet • Amprion • Eirgrid	Members (TSOs) Knut Hornnes, Statnett Benjamin Marshall, National HVDC Centre Rui Pestana, REN Jun Bum Kwon, Energinet Bartosz Rusek, Amprion Mostafa Bakhtvar, Eirgrid	35	14:15-14:50
6	Reaction from EC DG Energy	George Paunescu, EC DC Energy	5	14:50-14:55
7	Closing remarks	Norela Constantinescu, Head of Innovation Section	5	14:55-15:00

We are using Sli.do

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We want to incorporate your opinion and expertise:

- ✓ Post your questions
- ✓ Answer polls throughout the webinar

Welcome & Introduction

TIME: 10 mins

- Welcome & Objectives of the webinar

Håkon BORGEN

RDIC Chair

Green shift is now!

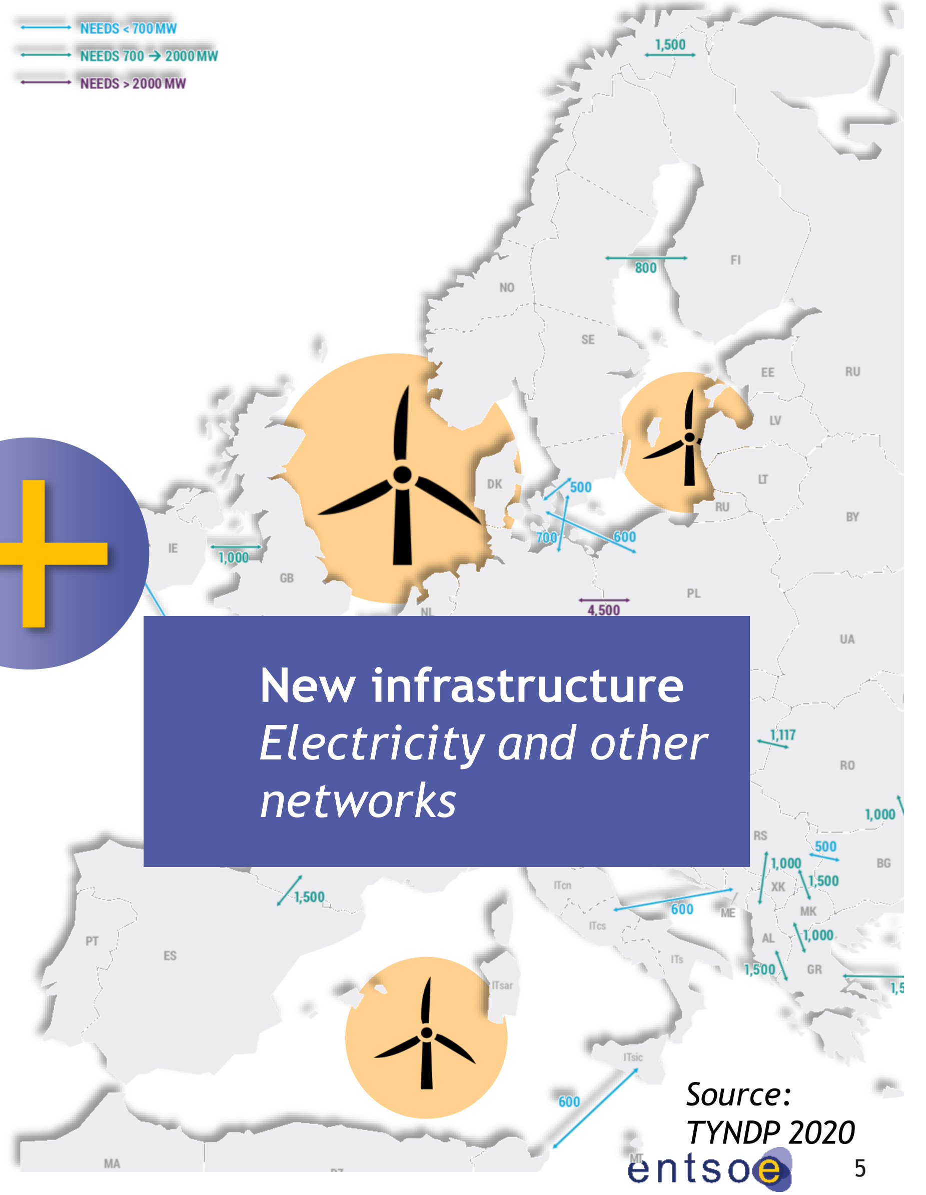
Reaching carbon neutrality even faster

- **10x wind & solar faster**

  Zero target gives radical changes of the power system in Europe

- **10 x more flex**

  Increased integration & cooperation between countries and sectors



New infrastructure
Electricity and other networks

- **Accelerated innovation is key:**
  - Fast deployment of mature innovative solutions
  - Long term : sustainability drives the innovation

Source: TYNDP 2020

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Much more flex & Grid needed ..

Increased integration & cooperation

External & Internal partnerships	Cooperation with manufacturers (RDI roadmap)
Industry (H_2, transport, Wind, Solar, heating +)	Offshore /onshore grids: Interoperabilty - HVDC /HVAC Grids
Manufactures	Power Electronic dominated Systems
DSOs	SF_6-free alternatives in high-voltage equipment
TSOs	Smart asset management to monitor and reduce CO_2 footprint
Authorities	Eco-design and lifecycle management: lead free HV (AC/DC) cables
Within TSOs Innovative solutions >> business utilization	

Accelerated innovation is key on priority actions

In spotlight: Stability management

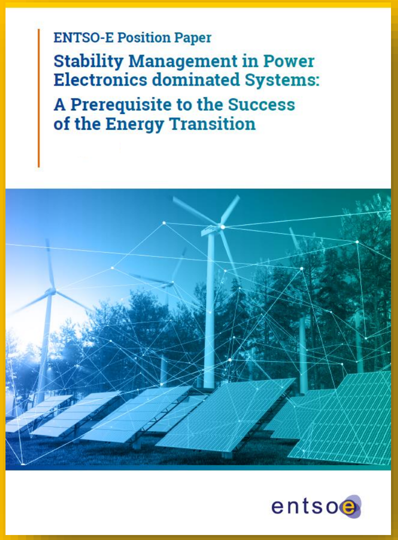
Data driven services

FOCUS TOPICS for **ACCELERATION**

1. Faster electrification of transport
2. Optimal cross-sector planning (incl. storage & H_2)
3. Need for flexibility & its value at all timeframes
4. Improved modelling & management of extended datasets
5. Multi-vendor, multi-terminal offshore solutions
6. New system stability management approach
7. Fully automated decision support system

Tackling the impact on grids

Stabilizing technologies must be deployed to counterbalance the increase of factors destabilizing the power system.



ENTSO-E RDI Implementation Report2021 – 2025: link

Questions 1-3

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Tackling System Stability:

A Prerequisite to the Success of the Energy Transition

TIME: 30 mins

- The Challenge
- Our contribution
- Timeline

Knut HORNNES

Convenor of the Stability Management Workstream

Grids with high penetration of power electronic based generation and transmission

Question 4

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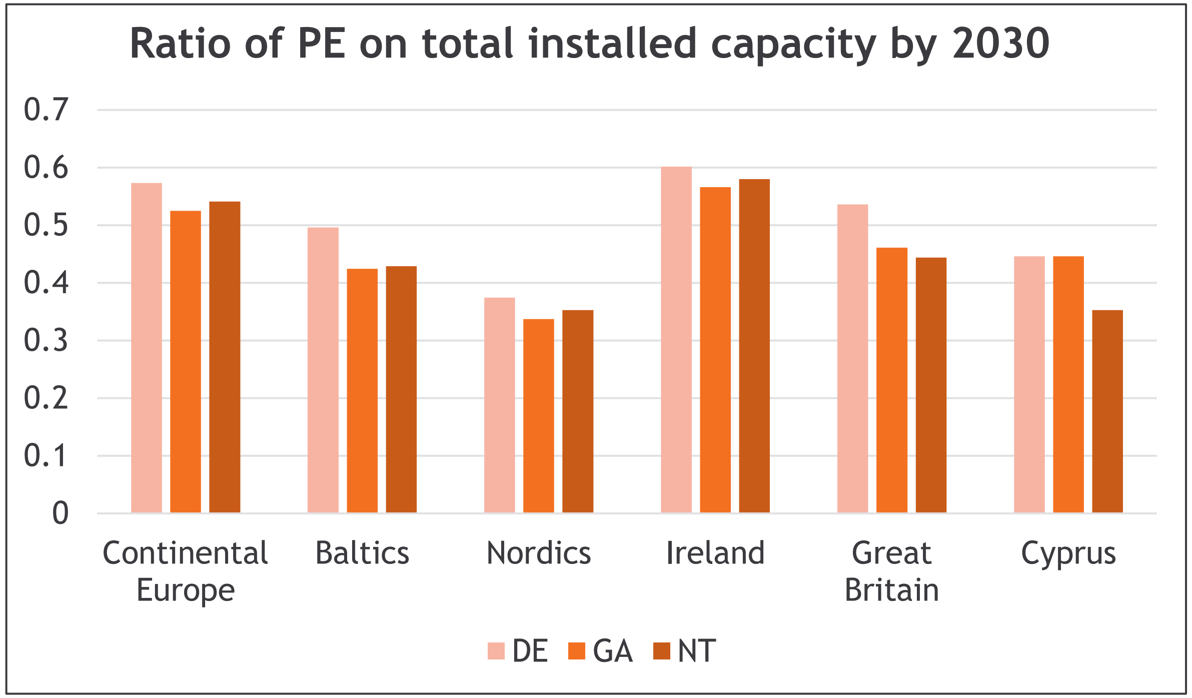
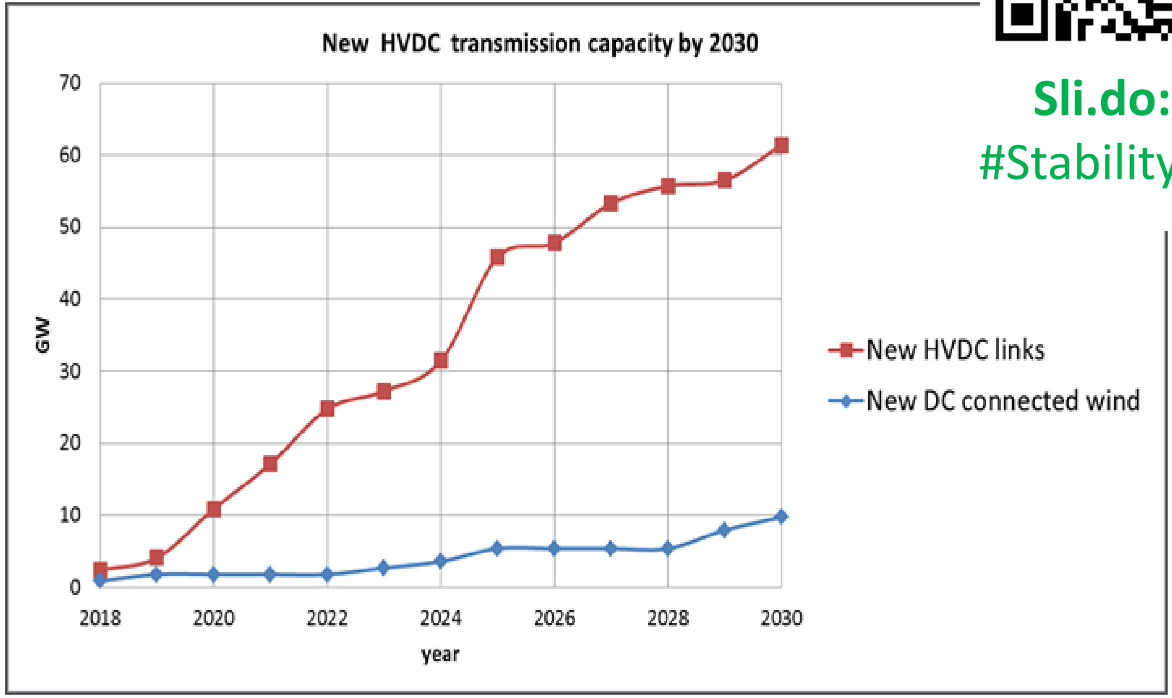
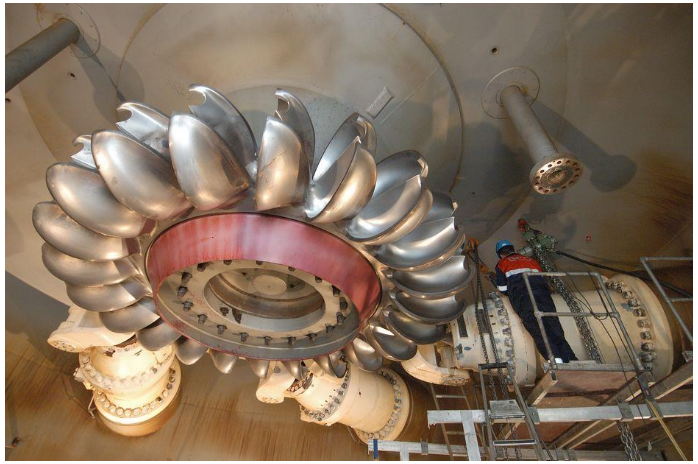




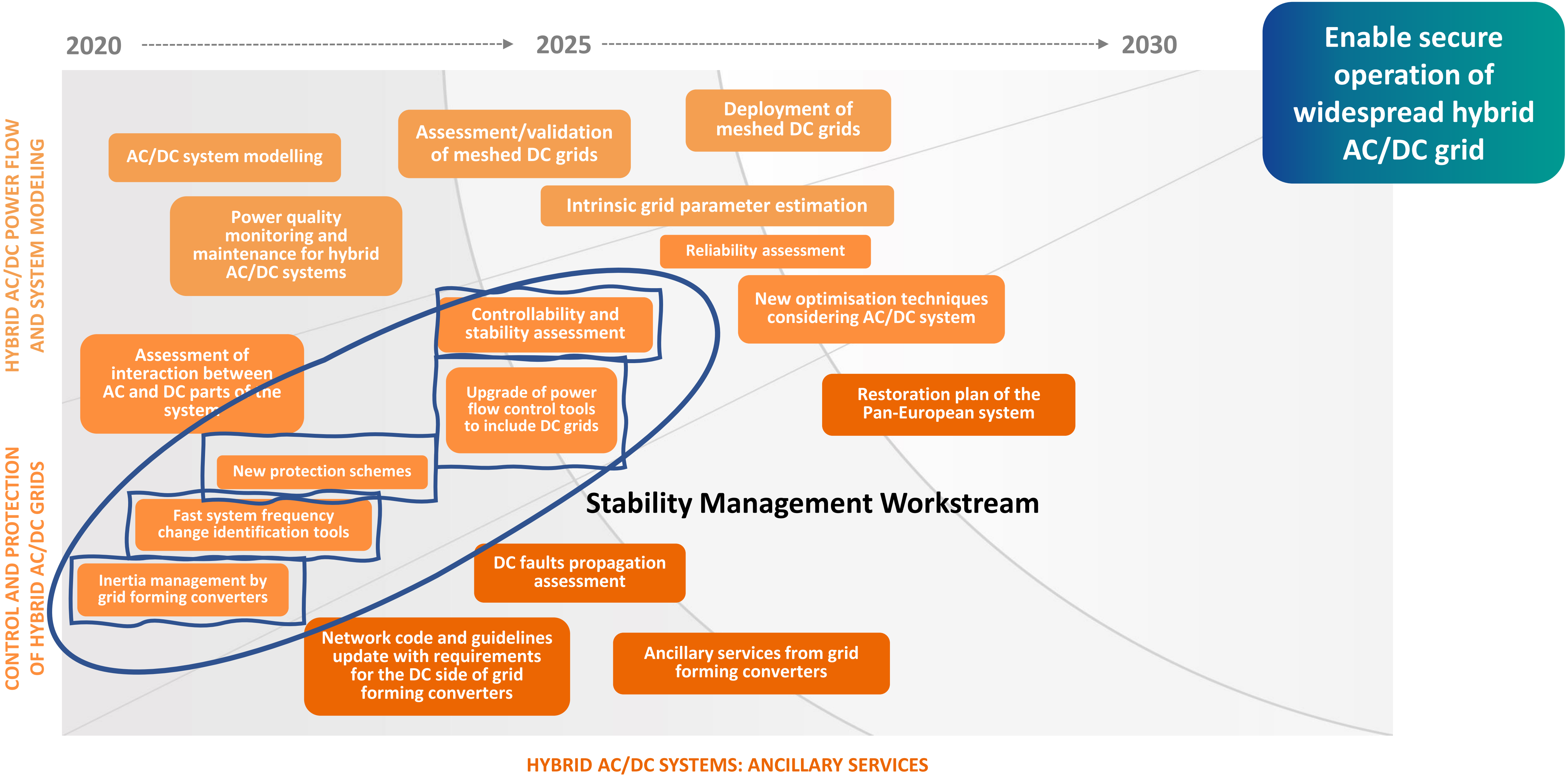
- The RES increase leads to an **increase of power electronics interfaced generation** connection
- Significant uptake of **high-voltage direct current (HVDC) transmission** driven mainly by **offshore development**

Units inherent properties are different

From heavy fast generator rotors to power electronics connected infeed



Flagship 5: Enable secure operation of widespread hybrid AC/DC grid



Stability Management in Power Electronics Dominated Systems

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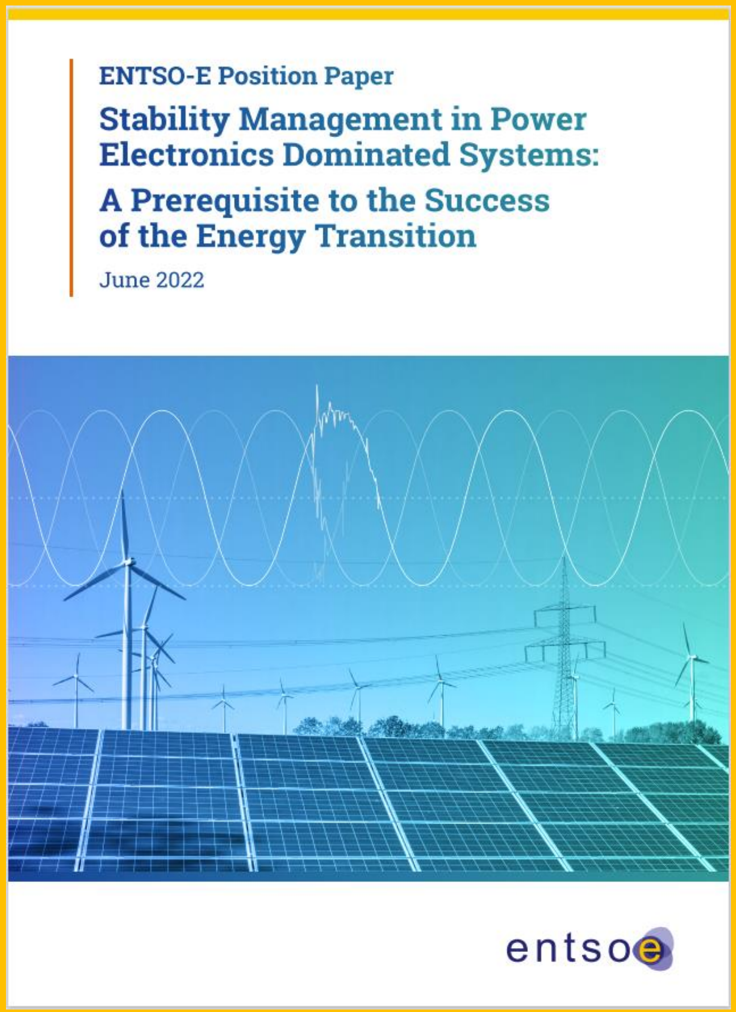
Research directions needed to solve technical, regulatory and market-related challenges

- **WP1: Long term power system planning and development**
- **WP2: Short term operational planning**
- **WP3: Sources for system services**
- **WP4: Real time power system operation**



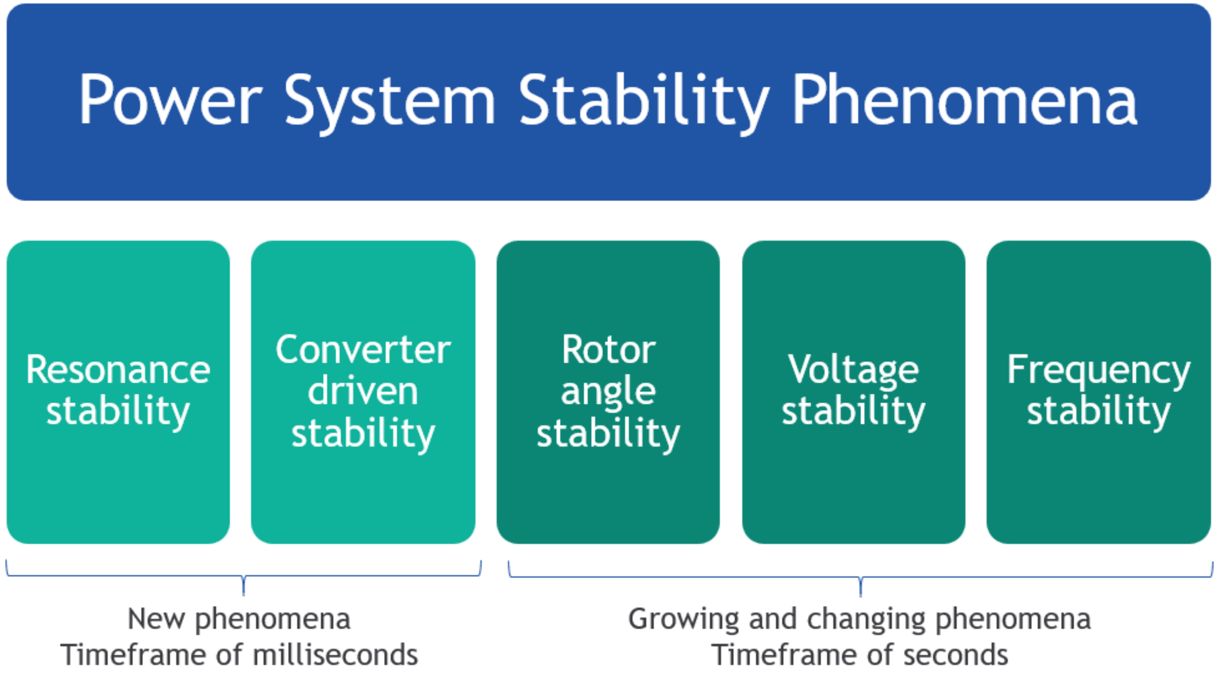
Power system stability phenomena and timeframes

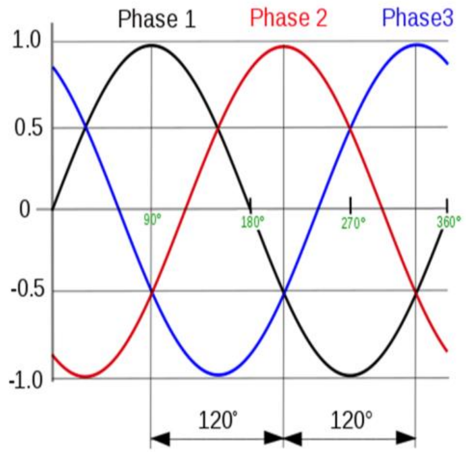
Old phenomena increase in rate and severity

- Rotor angle stability
- Voltage stability
- Frequency stability

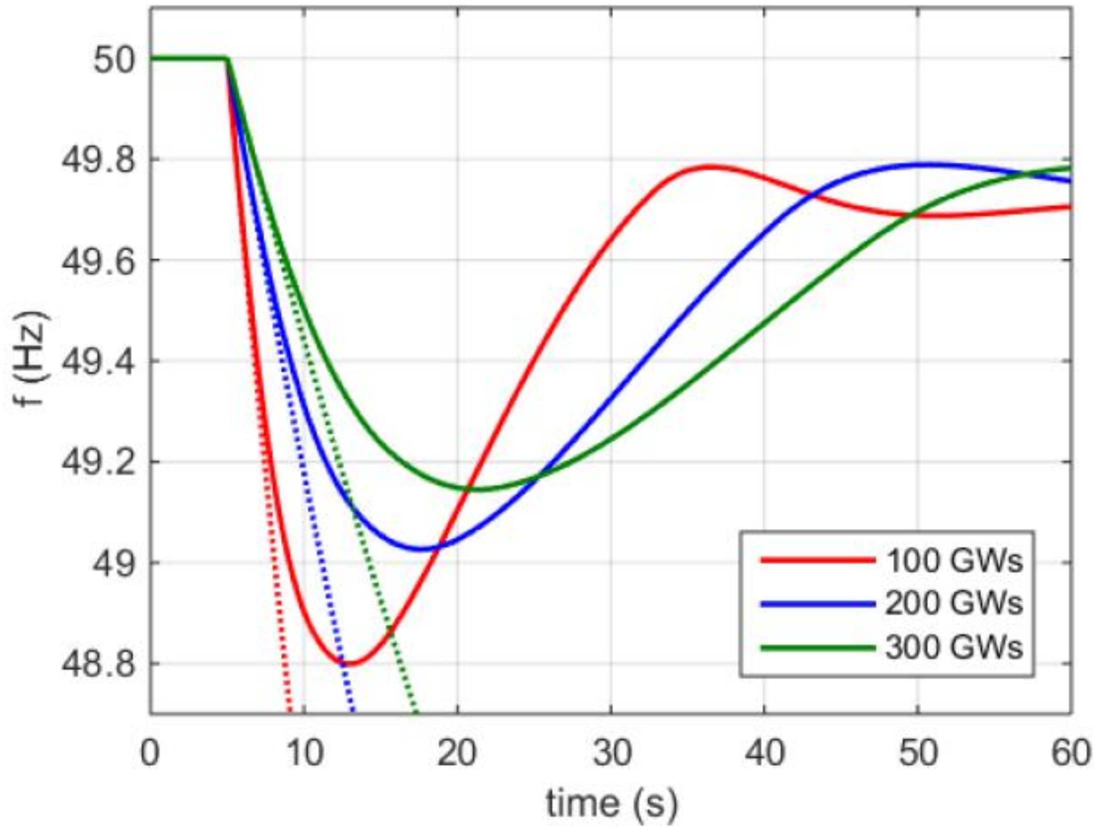
New power electronics related stability phenomena

- Resonance stability
- Converter driven stability

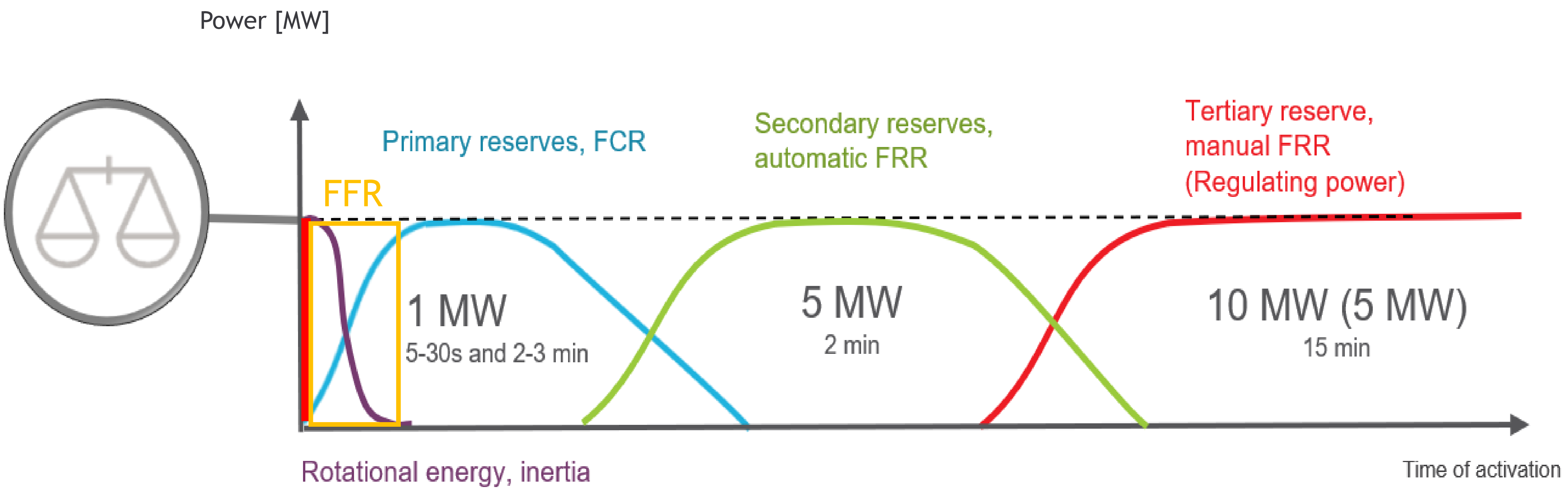


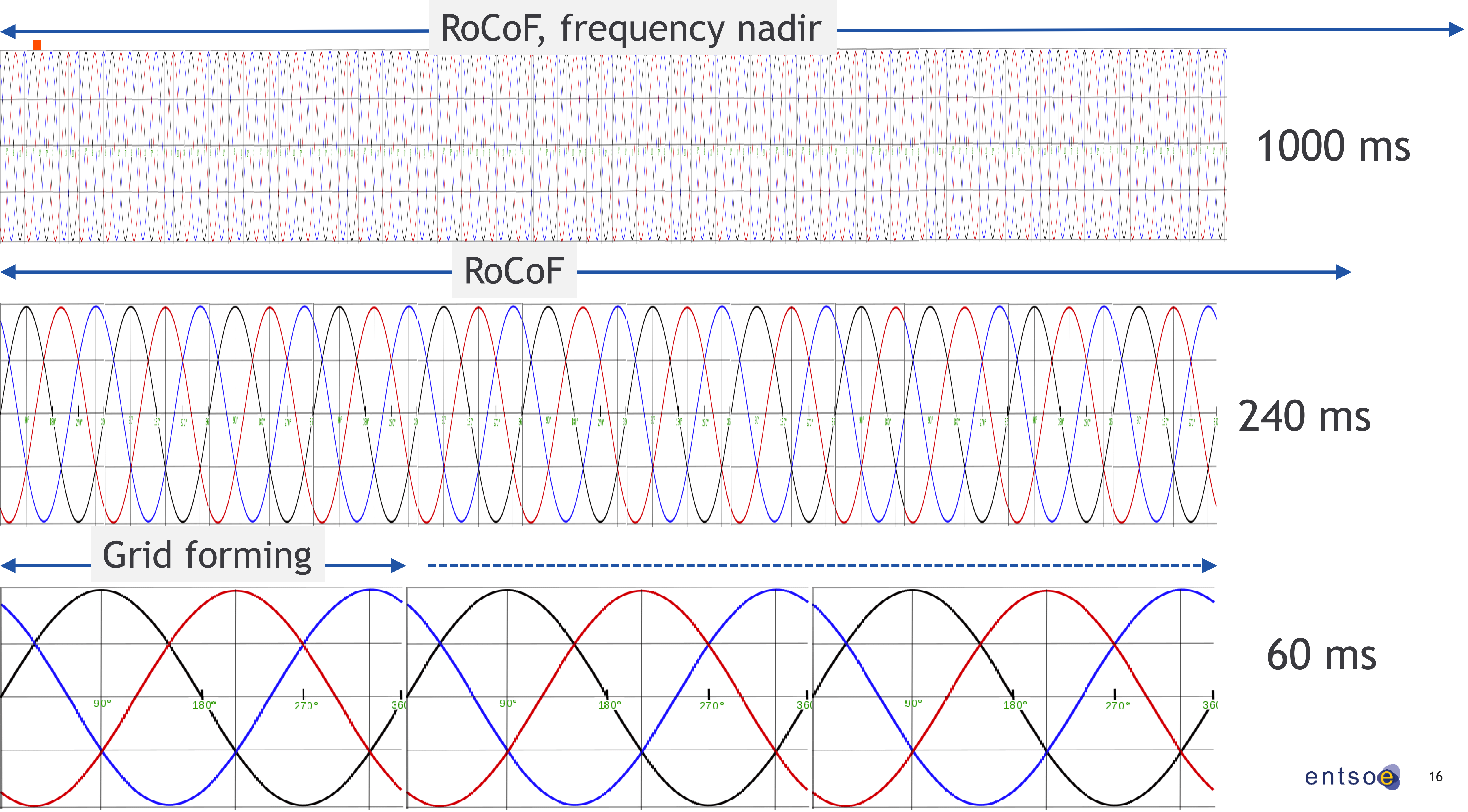


RoCoF and frequency nadir



Frequency containment timeframes




RoCoF, frequency nadir
1000 ms
RoCoF
240 ms
Grid forming
60 ms
90°
180°
270°

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Stabilizing technologies must be deployed

Question 6

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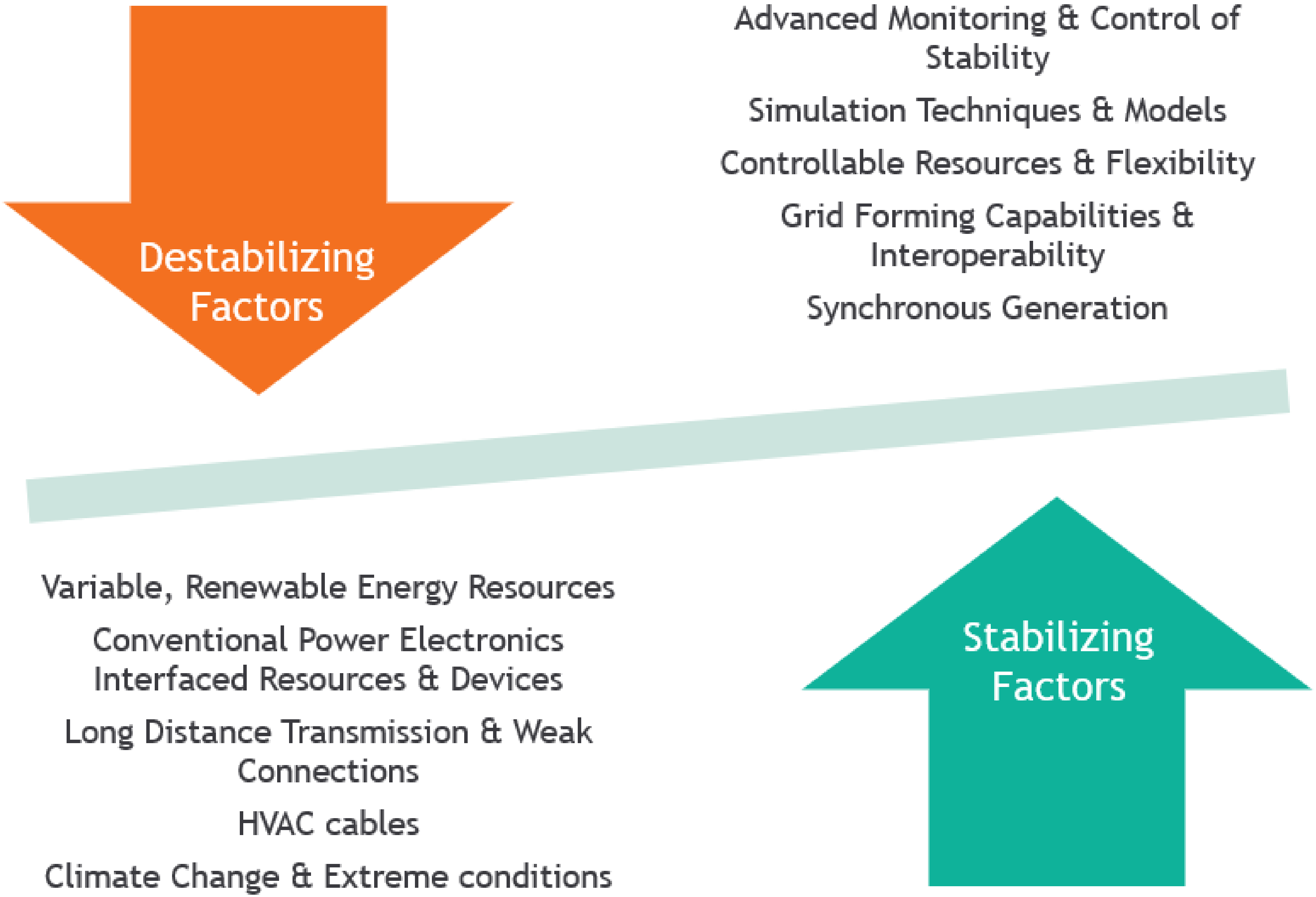

Urgent need for TSOs to develop, test and implement a new wide area system stability management approach

Question 7

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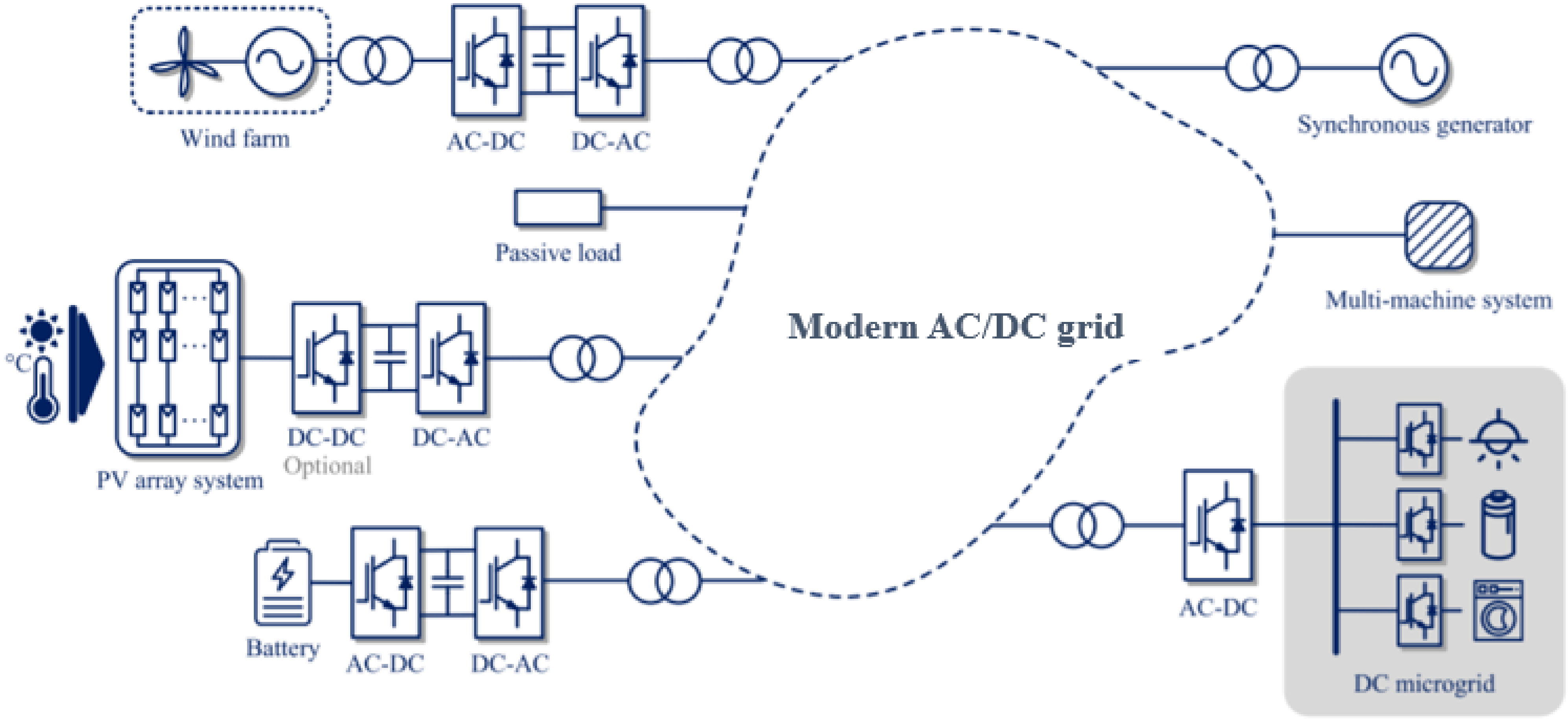

The Challenge

The success of the energy transition

The importance of reaching the goals stated in the European Green Deal has increased.

The transition to sustainable electricity production from renewable resources is a key to obtain climate neutrality.

Supported by investments in green technologies, sustainable solutions and new businesses, the Green Deal can be a new EU growth strategy.

Involvement and commitment of the public and of all stakeholders is crucial to its success.

The Urgency

The pace of the energy transition

The goals for carbon dioxide emission reduction has increased

The need for energy supply from non-fossil sources has increased

Mature sources for electricity production are based on power electronics

The required fast transition and amount of electricity from new sources deteriorate the power system stability

Stability phenomena are becoming increasingly concerning and diverse

Key Recommendations

The assessment and control of grid stability require consistent and pan-European methods

To maintain the pace of the energy transition, network codes shall be updated in a fast and harmonized process

New technical capabilities and system services are making it necessary to define new resilience requirements

Significant RD&I efforts and stakeholder collaborations are required to accelerate the uptake of new technologies for stability management

Question 8

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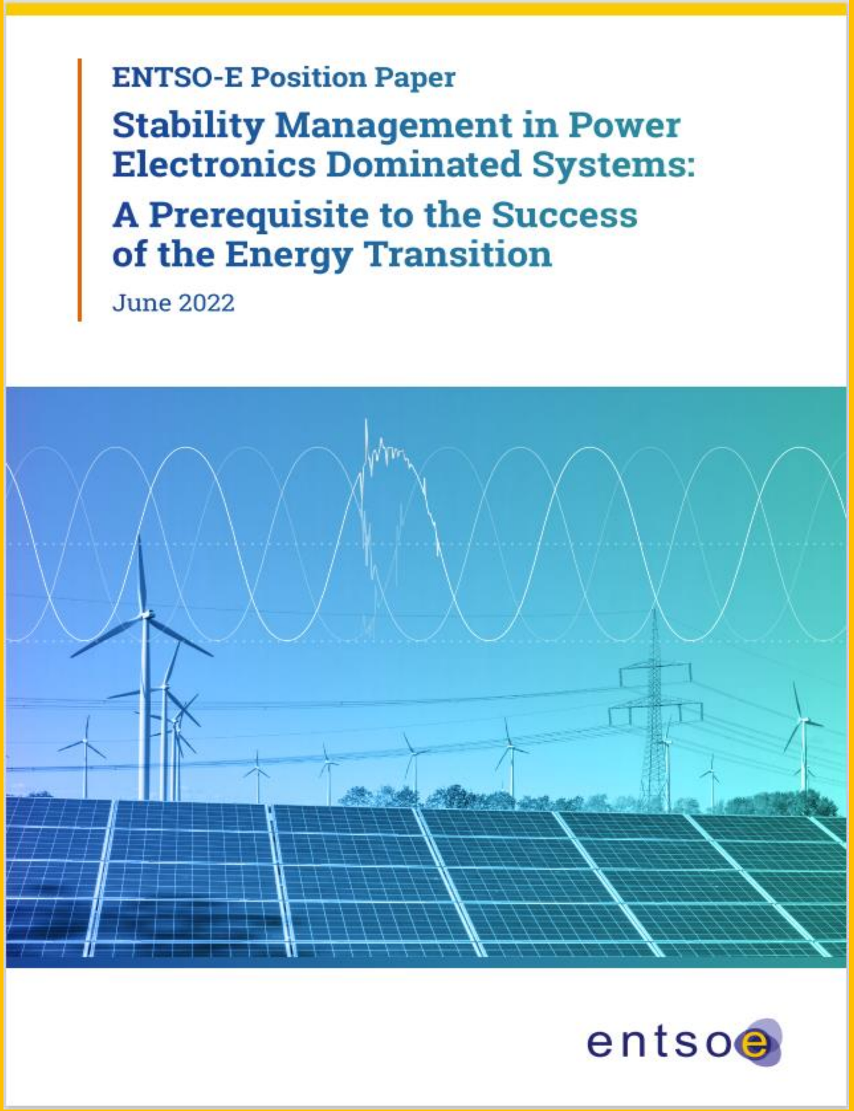
Thank you for your attention!



Project Inertia – Long term frequency stability scenarios

TIME: 20 mins

- Learnings and next steps

Joao MOREIRA

Project Manager, Project Inertia

Frequency stability in long term scenarios – framework (1/2)

WHAT

Cross–committee project set up by System Development Committee and System Operation Committee. It involves:

- TF Planning Standards; StG Connection Network Codes; WG System Protection and Dynamics

The project aim is to **assess the decreasing level of inertia and its impact on the future Continental Europe synchronous area**

WHY

- The system trends show a **decrease in the level of Inertia**
- Following an ordinary generation loss, **large RoCoF and frequency excursions** are not expected in Continental Europe. However, these **can be observed in case of a system split**
  - System splits are **realistic and serious disturbances**
  - System split events are **not a new issue**, but the trends show that the **underlying assumptions are shifting to a situation more challenging to withstand**
- It is **important to assess the expected RoCoF** values in a system split and **discuss the possible mitigation measures**
  - A high RoCoF reduces the available time for deploying the necessary fast balancing actions for preventing high frequency excursions leading to unstable behavior in the subsystems or even blackout

Frequency stability in long term scenarios – framework (2/2)

HOW

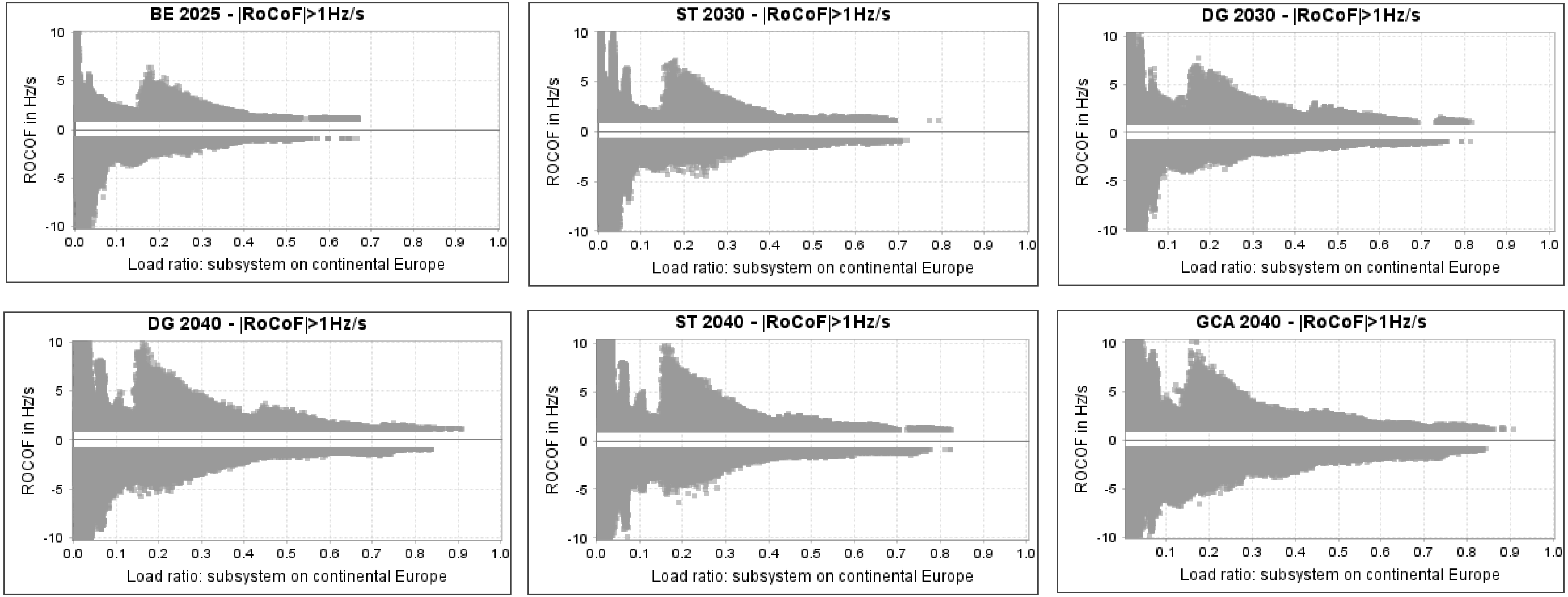
Starting from the **market data of TYNDP2018**, the study defined a **methodology** to enable a comprehensive perspective of the possible Continental Europe synchronous area split cases and the **essential causes** at the base of the **RoCoF values**

- Calculation of **all possible system split combinations** considering a subset of the TYNDP 18 market nodes (In total 23 million situations: scenarios x system split x hours)
- For each split combination, the **initial subsystems RoCoF is calculated based on the imbalance and inertia for every hour and every TYNDP scenario**
- **The study does NOT assess the probability of occurrence of a system split!**

The study considered **initial RoCoF values higher than 1 Hz/s as not manageable,** as per to System Operation Committee WG SPD "Inertia and Rate of Change of Frequency (RoCoF)*"

*https://eepublicdownloads.azureedge.net/clean-documents/SOC%20documents/Inertia%20and%20RoCoF_v17_clean.pdf

Subsystem RoCoF wrt load ratio: potentially unmanageable cases



- The highest RoCoFs are related to smaller subsystems
- From 2025 to 2040 there is a RoCoF increase for all sizes of subsystems, an increasing size of the subsystems exposed to |RoCoF|> 1 Hz/s and more cases exceeding |RoCoF|> 1
- **In 2040, 3 times more cases (case= one hour and one split) create RoCoFs higher than 1Hz/s**

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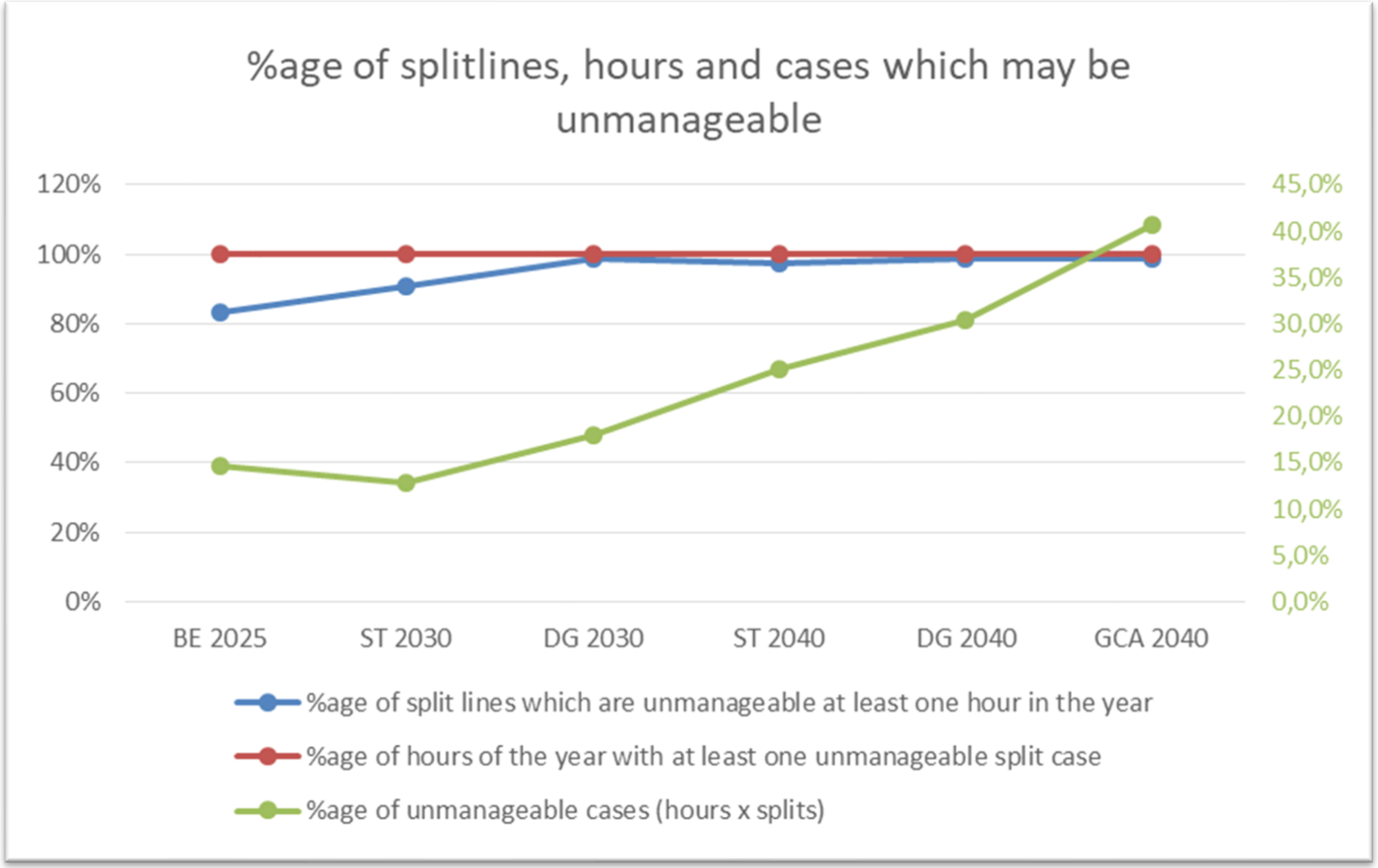
Subsystem RoCoF wrt load ratio : potentially unmanageable cases

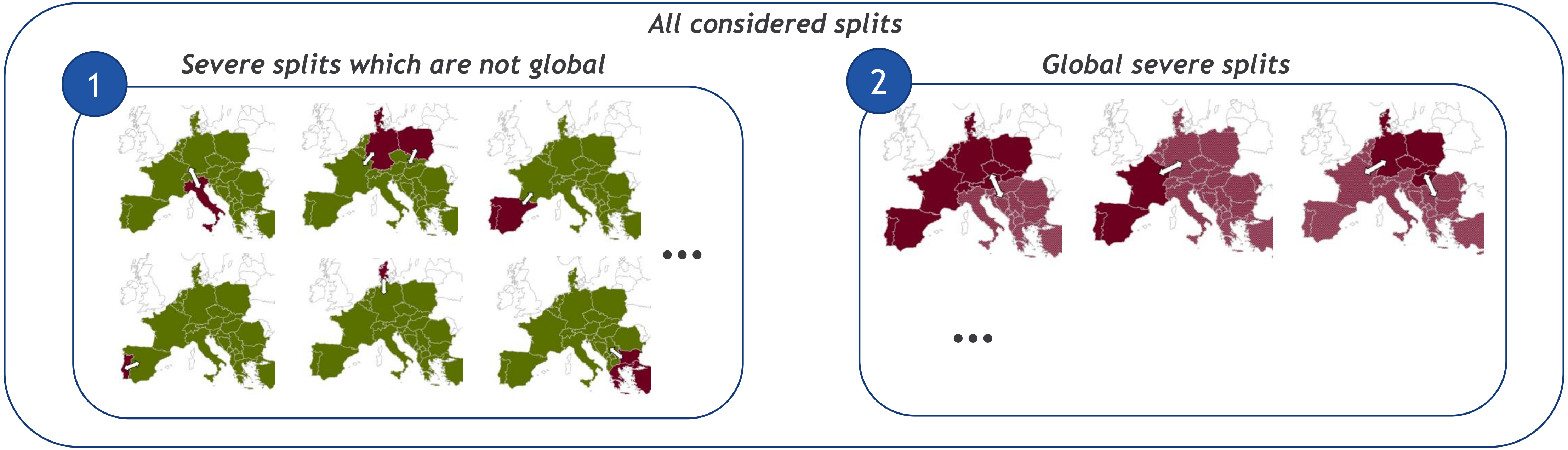


The red line at 100% shows that at any hour of the year at least one split can be unmanageable (RoCoF higher than 1Hz/s)

The blue line between 80% and 100% indicates that almost all splits can be unmanageable at least one hour of the year

The green line means that on all of the 3 800 000 cases (hours x splitlines) from 13% to 41% can be unmanageable depending on the scenario and time horizon

Digging further: The *global severe splits* approach allows a focus on the split cases that affect everyone in the Continental Europe system



System splits that could lead to a RoCoF > 1 HZ/s in one subsystem (red)

- A partial blackout could occur in the CE system

Global severe splits could lead to a RoCoF > 1 HZ/s in both subsystems

- A blackout could occur in the entire CE system

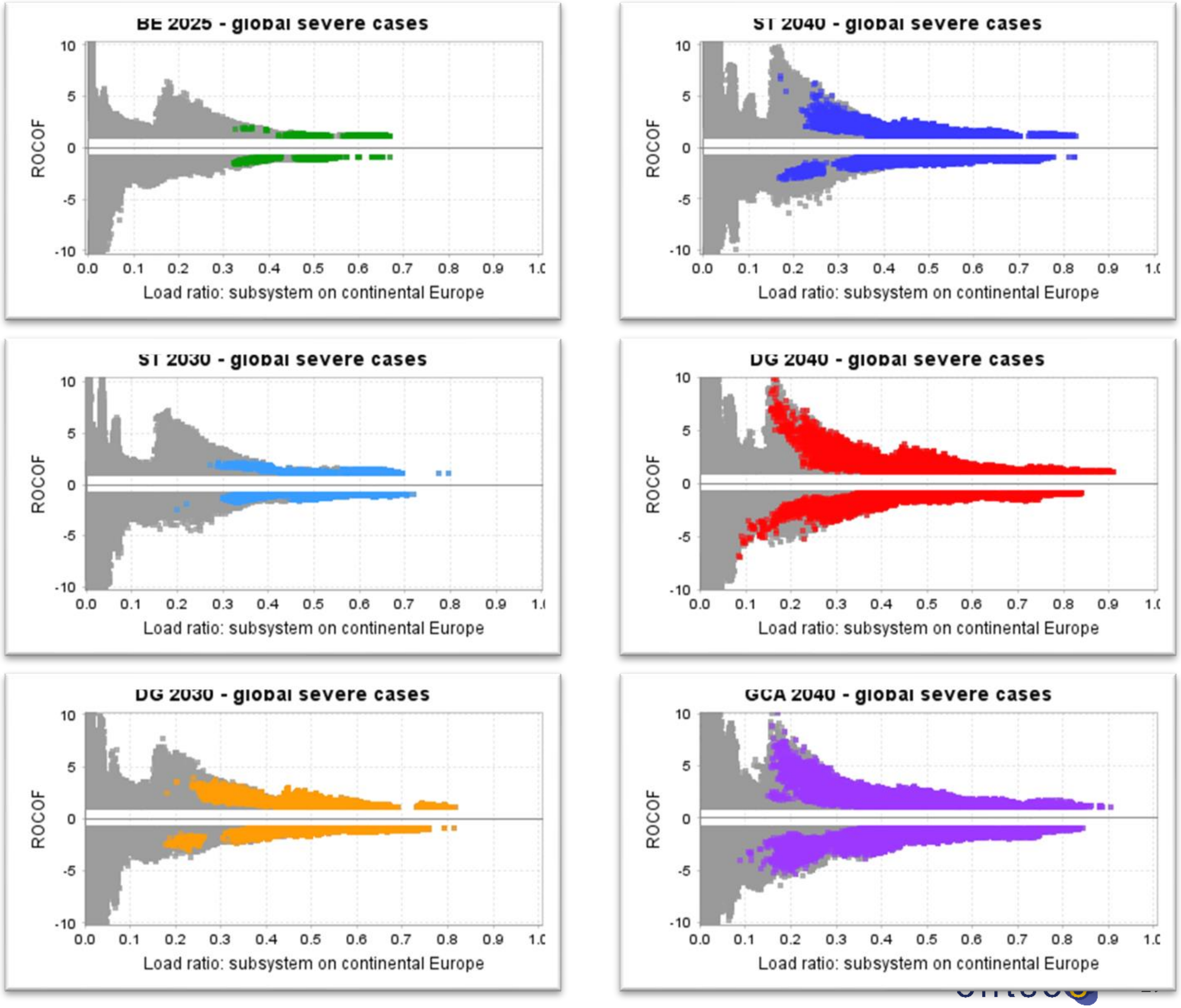
- **Global severe splits represent only a subset of the total challenge, but provide visibility to the global scale of the issue**
- **Severe splits which are not global are also relevant**

RoCoF WRT load ratio : global severe splits

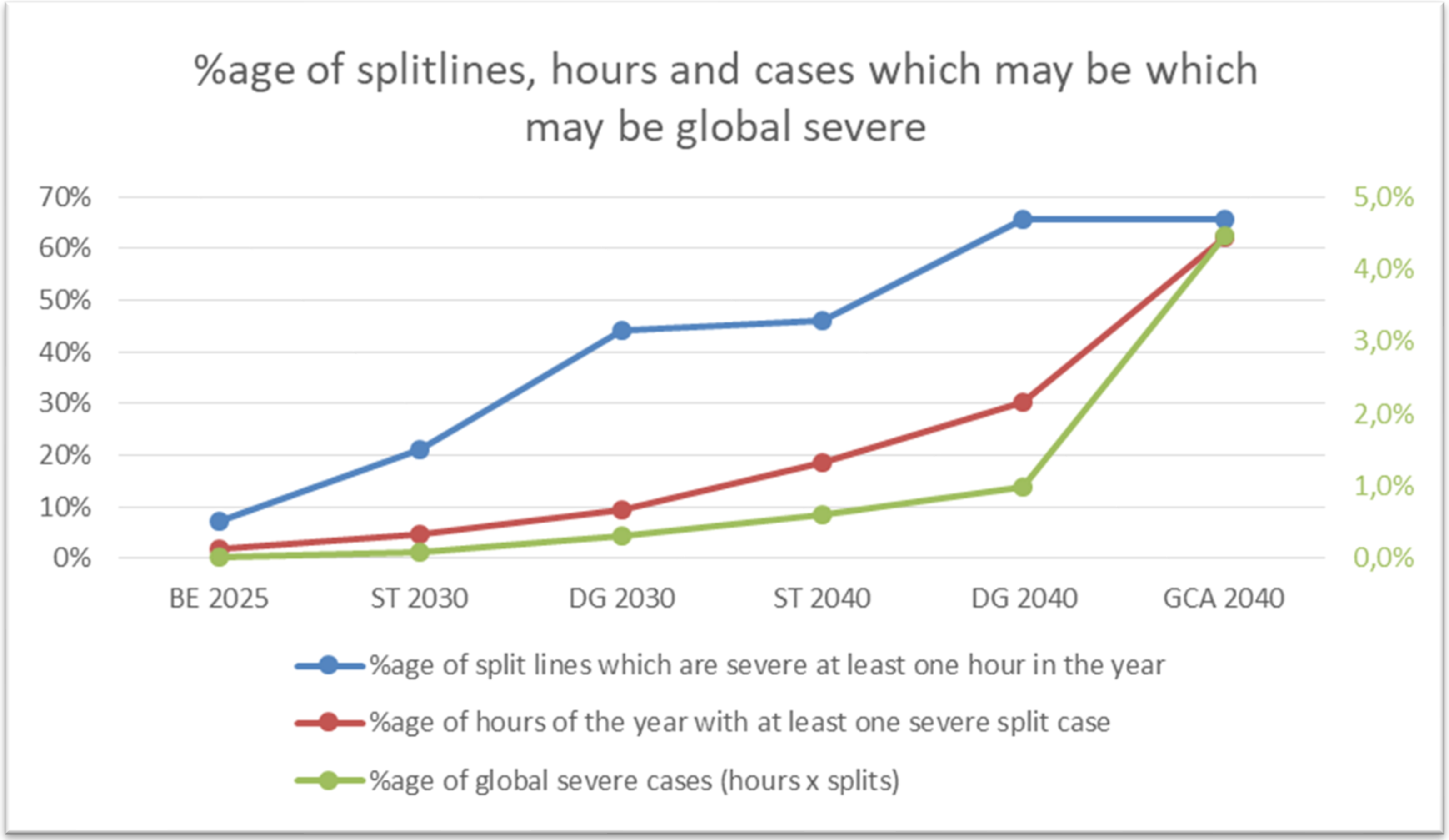
Global severe splits: both island with a |RoCoF| higher that 1 Hz/s. Potential risk for CE blackout

- The **number of cases is much lower than unmanageable cases** but the **consequences are much more serious** (Continental Europe blackout) and the numbers are still significant
- In GCA2040, all the splits isolating more than a third of the CE are globally severe, meaning they would affect the whole CE

Each global severe case corresponds to two dots: each of the two dots relates to one of the two split subsystems, showing its load ratio and RoCoF for one specific hour and one system split. Obviously, the two load ratios are complementary to 1 and the RoCoF are of opposite sign.



RoCoF WRT load ratio : global severe splits



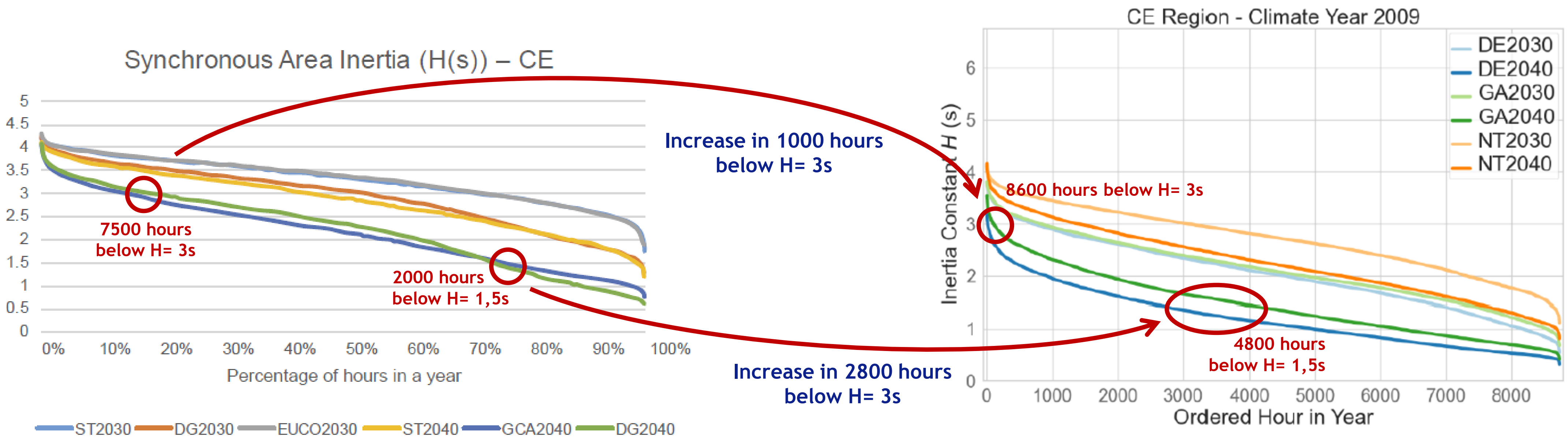
The red line shows that from 2% to 62% of the hours of the year at least one split can be global severe depending on the scenario and time horizon

The blue line indicates that from 7% to 66% of splitlines can be global severe at least one hour of the year depending on the scenario and time horizon

The green line means that on all of the 3 800 000 cases (hours x splitlines) from 0% to 4% can be global severe depending on the scenario and time horizon

Trends confirmation from the long-term scenarios

TYNDP 2018 Scenarios → **TYNDP 2022 Scenarios**



TYNDP 2022 scenarios display a situation that tends to be even more challenging than TYNDP 2018 scenarios, with a **larger number of hours experiencing reduced levels of inertia**

How to address the challenge?

Not a single solution: several measures should be considered and weighed

Provide additional inertia by renewable energies and battery storages (the precondition are grid forming and energy storage)
Provide additional inertia through STATCOM (the precondition are grid forming and energy storage), synchronous condenser or market-based procurement

Increase withstand capability of power generation units and establish faster-reacting system protection schemes (further develop the system so that |RoCoF| higher than 1 Hz/s can be handled).

Measures to **avoid a system split** (e.g. grid reinforcement, increased use of DC technology)

Countermeasures to **mitigate the effects of the system splits** (e.g. Special Protection Schemes, …).

As a last resort: **Market restrictions** as reduction of the power exchange or must run

How to address the challenge?

It is urgent to act – some examples regarding Grid Forming Capabilities in converters

RfG 2.0 amendment proposals introduce important requirements

- the inherent code amendment process and implementation timeline, means that the system availability of such requirements will not happen immediately (possibly by 2027)

Research and Innovation supporting activities

- create the conditions for the **integration of Grid Forming Capabilities as soon as possible**
- **improve modelling capabilities and availability of models**

Main conclusions

The assessment demonstrates that the **challenge posed by the decreasing level of inertia exists and, in the case of global severe splits, might involve the entire CE synchronous area.**

To cope with this challenge, different solutions should be assessed for the future system. **The installation of additional inertia is only one of the solutions.**

The decision on what is the 'acceptable' risk is not for the TSOs only, but involves all the stakeholders, industrial and institutional.

Follow up of the study

Question 10

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The work developed in the project "Frequency stability in long term scenarios" is **being continued to further support the information and dialogue with stakeholders**

What's Ongoing?

Project team set up to:

- Assess the risks of a system split with **updated input data from TYNDP 2022 and applying analytical and time-domain analysis**
- Provide more **quantification of the challenge and solutions**
- Further evaluate the **most appropriate set of solutions** and their extent to cope with a system split and its consequences

New Demand Units and Advanced Capabilities

TIME: 15 mins

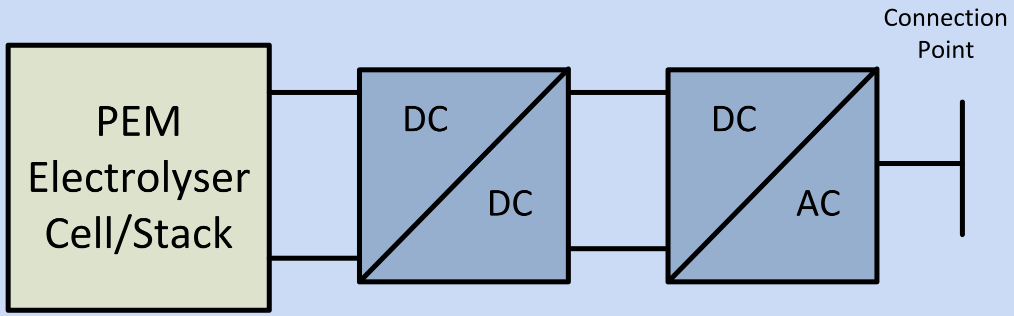
- Demand Unit Cases
- Future Research Topics

Mario NDREKO

StG CNC Convenor

How to explore the potential of converter based demand?

Demand Unit Case: Electrolysis



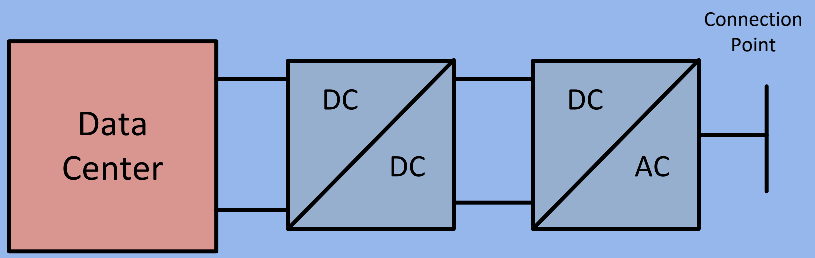
- Expected large demand capacity even in transmission level (GW scale at one connection point)
- Mostly are interfaced to the grid by AC-DC converters
- Voltage Source Converters based units must prevail in order to comply with similar requirement of power park modules (PPM)
- Electrolyser demand units can offer not only flexibility in grid operation and market but also system supportive functionality (frequency and voltage)

Future research topic:

- Demonstrate high TRL level of VSC-Interfaced Electrolysers that comply with CNC requirements (Q and U control, FSM, LFSM-U/O, FRT and grid forming)
- Effective simulation models for such systems to be used in grid planning but also compliance studies (RMS and EMT models for transmission connected demand facilities)

How to explore the potential of converter based demand?

Demand Unit Case: Data Centers



- Large increase in demand capacity is expected in the next years
- Voltage Source Converter interfaced to the grid
- Big potential to provide LFSM, FSM, reactive power capability and voltage control

Future research topic:

- Demonstrate highest TRL level of Data Center Demand Facility that comply with CNC requirements (Q and U control, FSM, LFSM-U/O, FRT and grid forming)
- Develop effective simulation models for Transmission connected Data center facilities (RMT, EMT and frequency domain)

How to explore the potential of heat pumps?

Demand Unit Case:
Temperature Controlled Units
(Heat Pumps)

- Large increase in demand capacity is expected in the coming years
- Mainly DSO connected but plans also for transmission connected demand facilities for industrial scale projects
- Voltage Source Converter interfaced to the grid
- Big potential (large demand capacity) to provide LFSM-U, FSM

Future research topic:

- Demonstrate highest TRL level of Temperature Controlled Units that complies with CNC requirements (FSM, LFSM-U)

How to explore the potential of EVs?

Demand Unit Case:
EV'S battery

- Large increase in demand capacity is expected in the next years
- Mainly DSO connected
- Voltage Source Converter interfaced
- Big potential (large demand capacity) to provide LFSM-U, FSM

Future research topic:

- Demonstrate highest TRL level for charging units offering (FSM, LFSM-U/O and potentially grid forming capability)

Thank you very much for your attention

Our values define who we are, what we stand for and how we behave.
We all play a part in bringing them to life.

EXCELLENCE

We deliver to the highest standards. We provide an environment in which people can develop to their full potential.

TRUST

We trust each other, we are transparent and we empower people. We respect diversity.

INTEGRITY

We act in the interest of ENTSO-E

TEAM

We care about people. We work transversal and we support each other. We celebrate success.

FUTURE THINKING

We are a learning organisation. We explore new paths and solutions.

We are ENTSO-E

6x5 National Examples

of stability related challenges and events

TIME: 35 mins

1) Statnett (Nordic examples) — *Knut Hornnes*
2) SSE Networks Transmission Operator — *Benjamin Marshall*
3) REN, Iberian System Split — *Rui Pestana*
4) Energinet.dk — *Jun Bum Kwon*
5) Amprion — *Bartosz Rusek*
6) Eirgrid — *Mostafa Bakhtvar*

Moderator:

Íris BALDURSDÓTTIR

Incident in Norway November 2.

Oscillations from converter connected wind farm

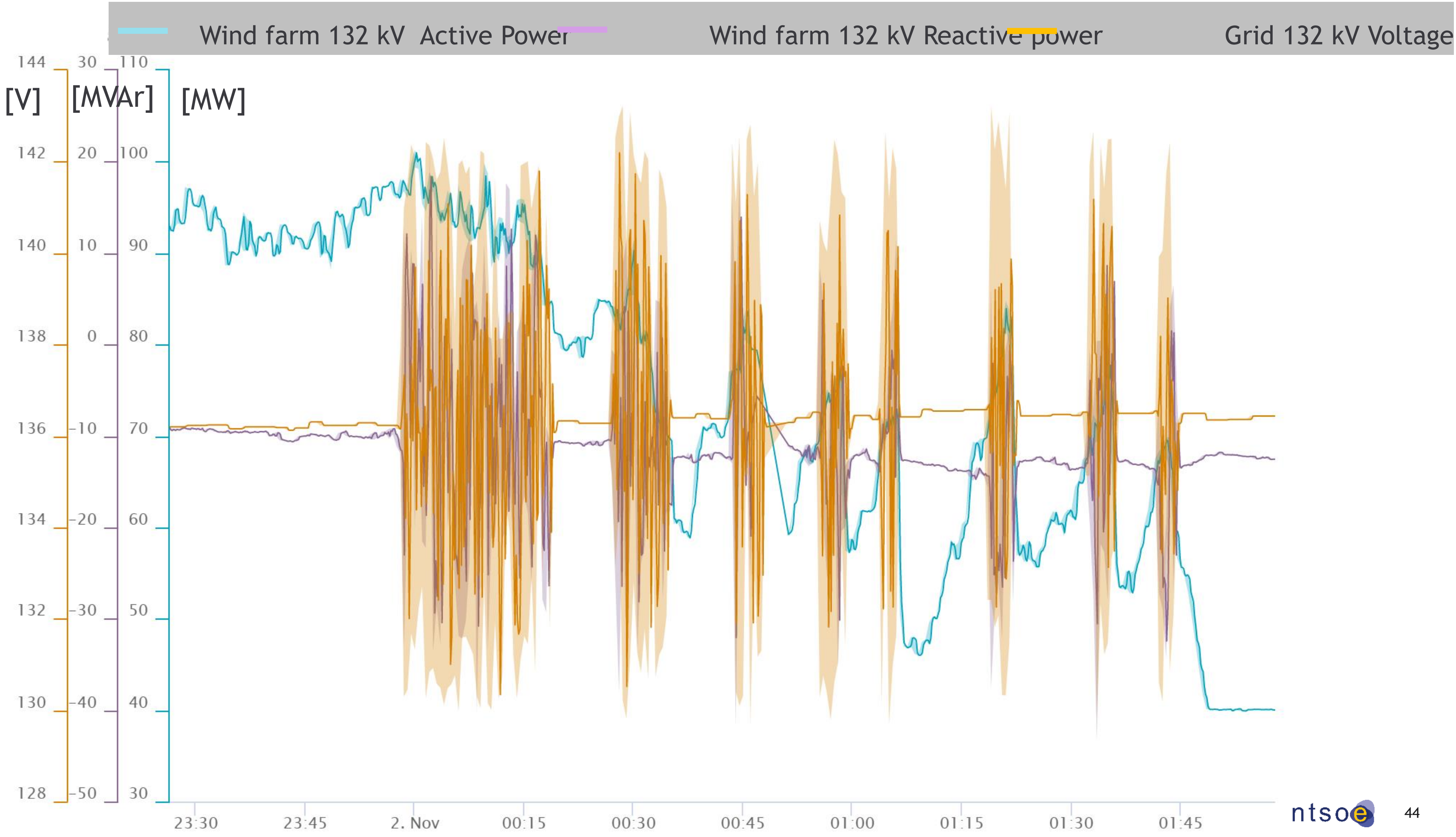
Oscillations in reactive power from wind farm

Oscillations in voltage

Reduced power production in wind farm, oscillations stopped

Oscillations started again when trying to increase production

Total reduction from 95-100 MW down to 40 MW


Wind farm 132 kV Active Power
Wind farm 132 kV Reactive power
Grid 132 kV Voltage
[V]
[MVAr]
[MW]
144
142
140
138
136
134
132
130
128
30
20
10
0
-10
-20
-30
-40
-50
110
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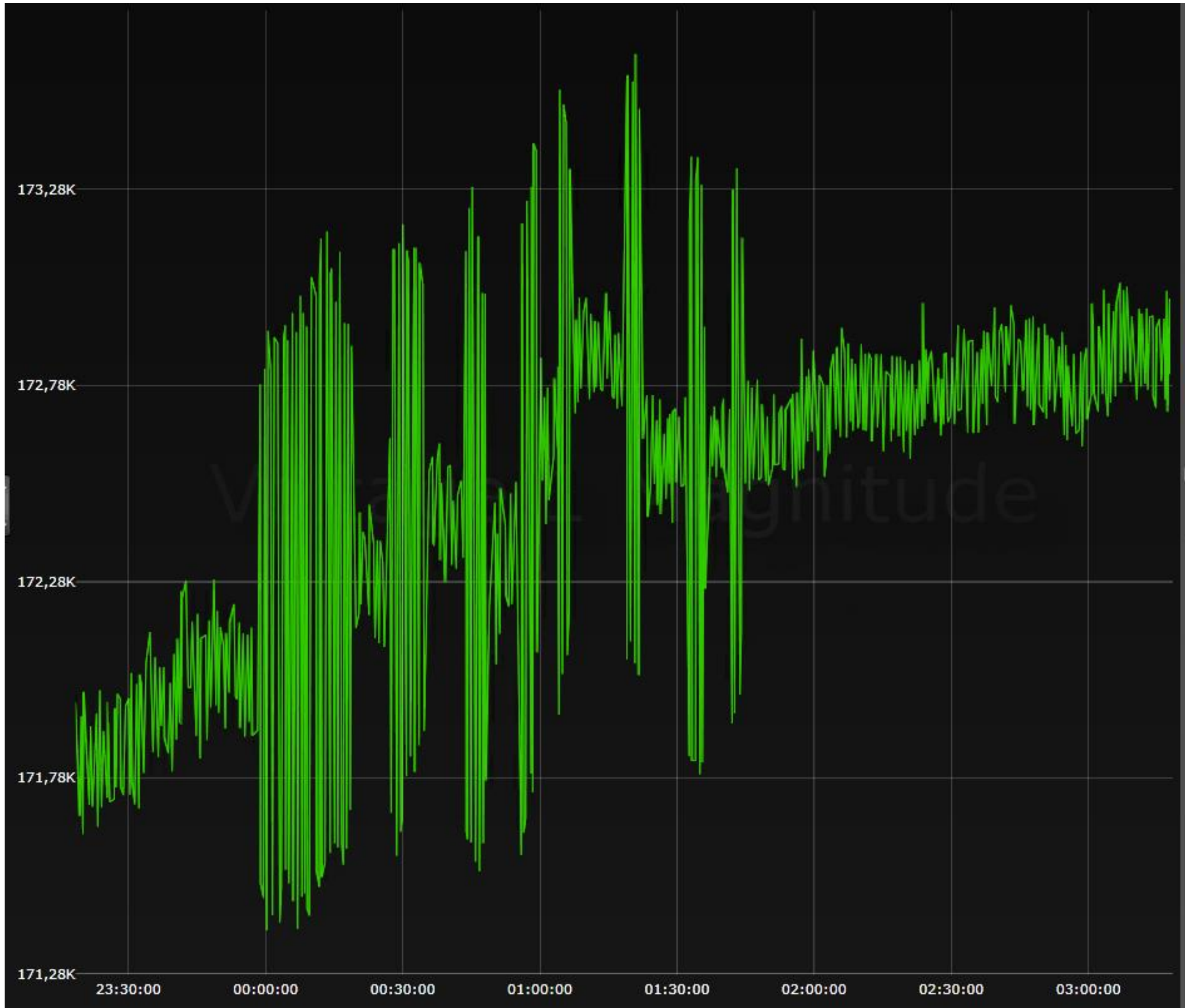
Impact 300 kV transmission grid

Voltage oscillations [V]

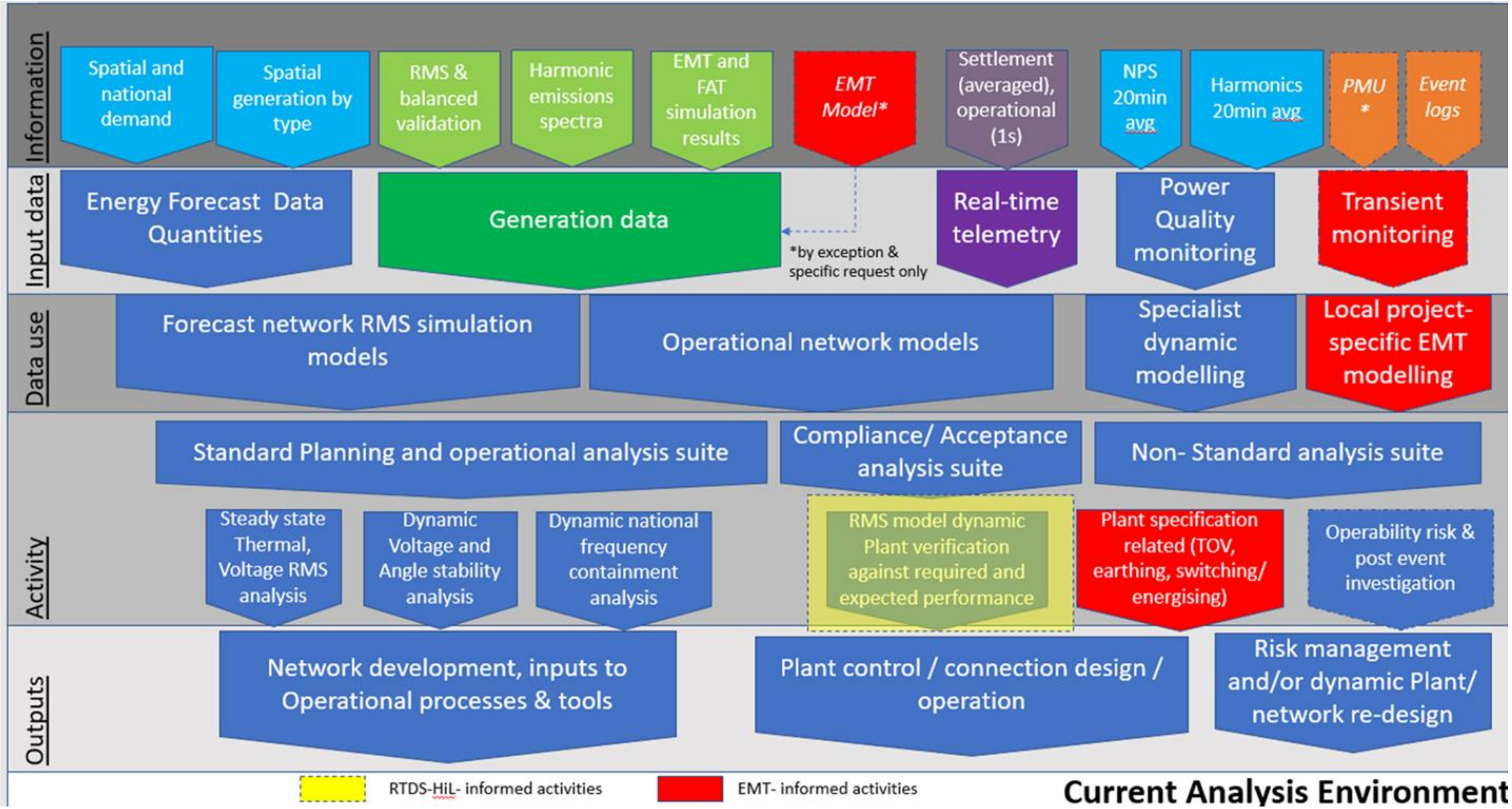


Power flow [MW]

Addressing HVDC and Large-Scale Power Electronics Network Stability in GB

Ben Marshall, Technology Manager, National HVDC Centre, GB

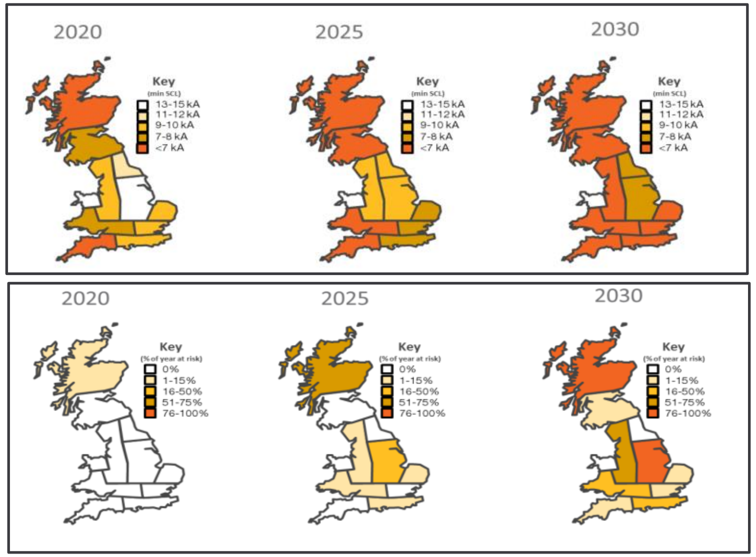
The National HVDC Centre



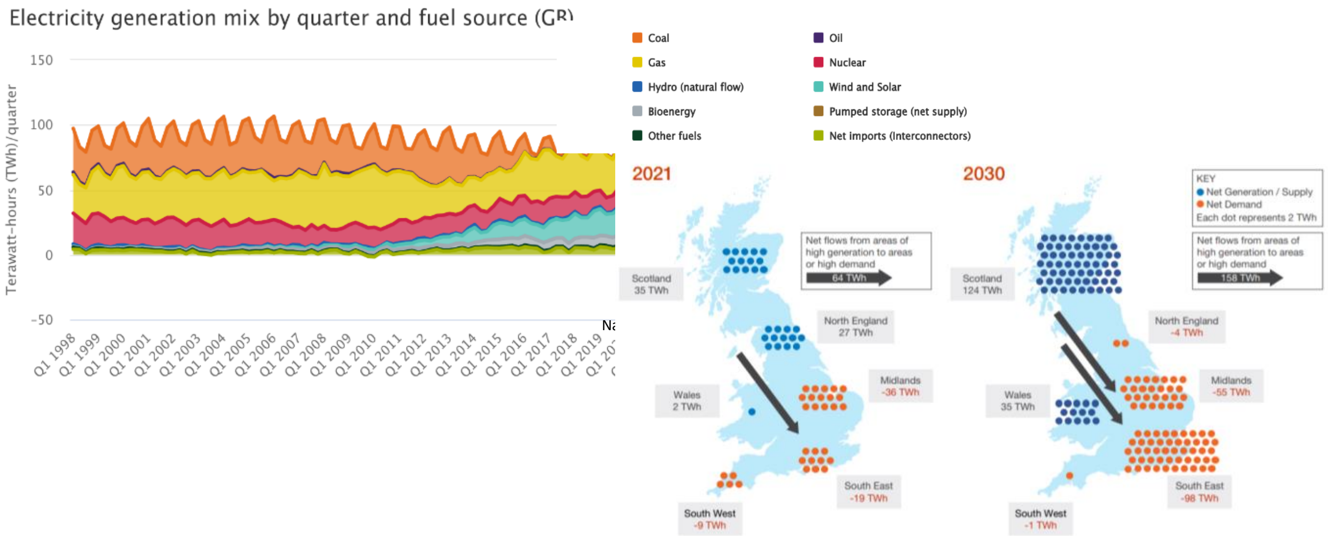
The National HVDC Centre

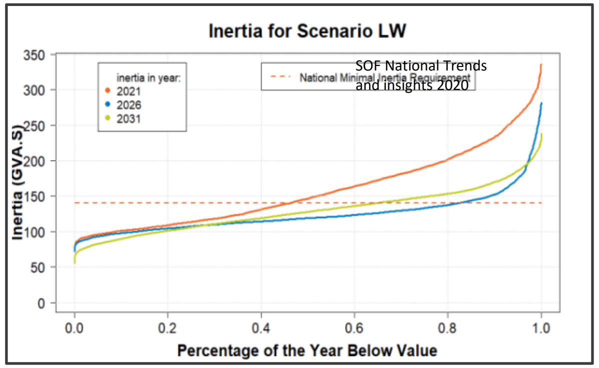
2) What is Changing in GB?

Challenge	Driver	Emergence	Effect
Short ciruit strength	Current loop control approach, regional inertia deficits	Defining new stability support	Wider stability impact from events, protection challenges, voltage recovery & regulation, power quality
Frequency domain	Network and control modes	Control interaction & tuning needs	Undamped oscillation, protective disconnection
Classical instability	PLL tracking, limited Q support.	increased need for EMT study	increased need for EMT study
Inertia	Convertor based technology displacement	Defining frequency control needs	Frequency regulation & containment+ inter-area effects in distribution



Impact of declining Short circuit level (A System Operability Framework Document), National Grid ESO, download (nationalgrideso.com)





Scottish & Southern Electricity Networks

3) GB System – Some Key Challenges

1) Declining Inertia

– from "typical" levels of 250GVAs to c. 100GVAs without intervention

– Minimums from 140GVAs to c. 50GVAs without intervention.

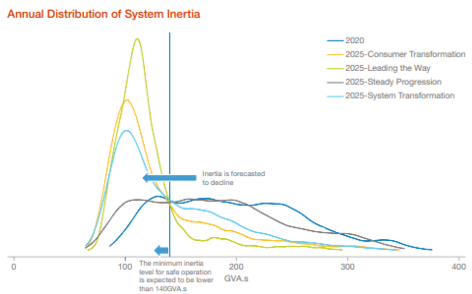
- Stability Pathfinder- future Stability Markets GB-GFC
- LoM & RoCoF relay replacement

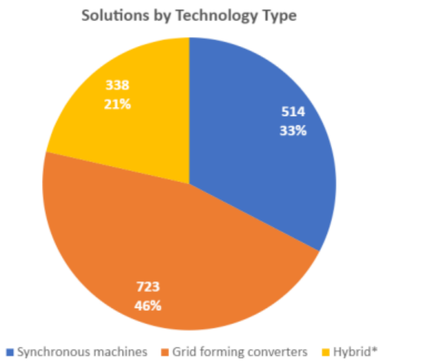
2) Frequency Regulation & containment

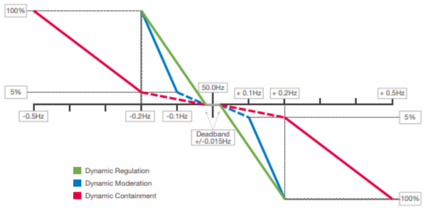
- faster frequency response to address larger loss (1800MW),df/dt (up to 0.5Hz/s- 1Hz/s)

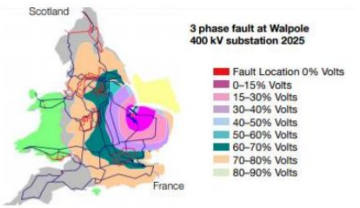
3) Declining fault level

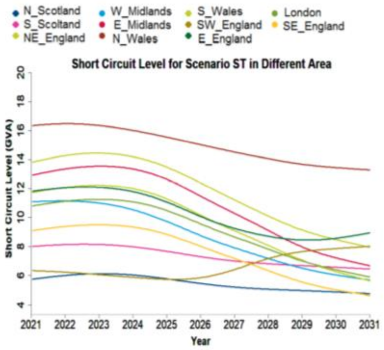
- Increasingly areas of SCR <1.5
- Greater area of impact from faults
- Protection, connection stability/ performance risks
- Additional local grid forming needs

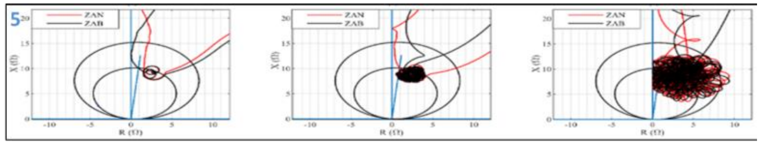


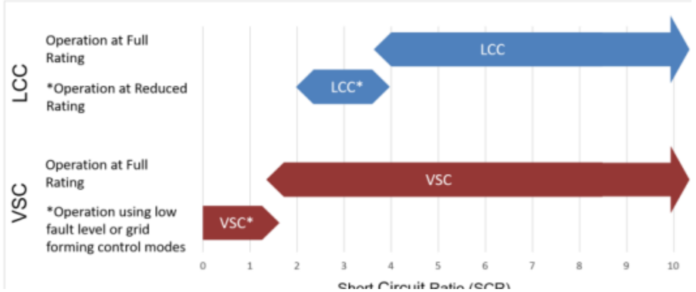












Scottish & Southern Electricity Networks

4) GB System – Some Key Challenges

4) Voltage stability

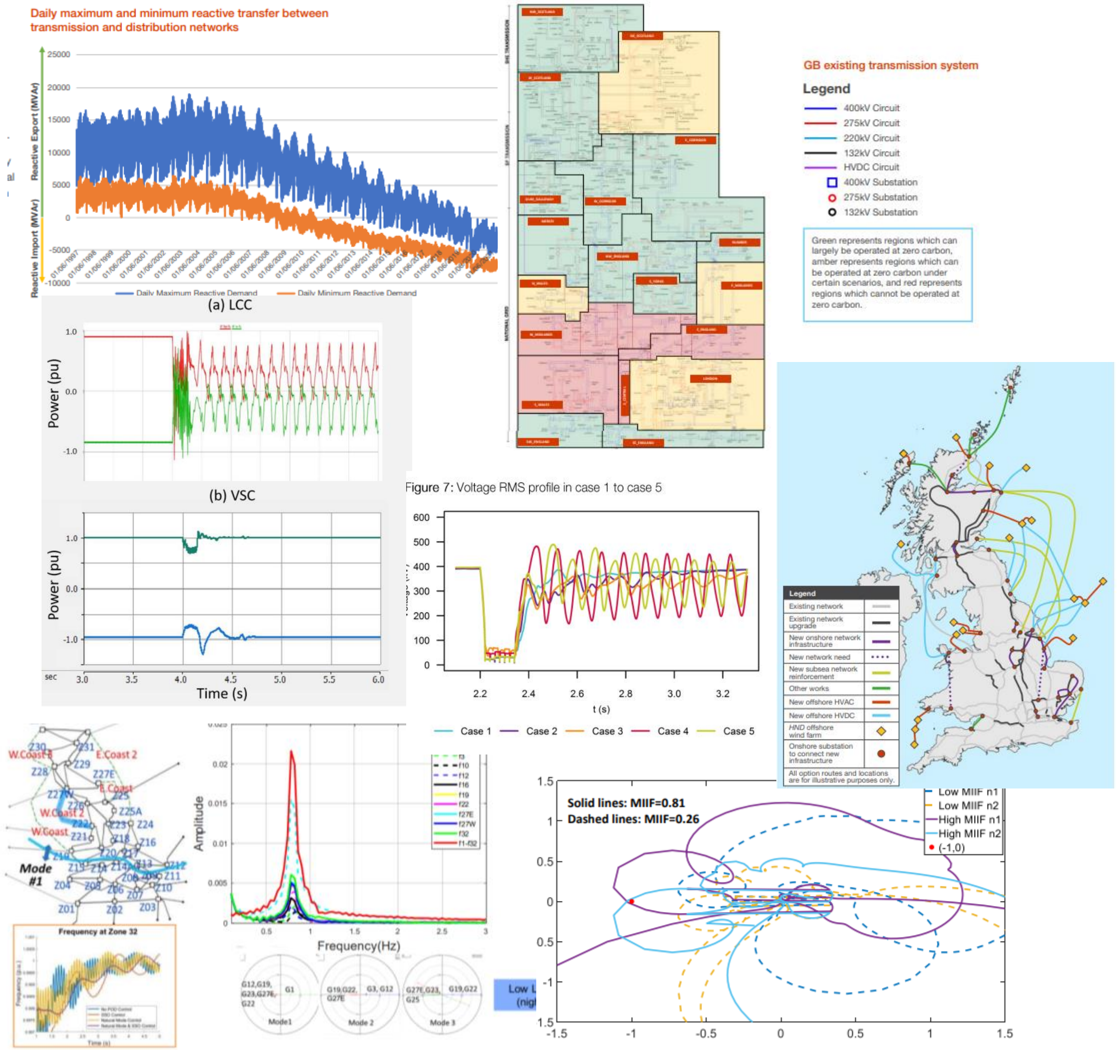
- Increasing periods of high voltage (lower damping, TOV sensitivity, higher voltage angle jumps)
- Converter related voltage stability considerations

5) Converter instability

- PLL tracking/ responses to classical instabilities
- Control hunting/ interaction risk
- Limited transient support
- Interoperability of devices

4) Resonance instability

- Converter related control interactions- small signal phenomena. More and new modes of oscillation.
- SSO, SSTI, SSR & Torque amplification considerations
- POD and other damping solutions

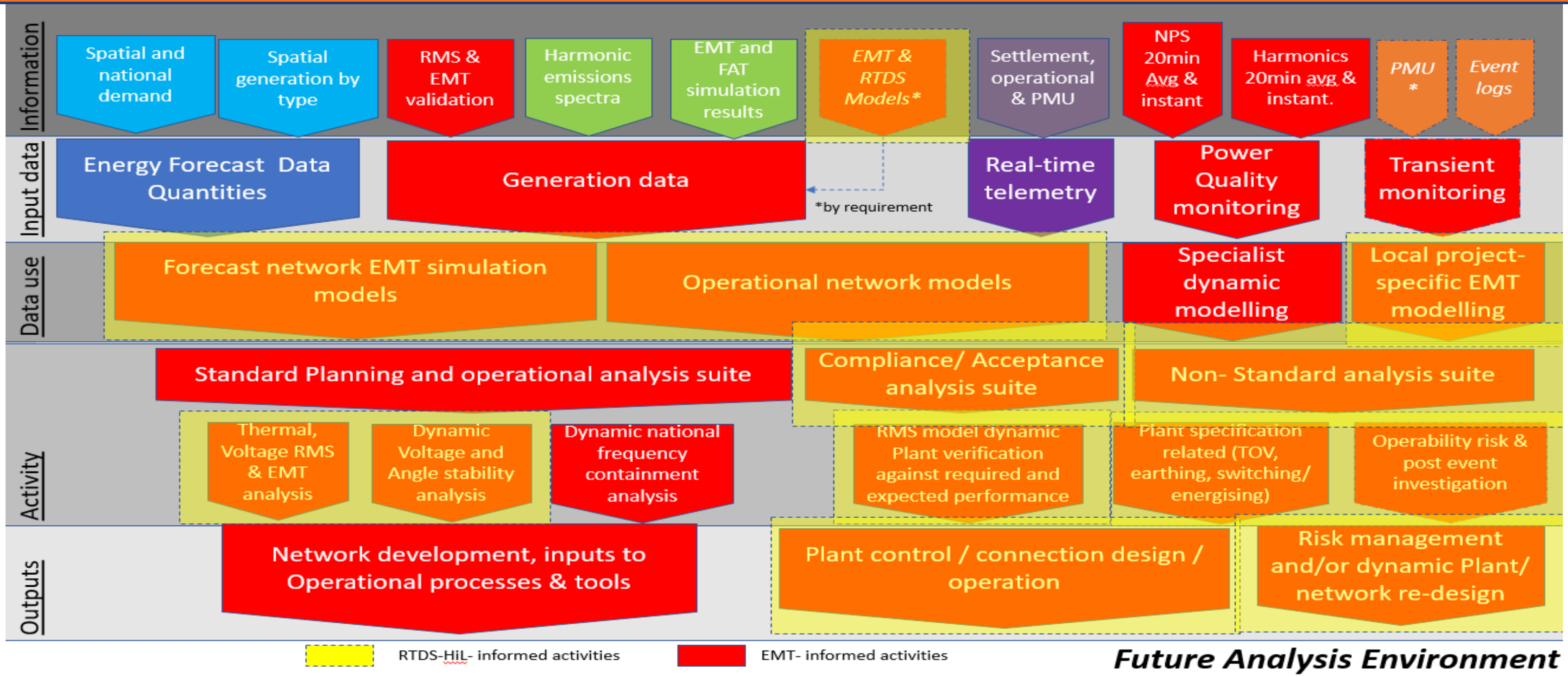


5) Conclusions

The National HVDC Centre

Our GB networks is changing, which marks ***a fundamental shift in analysis needs***-

1. **A Power system Converter (programmable logic) dominated system.** We need to **identify and specify converter control and withstand needs**, rather than inherently expecting capability to be present.***to deliver new and more efficient solutions/ services for stable Net Zero networks and avoid "cliff-edge performance risk"***.
2. **New Power system modelling required- focussing on how converters measure and respond to the system, and their vulnerabilities when doing so.** More offline and realtime EMT simulation integrating hardware affected ***to maintain security and efficiency of solutions & services***.
3. **Updating and verifying models and planning assumptions.** More detailed telemetry from the system (PMUs, new Alert systems)- these checked against models of the system and models/ hardware of devices ***to support secure operation and planning of the future network***.



Future Analysis Environment

Questions 11+12

Sli.do:

#StabilityM

Scottish & Southern Electricity Networks

Event of 24th July 2021

What happened?

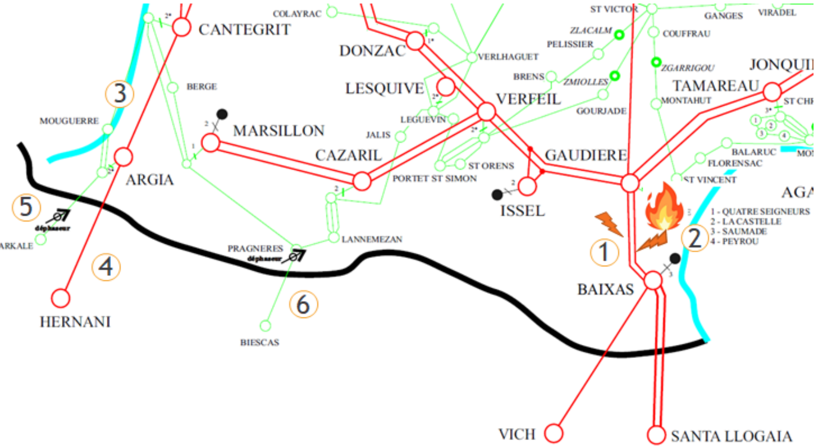
Iberian system Split

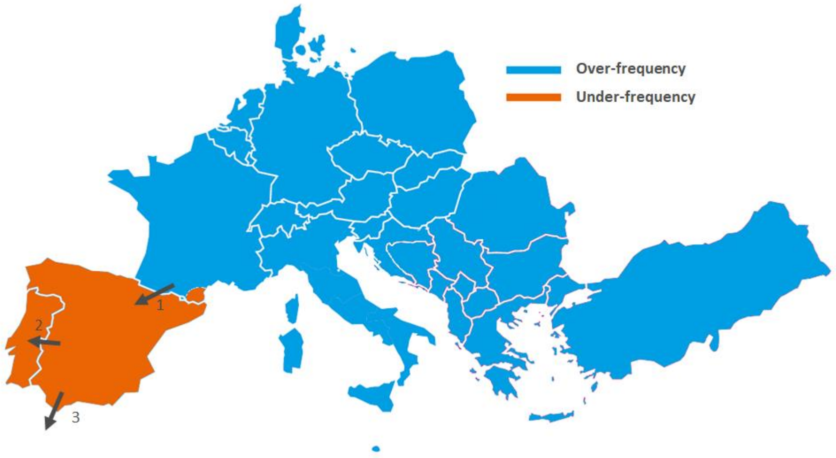
Iberian Peninsula, together with a part of French Pyrenees Orientale's, was separated from the rest of European grid.

France was exporting 2500 MW at the time of the separation, resulting into two areas.

13:00 : Fire starts in Moux area, near Gaudière (RTE not notified)

16:33.12 : Trip Baixas Gaudière 2 (400 kV)
16:35.24 : Trip Baixas Gaudière 1 (*lost of the 400 kV Mediterranean path*)
Overloads on lines Argia Cantegrit, Argia Hernani, Biescas Pragnères
16:36.37 : Trip Argia Cantegrit (*400 kV split, 220 kV interconnected*)
Voltage collapse + Power oscillation on the 220 kV border region
Frequency split
16:36:38 : Trip Biescas Pragnères (220 kV)
16:36:39 : Separation from Morocco (400 kV)
16:36:40 : Trip Argia Arkale (220 kV)
16:36:41 : Trip Argia Hernani (400 kV)

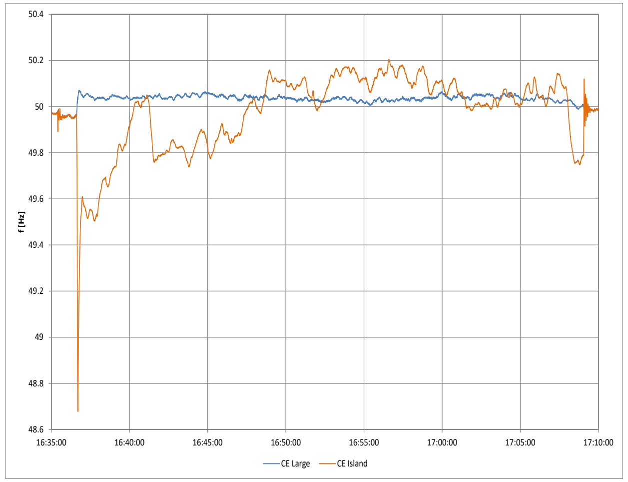


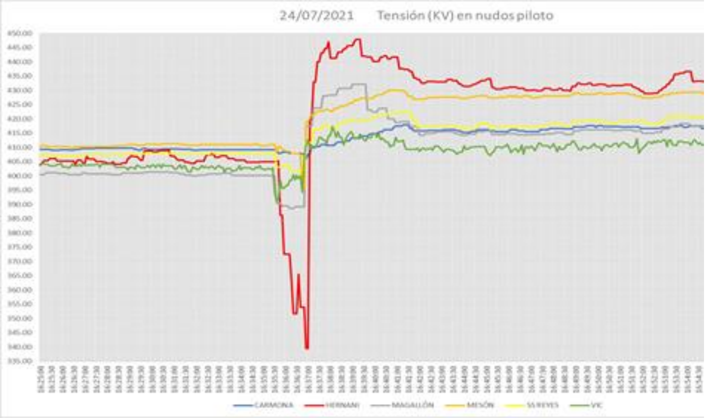


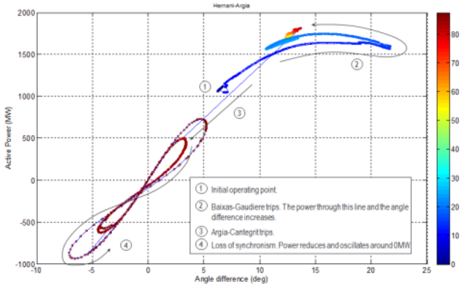
Event of 24th July 2021

Physical interpretation of phenomena

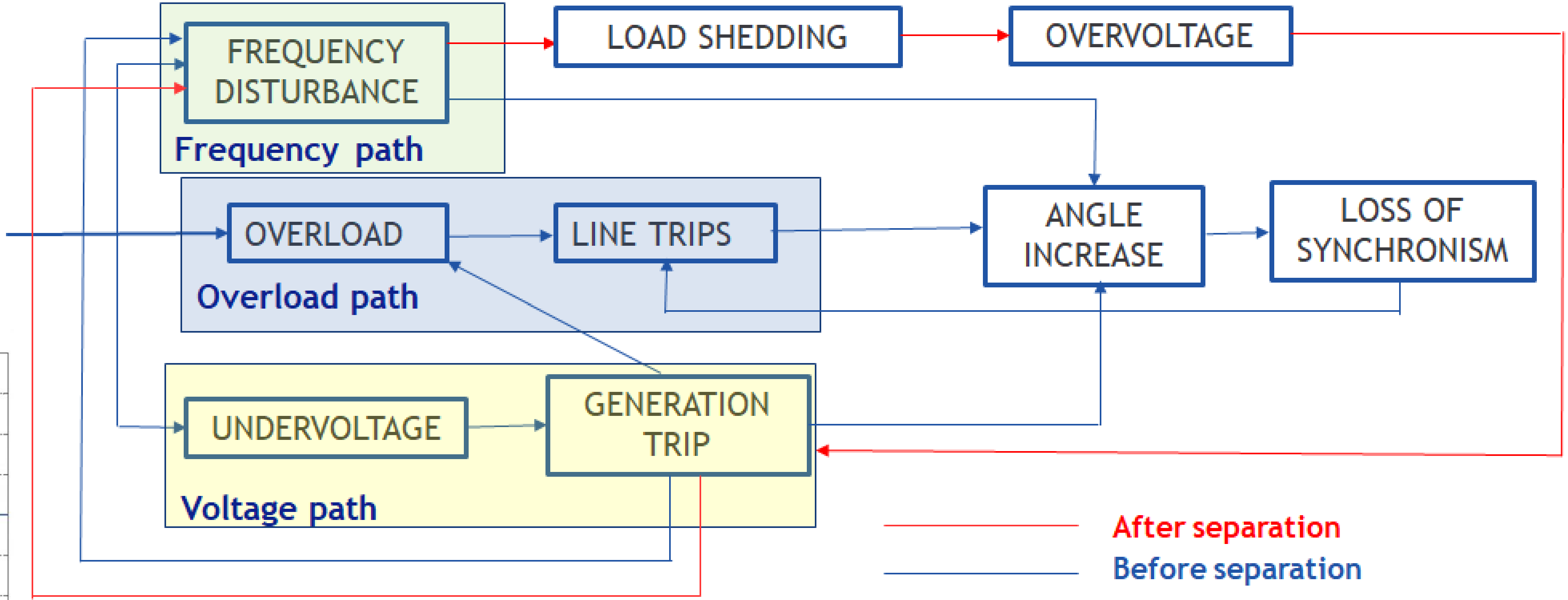
Complex combination of different phenomena

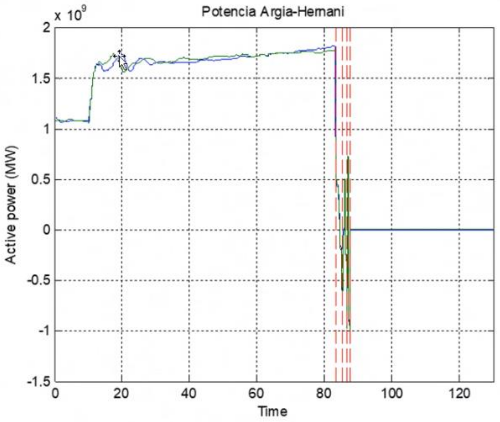






Trip of Baixas-Gaudière double circuit





Event of 24th July 2021

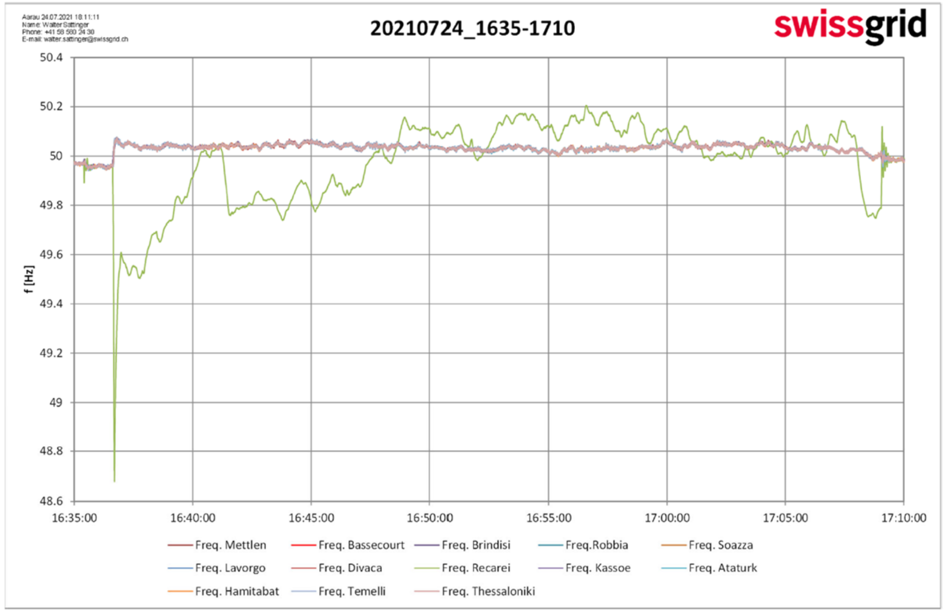
What saved the system?

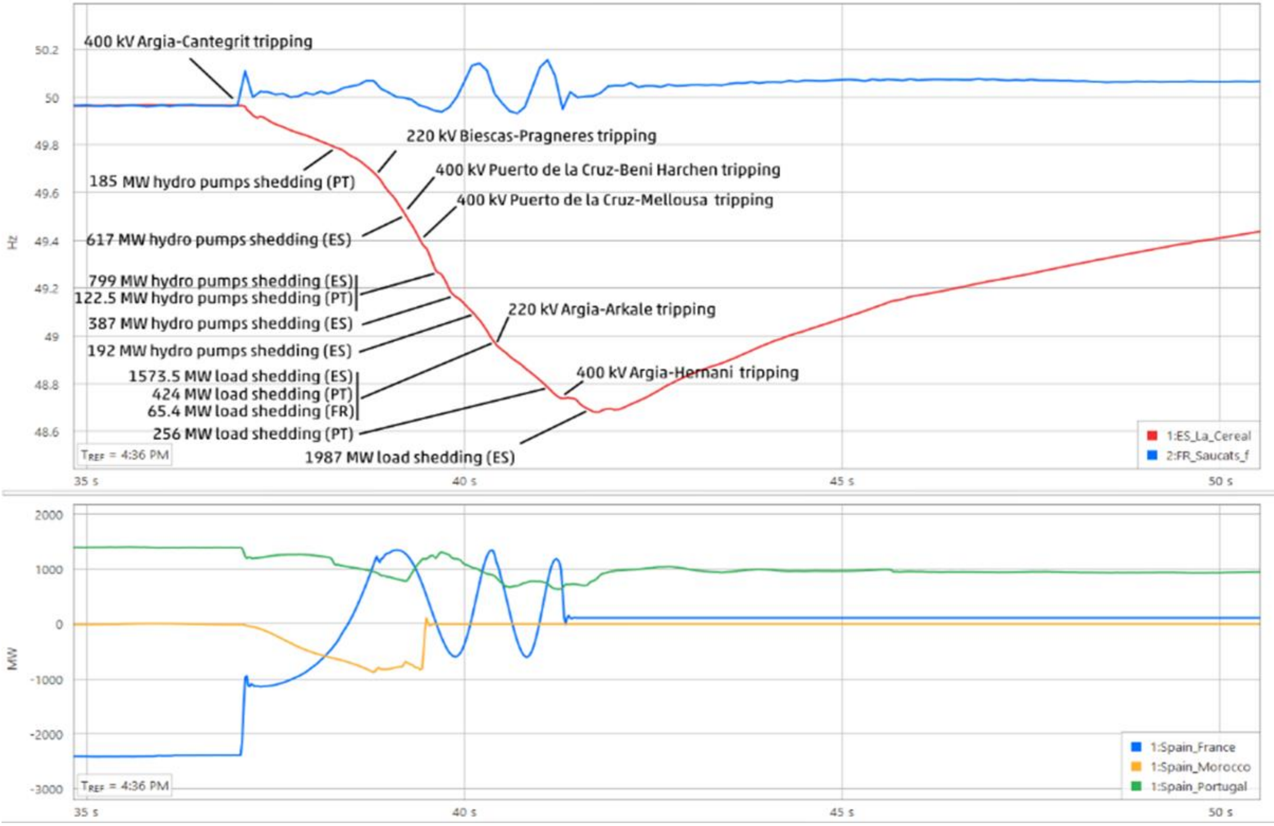
Iberian system Split

Frequency split after the lost of the 400 kV path in France activated the system defence plan:

- Trip of hydro pumps in Portugal and Spain
- Interruptible industrial load
- Load scheduling of domestic customers (2nd Step)

Before the physical separation of all interconnection in the French – Spanish border





Nadir was 48.67 Hz in 4.6 seconds

ENTSO-E Webinar
Stability management

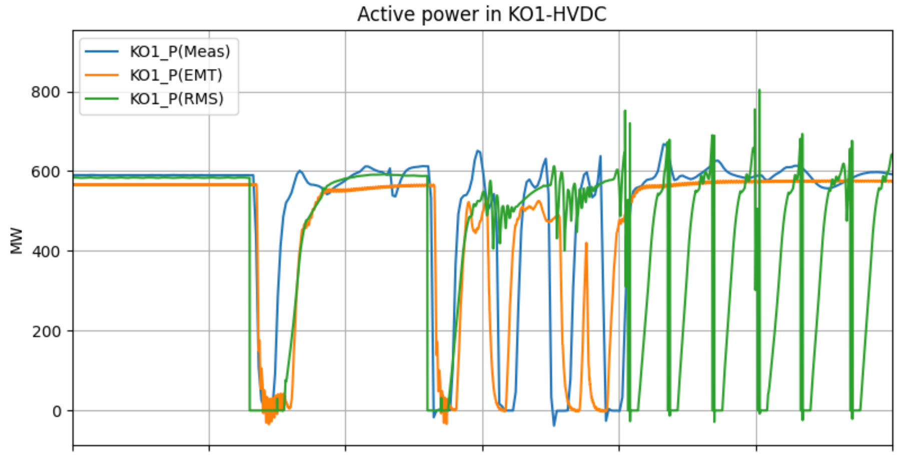
National example of stability related events and challenges – Energinet, Denmark

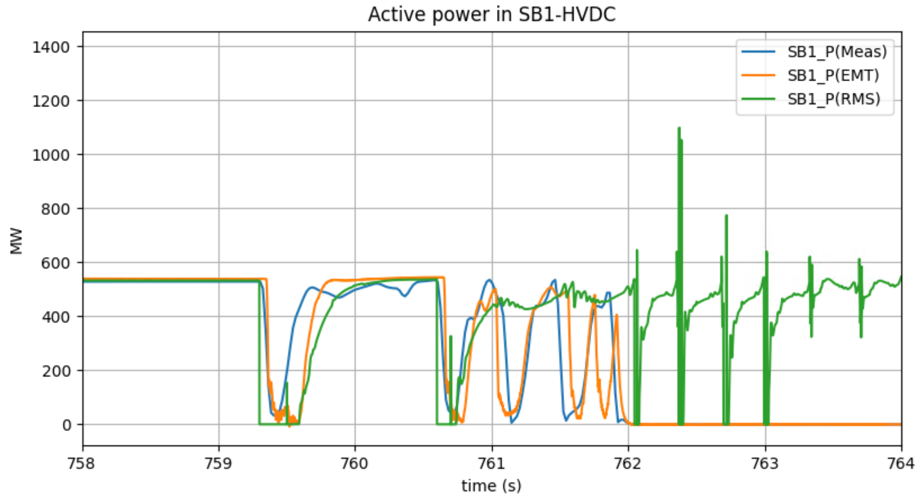
Jun Bum Kwon

System level simulation for stability analysis

Incident occurred at DK2 synchronized to Nordic country

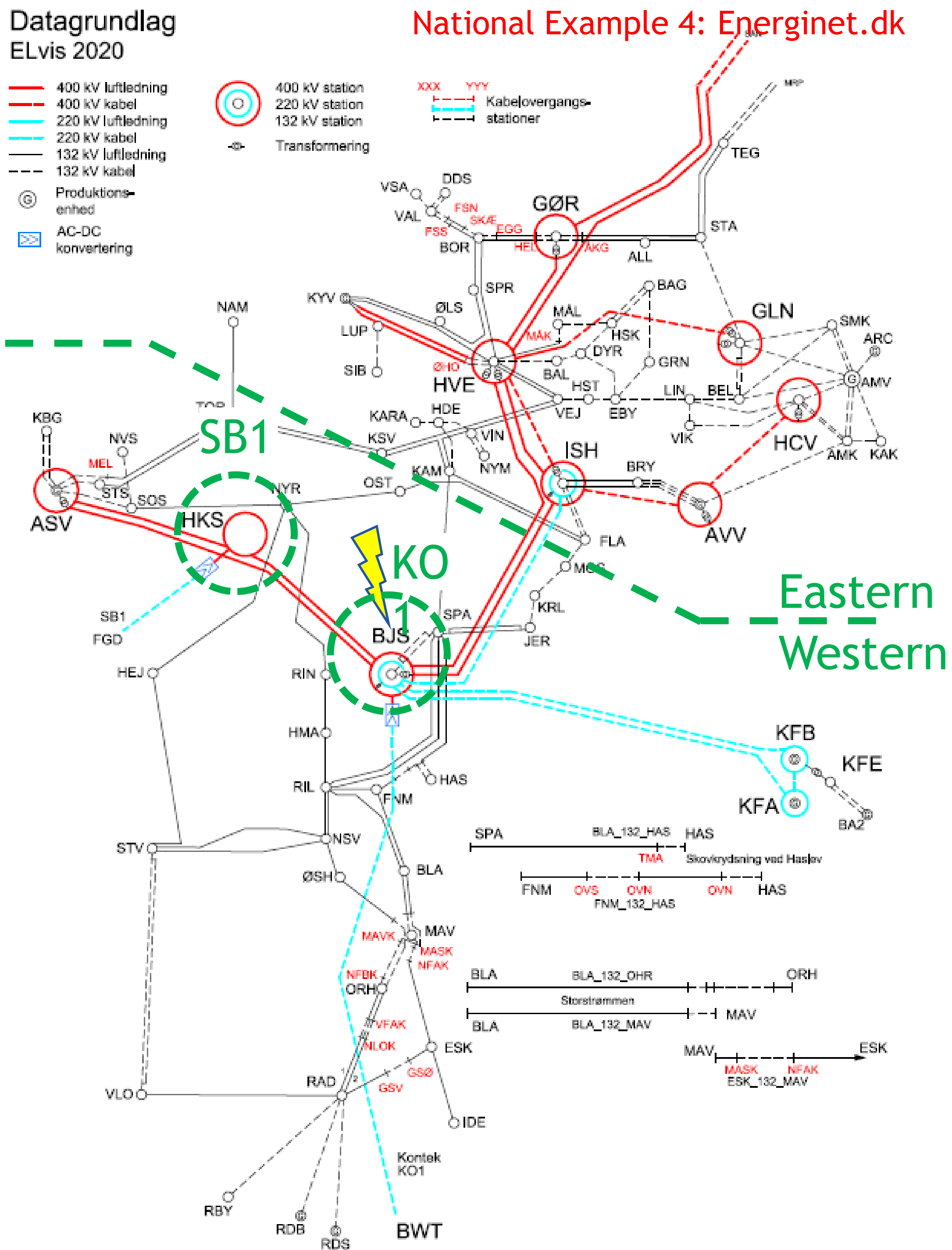
Comparison – Measurement vs RMS vs EMT





Note :
KO : KONTEK HVDC (LCC)
SB : Storbælt HVDC (LCC)

National Example 4: Energinet.dk



System level simulation for stability analysis

Incident occurred at DK2 synchronized to Nordic country

Key take away

- System level simulation is strongly required to analyze system level dynamics precisely.
- Correct representation of dynamics, protections, trips based on real code (e.g. EMT models, real time simulation, etc) is highly crucial to analyze sequential events, where classical SCR based evaluation of simulation models and studies do not provide deep insight of system level dynamics.
- In order to enable precise system level simulation, concrete grid connection process and model requirement are highly important for TSOs.
- To investigate further high frequency dynamics, osccilatory behaviour and system interaction in simulation, RMS based phasor domain model might not be enough to capture all dynamics, where new system level enviroment (e.g. EMT and RTDS, etc) is highly required.
- However, this doesnt mean that TSOs' always need to run heavy simulations, where correct evaluation of system needs and configuration of inverter based resources might be prerequisite prior to decisions to spend more resources.

STABILITY CONSIDERATIONS FOR ALEGRO HVDC-PROJECT

EXPERTS:

DR. TOBIAS HENNIG
KLAUS VENNEMANN

PRESENTER:

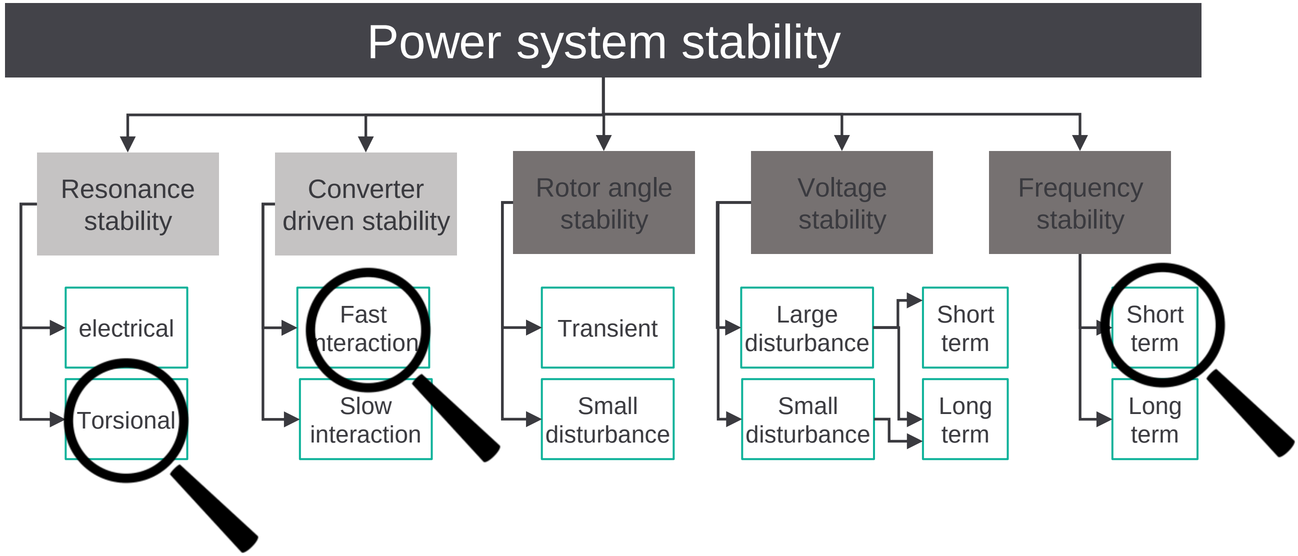
DR. BARTOSZ RUSEK

18.11.2022

amprion verbindet

Stability Considerations for a 320 kV HVDC

1 GW, 320 kV, 90 km cable



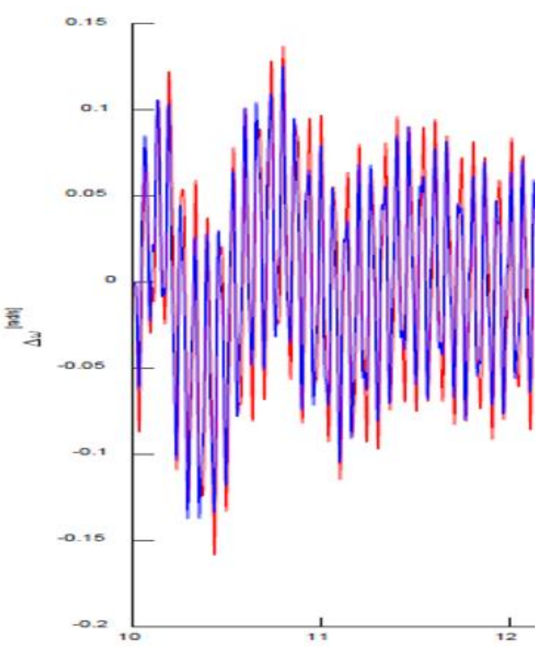
Analysis in different project phases necessary

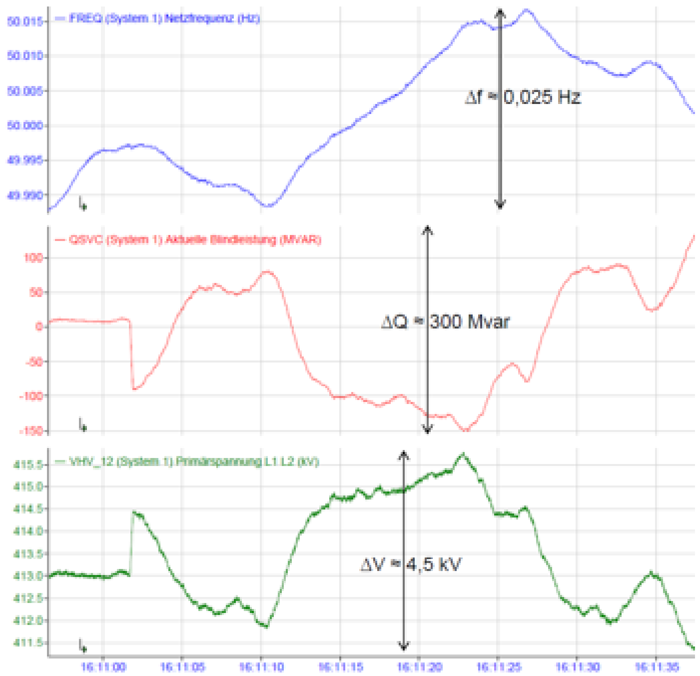
- Development (basic design, concepts of manufacturers)
- Commissioning (specification, tender process, network and system studies, type test, commissioning tests)
- Service (set points, updates, model verification)

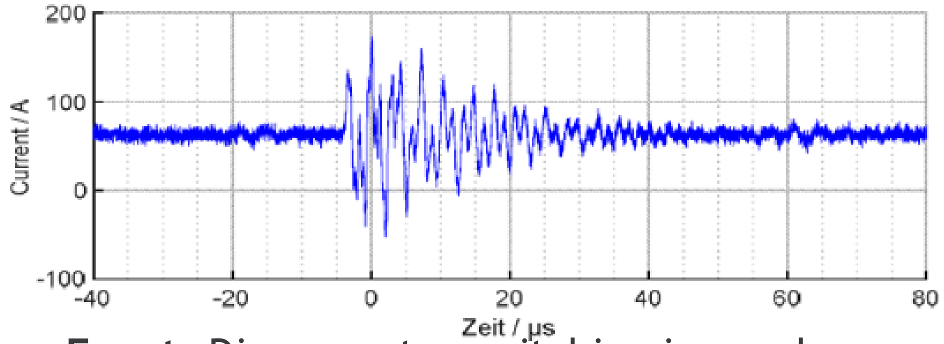
Stability Considerations Need to be More Extensive for Power Electronic Components

amprion

Resonance stability	Frequency stability	Converter driven stability







Positive: ALEGrO improves damping of torrosial oscillations

Challenge: Power Oscillation Damping acts in low frequency range already at low frequency change with high Q-injection

Solution: additional filter of transfer function necessary

Event: Disconnector switching in nearby substation caused high frequency wave. The converter blocs.

Solution: new low pass filter necessary

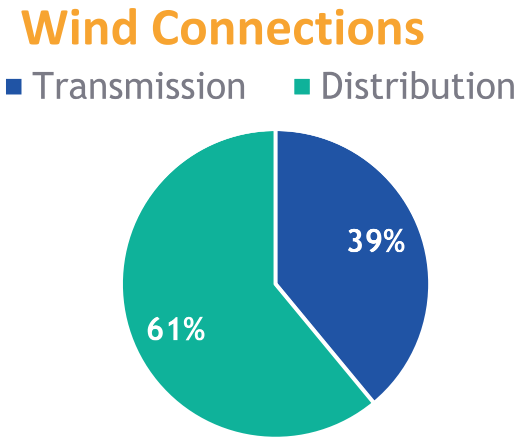
Low Carbon Inertia Solutions Procurement

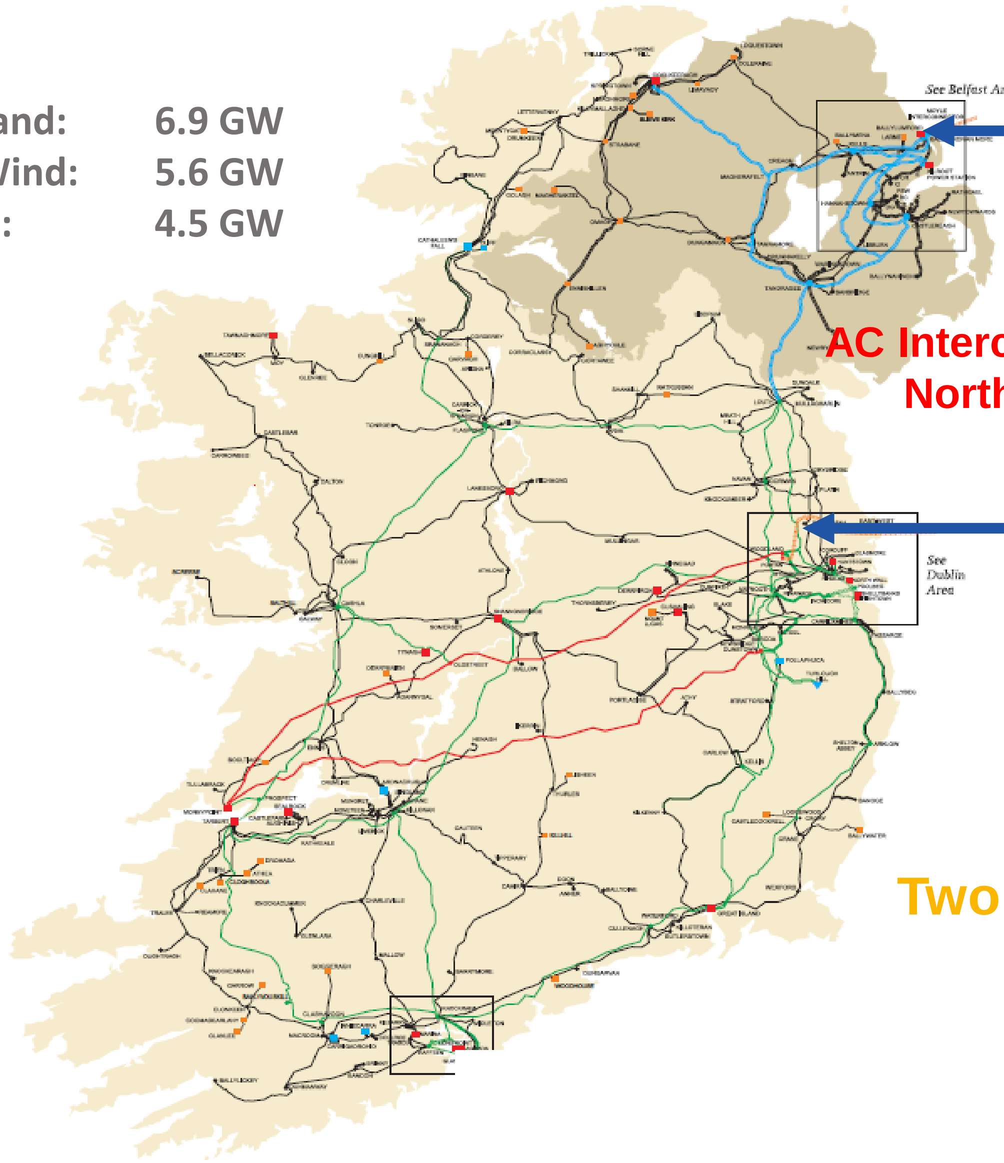
Technical Assessments

Dr Mostafa Bakhtvar
Senior Lead Engineer

mostafa.bakhtvar@eirgrid.com

Peak Demand:	6.9 GW
Installed Wind:	5.6 GW
Peak Wind:	4.5 GW





+/- 500 MW HVDC (LCC) to GB

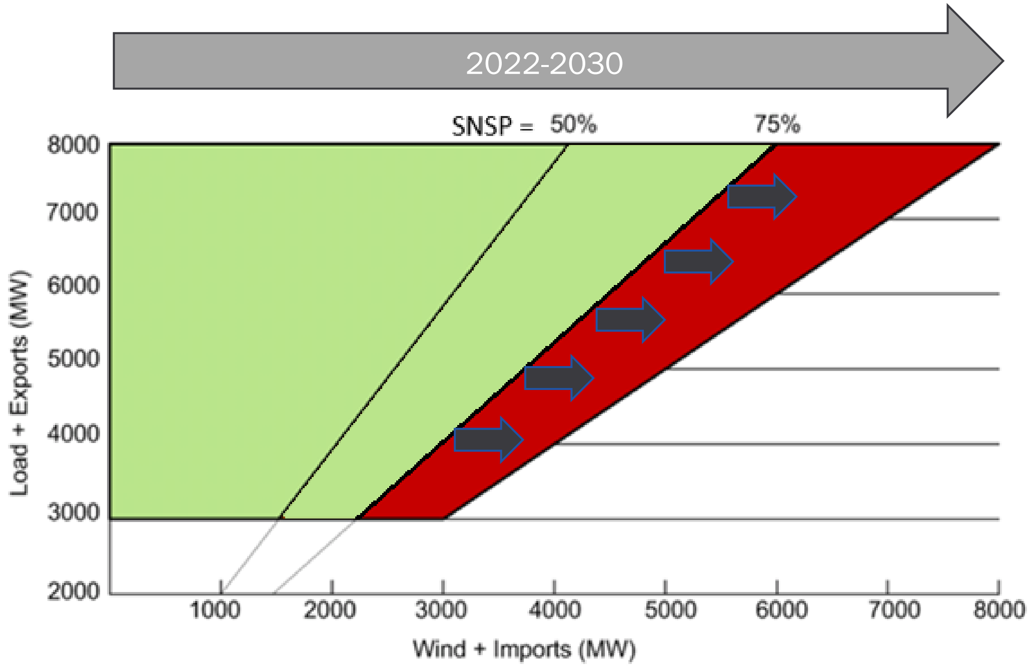
AC Interconnection: North-South

+/- 500 MW HVDC (VSC) to GB

Two Control Centres

EIRGRID SONI

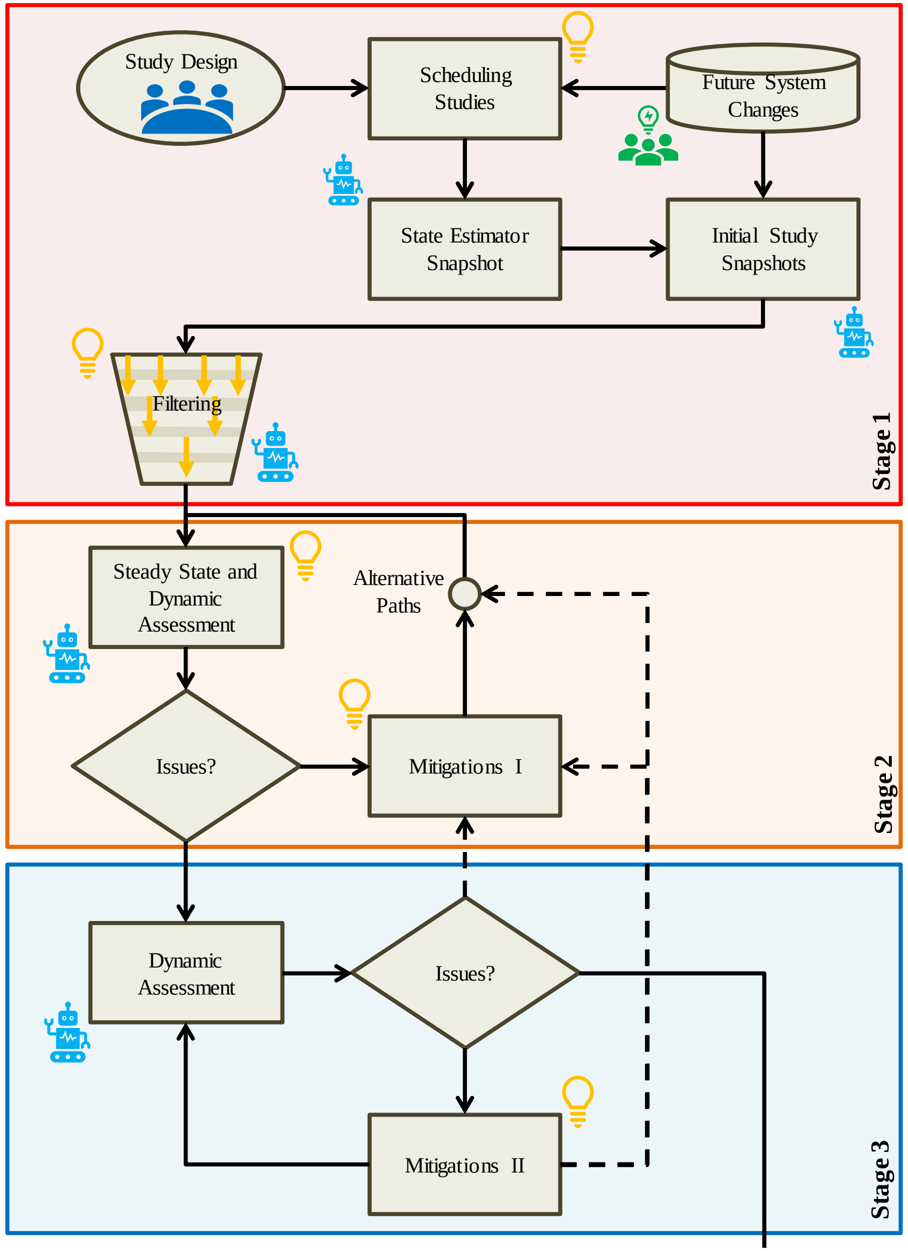
2026 Assumptions vs. Today



$$\text{SNSP} = \frac{\text{Wind + Solar + Imports}}{\text{Demand + Exports}}$$

1. Less conventional units – from eight to five
2. Significant BESS volumes
3. Two new interconnectors
4. Second N-S interconnector

EIRGRID SONI



Frequency – Dynamic Studies

New risks and factors to consider

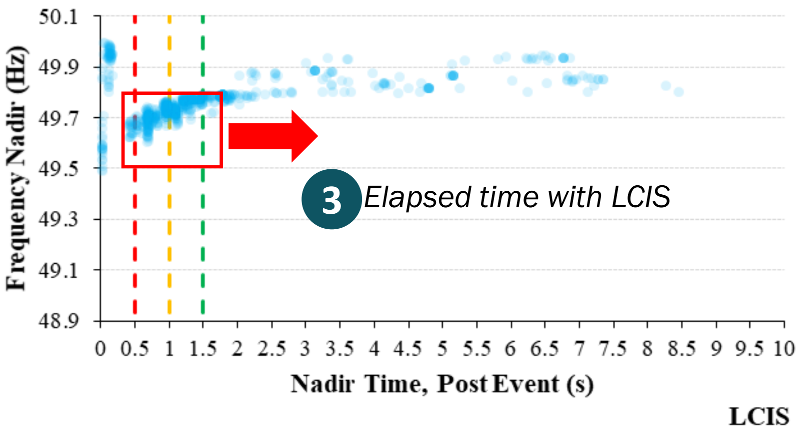
- There is a **risk for Inverter Based Resources (IBRs)** operating in areas with low system strength **to trip** through their protection when exposed to frequency and voltage excursions.
- **RoCoF might become rather a local phenomenon by 2026** - our studies demonstrate that there might be significant differences in terms of RoCoF across the system. We still calculate RoCoF as per our Grid Code (500ms rolling window).
- Looking into future entails **considering uncertain factors**. This requires imposing higher security/stability margins. We also considered sensitivity around disconnection of IBRs.

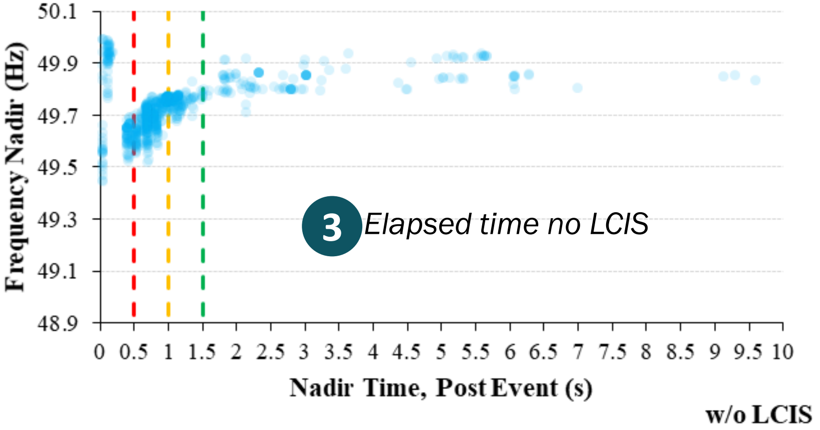
EIRGRID SONI

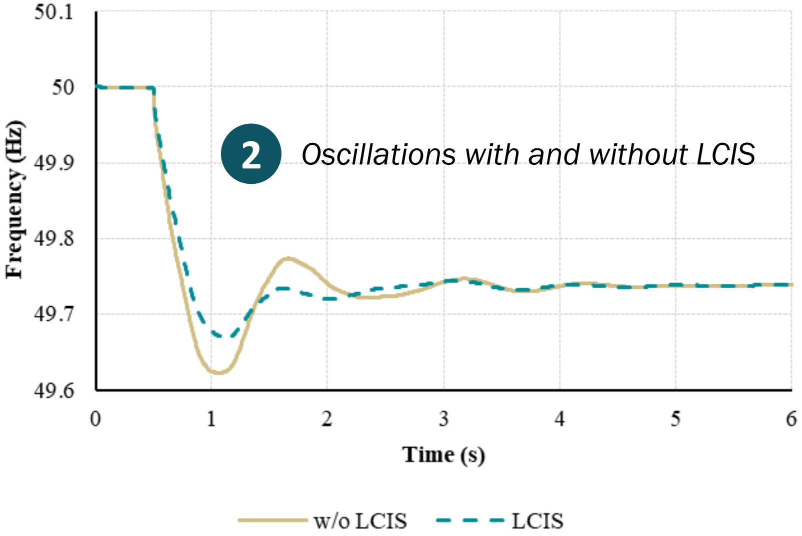
Frequency and ROCOF Observations

1. There is no frequency security concerns (f<49 Hz or f>51 Hz) however there are ROCOF concerns (ROCOF>0.8 Hz/s or ROCOF<-0.8 Hz/s *)
2. Oscillations are likely through frequency recovery period.
3. Elapsed time between incident (fault and/or loss) and frequency nadir/zenith is expected to be significantly shorter.
4. Low inertial response with a significant FFR and POR provided by IBRs (>90% by batteries and interconnectors).

* Grid code threshold is 0.5 Hz/s, we are currently trialing 1 Hz/s







EIRGRID SONI

Reaction from EC DG Energy

TIME: 5 mins

George PAUNESCU

Policy Officer, European Commission

Closing remarks

TIME: 5 mins

Norela CONSTANTINESCU

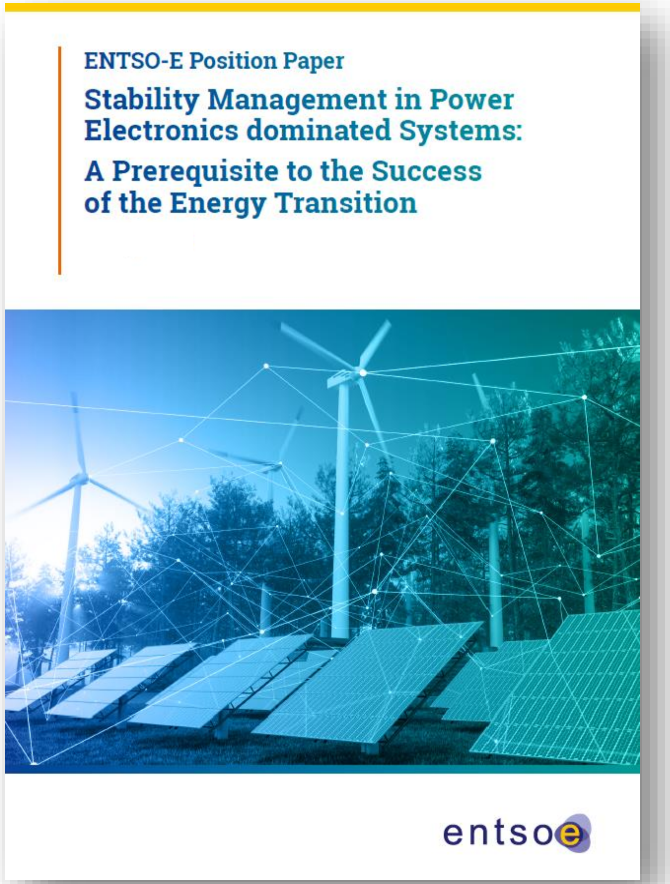
Head of Innovation Section, ENTSO-E

Stability Management in Power Electronic Dominated Systems, High-Level communication paper

Main messages

To keep up with the pace of the energy transition we need:

- new and consistent methods for analysis, especially for new stability phenomena and processes for data exchange
- a fast and harmonised process for further development of network codes.
- new technical capabilities and system services, as well as the definition of new resilience requirements.



Significant RD&I efforts and stakeholder collaborations are needed to accelerate the uptake of new solutions for stability management.


Accelerated Energy transformation
Cooperation & Innovation & Sustainability

Thank you for your participation!

Sli.do Poll results and other statistics from the webinar

Webinar attendees and activities

Total number of attendants:

Registered: 412

Attending: 300-350

Thereof active Sli.do users:

Active users
207

Engagement score	1291
Engagement per user	6.2

Poll results

This is the number of people answering the question:

1. Whom do you represent/work for? 148

Answer	Share
Transmission System Operator	57 %
Distribution System Operator	3 %
Policy maker	1 %
RD&I Institution, University	10 %
Generator	3 %
Manufacturer, technology provider/vendor	19 %
Electricity User	0 %
Electricity Market Operator/Ancillary Service Market Operator	1 %
Consulting	3 %
Other	3 %

2. My role is: 168

Answer	Share
Technical	86 %
Legal	0 %
Project management	3 %
Leadership, management	4 %
Sales and market	0 %
Other	7 %

Poll results

3. Challenges that I or my organization needs to solve in terms of stability management in the PE dominated grid:

132

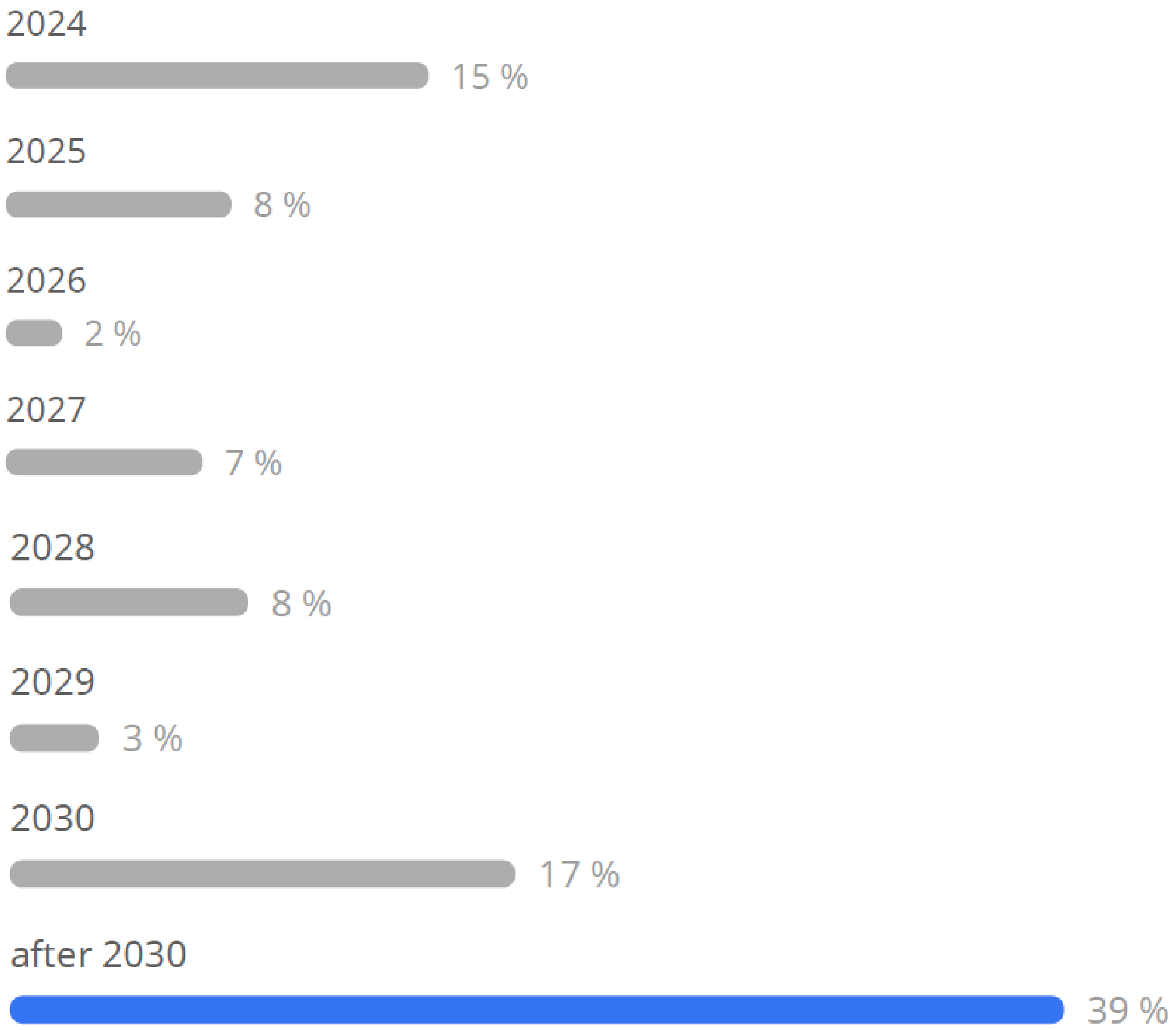
lack of harmonized requirement
ensure system stability
Rate of Change of Frequency
phase shift
Understanding value
standartization
Grid Forming Control
Standarization
Grid forming
reclosing
FRT
Interaction
Security of supply
User Model
Knowledge
Inertia
Modeling
Validation
Lack of inertia
stability for IBR
Modelling
voltage stability
ressources
grid forming HVDC support
Models
interoperability HVDC
Grid-Forming Converters
Technical standards
Frequency
Grid connection
system strength
stable power control
multiterminal
huge demand facilities
unintentional islanding
stability aware opf

Poll results

4. In relation to the pace of the energy transition, when in time do you expect to reach the 65% momentary share of PE connected infeed where stability is no longer guaranteed?

Answer for the part of the electric power system that you are familiar with.

109



entsoe

Poll results

6. What technical capabilities and solutions are you planning to further deploy/investigate/develop/study in your organization to manage stability?

077

Voltage control by wind genera
RoCoF Withstand Capabilty
large scale simulation
system control coordination
Synchronous Condenser
Monitoring
PID controllers
grid forming control
Simulation
WAMS
Simulation Model
Grid Forming Inverter
virtual inertia
PSS
Inertia
Impedance
Rotoranglestability
better tools
Sync comps
grid forming
Synch comps
Testing for GFC
GFM
Vsg
GridForming
Inertia by Ucaps
WAMS automatic
converter stability
synchronous condensers
grid-forming inverter
synchronous compensation
BESS
VISMA
Synchronising power transmissi
include stability more in plan
Grid indicators

Poll results

5. Which research directions do you think are the most important to tackle system stabil challenges?

126

Create new technical solutions
31 %

Create regulations on a pan-European level
12 %

Create pan-European market solutions for system services
7 %

All of the above
50 %

7. Who needs to collaborate to achieve a successful green transition?

104

TSO-TSO
7 %

TSO-DSO
3 %

TSO-DSO-Consumer
10 %

The whole ecosystem
81 %

Poll results

8. What risks does your organization face with regards to stability management challenges?

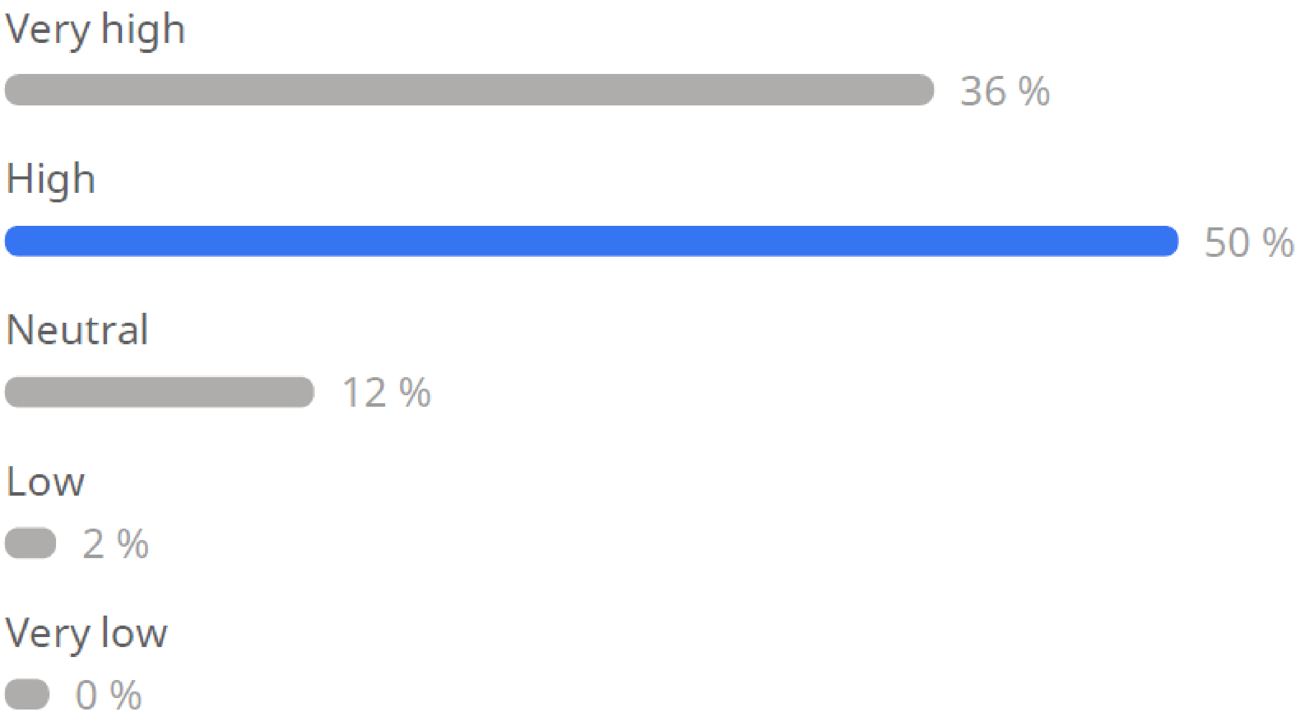
0 6 5

Power quality issues
Unexpected effects
Rotoranglestability
lack of system strength
Minimum stable generation
converter interactions
mismatch planing x operation
blackout
Validation
lack of time
lack of inertia
Resources
Unreadiness of Tools
lack of tools
bad regulation
lack of reserves
ressources
local grid strength
Inertia
islanding
stability managment
Reactive Power
common grid codes
Economic
speed of the transition
interarea oscillations
knowhow
Blackbox
modelling and verification
System Split
Root cause of instability
Lack of accurate models
Value
changing system conditions
Oszillation
Uncertain policy scenarios

Poll results

9. According to your perception, what is the risk of the system due to a system split event in the context of a decreasing level of inertia?

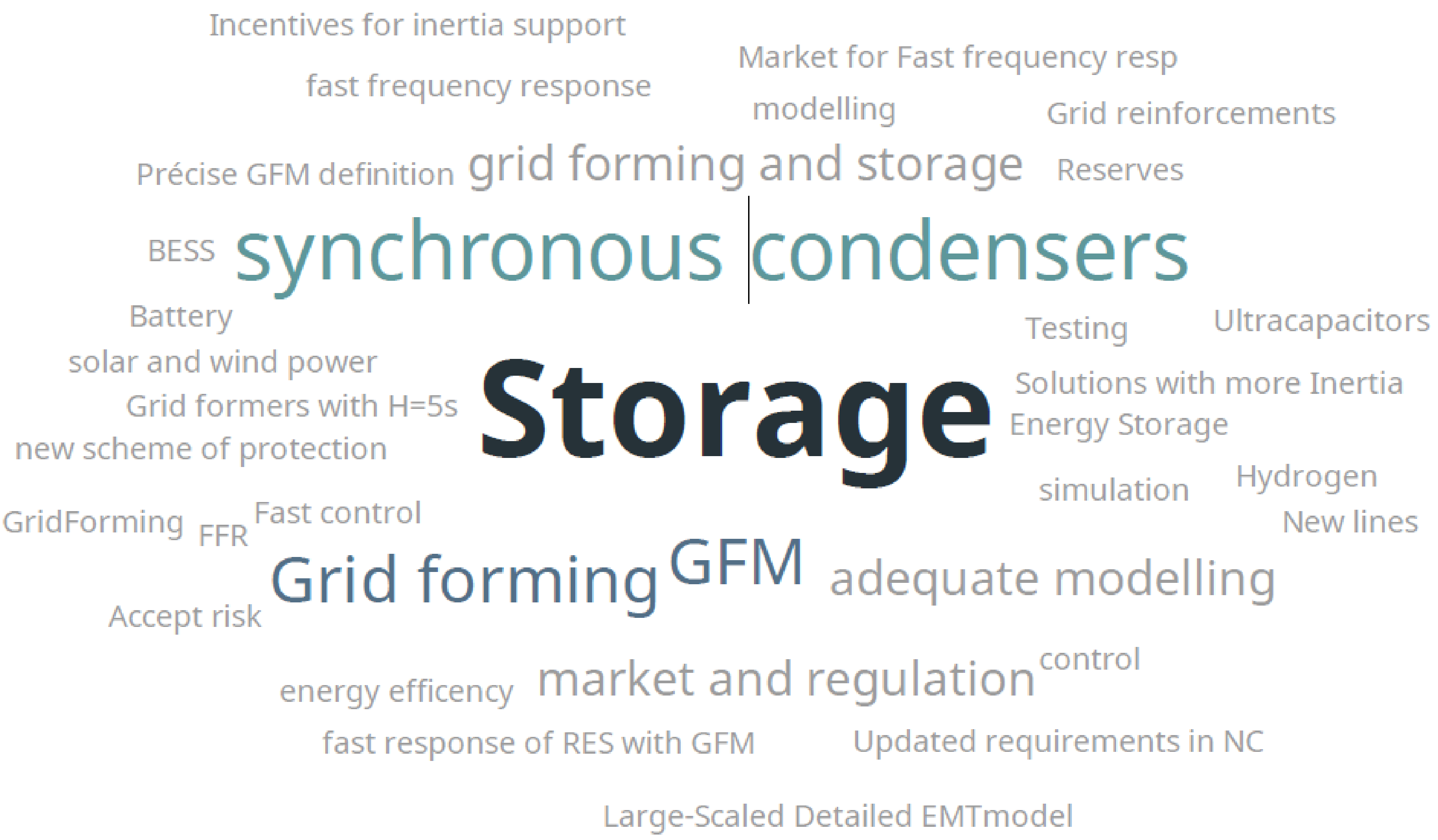
0 9 2



Poll results

10. Which solutions do you consider the most necessary/urgent to deploy?

073



Poll results

11. Which of the topics discussed as emergent in GB do you believe are most important to address across ENTSO-E areas in the next 5-10 years?

0 2 8