Research Agenda for Transformed Power Systems

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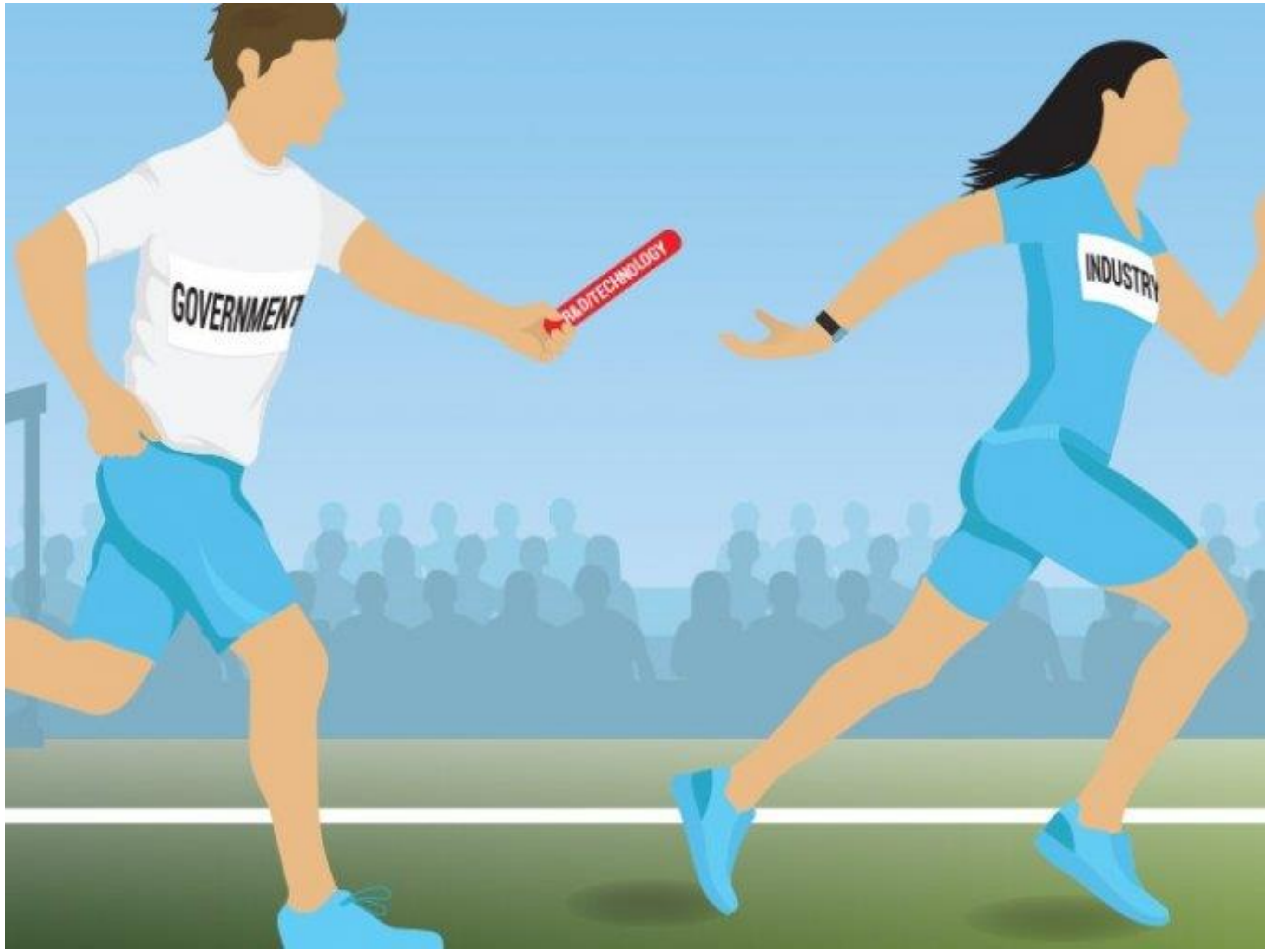
Co-Chairs of G-PST Research Agenda Group

30th November 2021

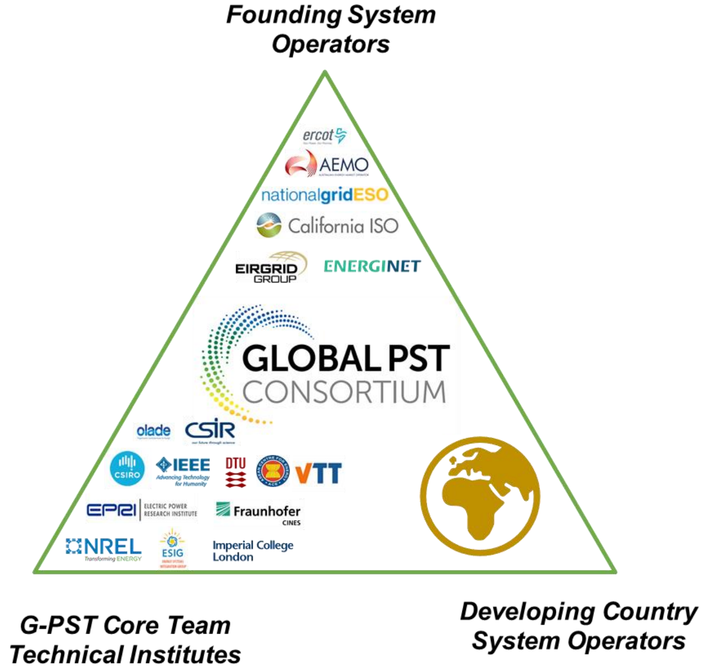
We are teeing it up as we want you to get engaged

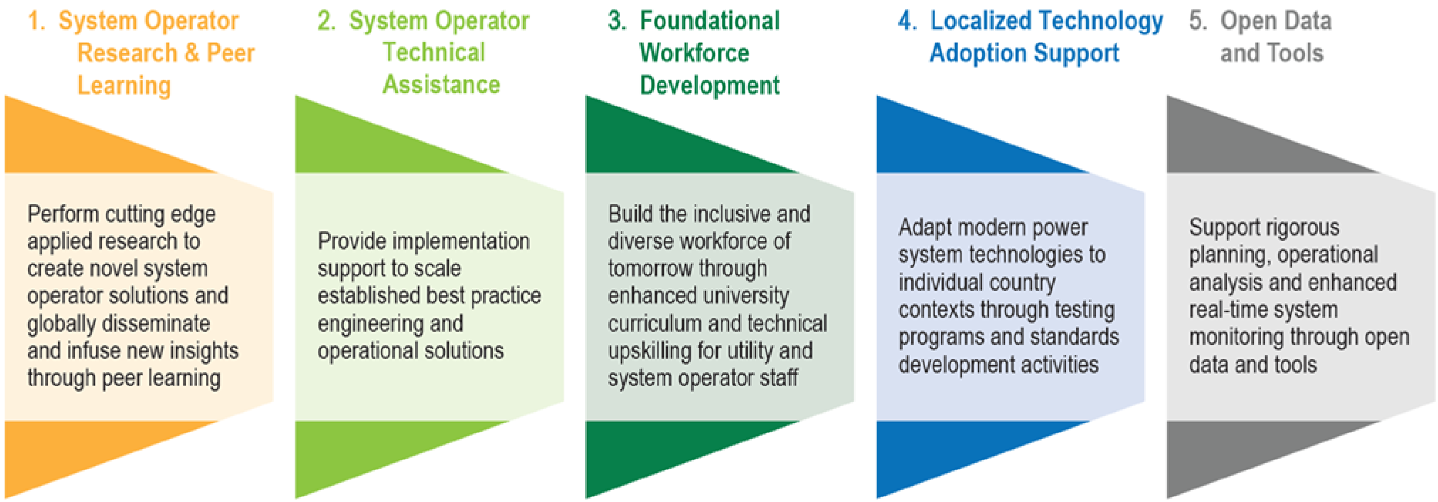
Outline

- What is G-PST
- Pillar 1 & the Research Agenda
- A few “shallow dives”
- What we have achieved so far
- Why you should get involved
- How you can get involved



G-PST – a global response to an urgent need






GLOBAL PST CONSORTIUM

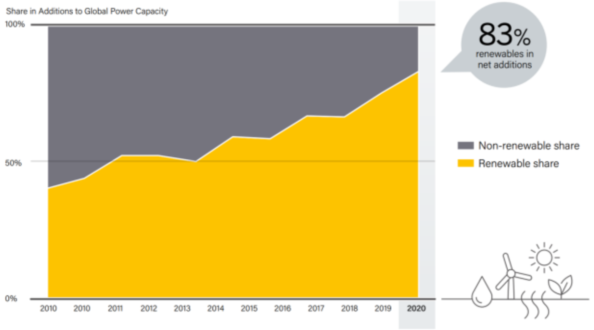
Inaugural Research Agenda

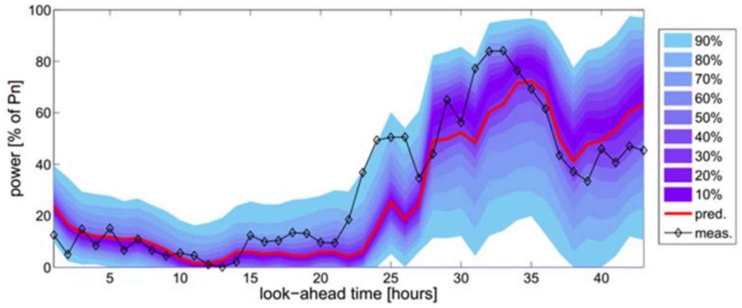
March 2021

https://globalpst.org/

https://globalpst.org/wp-content/uploads/042921G-PST-Research-Agenda-Master-Document-FINAL_updated.pdf

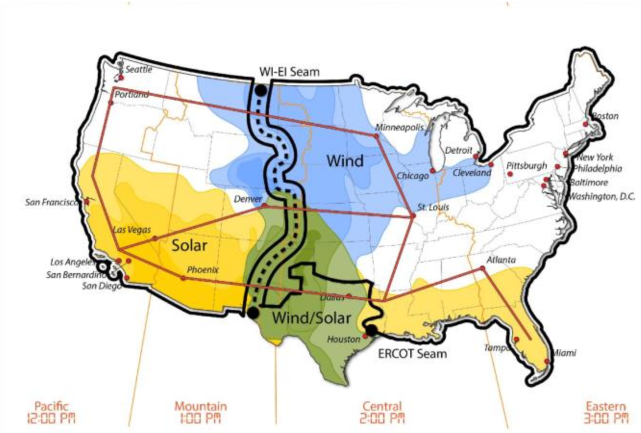
Characteristics of variable renewable energy resources



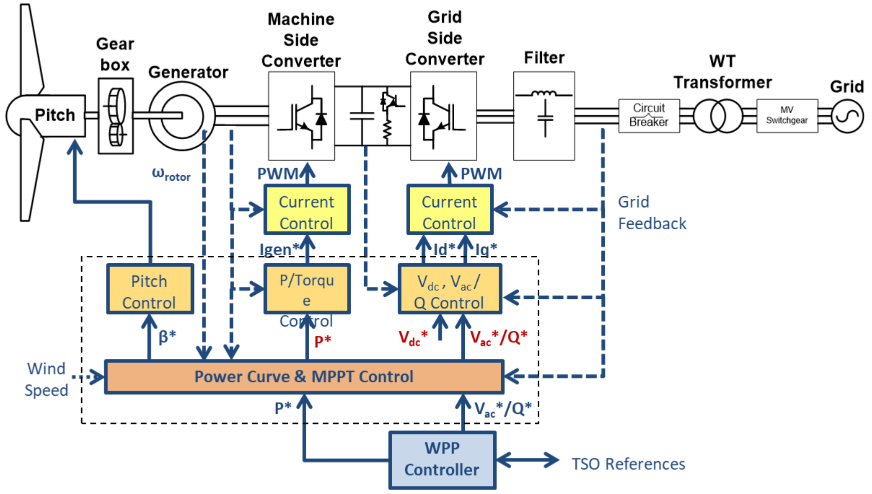


Pinson, P., Madsen, H, Nielsen, H., Papaefthymiou, G. and Klöckl, B., From probabilistic forecasts to statistical scenarios of short-term wind power production, Wind Energy, volume 12, issue 1, January 2009

- Growing rapidly
- Spatially disperse
- Variable and somewhat difficult to predict
- Inverter Based Resources (IBR)
- Thermal, voltage, frequency, instability etc.



NARIS, National Renewable Energy Laboratory



Nicolaos Cutululis – Technical University of Denmark

Inaugural Research Agenda

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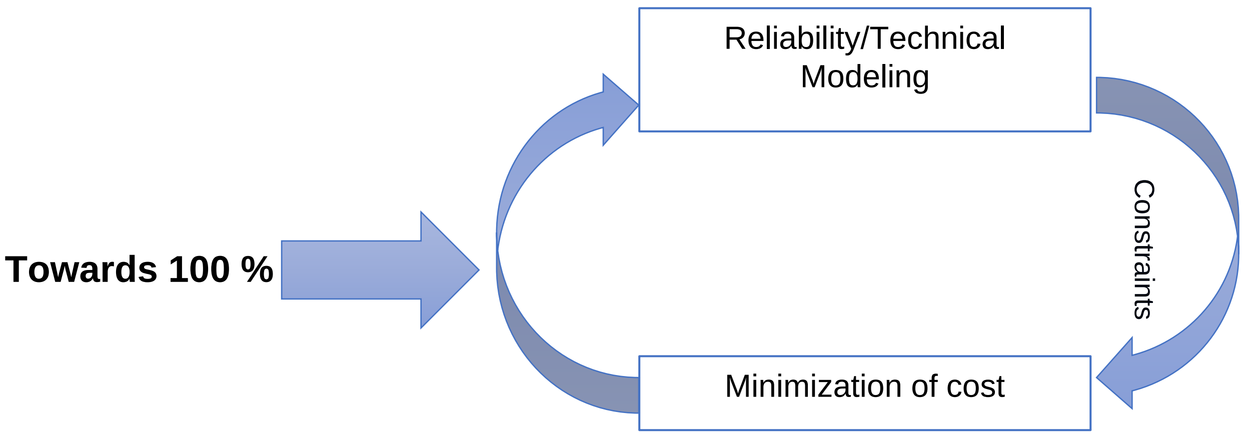
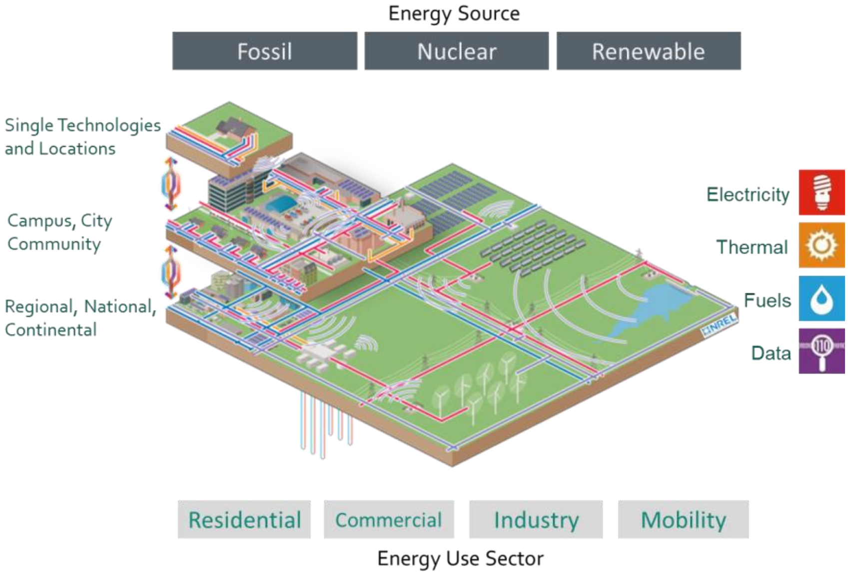
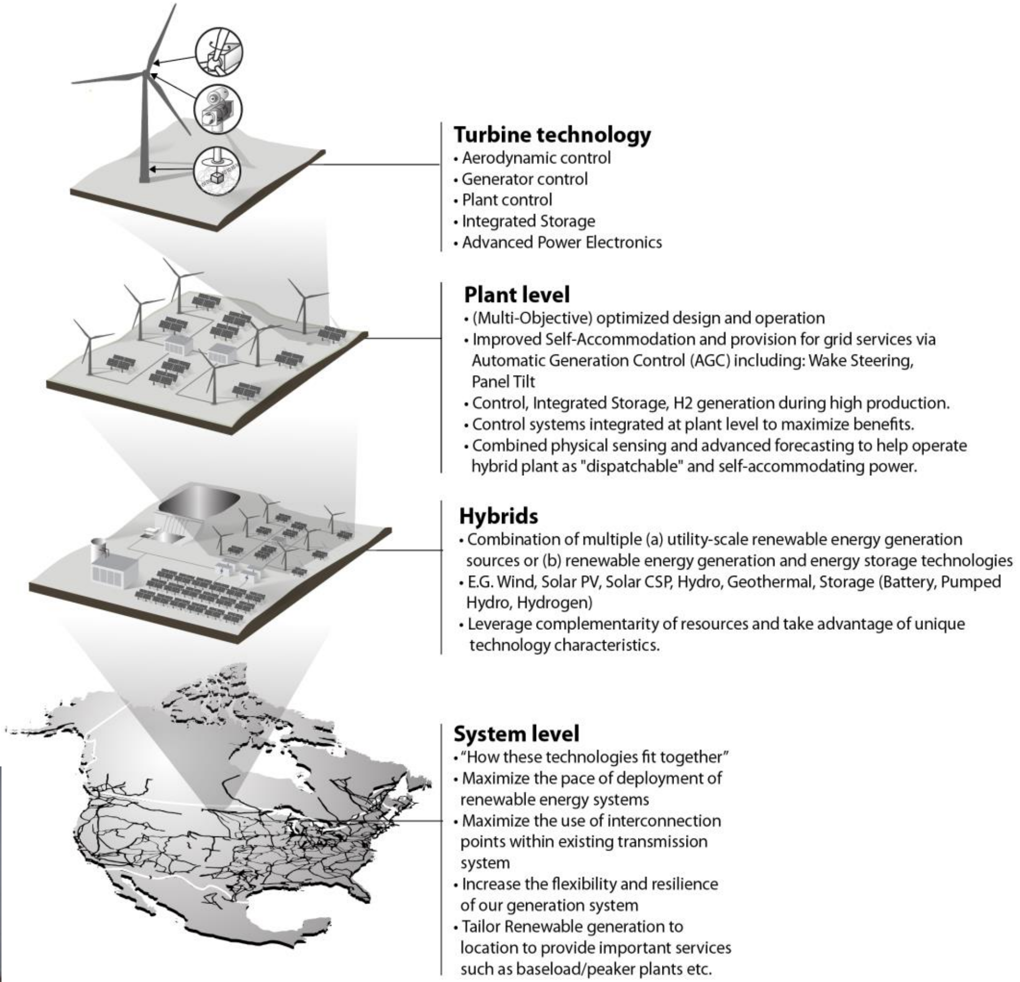
Cost effective reliability of the grid an integrated problem

Cost reliability trade off



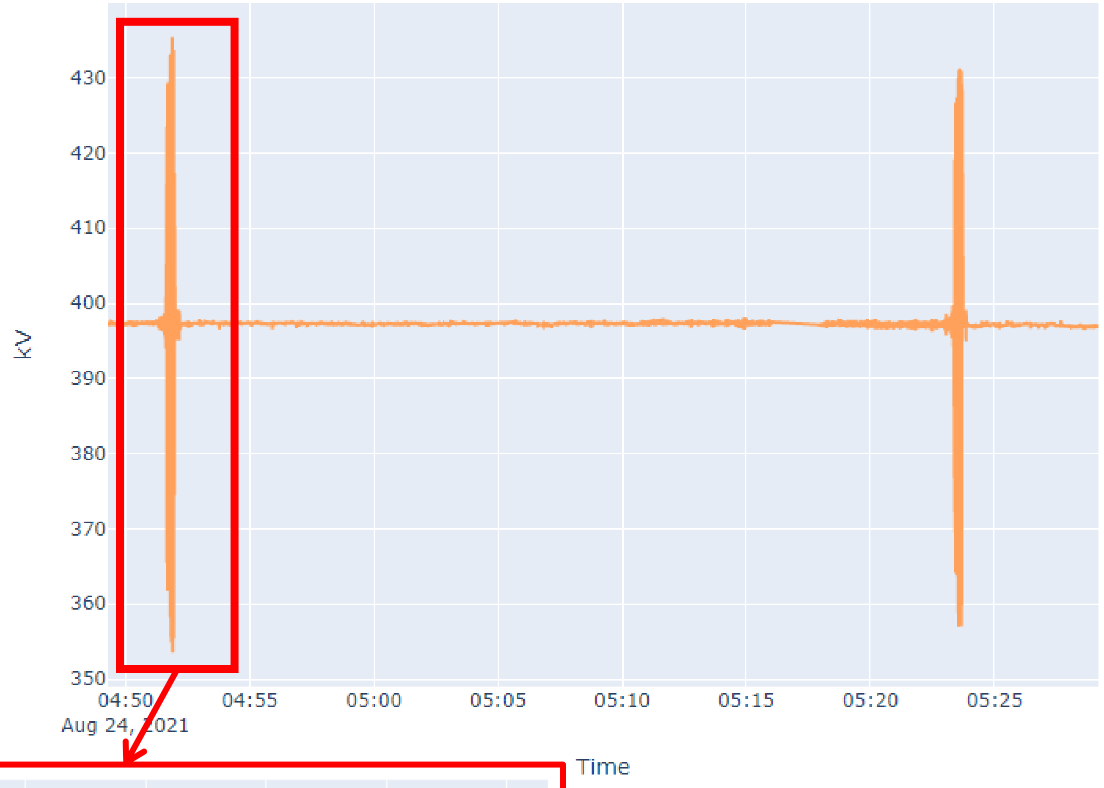


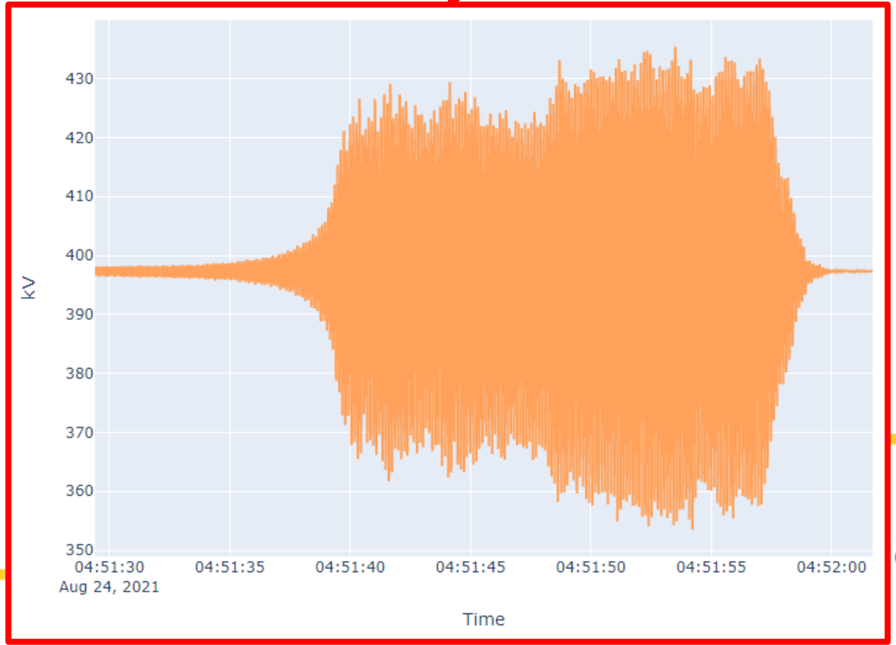


Voltage Oscillations in Scotland in 2021

Background

- On 24/08/2021 severe voltage disturbances were observed on the SSEN-T and SPEN transmission systems.
- Major disturbance lasted 20-25 seconds on two occasions, approx. 30 minutes apart
- Investigation of available data suggests:
    - The oscillations with the largest magnitude were in the north of Scotland
    - The oscillations had a frequency of ≈8 Hz
- Some Users tripped off during the disturbances





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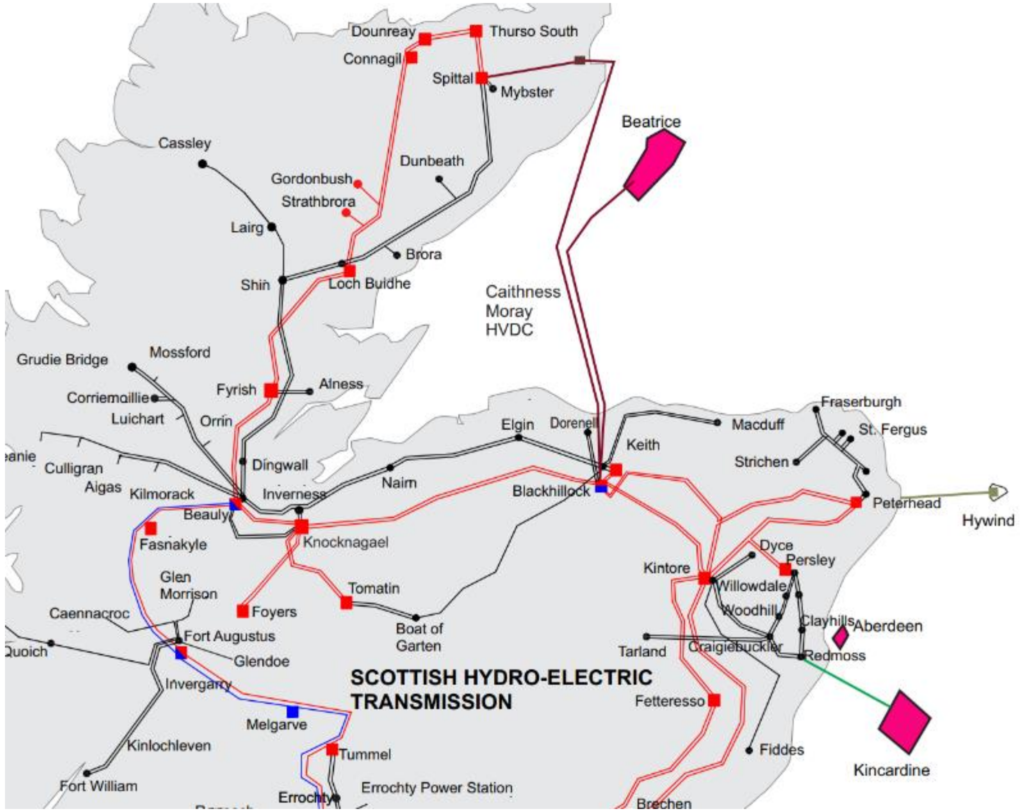
What is being done?

- We provided short term operational advice to our control room, focussing on system strength
- We need to understand nature of these oscillations and their source:
    - Data requested from Users (see next slide)
    - Working group convened with ESO and TO representatives to investigate events in more detail, aiming to:
        - Investigate the underlying drivers for the oscillations
            - EMT modelling of the supergrid network in the north of Scotland
            - Analyse events to explore underlying system behaviours
        - Investigate and recommend remedial actions that can be explored further with Licensees and/or Users as appropriate
        - Assess suitability of alternative screening techniques for use in operational timescales



Data requested

- To assist with the investigations, and to help identify potential triggering events or conditions, Users in Scotland were asked to provide:
    - Metering data at the times of the oscillations
    - Any alarms or actions from protection systems that may have taken place during the events
    - Other SCADA alarms or events that indicate abnormal or unusual operating conditions during the events
    - Their network configuration including number of turbines in service
    - Any change in state of plant, such as turbines being taken in or out of service
    - Any available fault recorder traces
    - Any controller tuning or framework updates carried out in the preceding months
- These can help in the modelling and analysis work to identify and assess potential triggers

Innovation projects on modelling

- Having accurate/representative of models of the network and the users is very important
- Understanding the risk of control system interactions as converter based generation increases will requires detailed electro-magnetic transient (EMT) studies to be carried out which in turn requires more detailed modelling of the network as well as the converters
- Innovation Project **Transmission Owner Tools for EMT Modelling (**TOTEM)
  - TOTEM which is developing a full GB network model in the EMT environment
  - https://smarter.energynetworks.org/projects/nia_shet_0032/
- Innovation Project **Developing Enhanced Techniques to Evaluate Converter-dominated Transmission System Operability (**DETECTS)
  - DETECTs is exploring the best practices for conducting such EMT studies using a specific study case in an area where converter-based generation is already prominent
  - https://smarter.energynetworks.org/projects/nia_ngso0031/
- Innovation Project **Probabilistic planning for stability constraints**
  - This is exploring, developing and testing cutting-edge automated and probabilistic approaches for modelling of angular stability. This will enable year-round boundary capability calculation for stability accounting for a number of sources of variability and uncertainty and enabling ESO to consider the possible issues across the system.
  - https://smarter.energynetworks.org/projects/nia_ngso0036/

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UNIFI Consortium

universal interoperability for grid-forming inverters

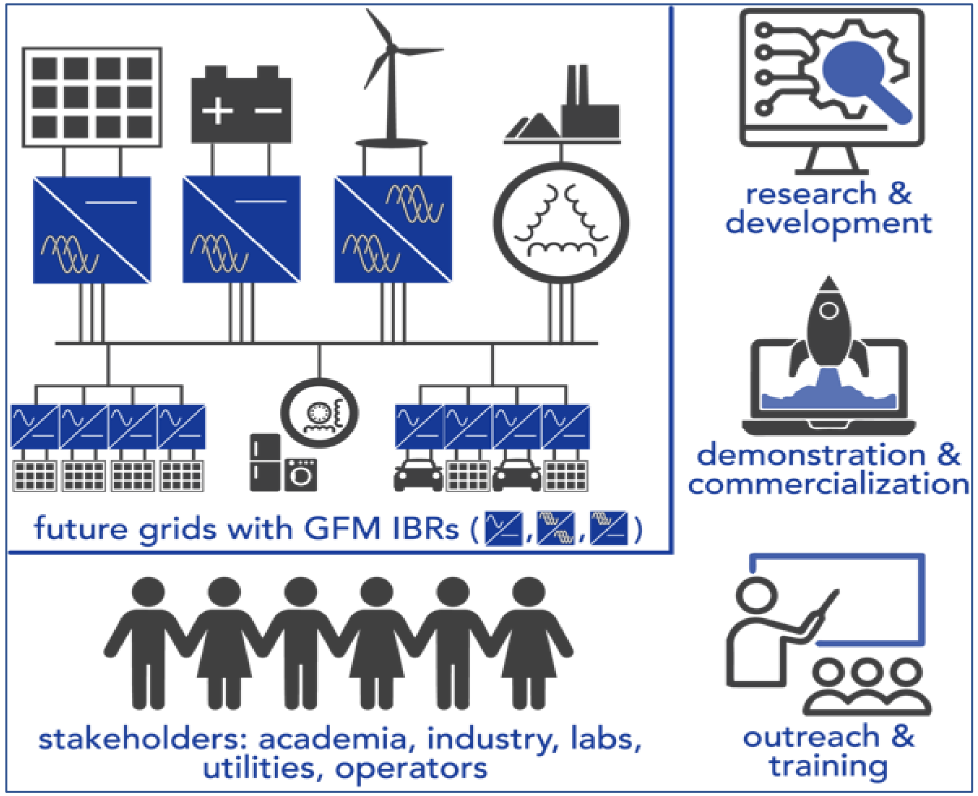
Co-led by NREL, University of Washington, and EPRI

The **UNIFI Consortium** is a forum to address fundamental challenges to the seamless integration of grid-forming (GFM) technologies into power systems of the future

Bringing the industry together to unify the integration and operation of inverter-based resources and synchronous machines

Three major focuses:

- **Research & Development** (Modeling, Controls, Hardware, Integration & Validation)
- **Demonstration & Commercialization** (Large Demonstrations, IP Management, Products, Standards)
- **Outreach & Training** (Education, Workforce Development, Communications, Events)



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IBR research Team

https://globalpst.org/wp-content/uploads/Tools-Team-Presentation.pdf

Stability Centric Environment

Follow (click) each tool for more detailed discussion

"Economics" tools
- Production Simulations
- Reliability (ELCC, LOLE, ...)
- Capacity Expansion

Initial conditions

Boundary conditions

Positive Sequence Phasor analysis
- Stability
- Loadflow

Model

Meta-tools

Validation, refinement, model data

Conditions for study, Boundary conditions

"Physics" tools
- EMT
- Protection design
- State-space, SSS
- Impedance based techniques
- Voltage stability, static tools,
- Measurement based tools
- RTDS, HIL tools
- Harmonics, PQ
- Aggregation & Equivalencing
- Hybrids (e.g. Phasor + EMT)

How these tools are used depends on the problem/activity:
See application matrix.

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Table 4. Control Room of the Future Research Programme Questions
20. How can operators identify critical stability situations in real-time and optimize system security?
21. How can system operators get relevant real-time visibility and situational awareness of the state of the power system with increasing penetrations of IBR and DER?
22. How can system strength, inertia and limits of stable frequency range be monitored in real-time in high IBR systems?
23. What are the appropriate methodologies to visualize and interpret relevant information for improved decision support for fast real-time control actions?
24. What quantities must be monitored, screened, and validated in real-time to ensure that there will be adequate flexibility availability from uncertain system resources in the near-term?
25. How can control capabilities for IBR-based system assets (FACTS, Line Impedance adjusters, etc.) and network flexibility more generally be maximized to enhance reliability and/or reduce costs.
26. Are there sufficient flexibilities available in the near-term to compensate variations in load and generation (fast changes as well as long lasting extreme situations such as prolonged periods of no solar and wind)?
27. How do control rooms address uncertainties in weather conditions that impact loads and renewable energy output and rate of change (ramps)? How can probabilistic forecasting techniques be better incorporated into real-time operations?
28. How can data be best utilized to ensure system operations include the ability to detect and mitigate a range of uncertain disturbances?
29. What quantities must be monitored, screened and validated to ensure reliable service provision from aggregated flexibility resources in distribution systems, supporting stable system operation?
30. What type of digital architecture is necessary to enable the variety of software required to operate a control room in real-time, near real-time and in auto pilot mode?
31. How can grid topology be flexibly adapted at various operating conditions?'

32. What is a suitable data architecture for DER monitoring & modelling? Once DER resources have been aggregated spatially and temporally, how should this information be provided to the control room? Can DER categories be developed that allow groupings based on their ensemble response to system level events? What is the appropriate data architecture required to monitor/predict and control DER in real-time?
33. What is the communication capability needed to support monitoring and control of DER? What is the suitability of existing communications infrastructure – in terms of reliability, latency, bandwidth, (cyber)security – relative to investing in a bespoke system? For DER control purposes, what 2-way communication protocols are necessary?
34. What are the relative merits of different control architectures for DER? What might an efficient distributed control architecture be for DER which: (1) makes use of appropriate device characterizations and real-time monitoring data; (2) accounts for practical constraints around device-level communication; and (3) accounts for heterogeneous subgroup controls of DER and various existing DSO/TSO control schemes?
35. What is the best way to integrate large data sets, streaming information, and historical system performance to create actionable operational insights?
36. How can the status (generation output, state of charge, etc.) of each key category of DER be monitored/estimated in real-time? What are appropriate DER categories and the appropriate spatial and temporal resolution to monitor DER effectively? What are the appropriate technical means of achieving this level of aggregation?

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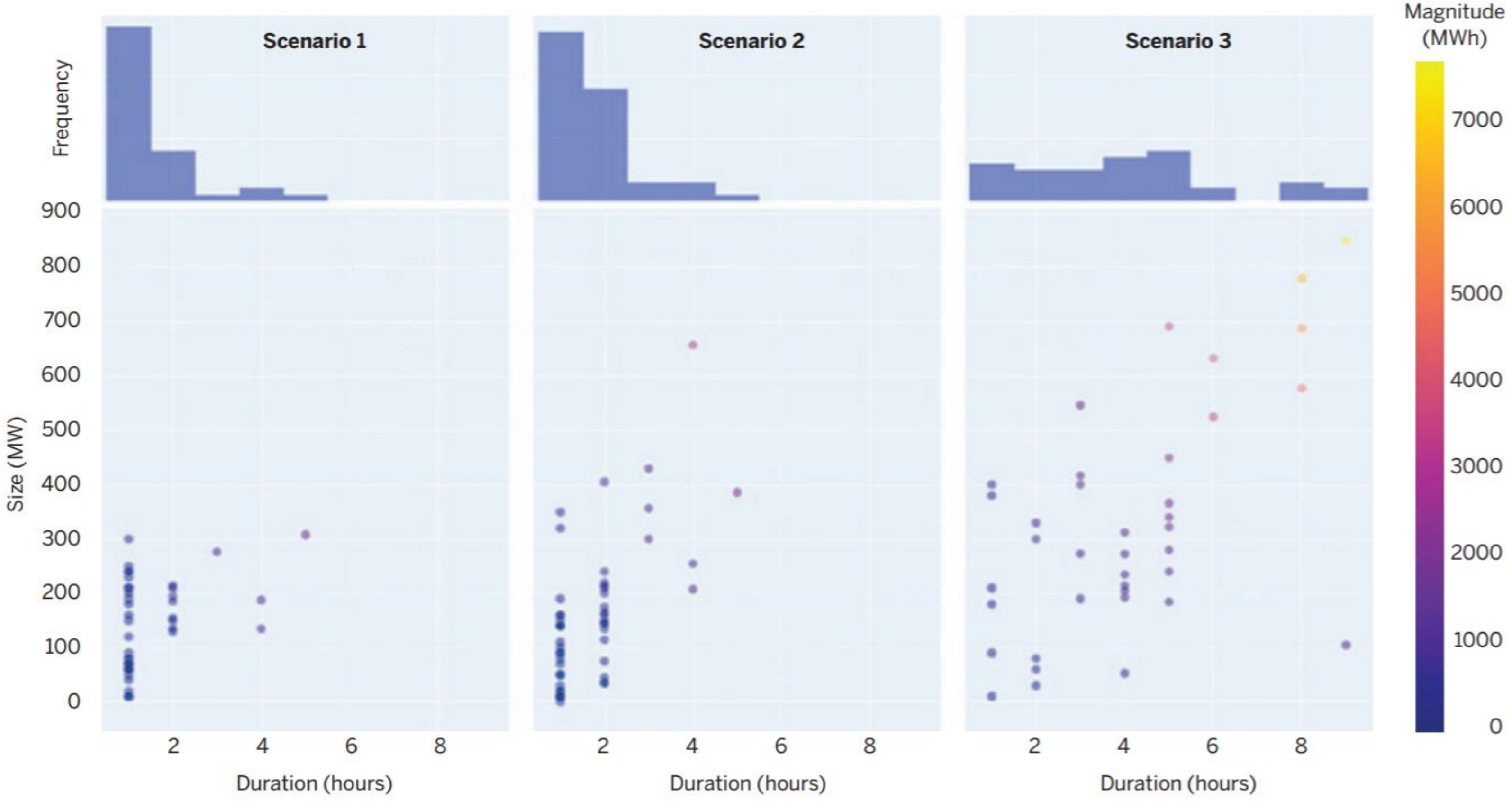
Resource Adequacy Research Team

FIGURE 8

Scatter Plot of Size, Frequency, and Duration of Shortfall Events with Energy-limited Reliance on Energy Limited Resources



Source: Energy Systems Integration Group.

https://www.esig.energy/wp-content/uploads/2021/08/ESIG-Redefining-Resource-Adequacy-2021.pdf

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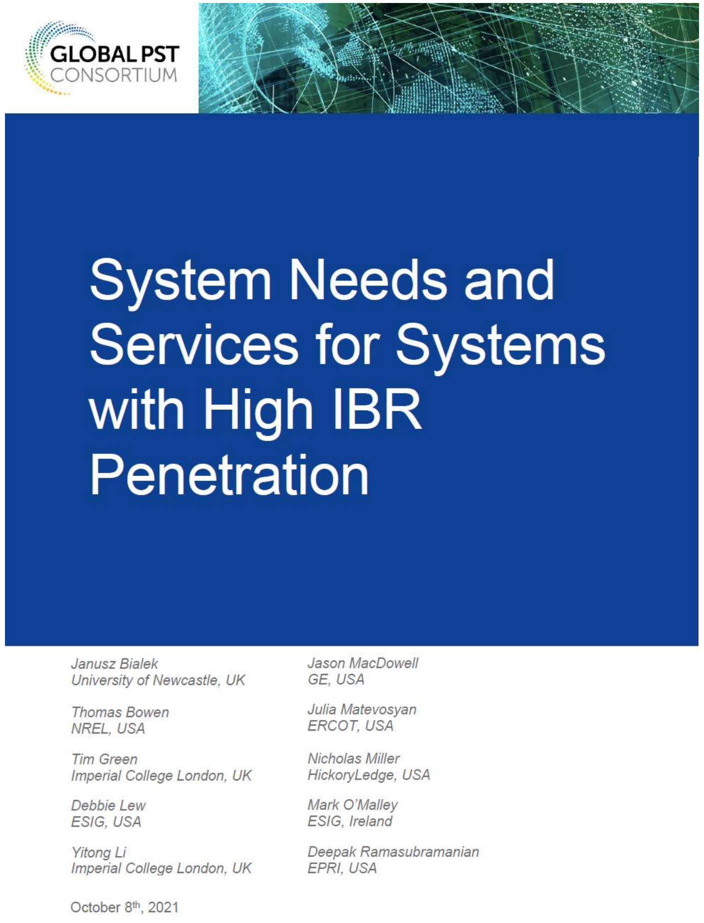
IBR Research Team



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System Needs and Services for Systems with High IBR Penetration

Janusz Bialek
University of Newcastle, UK

Thomas Bowen
NREL, USA

Tim Green
Imperial College London, UK

Debbie Lew
ESIG, USA

Yitong Li
Imperial College London, UK

Jason MacDowell
GE, USA

Julia Matevosyan
ERCOT, USA

Nicholas Miller
HickoryLedge, USA

Mark O'Malley
ESIG, Ireland

Deepak Ramasubramanian
EPRI, USA

October 8th, 2021

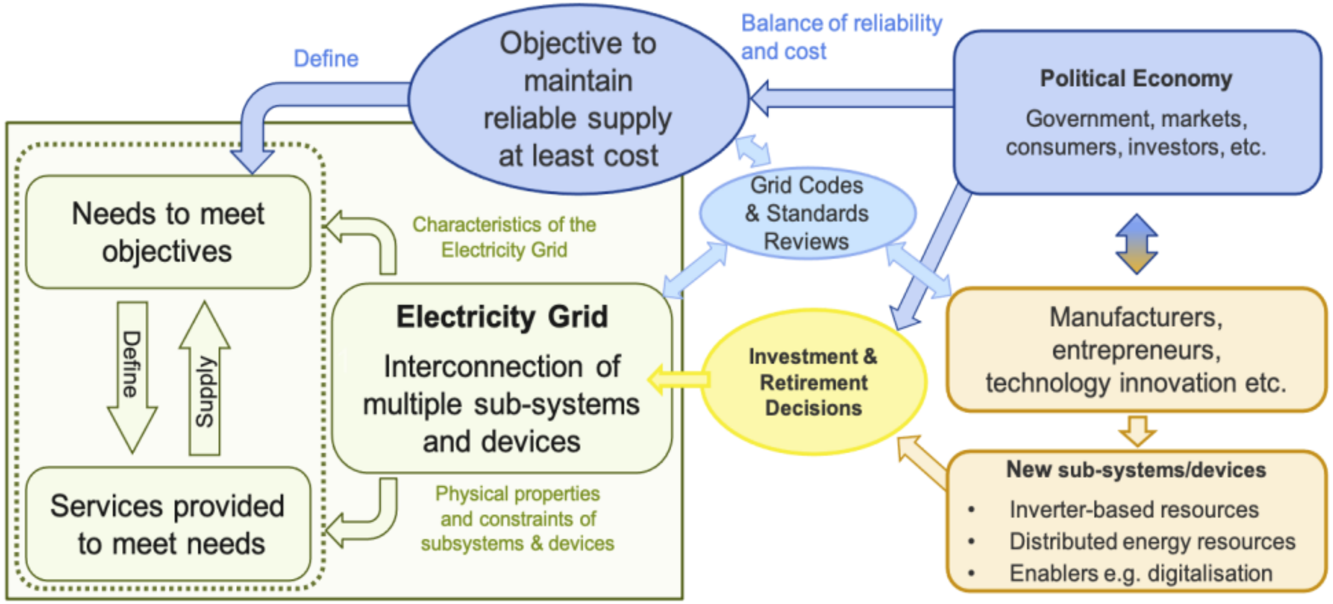

Figure 1: Schematic diagram of system needs and services with recognition of physical properties of grid, technology innovation and the regulatory and policy context.

GPST-IBR-Research-Team-System-Services-and-Needs-for-High-IBR-Networks.pdf (globalpst.org)

A Services Approach

Ongoing initiatives to meet stability challenges

- NOA Stability Pathfinder Projects
  - Phase 1 – awarded contracts in Jan 2020 for 12.5 GW.s of inertia https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-1
  - Phase 2 – will buy inertia of 6 GW.s and SCL of 8.4 GVA in Scotland https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-2
  - Phase 3 – will buy inertia of 15 GW.s and SCL of 7.5 GVA in areas of England & Wale https://www.nationalgrideso.com/future-energy/projects/pathfinders/stability/Phase-3
- Introducing GB Grid Code change for Grid Forming Technologies
  - Grid Code Working Group GC0137 https://www.nationalgrideso.com/industry-information/codes/grid-code-old/modifications/gc0137-minimum-specification-required
- Stability Market development Innovation project
  - Aims is to understand if there is a need for a stability market https://www.nationalgrideso.com/future-energy/projects/stability-market-design
- Accelerated Loss of Mains Change Program (ALoMCP)
  - Under which initiative the electricity distribution companies are updating settings for the RoCoF loss of mains protection relays from 0.125 to 1Hz/s, with a definite time delay of 500ms
  - This will allow us to reduce spend on RoCoF related system constraints.

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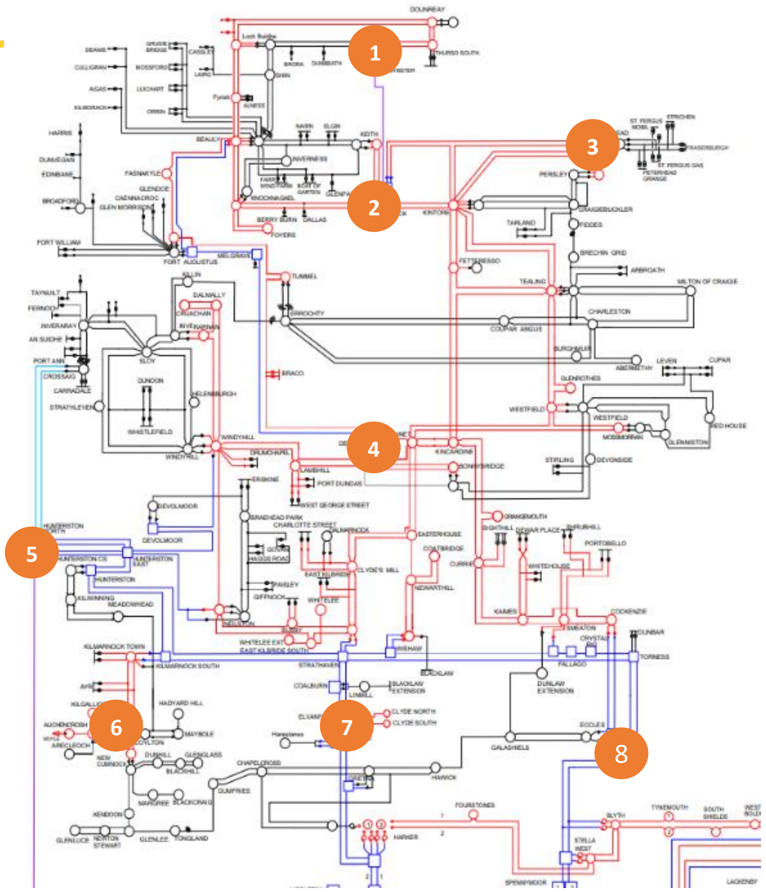
Stability Phase 2 requirement

The primary requirement for stability pathfinder Phase 2 is for regional short circuit level. However, we have included a requirement for national inertia as we value inertia contribution alongside SCL.

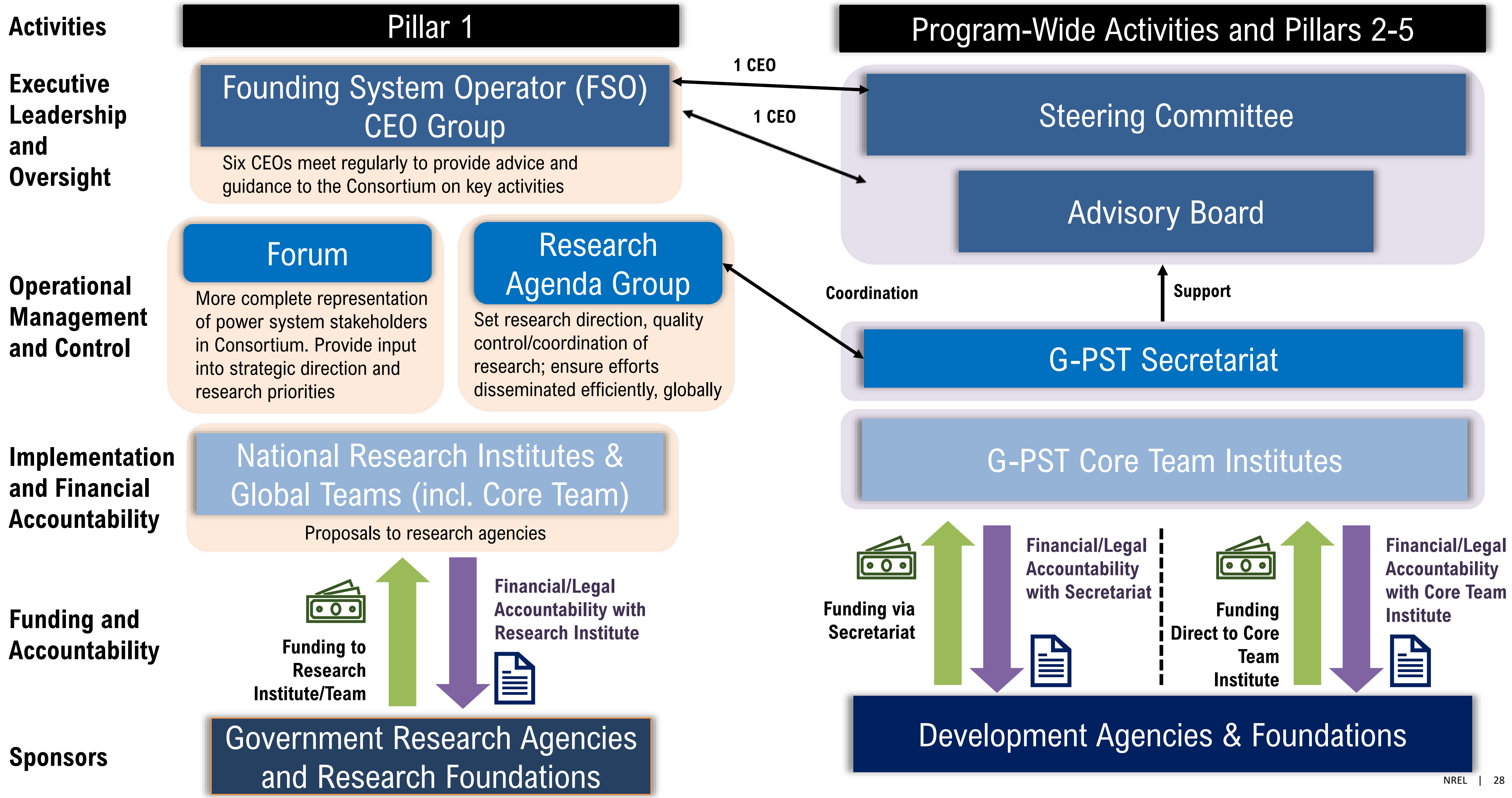
Location	Ref	Requirement (MVA)
Spittal	1	600
Blackhillock	2	1,300
Peterhead	3	1,300
Longannet area	4	600
Hunterston	5	1,200
Mark Hill/ Coylton area	6	400
Moffatt/ Elvanfoot area	7	1,800
Eccles area	8	1,200
Total		**8,400**

	Requirement (MVA.s)
Inertia	6,000
Total	**6,000**



The total requirement for SCL is for 8.4GVA across the 8 locations as above. As any solution at one location will have a positive knock-on impact on all the other 7 locations, the totality of volume procured across all sites is expected be less than 8.4GVA.

G-PST Consortium Governance & Funding Model



Conclusions

- The Research Agenda is focussed and is a consensus between the six FSOs
- Great opportunity for the research community to get involved and have a real impact
- G-PST is an enabling and catalytic organisation
- G-PST has put out some initial "resources" please review
- Feedback welcome globalpst@nrel.gov

Resources

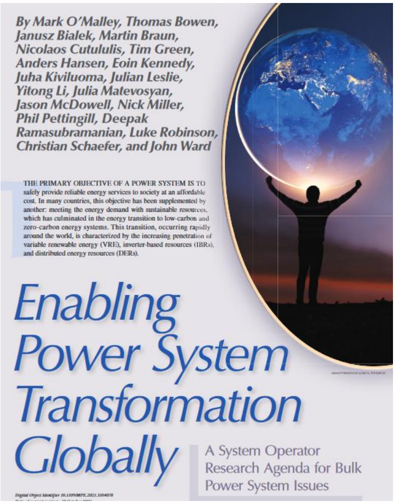
21st April 2021

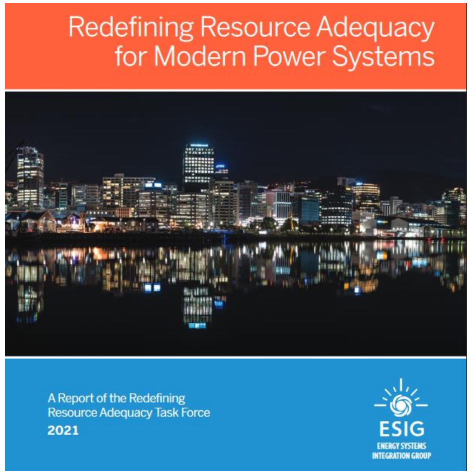
COP26 Events

- [Unlocking Grids to Decarbonize Power Systems Globally]()
- [Accelerating Power System Transformation through Technical Innovation]()

Pillar 1 Resources

- Key Research Needs
- Research Agenda (IEEE PES Article)
- IBR Research Team
    - System Needs & Services (feedback)
    - Stability Tools Inventory (feedback)
- Resource Adequacy Research Team
    - Report
    - Policy Brief
- Additional Webinars





All these resources are accessible from: https://globalpst.org/