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Redefining Services for IBR-dominated Power Systems

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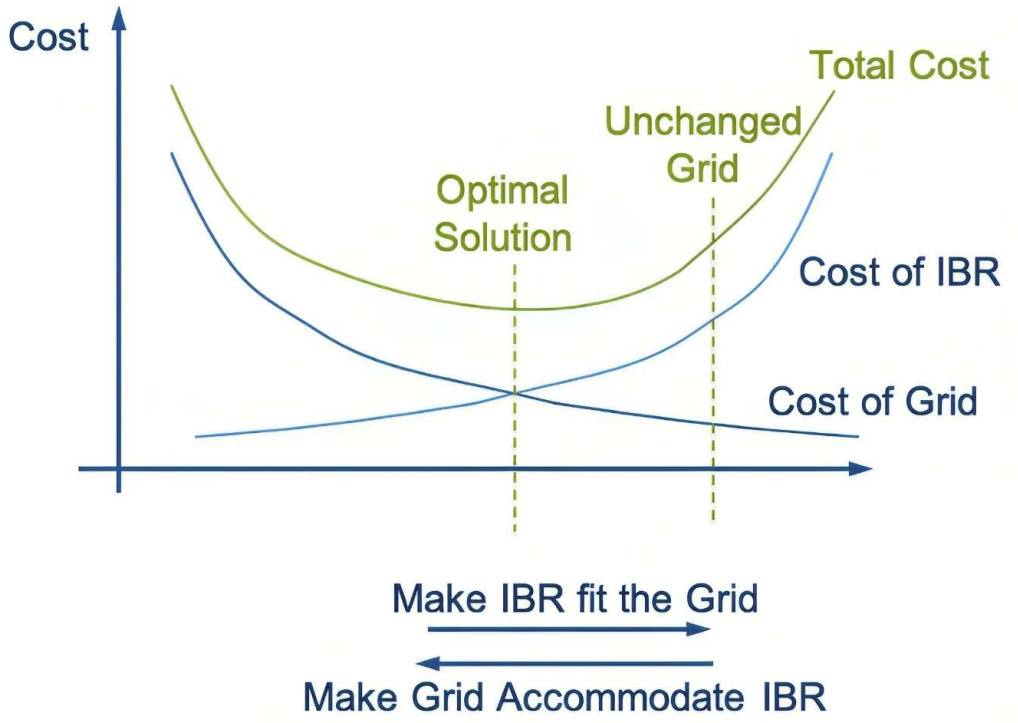
EPICS, Newcastle Australia, Jan 28th 2026

Optimising the Cost of Operating IBR-Dominated Power Systems

- Changing power systems towards IBR-dominated systems requires both changing the grid to accommodate IBRs and making IBRs work in existing grids
- An example of open research question: What will be cheaper? Design of IBRs with (transient) over-current capability to provide fault current **OR** Re-design of existing protection systems in the grid

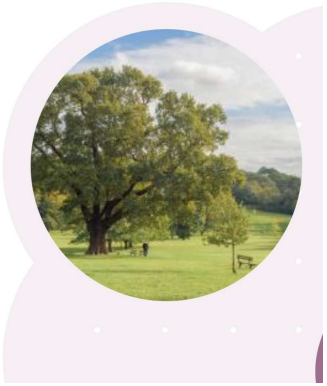


What does this problem look like ?

First phase of stability pathfinders delivered

As part of the ESO's legal separation from the National Grid Group in 2019 the ESO announced a new ambition, to be able by 2025 to operate for the first time, a 100% zero carbon national electricity transmission network.

Future energy - 5 Apr 2023 - 4 minute read



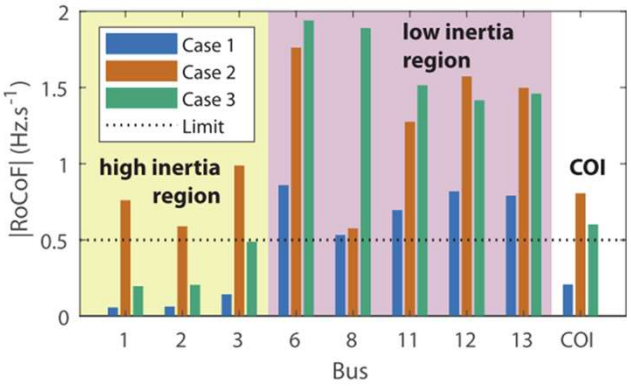
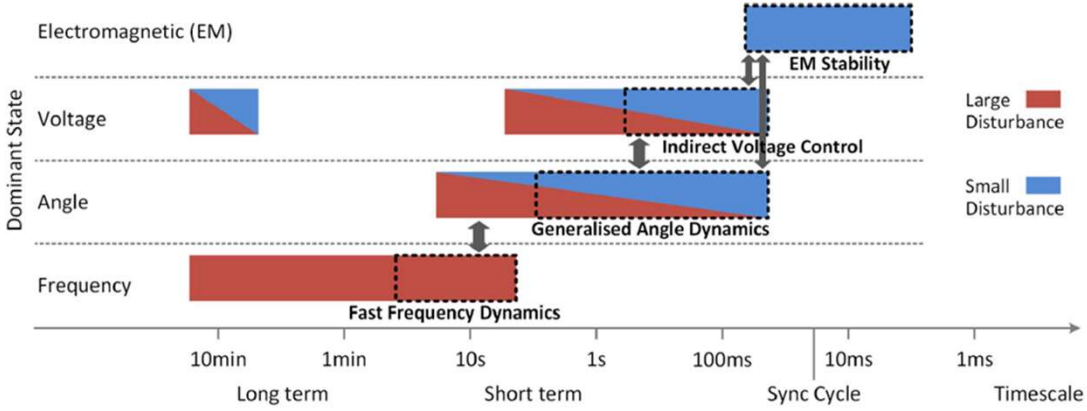
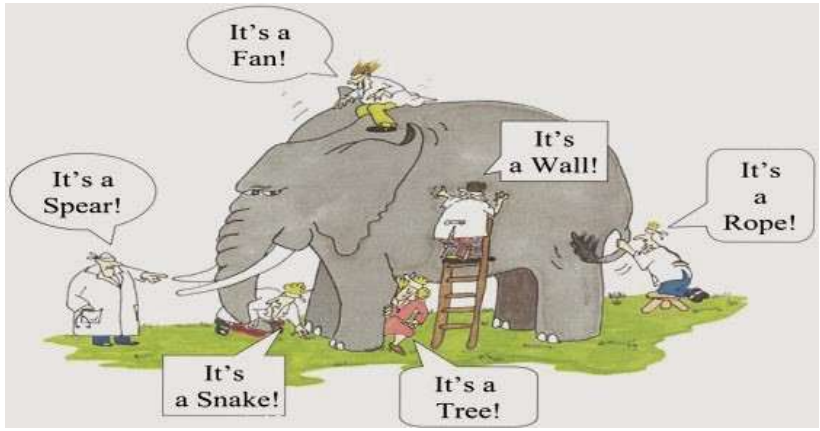


Fig. 6. Simulated absolute initial RoCoF of individual buses and COI for cases 1, 2 and 3.

E. A. S. Ducoin, Y. Gu, B. Chaudhuri and T. C. Green, "Analytical Design of Contributions of Grid-Forming and Grid-Following Inverters to Frequency Stability," in *IEEE Transactions on Power Systems*, vol. 39, no. 5, pp. 6345-6358, Sept. 2024, doi: 10.1109/TPWRS.2024.3351530.



Y. Gu and T. C. Green, "Power System Stability With a High Penetration of Inverter-Based Resources," in *Proceedings of the IEEE*, vol. 111, no. 7, pp. 832-853, July 2023, doi: 10.1109/JPROC.2022.3179826.



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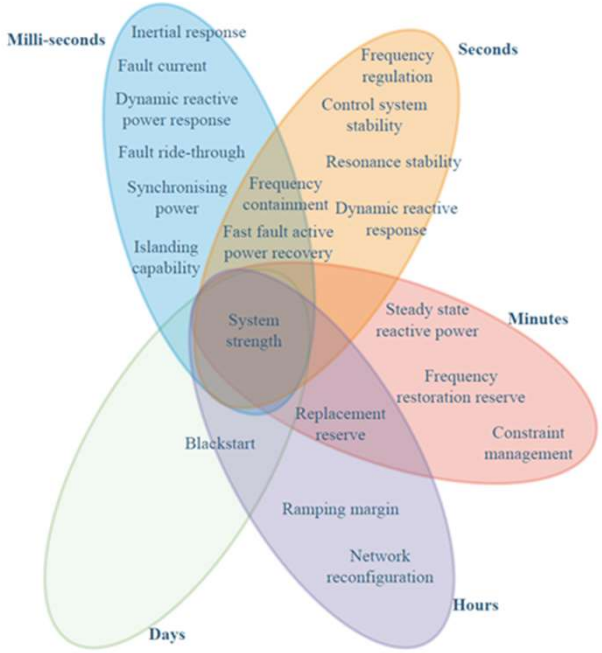
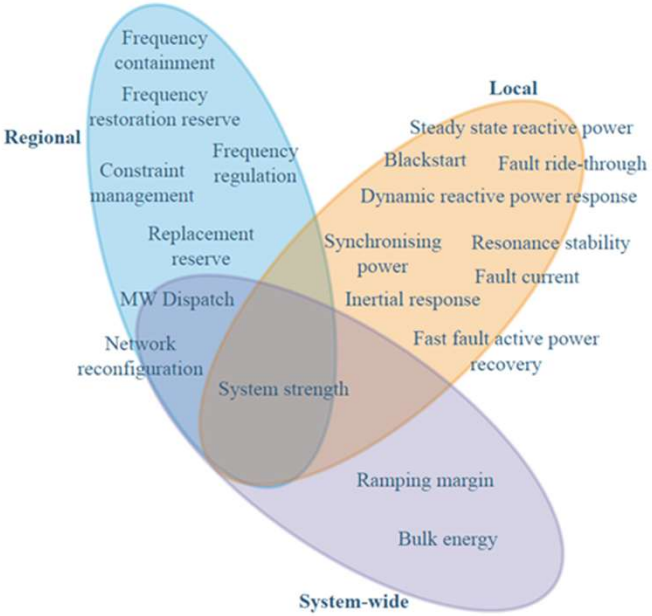
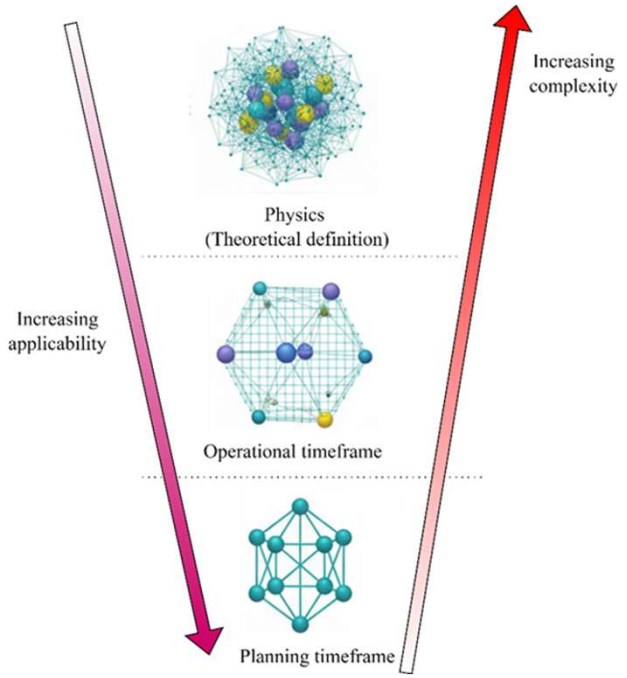
Temporal spatial complexity







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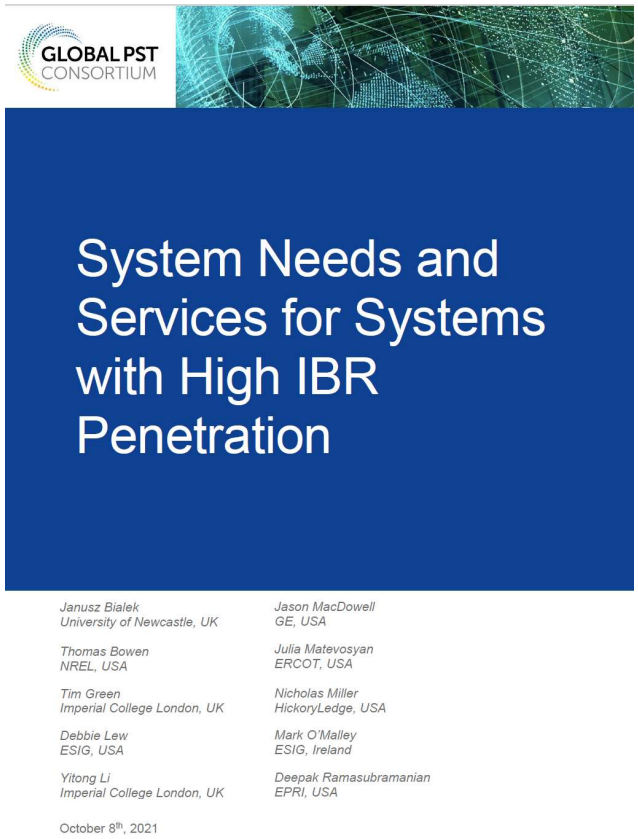
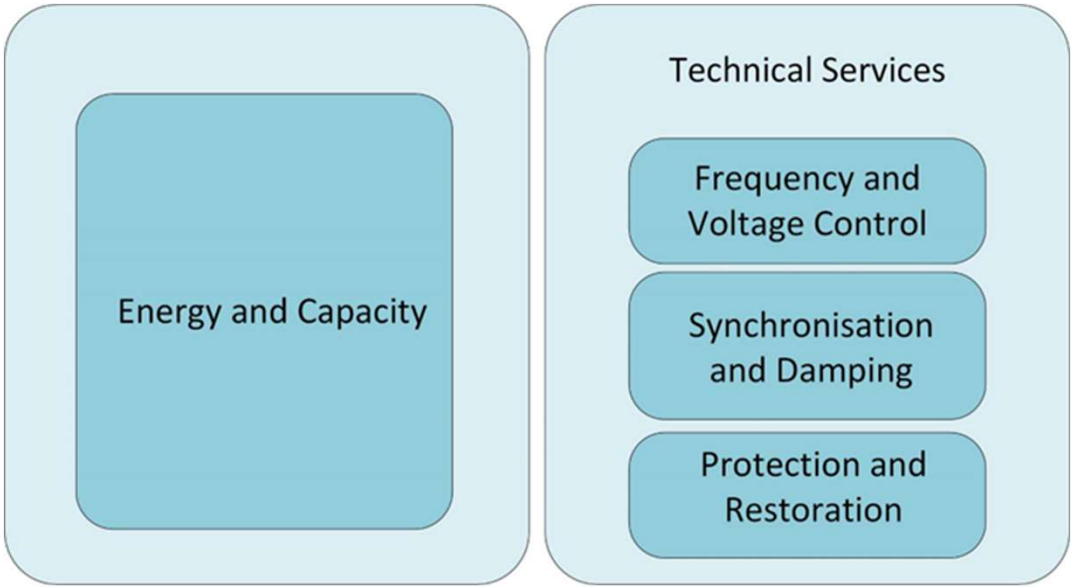
The G-PST, IBRs and Services





GLOBAL PST CONSORTIUM

The Needs and Services paradigm

Objective to maintain reliable supply at least cost

Define

Balance of reliability and cost

Political Economy

Government, policies, market outcomes, consumers, investors, etc.

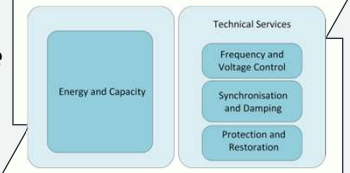
Needs to meet objectives

Characteristics of the Electricity Grid

Electricity Grid

Interconnection of multiple sub-systems and devices with a market

Define



Supply

Services provided to meet needs

Physical properties and constraints of subsystems & devices

New sub-systems & devices installed and some older retired

Investment Decisions

Manufacturers, entrepreneurs, technology innovation etc.

New sub-systems/devices

- Inverters based resources
- Distributed energy resources
- Enablers e.g. digitalisation

Scenarios, High IBR in grids with wind, solar, nuclear etc.

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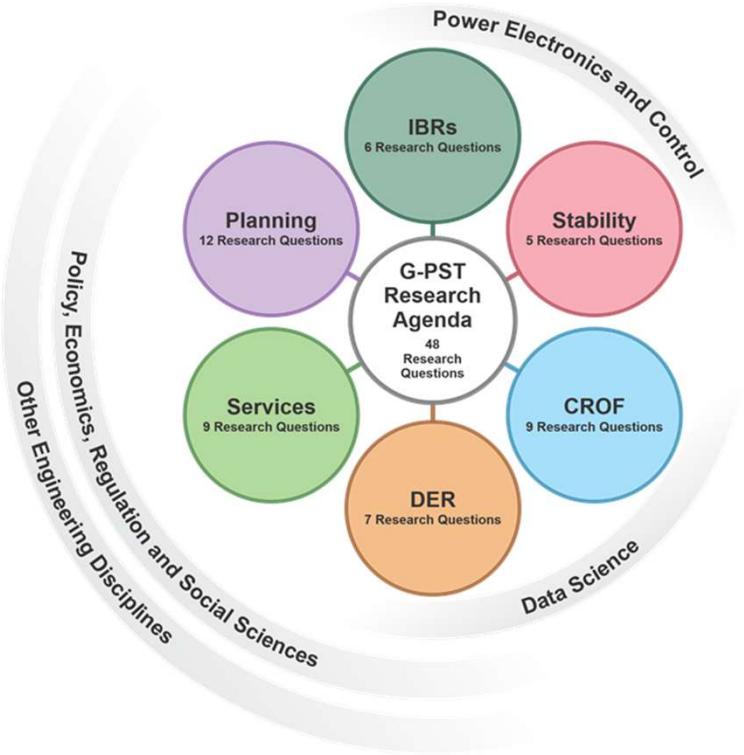
G-PST Research Agenda 2025 & Services Research Program



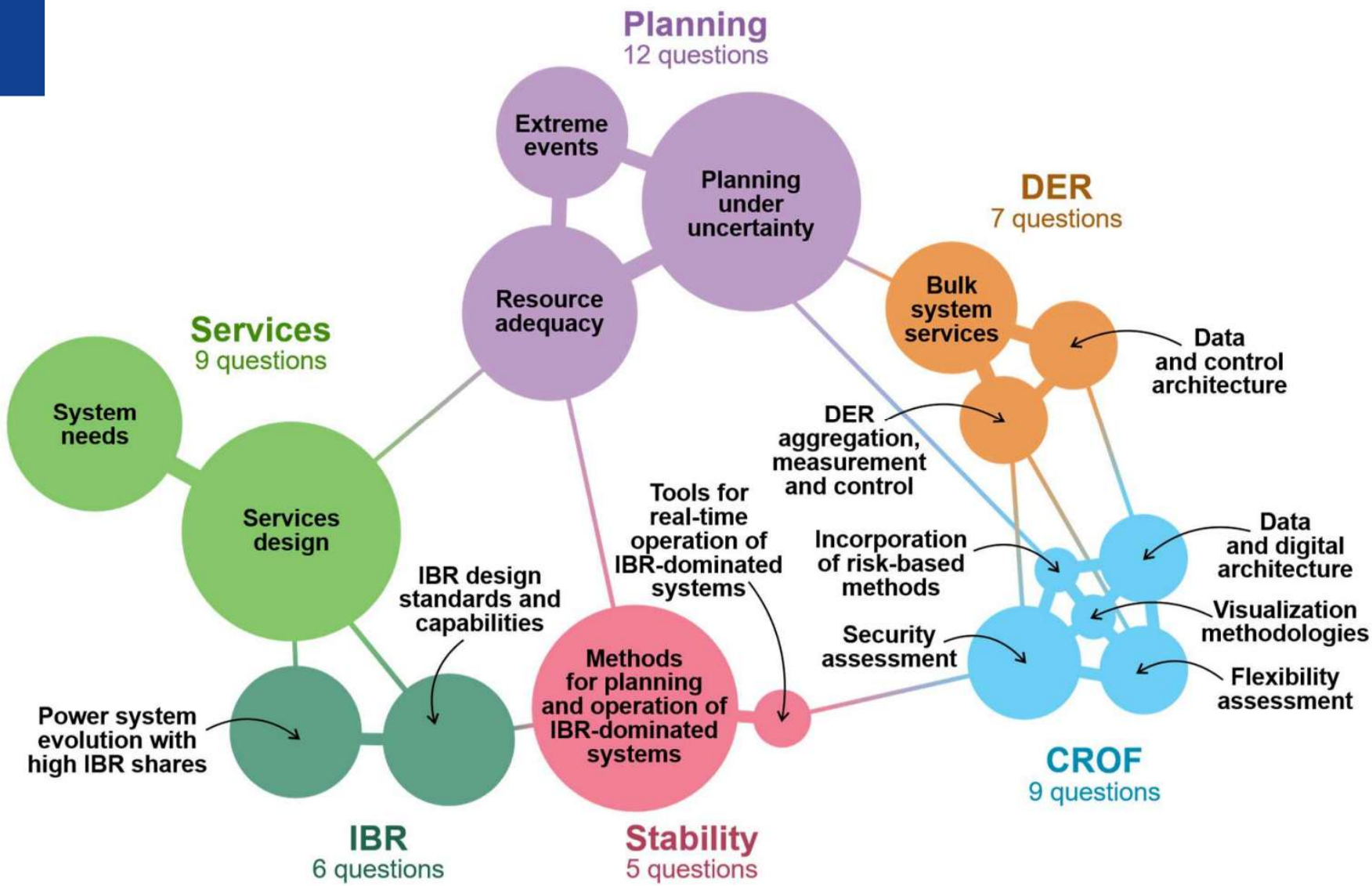
#	Services Research Questions
28	What system services are needed across different timescales and to the extent that **services coexist within the same timescale**, how should these services be designed to avoid competition and overlap?
29	What are the needs of a power system expressed in technologically neutral form and how do these needs map to services that any resource (including data centers, other IBRs, DERs, high-voltage direct current links, etc.) can provide?
30	How can system performance requirements be translated into reliable new technology solutions?
31	For each **service, how feasible is it to provide from IBR, what "cost" does** it add, what limitations exist on its magnitude and duration and what are the tradeoffs between the provision of services?
32	How should system restoration services be structured and organized in systems with few or no synchronous machines, relying on IBR technologies and variable energy resources?
33	How should the **definitions of services for IBR-dominated grids be** structured and can standard services and standard characteristics be defined as reasonable for large and small IBRs and across variable renewable energy, storage, demand response interfaces and for differing procurement mechanisms?
34	What methods could determine the need, sufficiency, and **locational nature of IBR voltage control and system strength services for a given area?**
35	What models and methods, including testing, are necessary to quantify the ability of variable renewable energy to provide essential reliability services to the grid, and how do system operators quantify the value of these reliability services (for example, as an input to system-specific market/incentive design questions)?
36	What system services can be designed to enable response from IBRs that can be a substitute for inertia (i.e. very fast frequency response)?

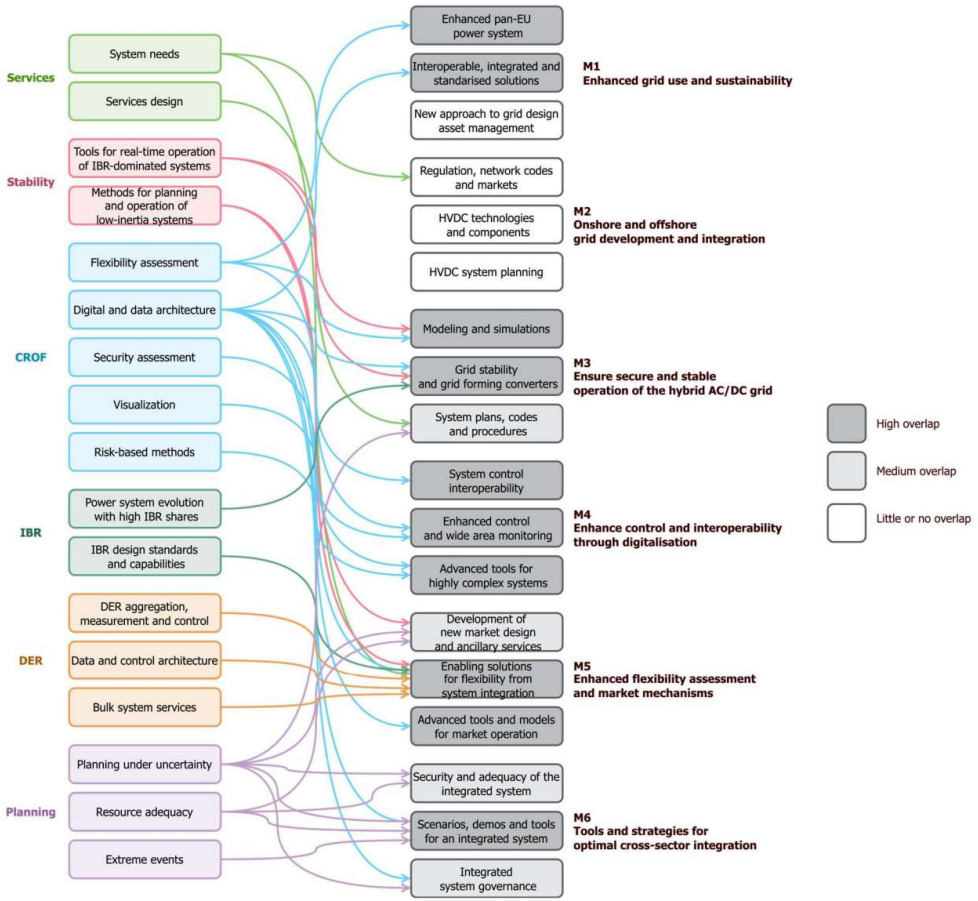
G-PST Research Agenda 2025

G-PST - Stability Research Program

#	Question	Sub Programs
7	What approaches can be taken to track the dynamic response of IBR-dominated systems near real time and detect any emerging stability problems?	Tools for real-time operation of IBR-dominated systems
8	What methods, including data types, and analyses can be used to identify the risk of poorly damped IBR-induced oscillations in planning studies and trace their root cause?	Methods for planning and operation of IBR-dominated power systems
9	What analytical tools and models should be provided to planners and operators for robust assessment of system performance in IBR-dominated power grids?	
10	What methods and tools should be used in planning and/or operation to determine the appropriate mix, location, and capabilities of grid-forming and grid-following inverters to mitigate stability problems for a given power system?	
11	In what form and fidelity should the original equipment manufacturers/developers and system operators exchange the IBR and grid models for comprehensive stability assurance of IBR-dominated grids?	

G-PST Research Agenda 2025





ENTSO-E

RDI Roadmap 2024–2034

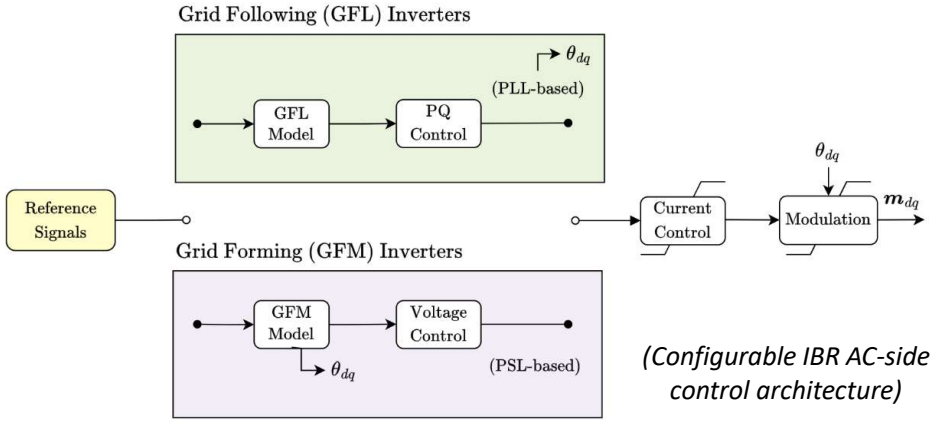
Innovation Missions to build the power system for a Carbon-Neutral Europe

entsoe

Optimal Control for Robust Dynamic Performance in Inverter-Dominated Power Systems

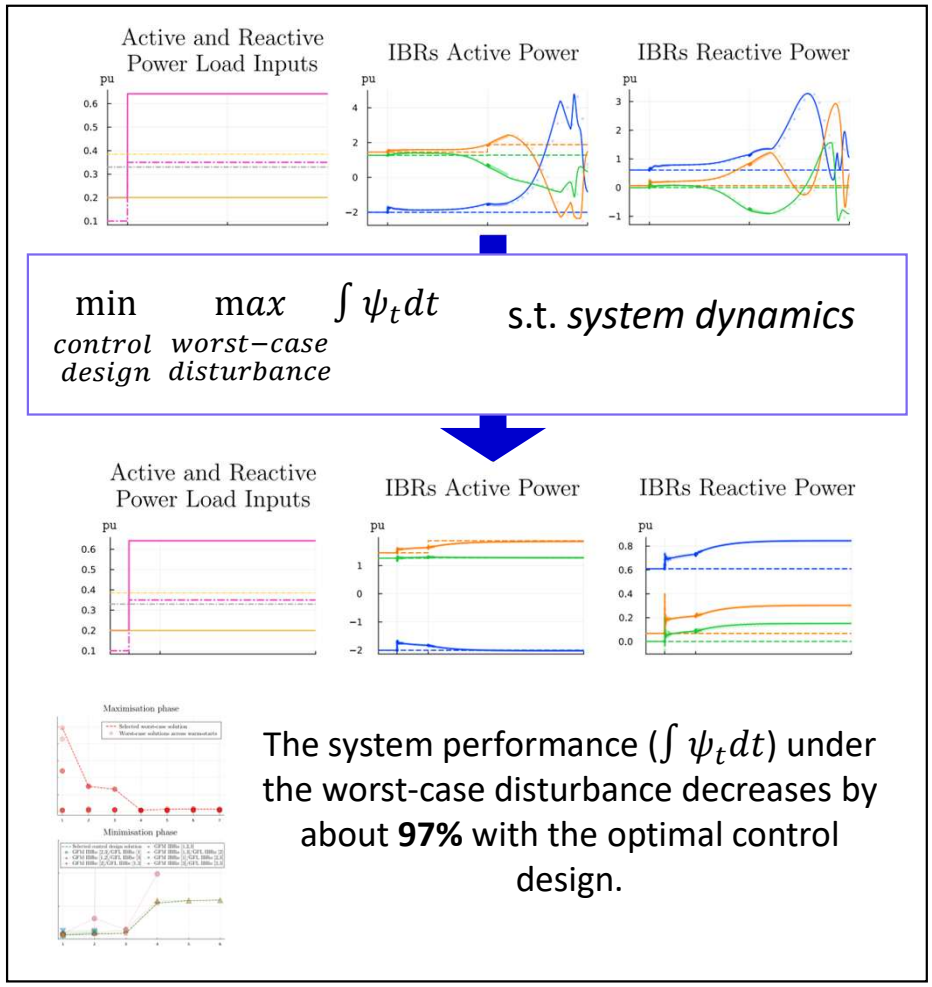
T. Ochoa

This work optimizes the control design of all IBRs in the system for best system performance under worst-case conditions.



(Configurable IBR AC-side control architecture)

Our continuous-time problem formulation captures the system's large-signal dynamic response by explicitly embedding nonlinear dynamics, dispatch mechanisms, and current saturation within the control design optimization process.



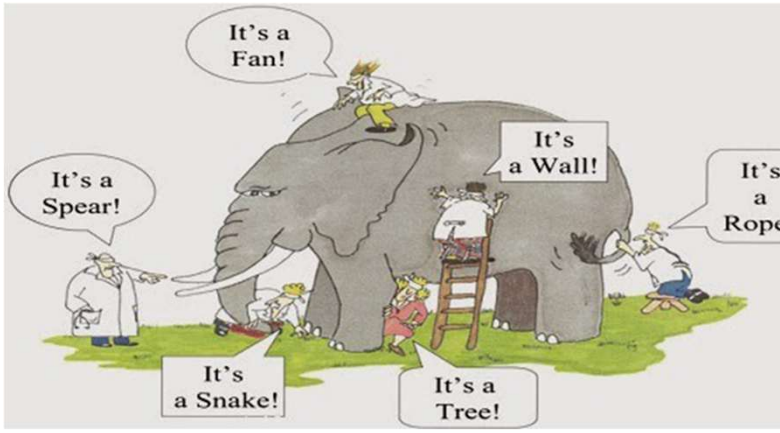
https://www.techrxiv.org/users/440656/articles/1320955-optimal-control-for-robust-dynamic-performance-in-inverter-dominated-power-systems-part-ii-optimization-and-results

https://www.techrxiv.org/users/440656/articles/1320954-optimal-control-for-robust-dynamic-performance-in-inverter-dominated-power-systems-part-i-modeling-and-problem-formulation

Imperial College London

Conclusions

- This is an emerging area – complex, overlapping, uncertain etc.
- We need significant research and practical experience to solve it
- Requires a holistic and collaborative approach between industry and academia and globally
- G-PST Research Agenda 2025 is a possible template to follow



Acknowledgements