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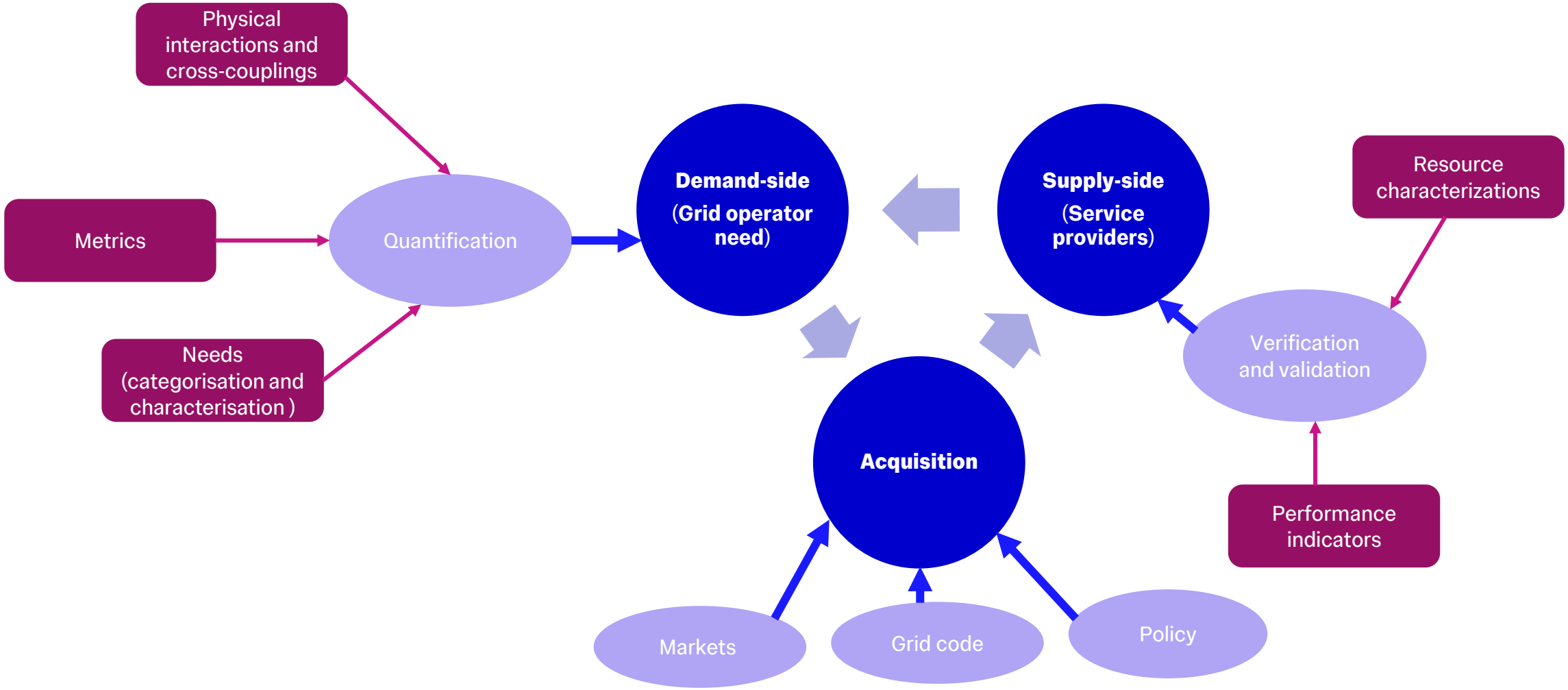
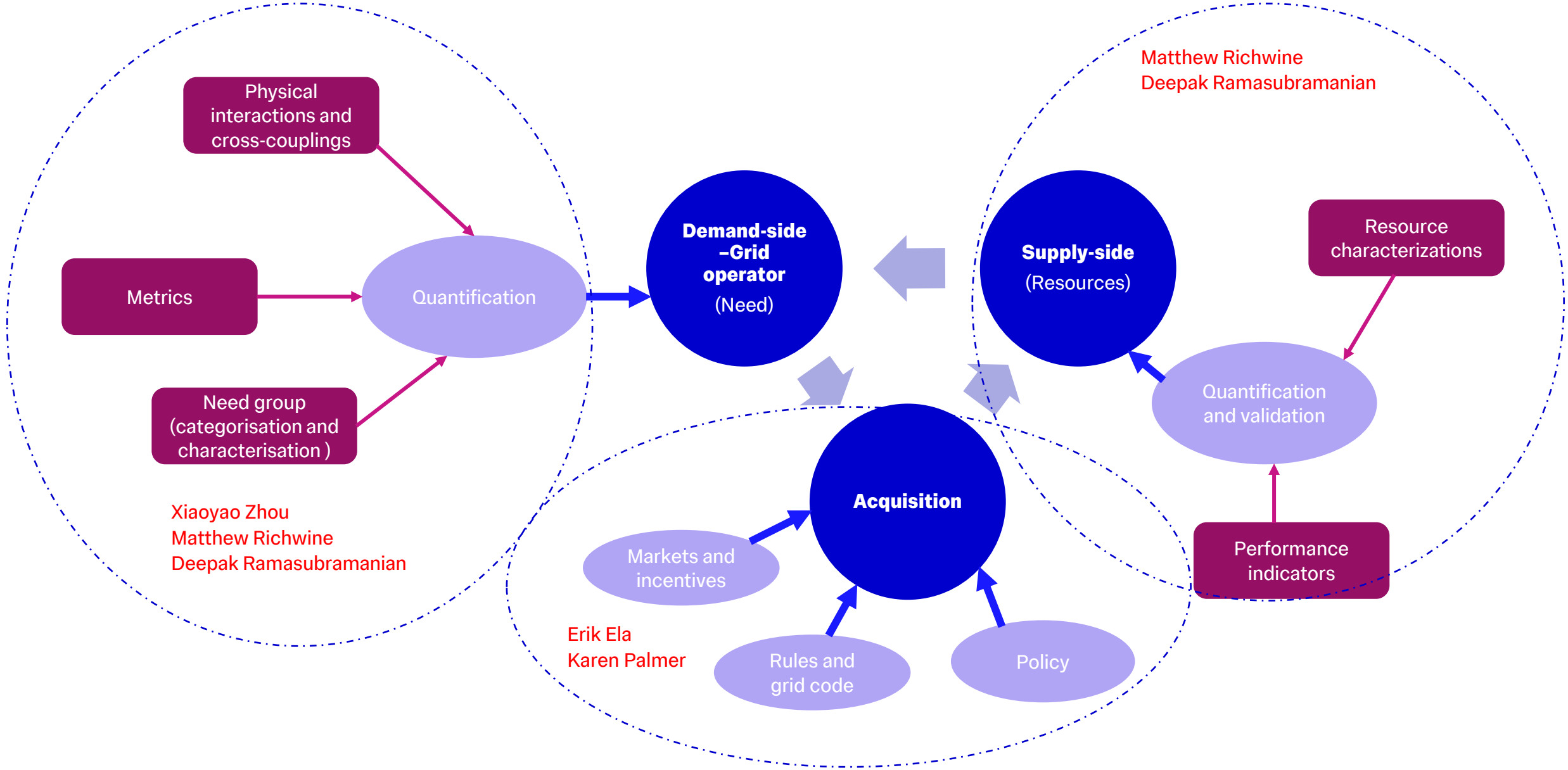
A holistic view of power system services:

Physics, metrics, incentives and quantification

Agnes M Nakiganda
30/10/2025

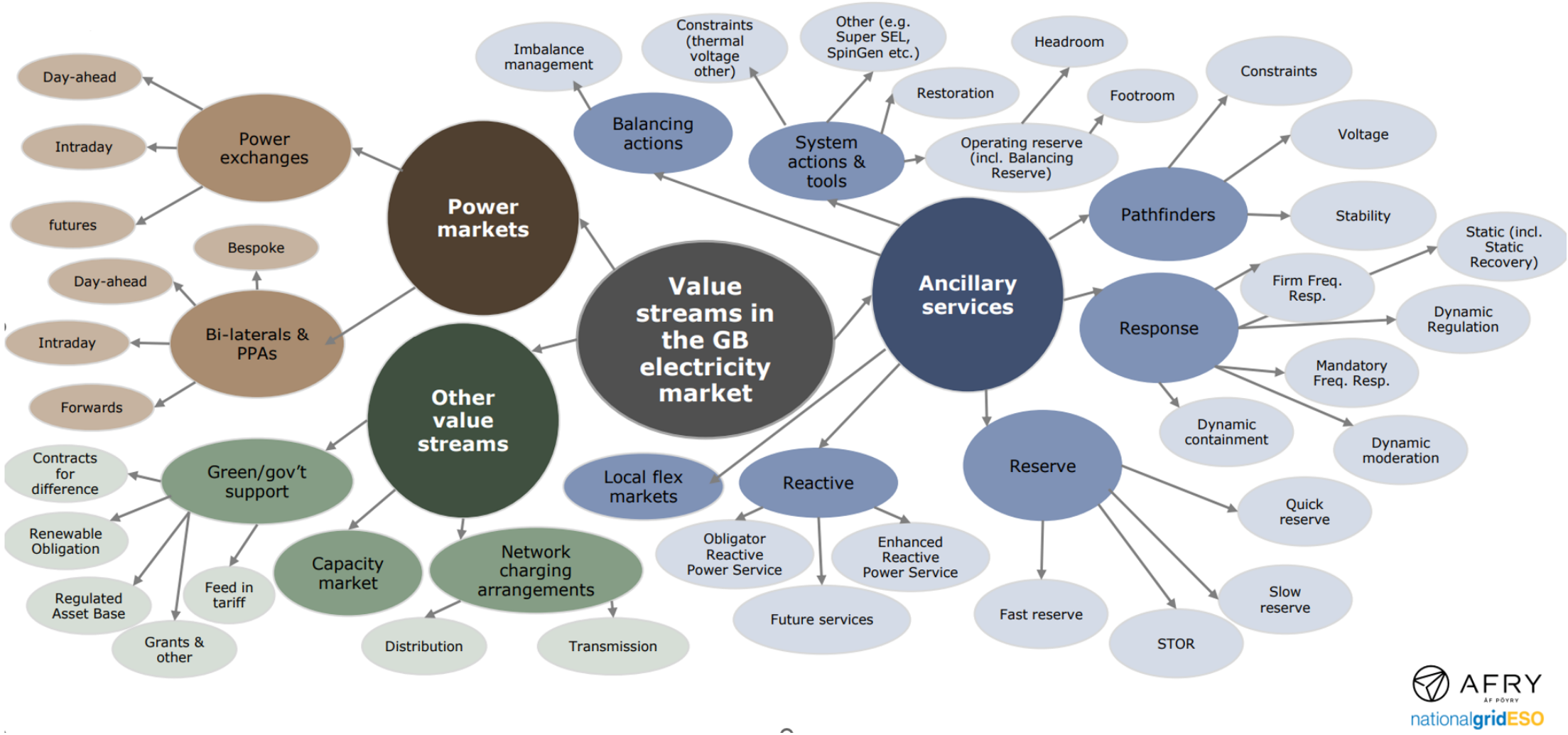
A framework for the study of system services




Physical interactions and cross-couplings
Metrics
Quantification
Need group (categorisation and characterisation)
Xiaoyao Zhou
Matthew Richwine
Deepak Ramasubramanian
Demand-side –Grid operator
(Need)
Supply-side
(Resources)
Matthew Richwine
Deepak Ramasubramanian
Resource characterizations
Quantification and validation
Performance indicators
Acquisition
Markets and incentives
Rules and grid code
Policy
Erik Ela
Karen Palmer

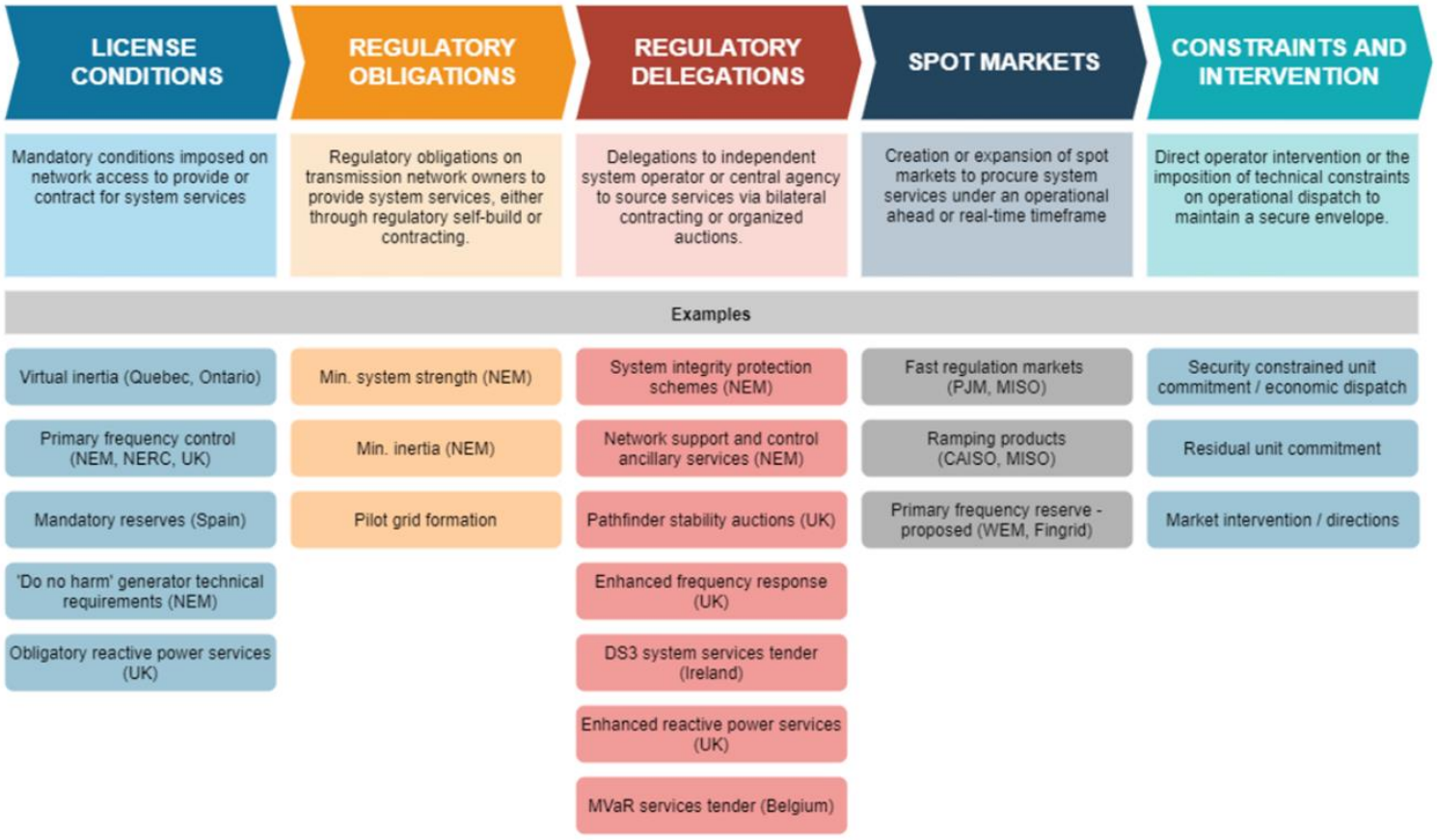
Markets

Market Products in the GB System



AFRY
nationalgridESO

Incentives and Grid codes



Source: authors, compiled from EU-Sysflex (2019); Rebours et al. (2007); Zhou et al. (2016)

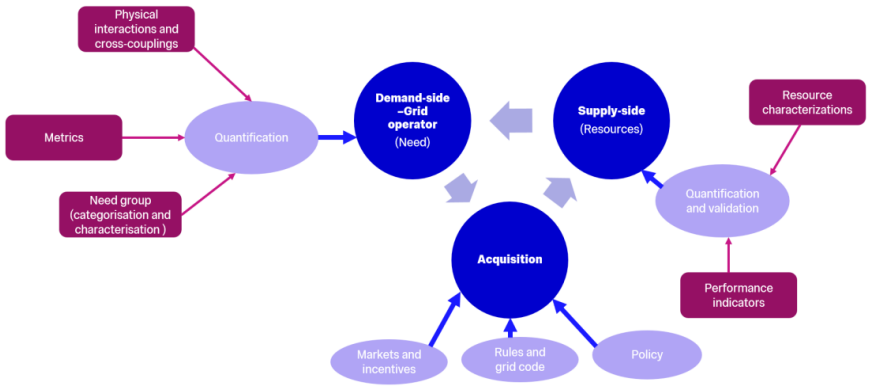
- What mechanisms are currently being adopted or proposed by system operators to enhance the provision of system services from the supply side?
- What are the benefits and challenges of approaches hinged on incentives, market and grid codes?
- How can we enhance existing metrics for different services to support the markets?

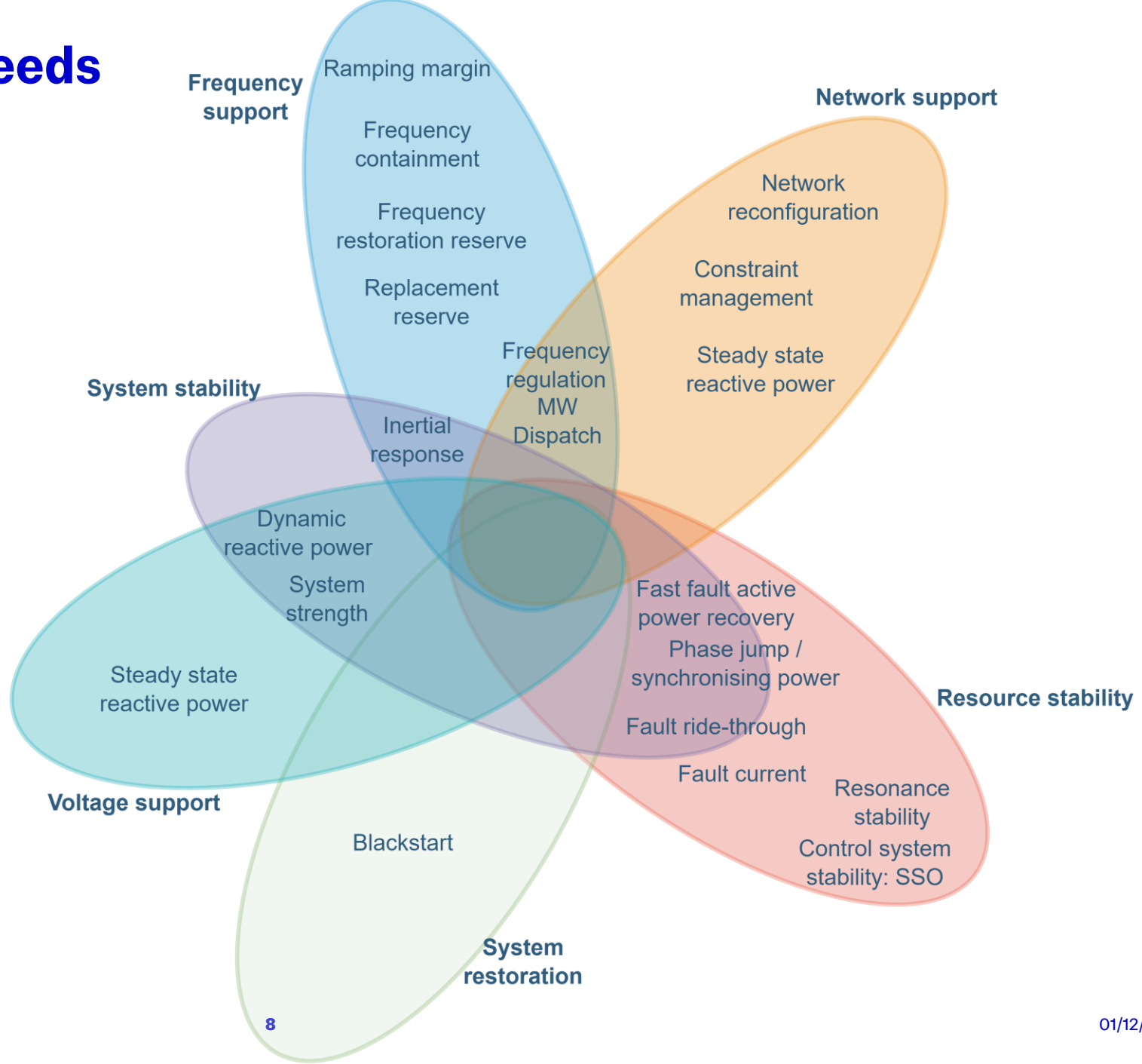
Physics

Classification of System Needs

By operational areas

Core to the overall gaps in power system operation from the system operator point of view

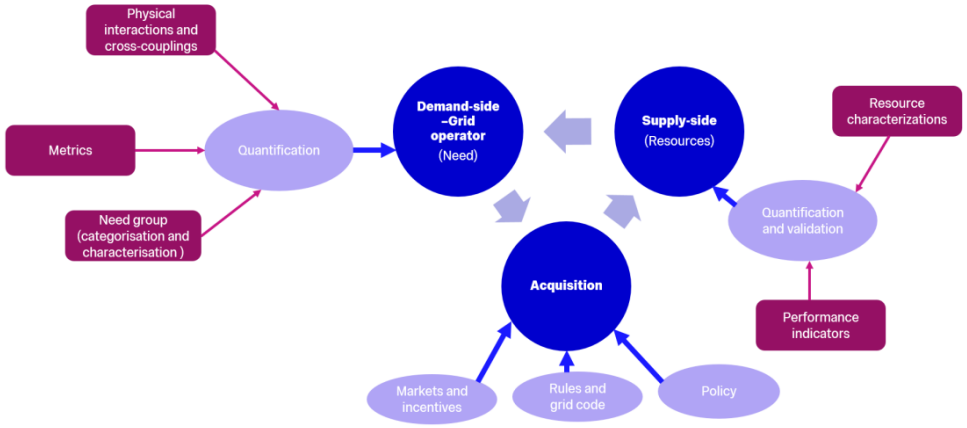


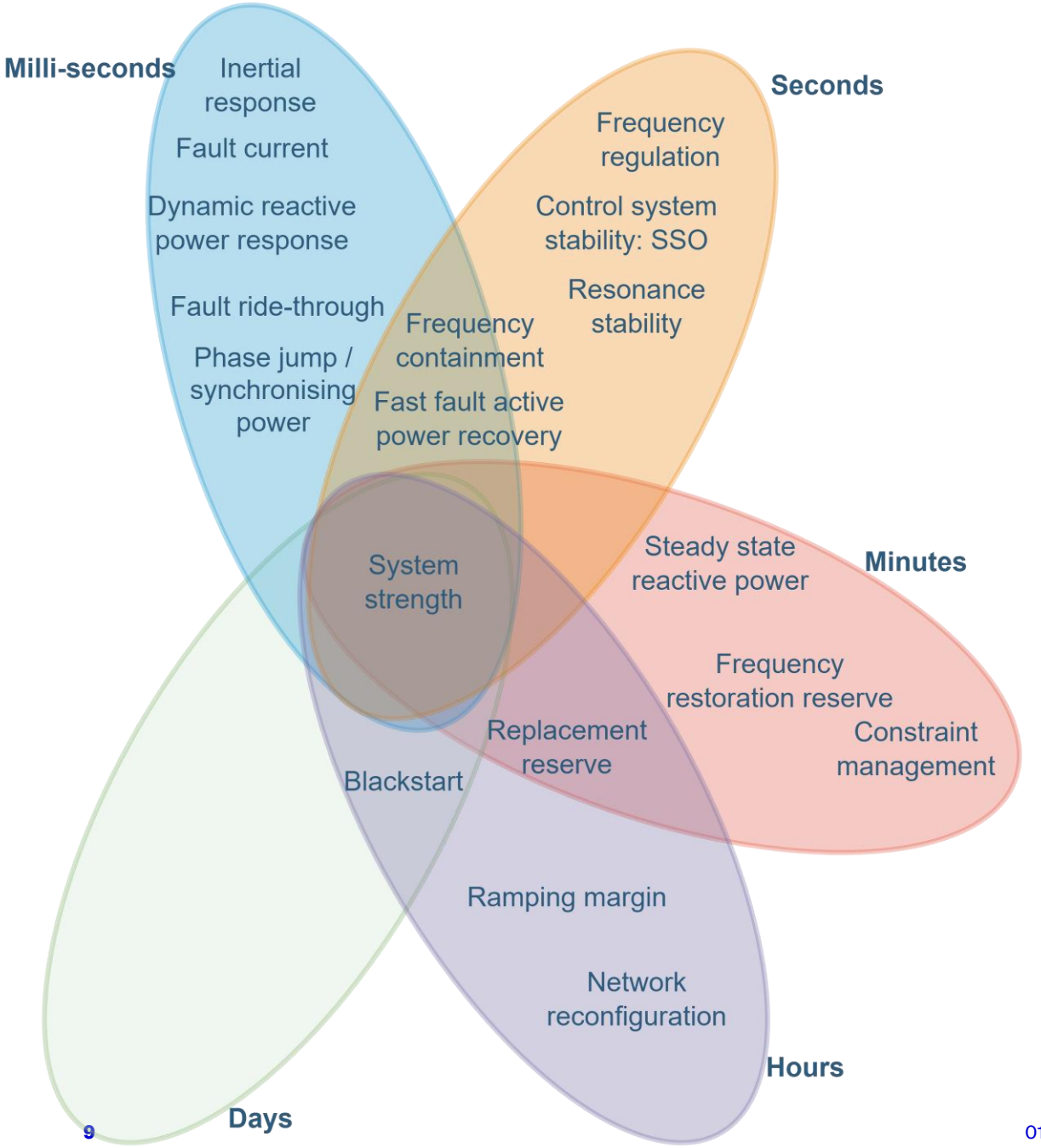


Classification of System Needs

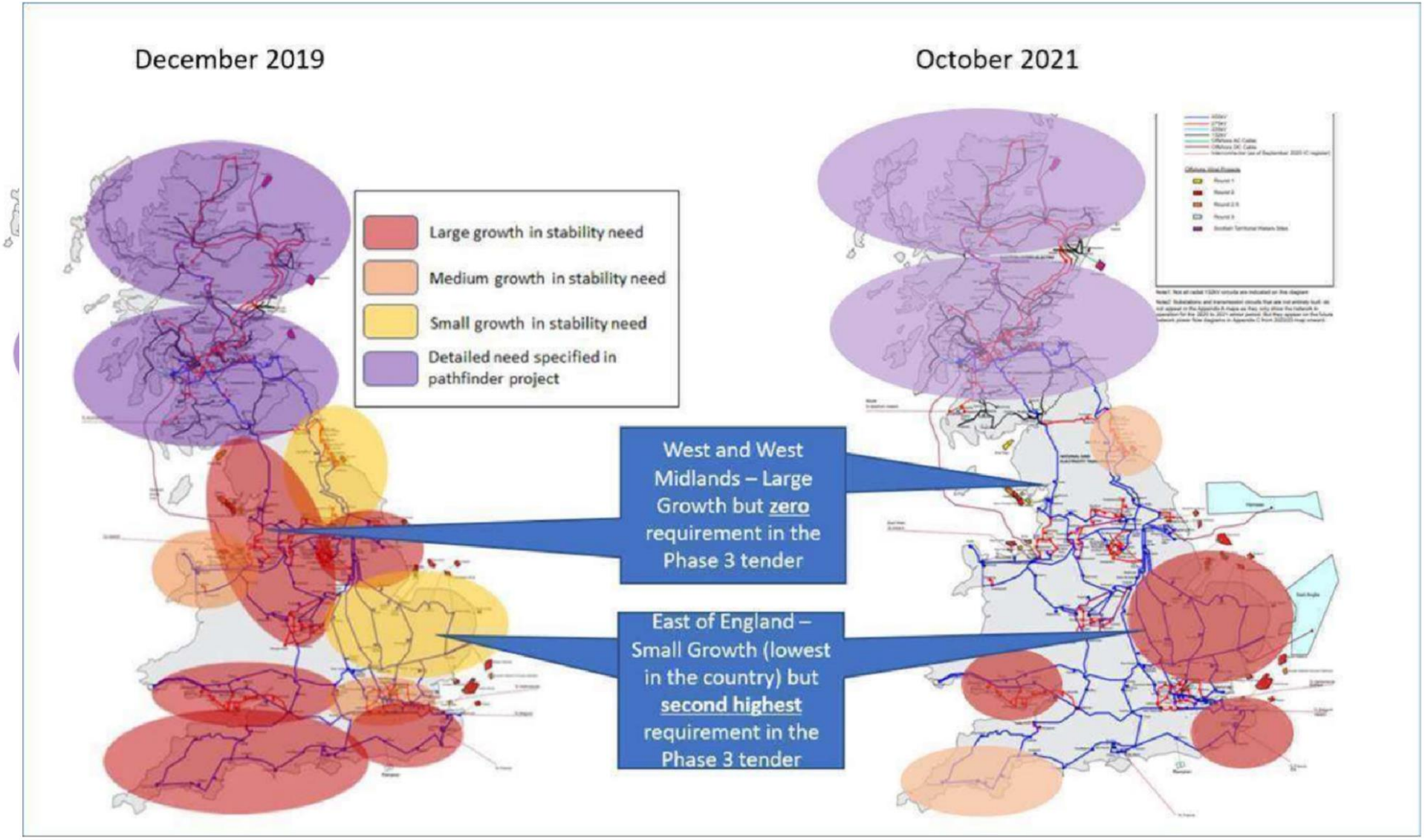
By delivery timeframe

Vital for analysing the dynamic evolution of services requirements during various operational events





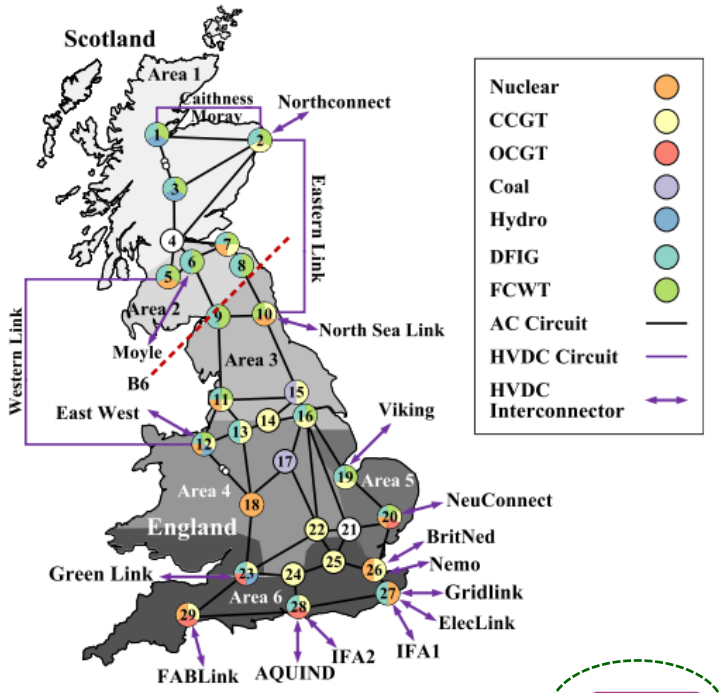
Dynamic Evolution in the UK stability needs

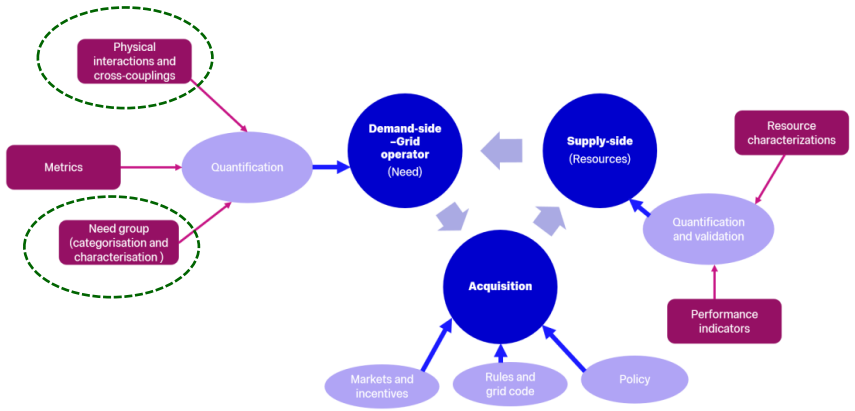


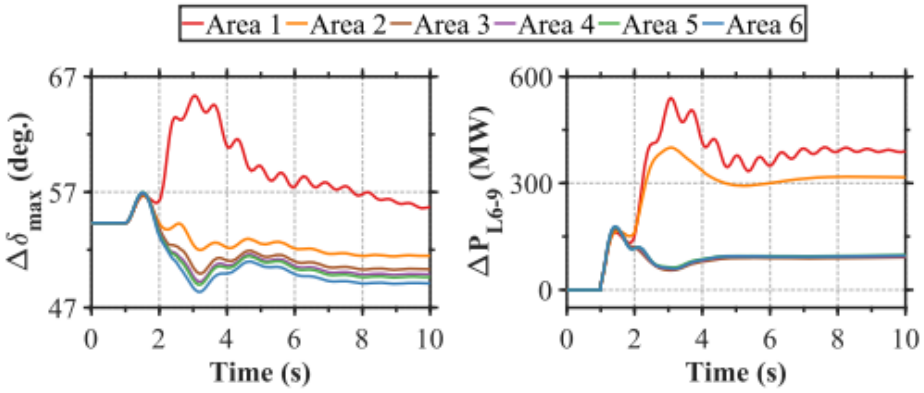
Source: https://www.ofgem.gov.uk/sites/default/files/2021-12/Statkraft%20part%201.pdf

Impact of FFR services on angular stability

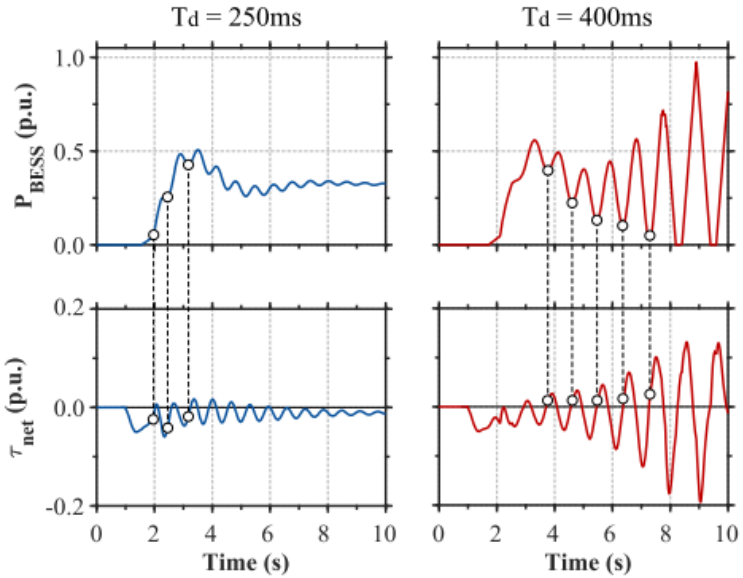
Effect of power deficit location, FFR placement, and FFR delay on the time evolution of angle divergence and power transfer between areas







Locational impact of power deficit and Dynamic Containment.



Oscillatory rotor swings introduced by Dynamic Containment.

Source: "Effects of inertia distribution on regional frequency heterogeneity": https://www.sciencedirect.com/science/article/pii/S0378779624002281

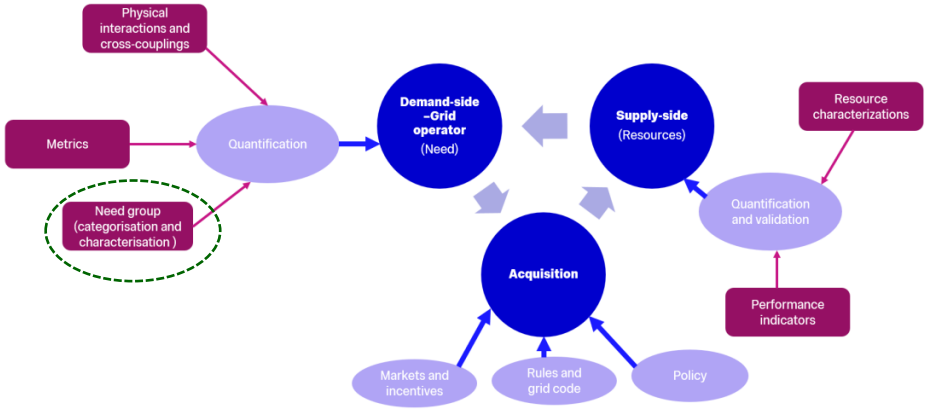
Impact of inertia distribution on frequency heterogeneity

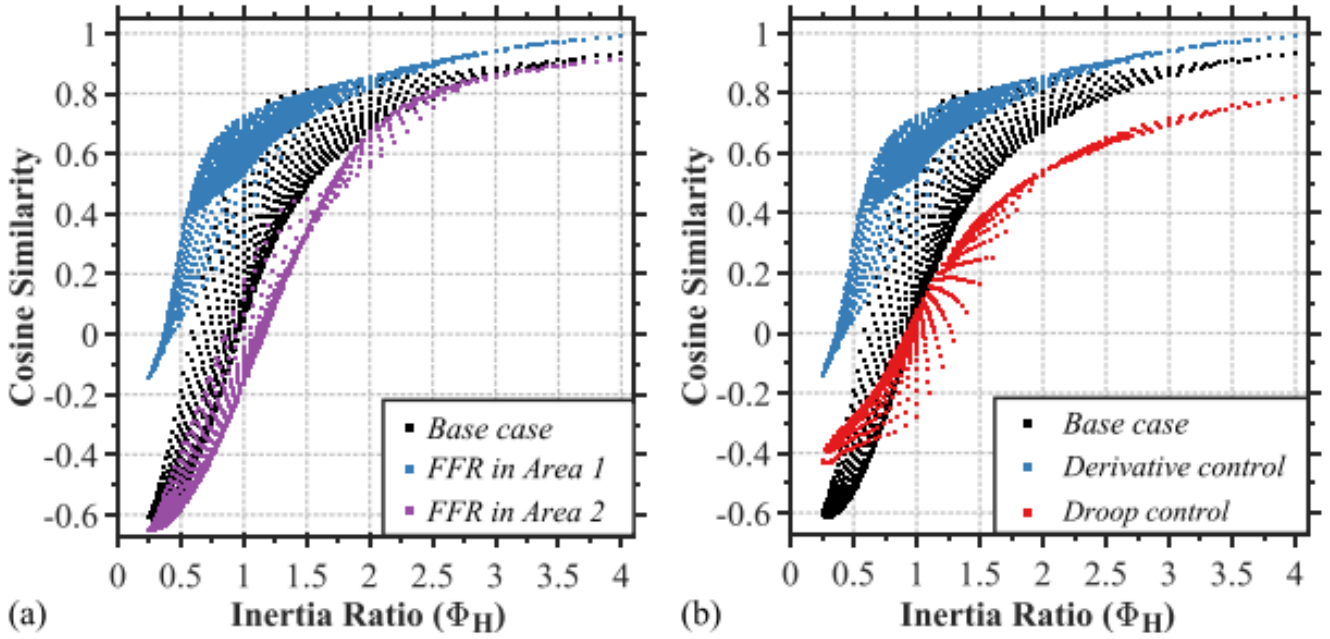
FFR and inertia

Impact of inertia distribution on frequency heterogeneity during an underfrequency disturbance event

- Disturbance in Area 1

- Increasing the quantity of inertial energy within the disturbance area is advantageous and improves the system performance.
- Conversely, providing the synthetic inertia services within the non-disturbance area would risk the system stability





Impact of FFR: (a) derivative scheme impacts on frequency heterogeneity; (b) comparison between different FFR schemes on alleviating frequency heterogeneity.

Z. Zhang and R. Preece, "Effects of inertia distribution on regional frequency heterogeneity," *13th Mediterranean Conference on Power Generation, Transmission, Distribution and Energy Conversion (MEDPOWER 2022)*, Hybrid Conference, Valletta, Malta, 2022, pp. 29-34, doi: 10.1049/icp.2022.3299.

Impacts of active and reactive power interactions on a planning timescale

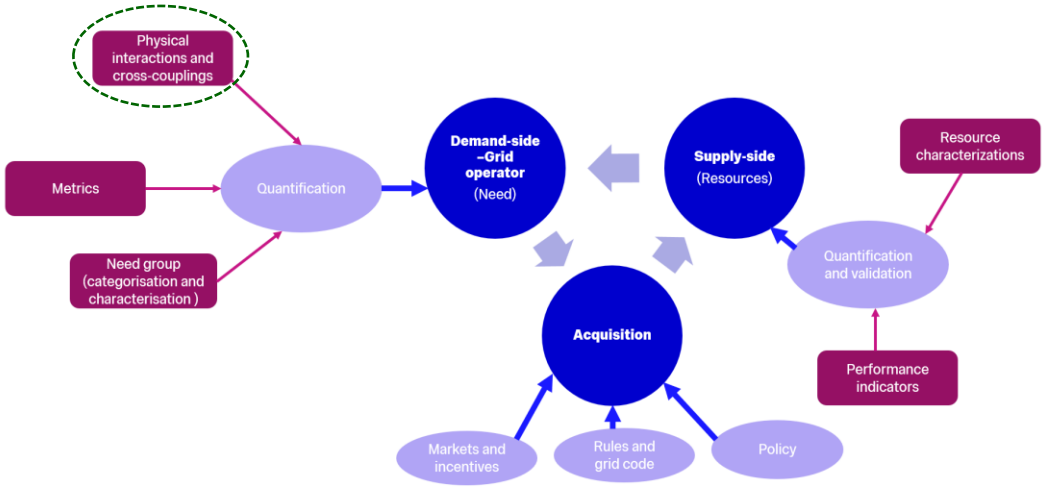
Market clearing impacts

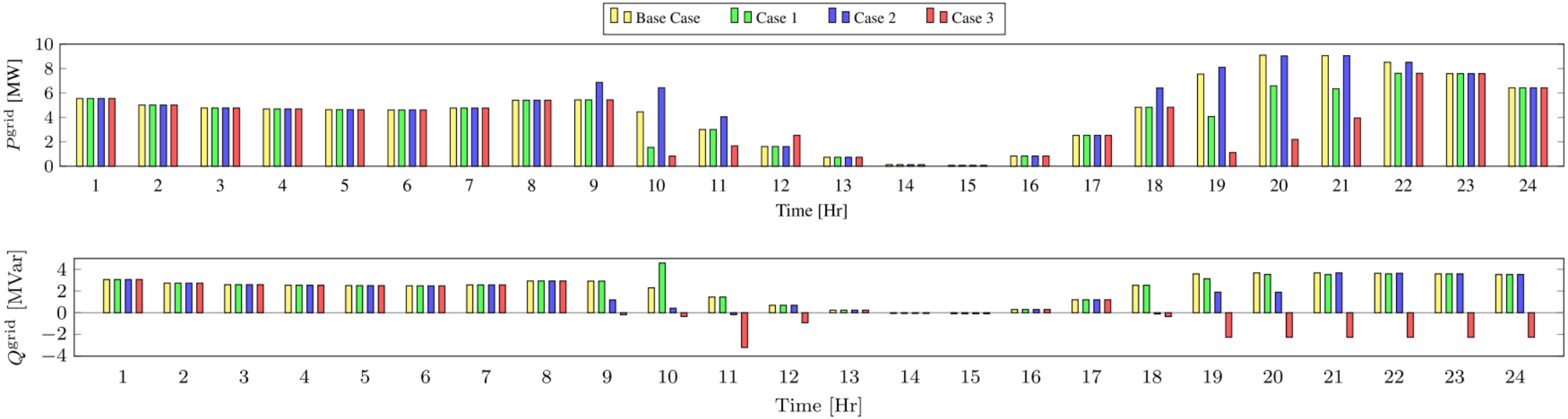
Base case: No transient security constraints. Only MG static islanding constraints

Case 1: The constraints of the Base case plus transient frequency security constraints

Case 2: The constraints of the Base case plus transient voltage security constraints

Case 3: The constraints of the Base case plus both transient frequency and voltage security constraints.





Quantifying system services: Coupling Effects in Service Delivery

How does the heterogeneous distribution of service provision affect the fulfilment of power system's needs?

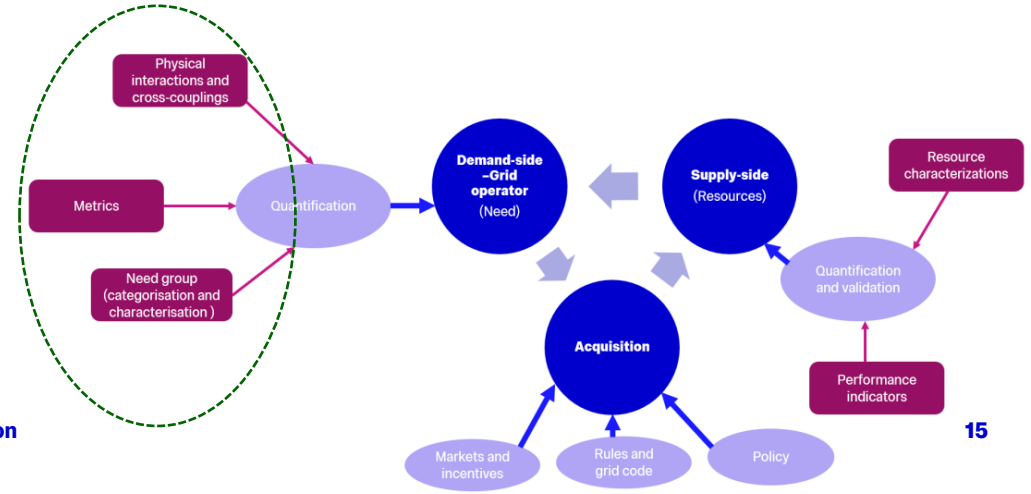
How can we account for the existing couplings to ensure reliable quantification and provision of system services?

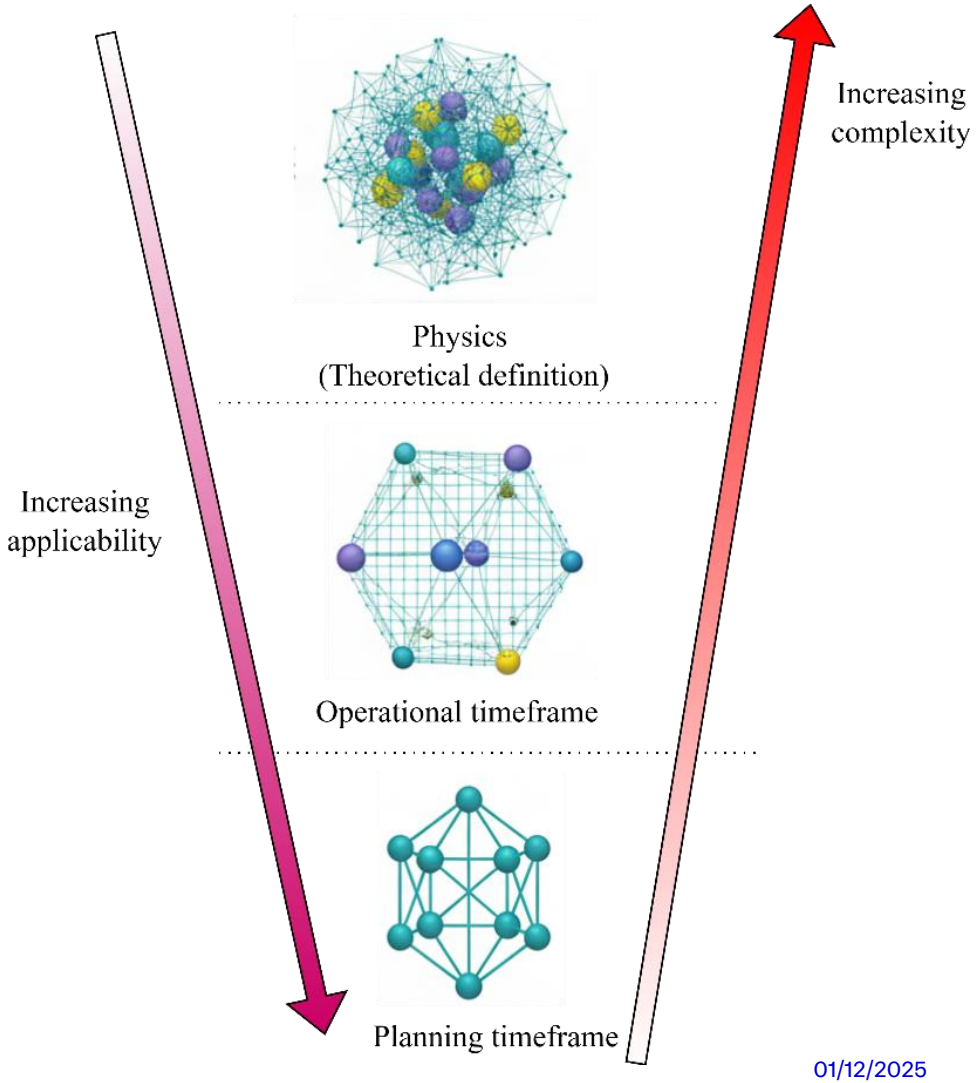
- Dimensionality of system services
- Physical couplings in different stability groups

Quantifying system services: Interactions and Metrics

How can we improve system metrics to aid in the quantification and optimisation of service provision?

- What constitutes appropriate metrics for effectively quantifying power system services across the planning and operational timeframes?
- How can these metrics be formulated to maintain conceptual simplicity while rigorously reflecting the system's underlying physical dynamics particularly within operational timeframes?
- How can the physical characterisation of these services be translated into actionable requirements for market design and or grid code compliance?





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Thank you

Presentation Title
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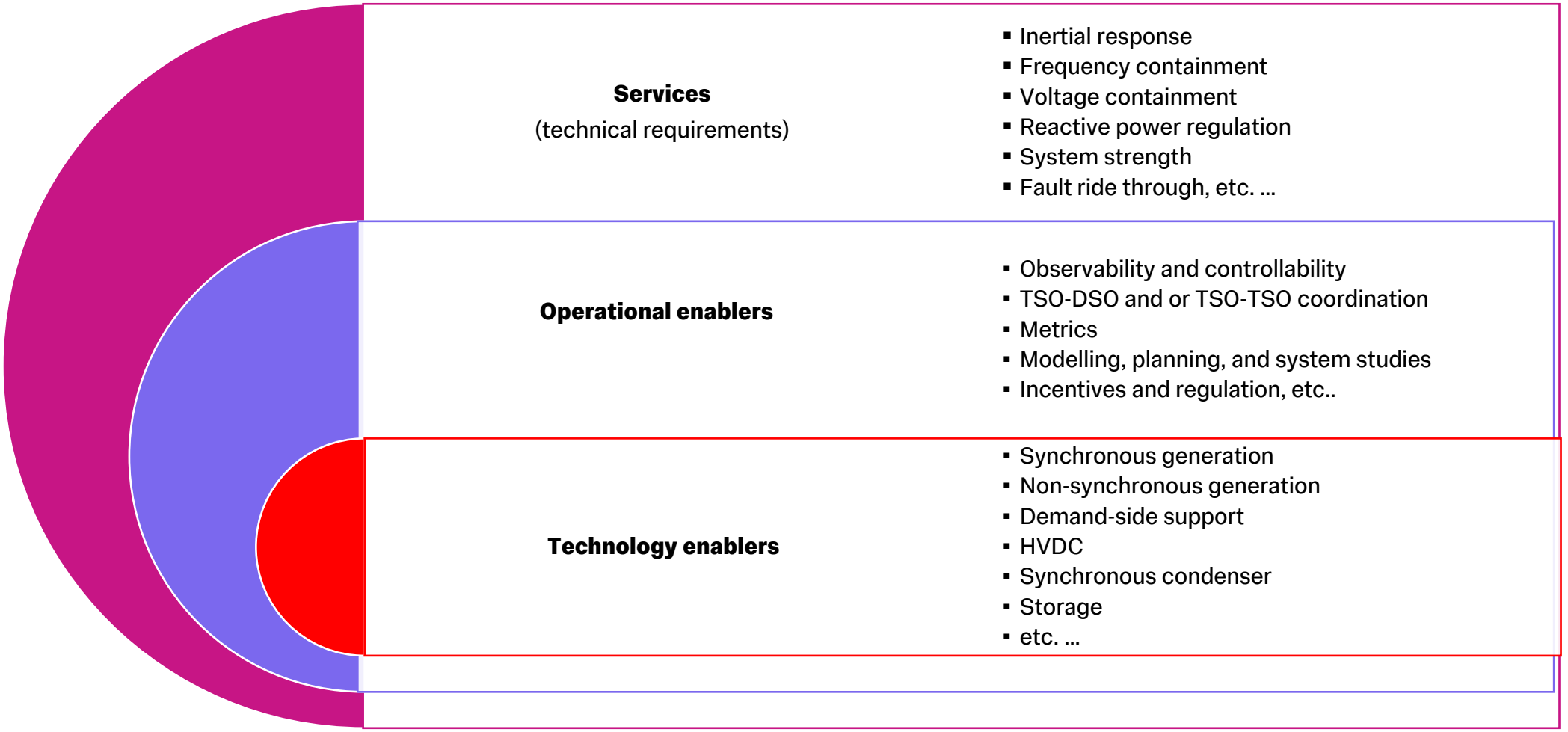
Framework for System Services Study

How do services evolve?

- **Behavioural changes** = Changes in dynamic and steady state characteristics of the system
- **Support gaps** = Lack of voltage and frequency support
- How do we ensure there exists sufficient capability in the system to satisfy these gaps as the power system evolves?

Services

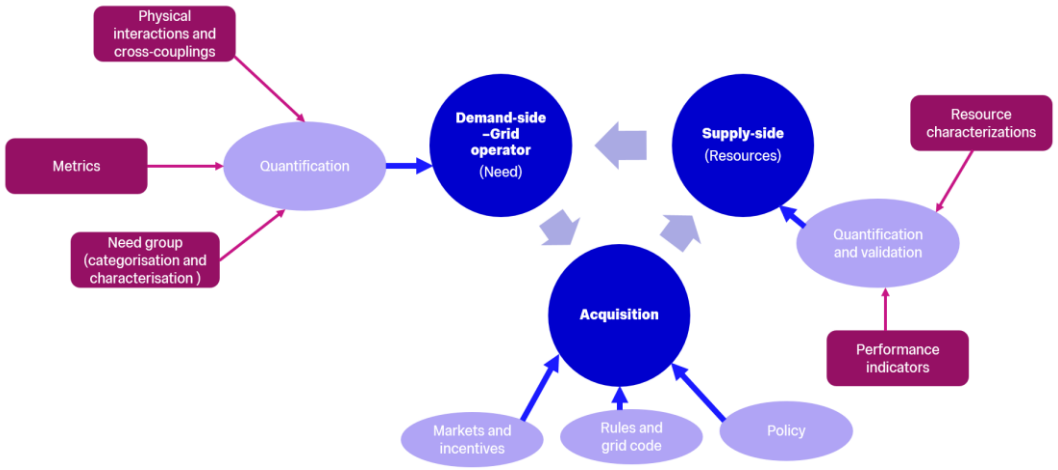
Ecosystem of system services

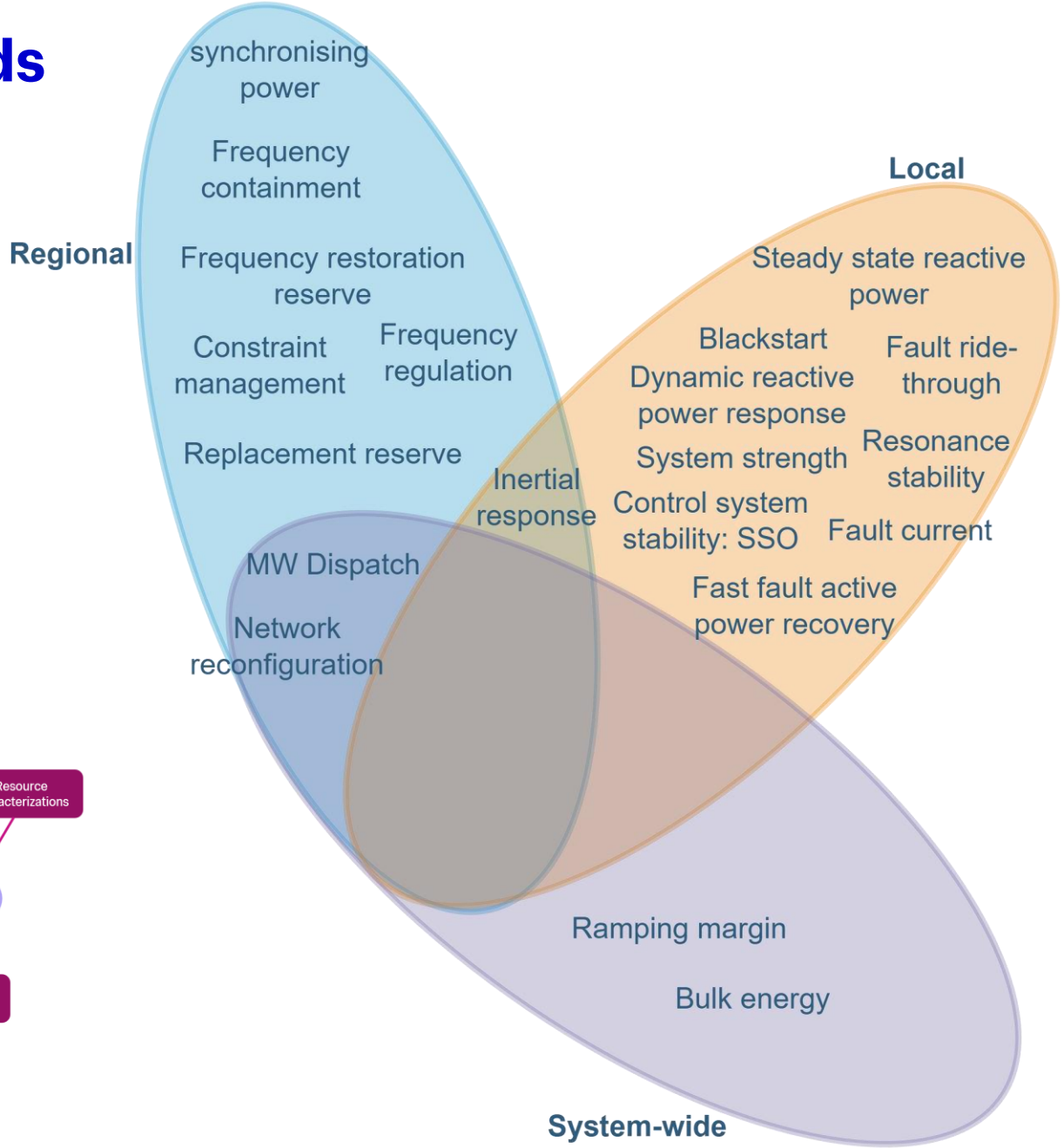


Classification of System Needs

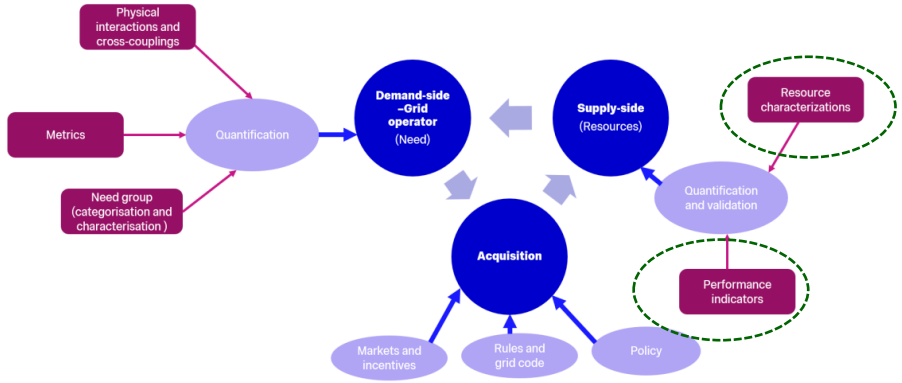
By spatial need

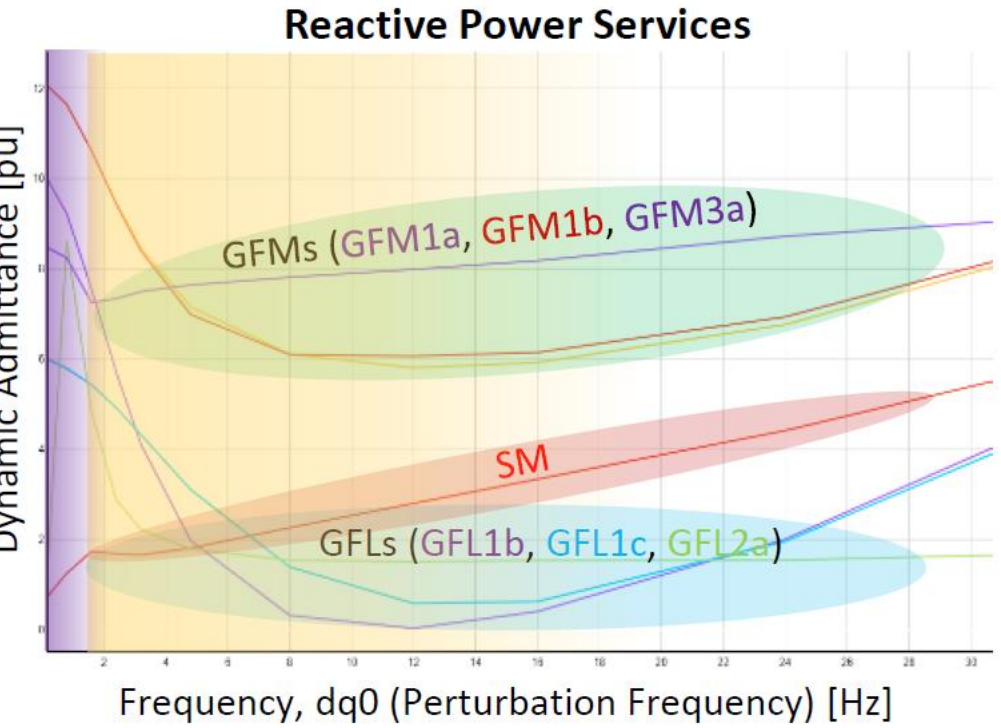
Accounts for the influence of technology mix, technology siting, and the resulting interdependencies between services

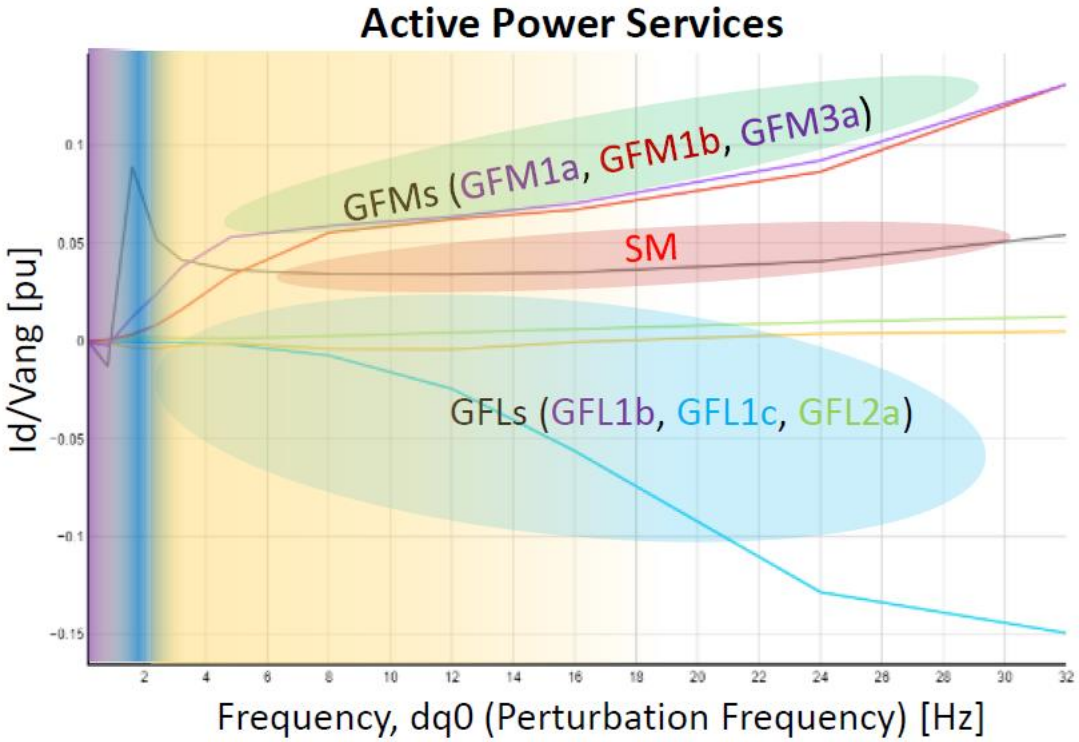




Resource Characterisation







Source : https://www.esig.energy/event/webinar-grid-stability-services/