Grid Stability Services:

A Framework for Quantifying Supply and Demand of Grid Stability Services

Matthew Richwine Nicholas Miller Deepak Ramasubramanian

ESIG Webinar - April 16, 2024

Agenda

- Why are we talking about this?
- Recent Progress around the World - Stability Services & Markets
- Elements of this Framework
- Next Steps for Demonstration

Key Questions for Grid Stability Services

What services do we need?

It's more than just inertia…

How much?

What are the units? How do different grid conditions change it?

How fast?

Fast and slow and sustained, it's all needed.

Where?

Location matters… more for some services than others.

There has been substantial progress in the industry here

Our work is focused on quantifying services

- Generalized
- Technology agnostic
- Repeatable

ESIG Services TF: Categories of Services from IBRs

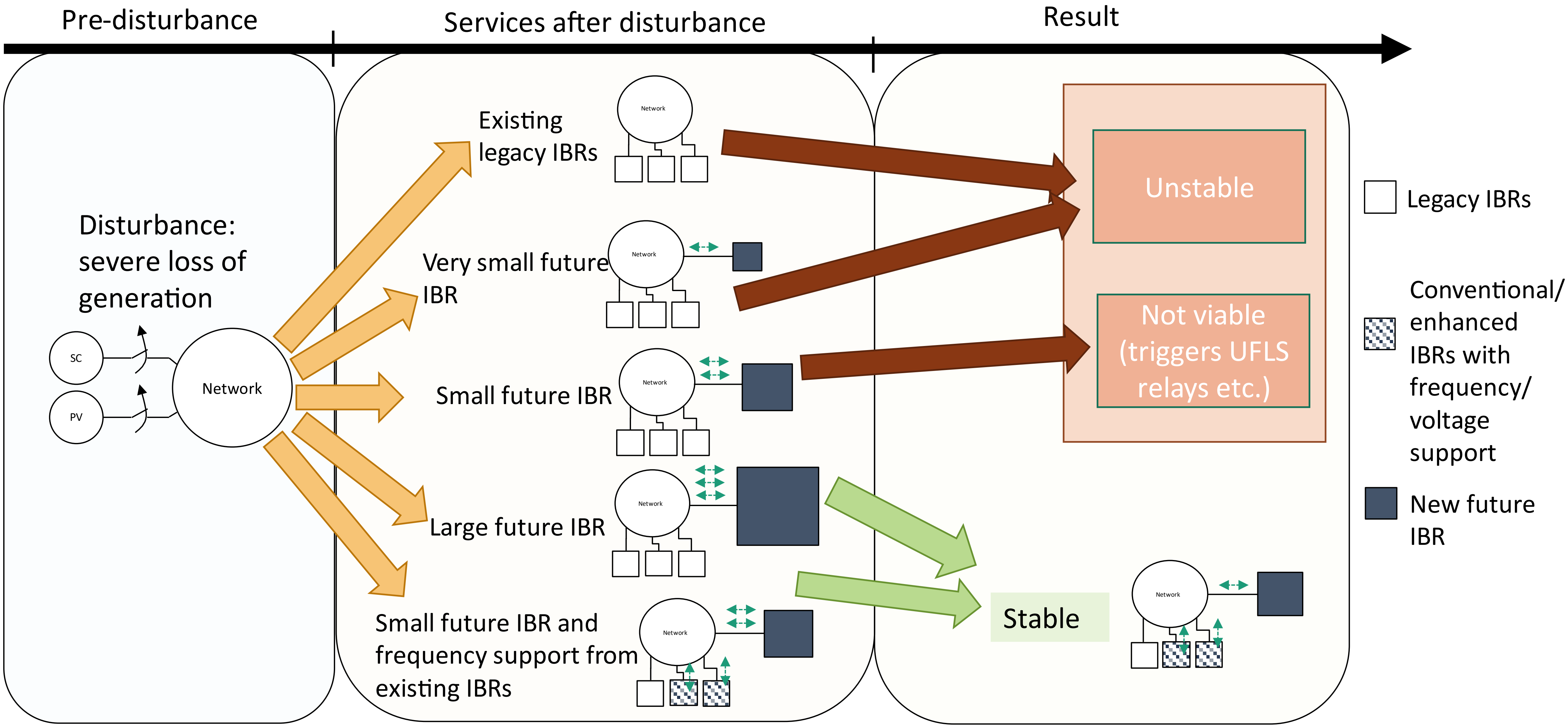
Need of network	Table from [1] **Service that IBR can provide**
Synchronization	Synchronization torque/phase jump mitigation
	First swing mitigation
	Phase jump ride-through
	PLL Stability Support
Frequency Control	Frequency containment
	Inertial response/limiting RoCoF
	Frequency stabilization
	Frequency recovery
Voltage control	Voltage containment
	Mitigate voltage collapse
	Fault ride-through
	Mitigate unbalance and harmonics
Damping	Damp sub-synchronous oscillations (SSO)
	Damp super-synchronous oscillations
Protection	Detect and locate faults
Restoration	Black start
	Cold load pick up
	Island operation

Points to note:

- Need to identify situations where the service is important/can be tested
- Not every service is required at all points in time

[1] B. Chaudhuri, D. Ramasubramanian, J. Matevosyan, M. O'Malley, N. Miller, T. Green and X. Zhou, "Rebalancing Needs and Services for Future Grids: System Needs and Service Provisions With Increasing Shares of Inverter-Based Resources," in IEEE Power and Energy Magazine, vol. 22, no. 2, pp. 30-41, March-April 2024

ESIG Services TF: Key Observations So Far



Efforts Around the World

- Evolution of system needs is driving a variety of efforts in grids around the world
- For example,UK Pathfinder, AEMO, Eirgrid and ERCOT have newly defined services, with varying temporal and locational targets
- This effort is intended to provide a framework to help define and clarify those targets

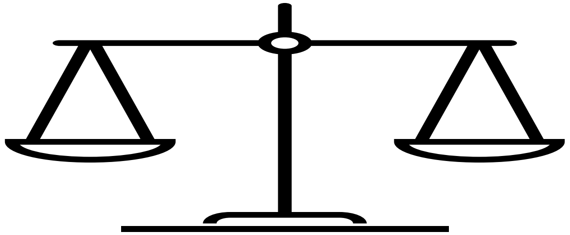
		UK	AEMO	EirGrid	ERCOT
Inertia	**Approx. Timeframe**	-	-	-	-
	Locational?	System-wide	System-wide	System-wide	System-wide Monitoring
Short Circuit Level	**Approx. Timeframe**	-	-	-	Regional
	Locational?	Regional	Regional	Regional	Regional
Active Power	**Approx. Timeframe**	~0.5 s	~1 s	~250ms	0.5s
	Locational?	-	-	-	-
Reactive Power	**Approx. Timeframe**	Pre- / post-fault steady state	-	~40ms	P2800 considered
	Locational?	Nodal	Nodal (case-by-case)	Nodal	Nodal

Grid Stability Services

A Framework for Quantifying Services

Stability Services Framework Overview

Supply
(Resources + Transmission)



Demand
+
Acceptance Criteria

Power Type	Timeframe	Location	Operations
Active	Fastest (cycles)	Local/Regional	Headroom
Reactive	Medium/Slow (seconds)	Network-Wide	Dispatch, Line loading

What’s Not in Scope

System Restoration

- Sometimes shown as a “black-start” service
- System restoration is far more complex than just having black-start resources

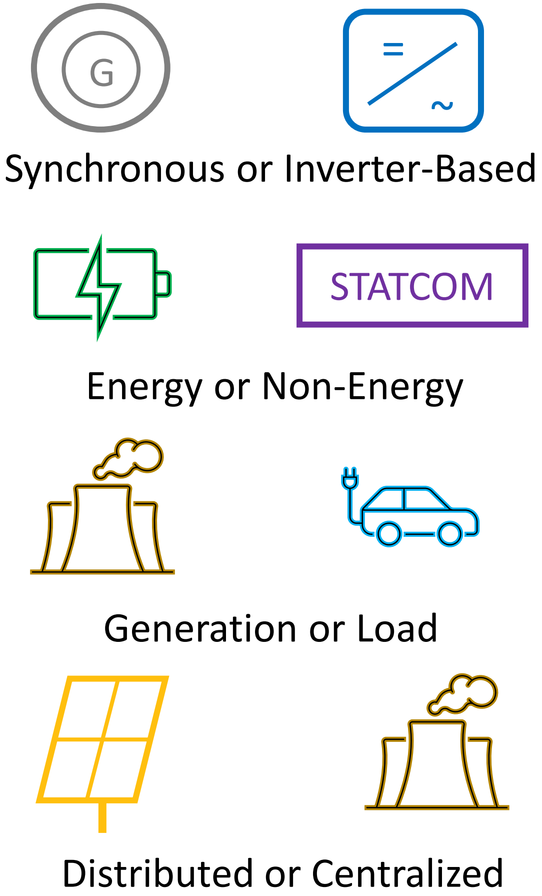
Protection

- Sometimes reflected as a service for “short-circuit current/level”
- Highly dependent on the protection scheme, communications, etc.
- Some protection schemes may pose a demand for certain other services like fault current, zero or negative-sequence current, but we’re not tackling this here

What Can Provide These Stability Services?

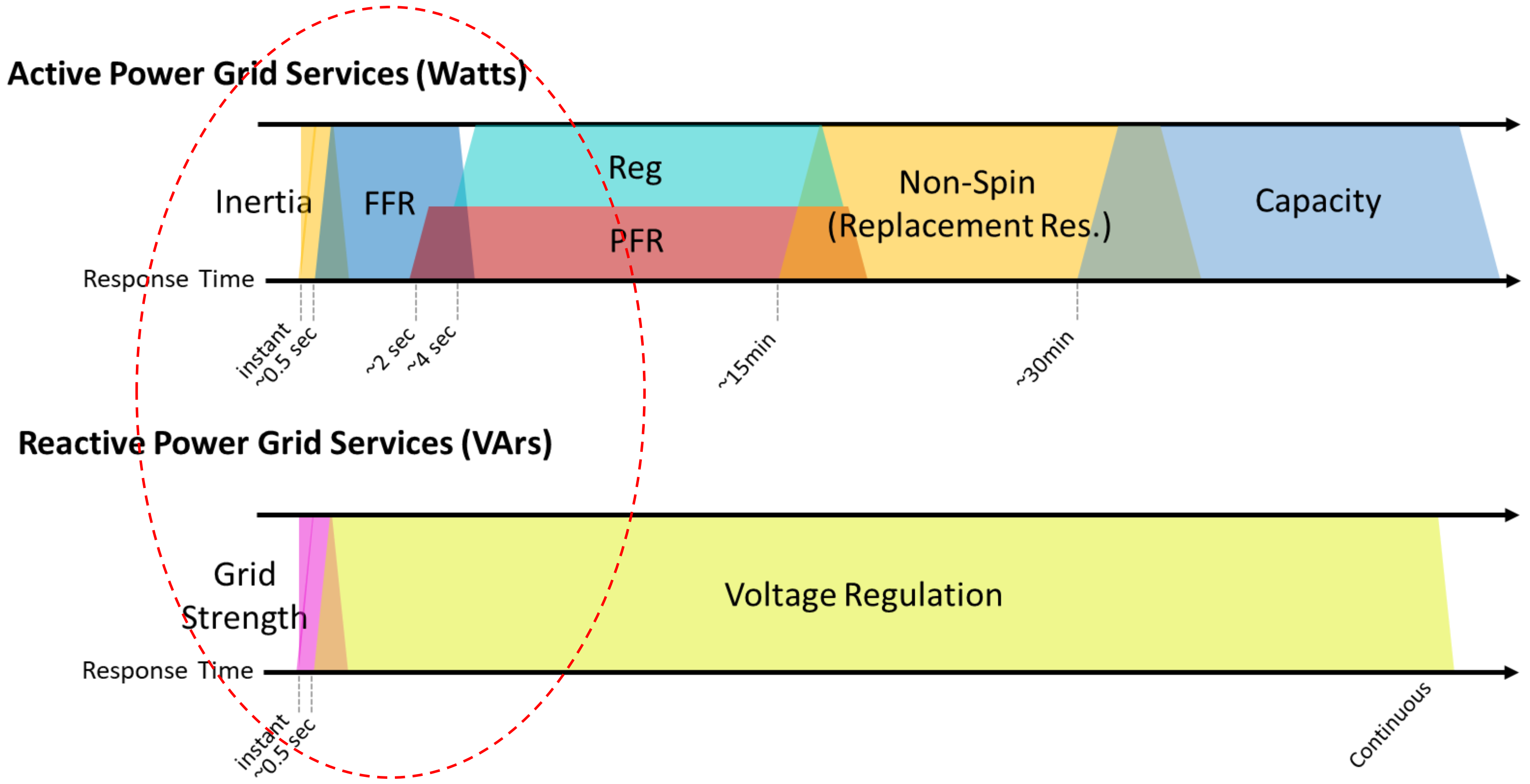
Resources, Direct Impact to Services

- All resources may provide one or more of the services
- The services rendered depend on the resource's characteristics & operating condition



Transmission, Indirect Impact to Services
Can "move/deliver" services to different locations

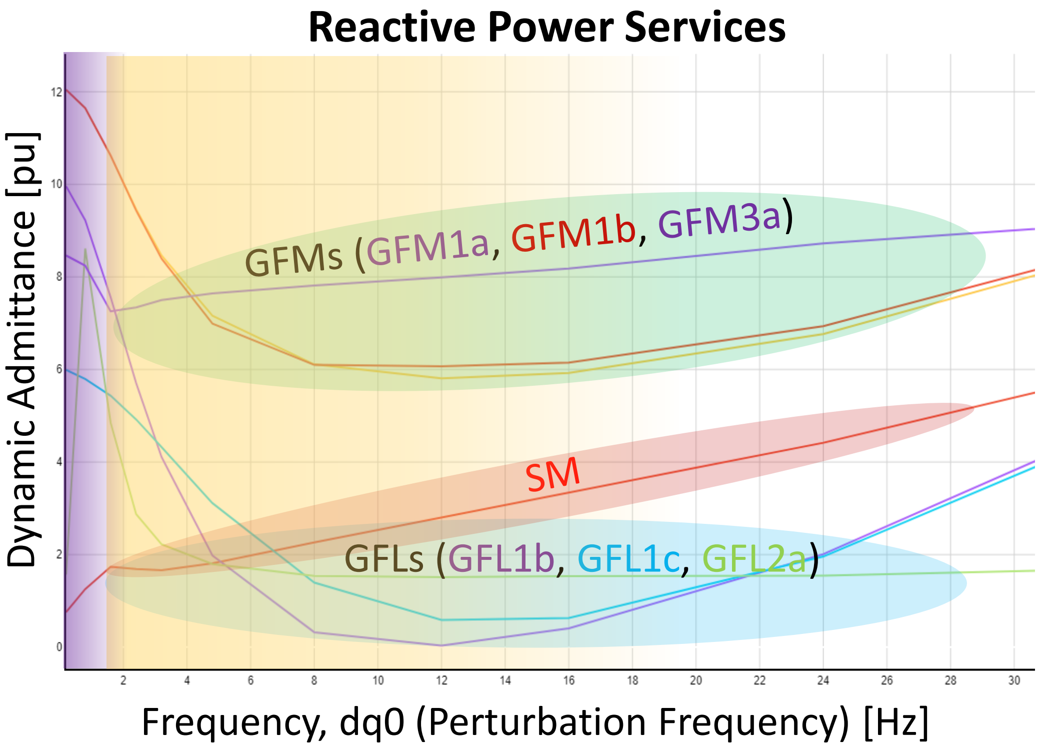
Power Type & Timeframe

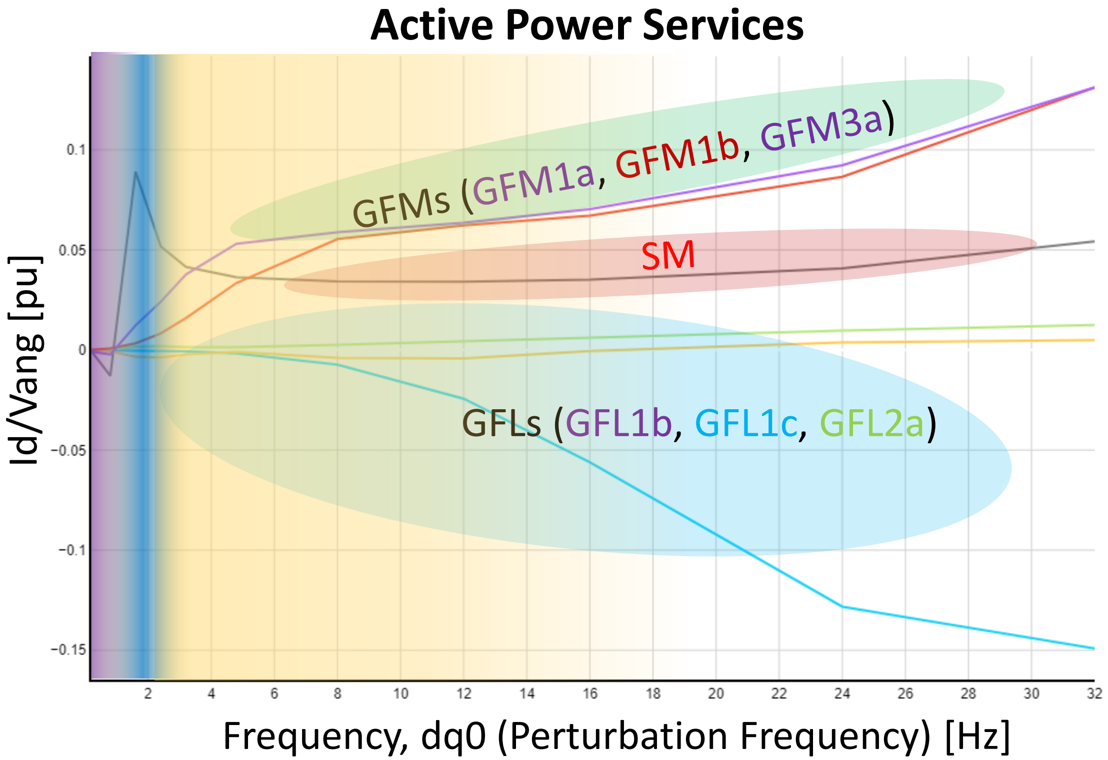


Our stability work will focus on the services in the shorter time frames

Timeframe: Assessing Performance of Resources

Slower (Plant Voltage Regulation) Services | Fast ("FFR") Services | Fastest Services "Inertia" or "Grid Strength"





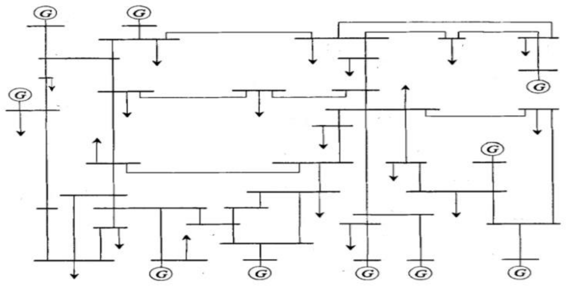
Apply Frequency-Scan Methods to Consistently Assess Responses and Timeframes in a Technology Agnostic Manner

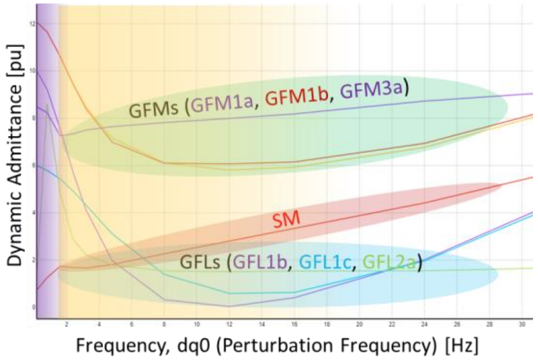
Location: Defining Grouped Regions

- Areas and zones from today's powerflow models are based on ownership/control regions
- It does not reflect the underlying fundamentals of the grid, nor how it is expected to evolve

There are two major physical attributes that guide our regional grouping:

Network connectivity (admittance matrix) AND Resources online & their characteristics





Location: Buoy v. Breakwall Resources

"Buoy" Resources

- Resources with little provision of stability services, particularly in the fastest timeframes
- i.e., GFL resources, small resources, resources with little/no headroom

https://www.pexels.com/photo/green-bouy-on-ocean-2350584/

"Breakwall" Resources

- Resources with large provisions of stability services, particularly in the fastest timeframes
- i.e., Large SM & GFM resources with headroom

https://www.pexels.com/photo/stone-wave-breaker-on-sea-shore-5113384/

Location: Grouping

Objectives

- Identify regions of the grid that “hang together”
- Identify important interfaces between groups/clusters

Use of Groupings

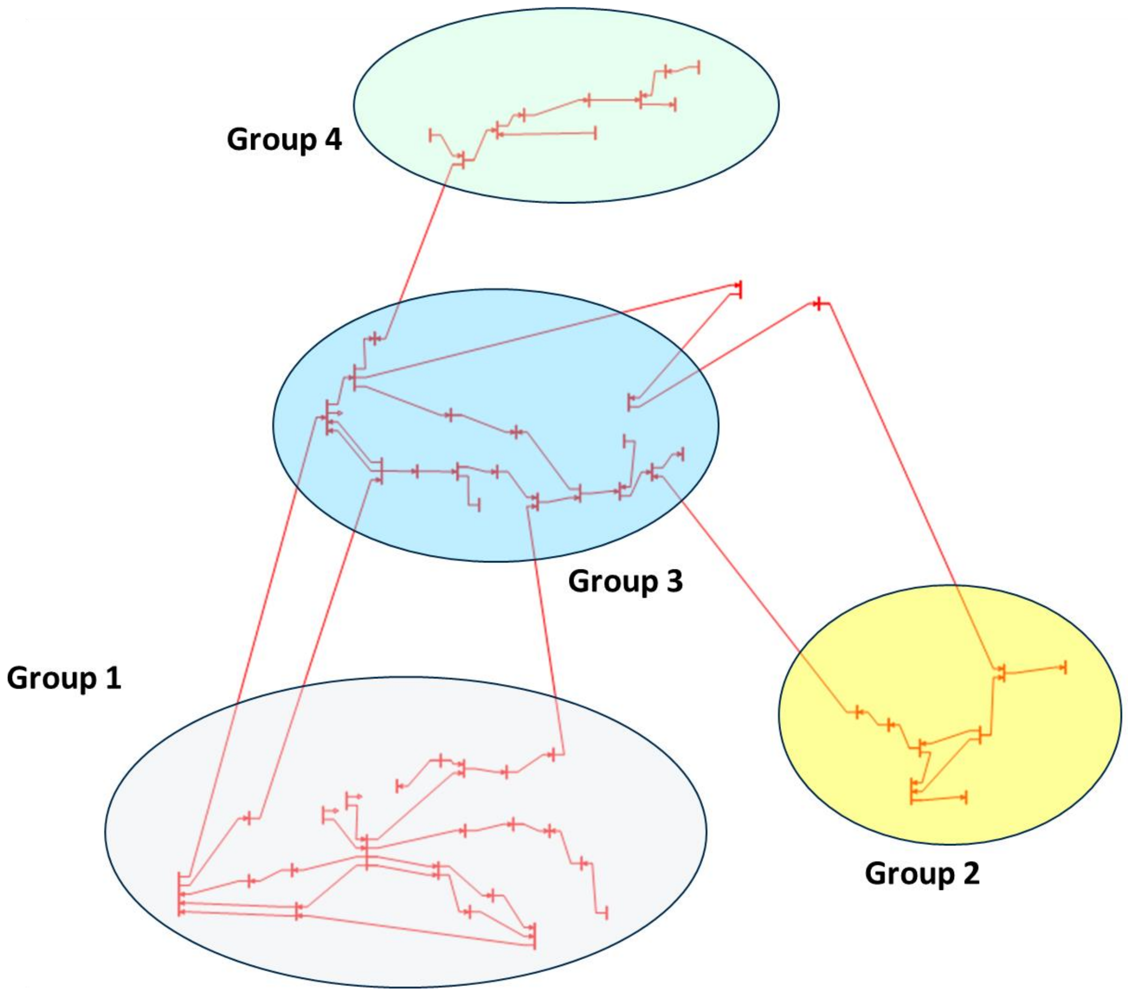
- Supply of services will be summed for all resources in a grouping
- Demand for services will be determined by largest contingencies within a group

Basis

- Grouped using “interaction factor” (ratio of the change in bus voltage of one bus to another)
- Hierarchical clustering algorithm is used
- Enables quantifying the coupling within a group AND the coupling between groups

Important Note

- This does NOT mean that each group needs to satisfy all its needs
- Exchange of services between/among groups is critical



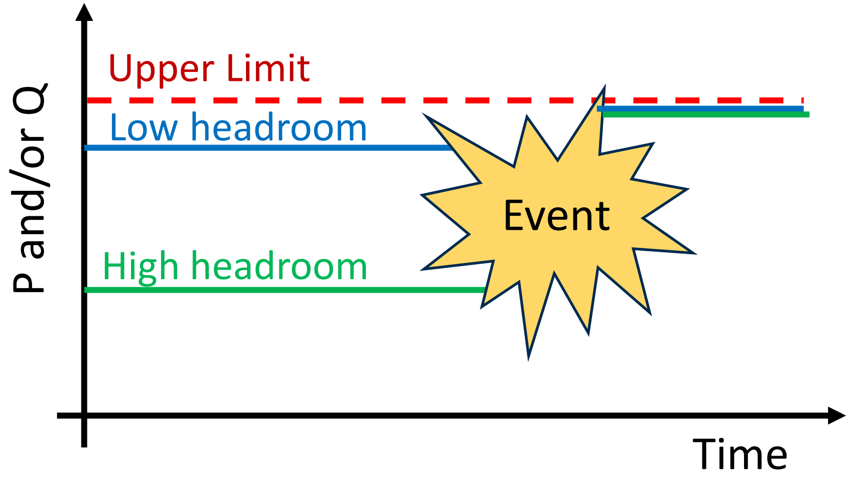
Operations: Grid Condition-Dependency

Supply-Side: Headroom constraints

- Margin to Active Power Limits – some resources may allow temporary violations
- Margin to Reactive Power Limits – some resources may allow temporary violations or trade-off active power

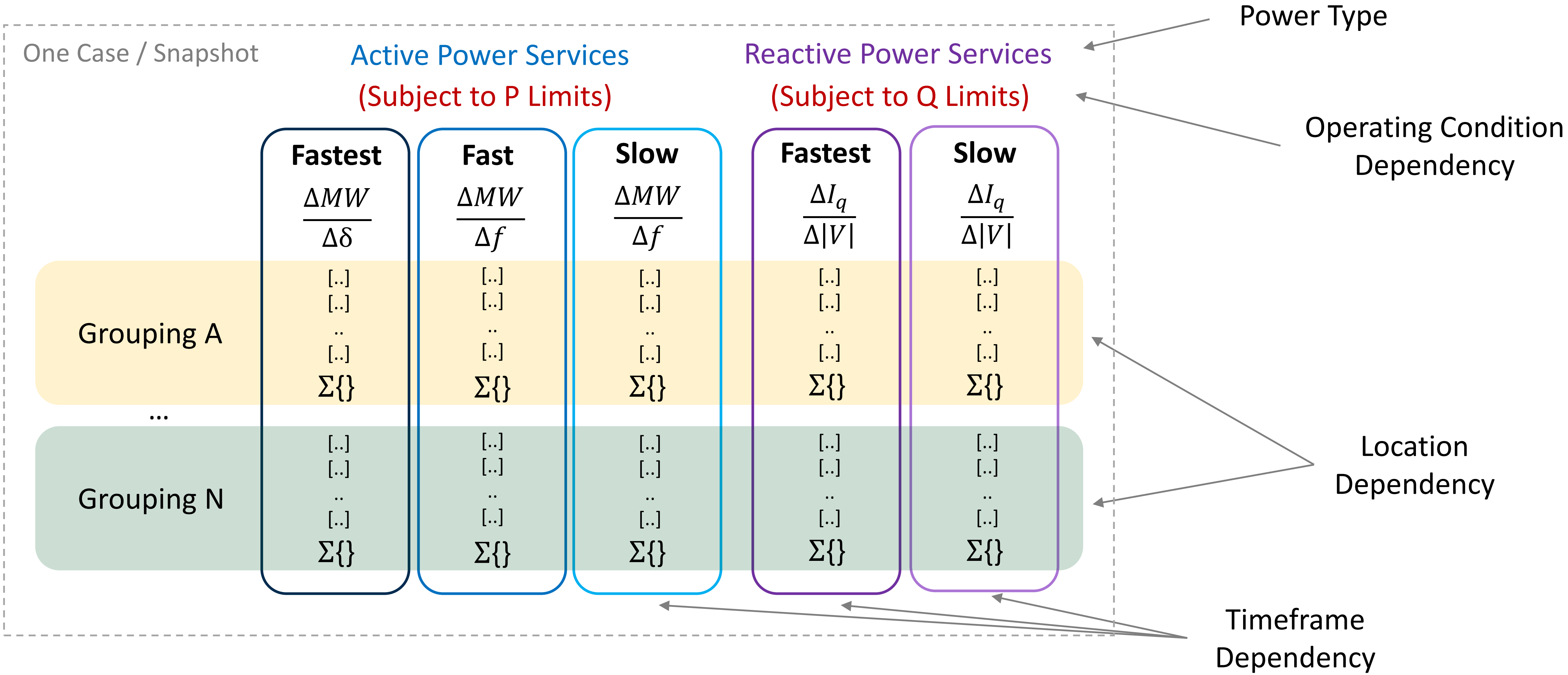
Demand-Side: Contingency Size

- Generation Dispatch – Higher dispatch results in a larger P-loss event
- Transmission Line Loading – High loading results in higher Q (I^2X) losses post-event

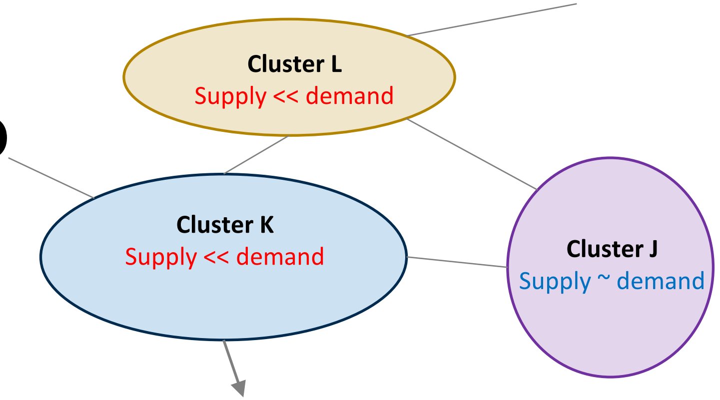


Bringing it Together, Supply Side

4 Pillars of Framework Covered



How Would the Framework be Used?



Summary of service deficits for scenarios

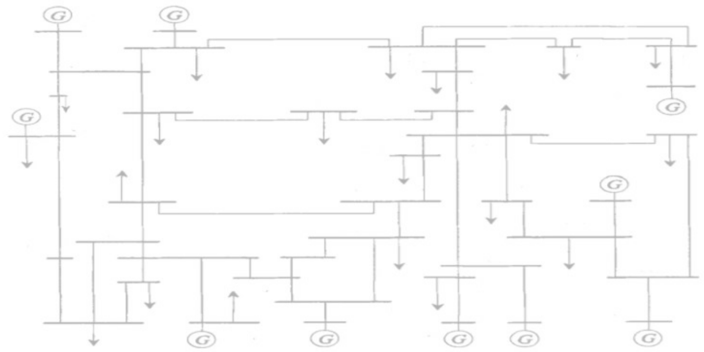
	Active Power Stability Services	Reactive Power Stability Services
Study Cases	No. Clusters with Deficiencies	No. Clusters with Deficiencies
SUM 2023	0	0
WIN 2023	0	0
SSH 2023	0	0
SML 2023	0	0
SUM 2024	0	0
WIN 2024	0	0
SSH 2024	0	0
SML 2024	0	0
SUM 2028	0	0
WIN 2028	0	14
SSH 2028	12	28
SML 2028	27	44
SUM 2033	0	7
WIN 2033	36	67

Details by Location & Service

Cluster Region	Active Power Stability Services						Reactive Power Stability Services			
	Fastest (Sup.)	Fastest (Dem.)	Fast (Sup.)	Fast (Dem.)	Slow (Sup.)	Slow (Dem.)	Fastest (Sup.)	Fastest (Dem.)	Slow (Sup.)	Slow (Dem.)
A	5937	2820	2969	1320	7718	3772	1294	891	2806	2672
B	4859	2820	2430	1320	6317	3632	958	729	2414	2187
C	3475	2820	1738	1320	4518	3452	579	521	1578	1564
D	3276	2820	1638	1320	4259	3426	530	491	1796	1474
E	5739	2820	2870	1320	7461	3746	1230	861	2735	2583
F	4632	2820	2316	1320	6022	3602	892	695	2329	2084
G	3330	2820	1665	1320	4329	3433	544	500	1818	1499
H	3168	2820	1584	1320	4118	3412	504	475	1552	1426
I	5595	2650	2798	1240	7274	3727	1184	839	2684	2518
J	4732	2650	2366	1240	6152	3615	921	710	2367	2129
K	2783	2650	1392	1240	3618	3362	415	417	1389	1252
L	2674	2650	1337	1240	3476	3348	391	401	1403	1203
M	4540	2650	2270	1240	5902	3590	865	681	2294	2043
N	2543	2650	1272	1240	3306	3331	363	381	1302	1144

Take Inventory of Grid Stability Services

Next: Demonstration of the Method



The primary purpose is to exercise the framework, not to perform a specific study

Desired attributes include:

- Real system, not fictitious
- Large enough to have real scale
- Not so large as to make it difficult to manage (avoid diminishing returns)

Candidates:

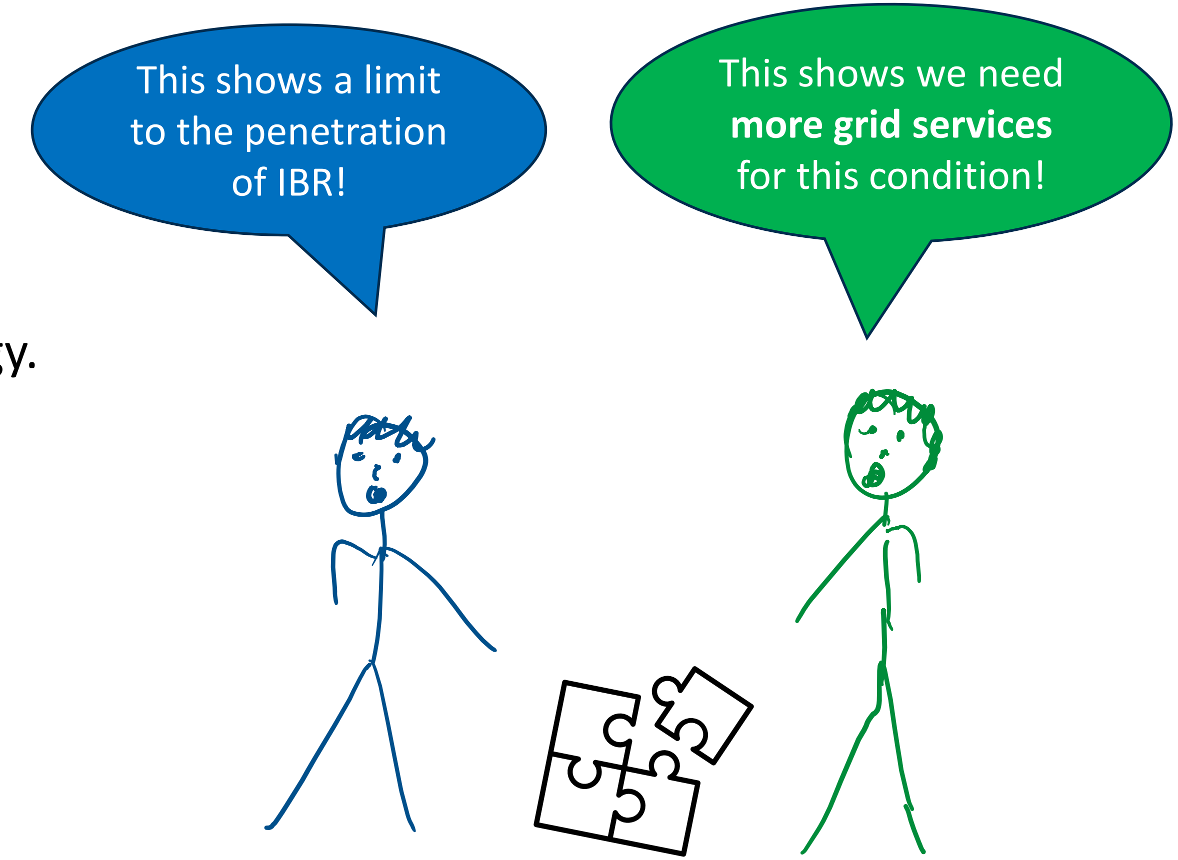
- Large system in the continental US with high and increasing levels of IBR

Major Scenarios for Demonstration:

1. **A "today" scenario:** This is primarily to establish a **reference** for a familiar, working grid.
2. A **near-term high-penetration scenario:** (50%-75% by MW in the region)
3. A **medium-term very-high penetration scenario:** (75%-100%, near-exclusive IBR region, except perhaps for some non-fossil SMs)

→ Layer on sensitivities

A Tweaked Paradigm



It's no longer about "can we get to 100% IBR?" There is no fundamental limit to IBR with currently-available technology.

It is a matter of providing <u>locationally</u> sufficient & timely stability services on any grid to cover all planned operating conditions.

Services should be

- rigorously defined,
- technology-agnostic, and
- systematically quantified.

This framework should be applicable for all grids.

Appropriate Framework → Efficient Analysis → Effective Planning

Thank You! Questions?

Special thanks to our sponsors!

Nick Miller

Nicholas@hickoryledge.com

Matt Richwine

Matthew.Richwine@telos.energy

Deepak Ramasubramanian

dramasubramanian@epri.com