Grid Stability Services: Demonstrating a New Framework on a Large, High IBR System

ESIG Fall Technical Workshop | October 2024

Agenda

- Motivation
- Framework Overview
- Applying & Benchmarking the Framework
- Learnings & Next Steps

Key Questions for Grid Stability Services

Stable Operation at 100% IBR is Possible… What Stability Services are Needed to Get There?

What services do we need?

It's more than just inertia…

There has been substantial progress in the industry here

How much?

What are the units? How does 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.

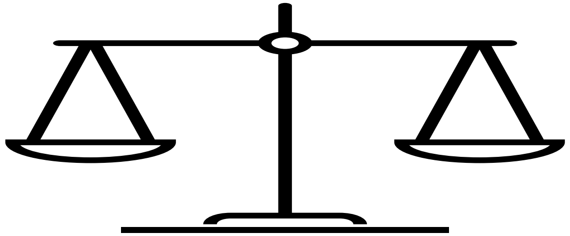
Our work is focused on **quantifying** services

- Generalized
- Technology agnostic
- Repeatable

To develop a **framework** that can be **rolled out to all system operators & planners**

Stability Services Framework Overview

Provision of Services
(Resources + Transmission)



Need for Services
+
Acceptance Criteria

Power Type

- Active
- Reactive

Timeframe

- Fastest (cycles)
- Medium/Slow (seconds)

Location

- Local/Regional
- Network-Wide

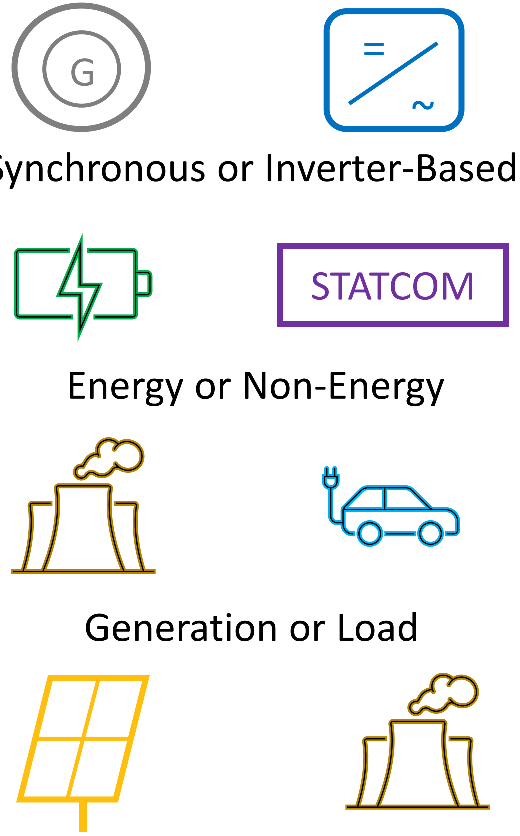
Operations

- Headroom
- Dispatch, Line loading

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



Synchronous or Inverter-Based

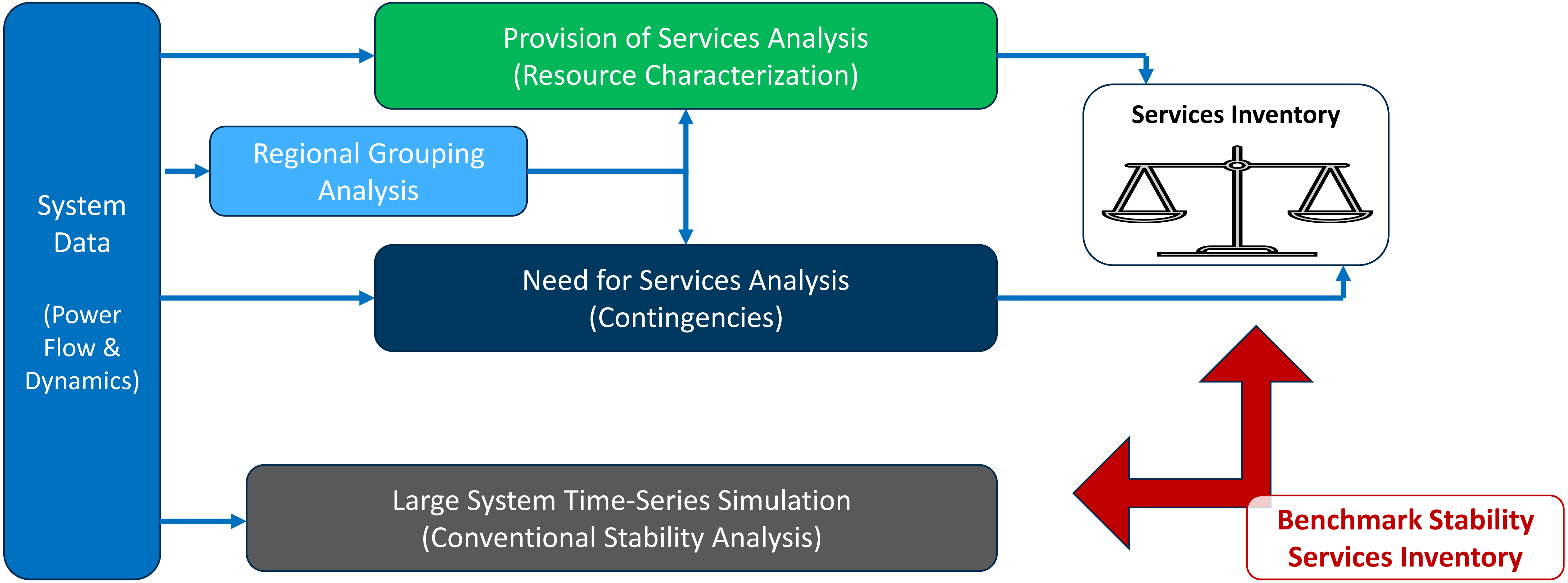
Energy or Non-Energy

Generation or Load

Distributed or Centralized

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

How Are We Testing the Framework?

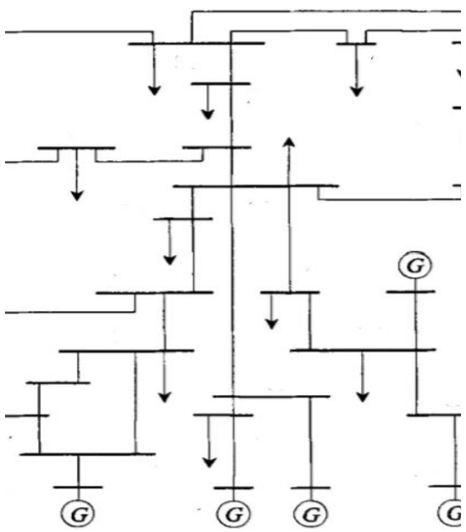


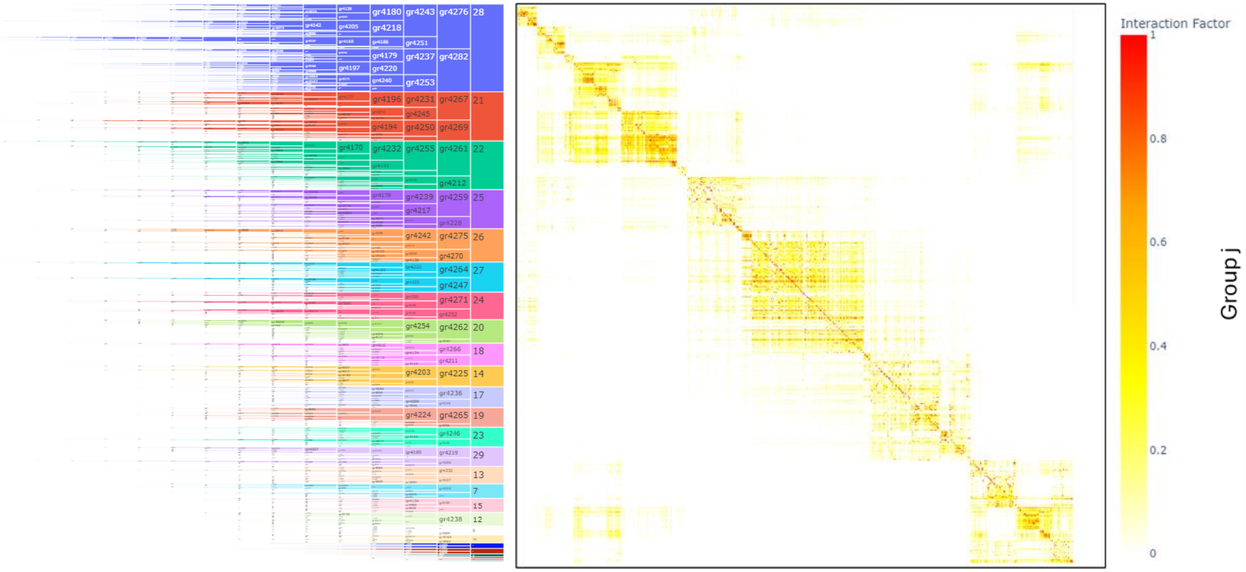
Regional Grouping Analysis

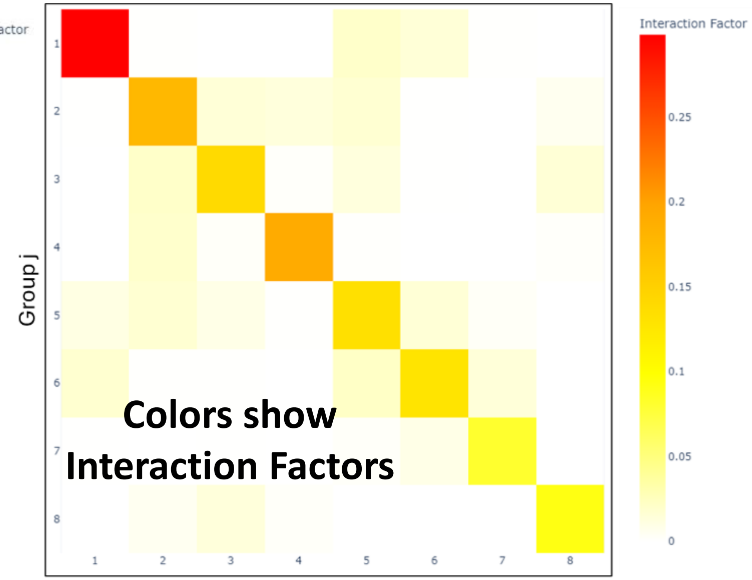
Objective: Group not by historical/ownership boundary, but by electrical attributes

Electrical attributes include both **topology** AND **resource characteristics**

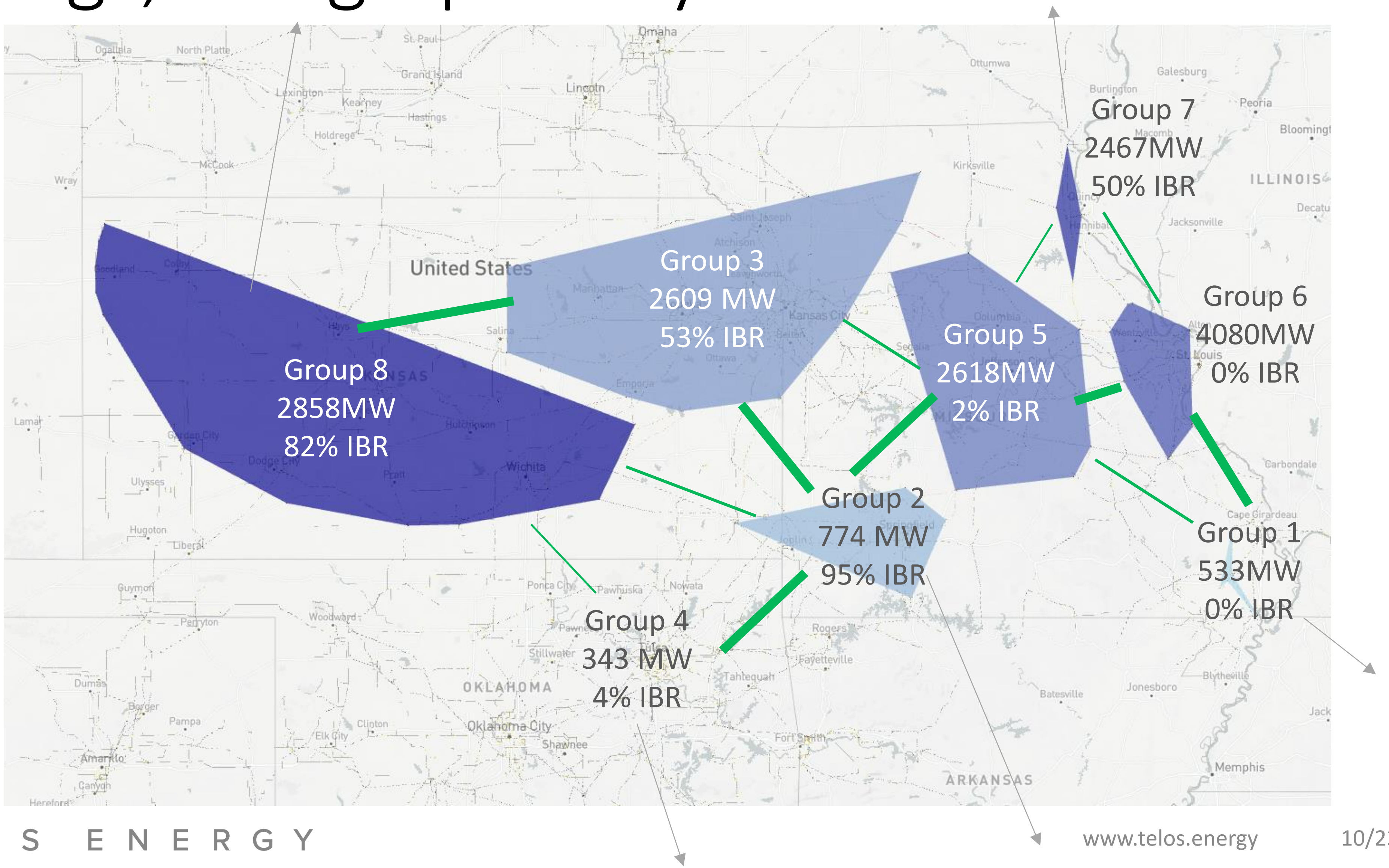
System Data → Hierarchical Grouping Algorithm → Regional Groupings







Groupings, Geographically



Resource Characterization

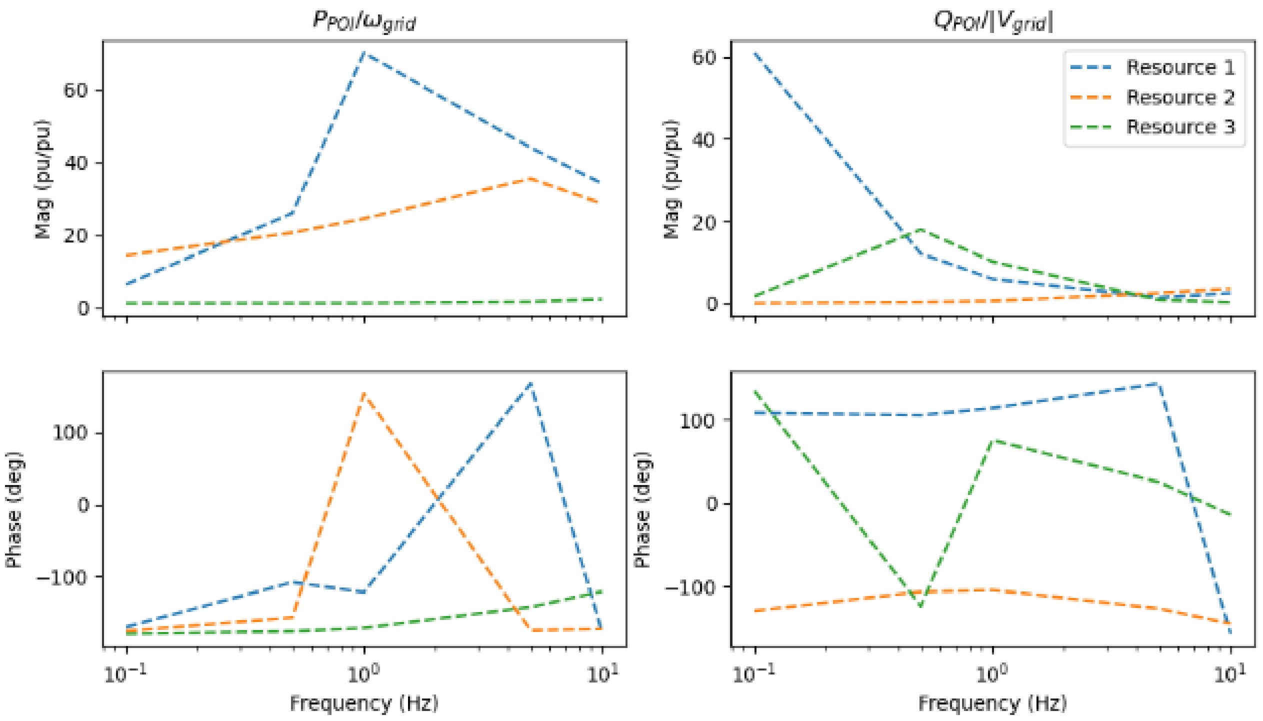
Provision of Services Analysis

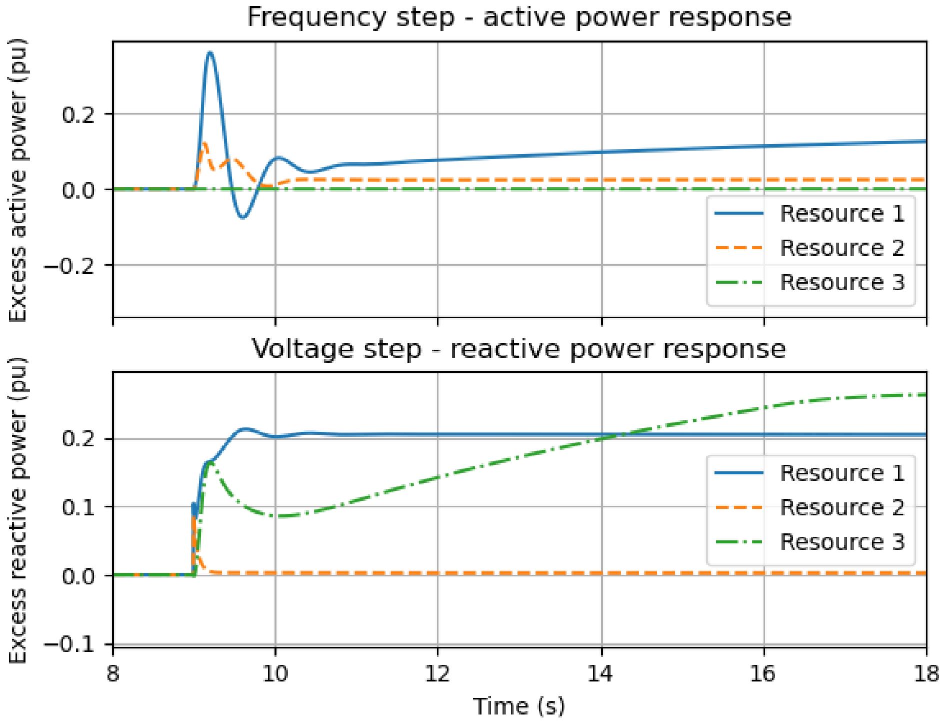
Generators are characterized in fast, medium, and slow time frames using frequency scans

Resources		Sufficiency		Timeliness of Delivery		
Resource Name	Rated Output	Response Enabled	Headroom	Fast (i.e., Inertial, Grid Strength)	Middle (i.e., FFR, Terminal Vreg)	Slow (i.e., Plant-Level, Governor, Exciter)
Resource A Resource B, etc.	[MW], [MVAr]	True/False	Per-unit MW on MW base	< 0.1 seconds $[\Delta P_{pu}/\Delta f_{pu}]$, $[\Delta Q_{pu}/\Delta V_{pu}]$	0.1s – 2.0s $[\Delta P_{pu}/\Delta f_{pu}]$, $[\Delta Q_{pu}/\Delta V_{pu}]$	2.0s – 10s $[\Delta P_{pu}/\Delta f_{pu}]$, $[\Delta Q_{pu}/\Delta V_{pu}]$

Resource Characterization Analysis

Generator characterizations in frequency-domain are validated against time-domain



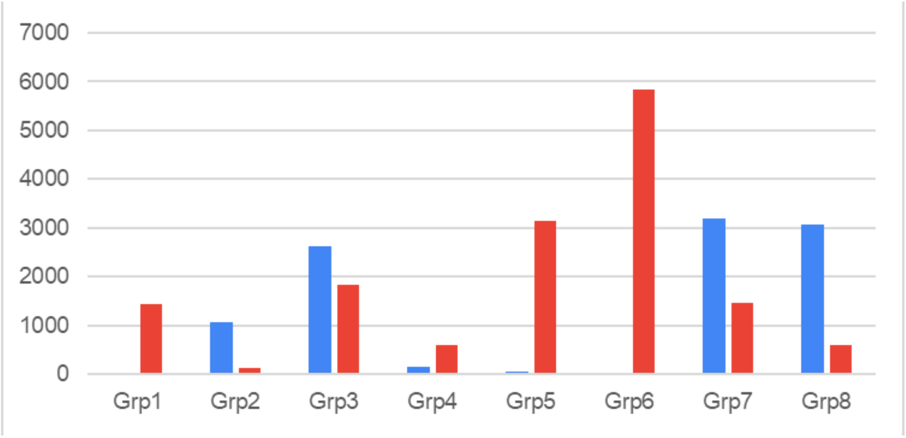


Resource 1 – SM | Resource 2 – Type 2 WTG | Resource 3 – IBR

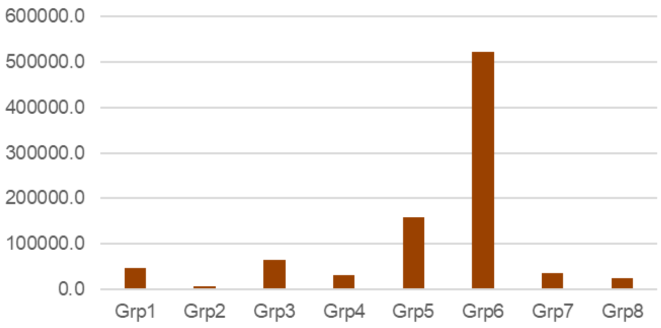
Provision of Services Analysis

Inventory of Services – Provisions

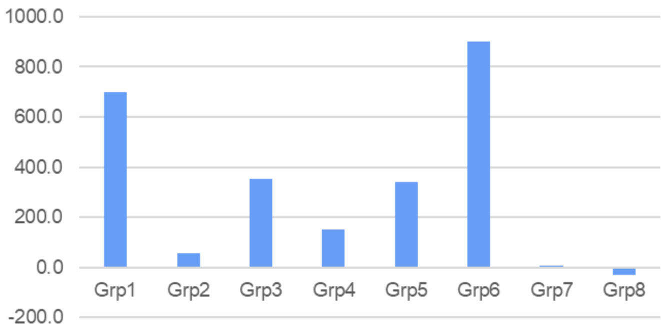
MVA of Online Resources [SM, IBR]



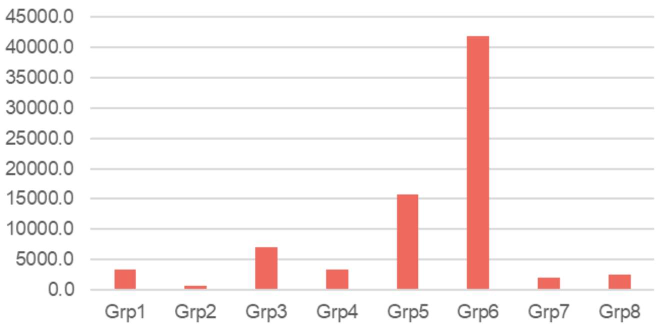
Fast Active Power [$\Delta MW/\Delta f_{pu}$]



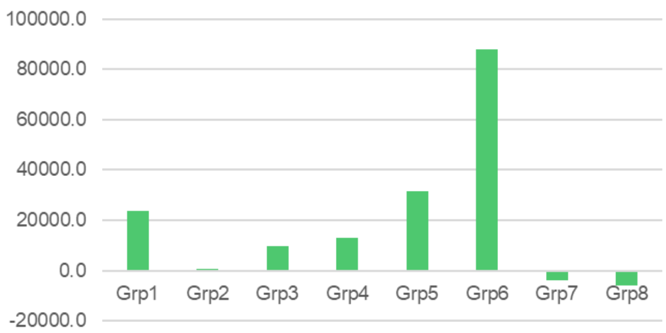
Slow Active Power [$\Delta MW/\Delta f_{pu}$]*



Fast Reactive Power [$\Delta MVAr/\Delta V_{pu}$]



Slow Reactive Power [$\Delta MVAr/\Delta V_{pu}$]*



*Slow services are limited by headroom

Need for Stability Services

Generation Contingencies

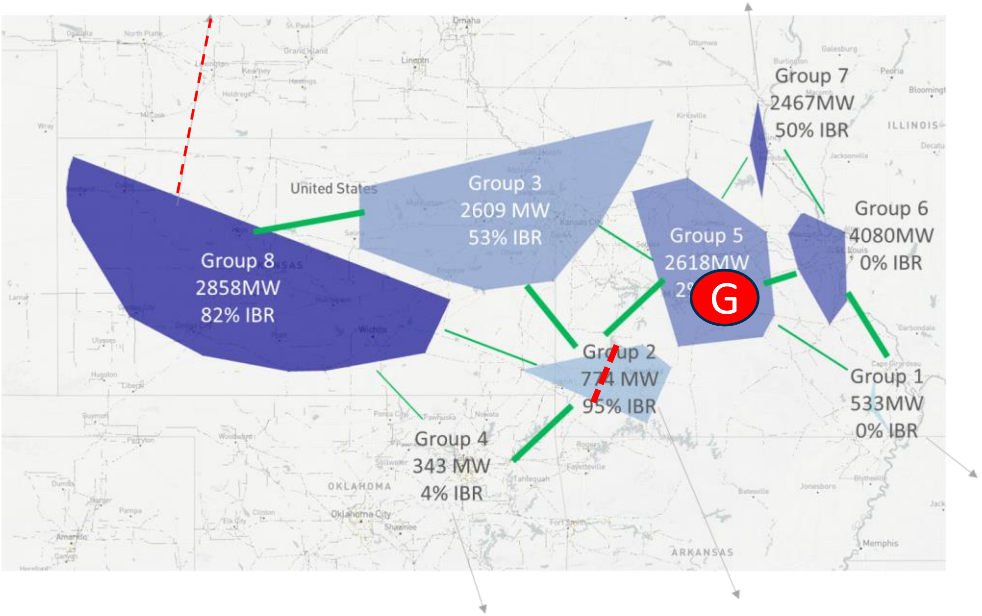
- Trip single largest generator by MW output in each "Group"
- Usually also the largest by MVA, but not always

Transmission Contingencies

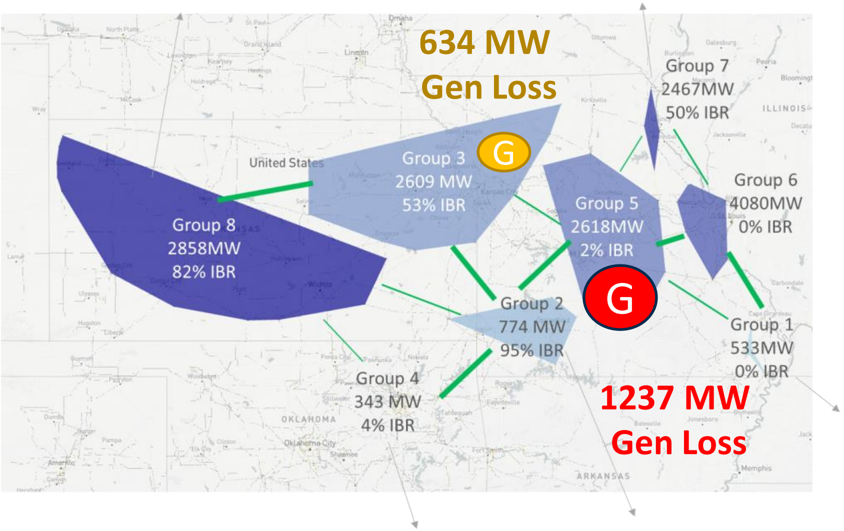
- Trip single line/transformer with highest MW flow in each group
- These are usually within a group or to the external system (flows between groups are usually not high)

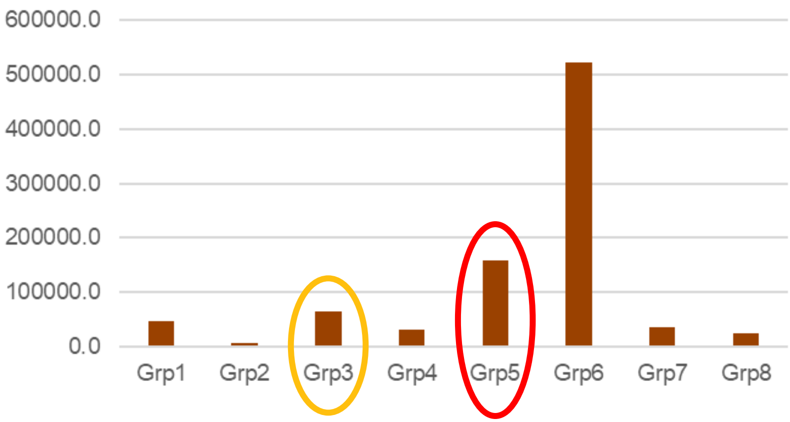
Monitor Dynamics

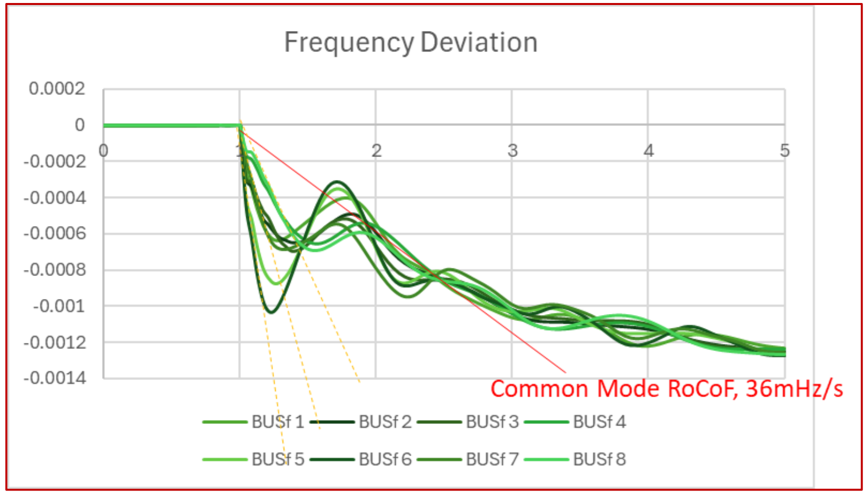
- Voltage & frequency of buses, aggregated by "Group"
- P & Q of all resources, aggregated by "Group"

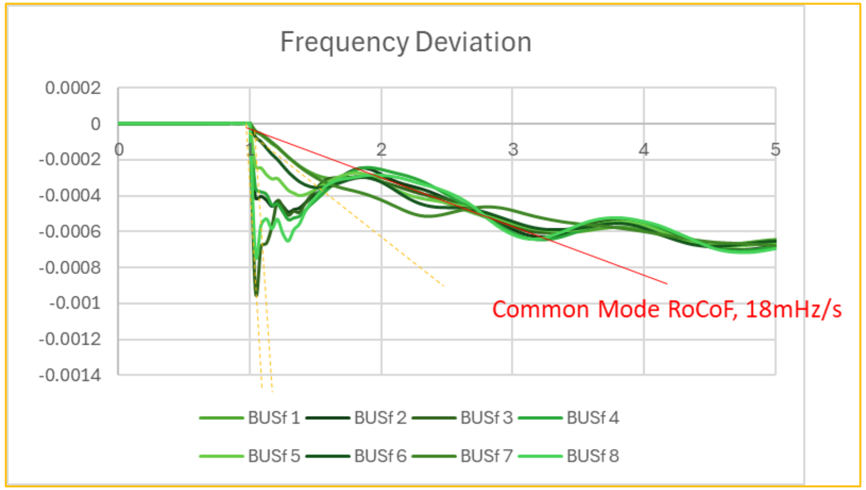


Benchmarking: Framework v. Dynamics









While the generation lost in Group 3 is smaller, but with fewer services in the region, the local stress is more pronounced

Framework Applications

- Highlight in future scenarios / resource portfolios where there are "**weak pockets**" lacking sufficient services
- Inform how **transmission investments** may be located to deliver energy AND stability services
- Identify **potential plant retirements** that would likely to cause stability problems
- Inform where **Grid-Forming (GFM) inverter technology** should be strategically located, and how much, what reserves to maintain
- Show how **changing grid operations** (even within a day/week/seasonal) can impact the level of services and therefore, stability

Applications for Planning

Applications for Operations

Findings & Next Steps

Initial Findings

- Services framework is a fast way to understand large system stability & risks
- Model quality is foundational and continues to be a challenge
- Applications in planning and operations horizons

Next Steps

- Test framework for higher IBR futures 80%+ IBR
- Evaluate the impact of new transmission projects
- Evaluate the impact of GFM v. GFL dominant futures

Thank You! Questions?

Special thanks to our sponsors!

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Sushrut Thakar