APS IBR Grid Services Update

Transmission Operations Engineering

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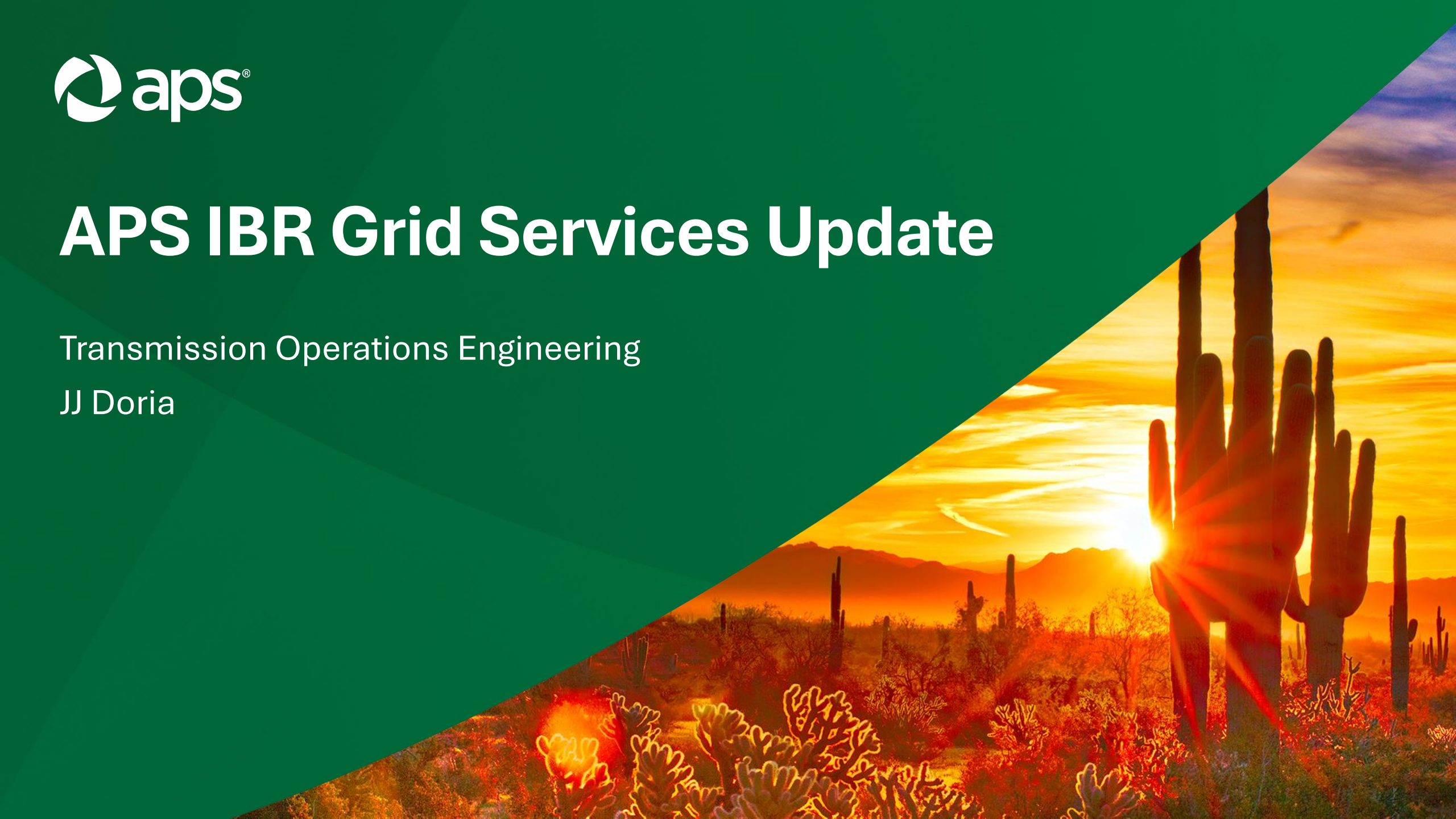

IBR Grid Services

GFL

GFM

No Grid Services

All Grid Services

Category 1	• Inject MW at unity power factor • No grid support services	**APS Today**	**Most IBR**
Category 2	• Frequency and voltage response • Full response over multiple seconds	**APS Today**	**Few IBR**
Category 3	• Full F/V response within 1 second • Operate through loss of last sync machine	**APS GFM Goal**	**Very few IBR**
Category 4	• Capable of blackstart • Single IBR could ride through extreme load-gen mismatch		**Small island IBR**

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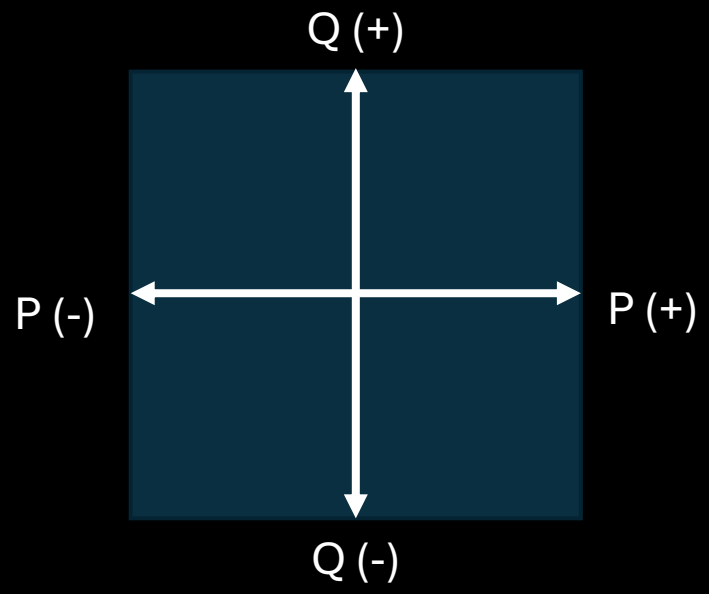
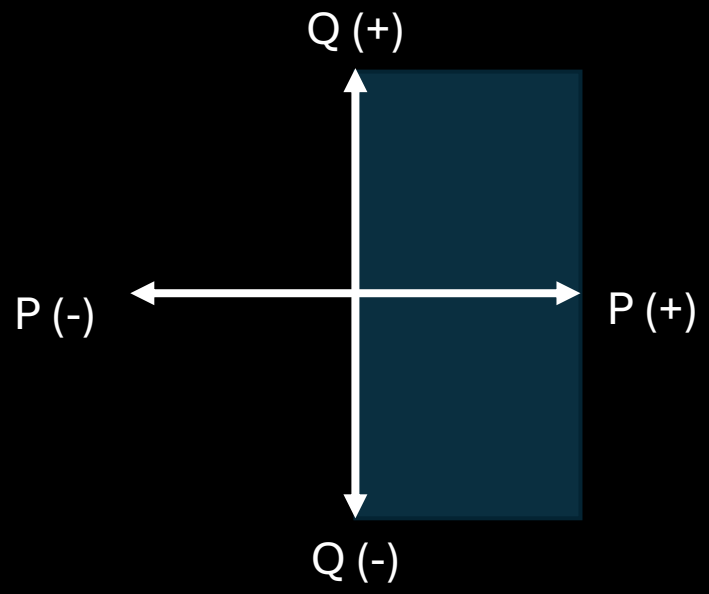
What is the best resource for GFM capability?

Battery Energy Storage System (BESS)



- **Bi-directional power operations**
  - 4 quadrant inverter
- Scheduled availability

Solar PV and Wind



- **One-way power operations**
- Intermittent

APS Process

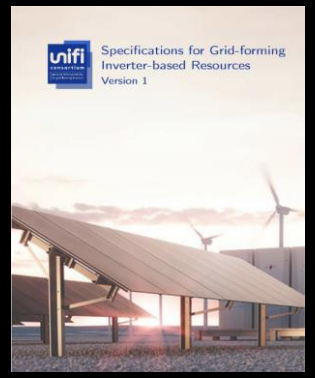
Complete

- APS developed IBR Technical Interconnection Performance Requirements which covers grid following inverters and fast-frequency response
- Provided GFM BESS Recommendations to APS Resource Planning
- Gathered RFP responses from developers on additional cost for GFM at IBR sites

Upcoming

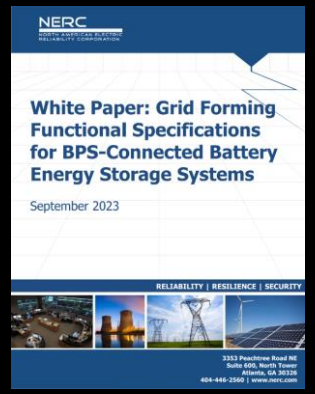
- Discussing additional GFM capabilities and cost with IBR sites in contractual/construction phases
- Developing study process internally to identify which locations in the APS system need IBR grid services
- Choosing one IBR facility from APS RFP or site currently under development for potential GFM capability deployment

GFM BESS Recommendation Sources



NREL: UNIFI Specifications for Grid-Forming Inverter-Based Resources

- GFM operations within normal grid conditions
- GFM operations outside normal grid conditions



NERC: Grid Forming Functional Specifications for BPS-Connected BESS

- Less % of BESS with GFL FFR = More % of BESS need to be GFM
- Functional Specifications for GFM and GFL BESS
- Functional Specifications unique to GFM BESS

GFM BESS Recommendation

- Inertial Response
  - Ability to provide near-instantaneous frequency and voltage support. This includes autonomously supplying power to support grid voltage and frequency due to loss of generation and absorbing power to support grid voltage and frequency due to loss of load. Coordination with traditional generation is necessary to ensure frequency and voltage do not have rapid changes.
- Stable Operations
  - Ability to stably operate through and following the disconnection of the last synchronous machine in its portion of the power grid.
- System Strength Support
  - Ability to help reduce the sensitivity of voltage change for a given change in current within milliseconds after a disturbance event.

Locations for GFM BESS Development

- Weak Grid Areas
  - Low inertia area with high risk of rapid frequency swings
  - Requires Short Circuit Ratio (SCR) study of APS system
  - **Transmission substations with lowest SCR are optimal for GFM BESS**
    - *Most GFL inverters will not continue to operate below 5.0 SCR*

- Stability Constrained Areas
  - Transmission capacity constrained areas
  - Renewable generation hubs with high intermittency (wind/solar)
  - Large dynamic non-conforming load areas (data centers/manufacturing)

APS Big Questions

- How do we coordinate with other generators/utilities so that our system is responding appropriately?
- Who is responsible for addressing the RoCoF challenges our system will encounter in the future with the integration of IBRs?
- Is loss of inertia an interconnection wide issue or a TOP/BA issue?
- What is the optimal location for GFM IBRs on our system?
  - When would we need these resources?
- How do we successfully model GFM IBRs?
- How do we develop GFM IBR performance field testing guidelines?