Special Topic Workshop: Grid Forming IBRs

Opening Remarks

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ESIG
ENERGY SYSTEMS INTEGRATION GROUP

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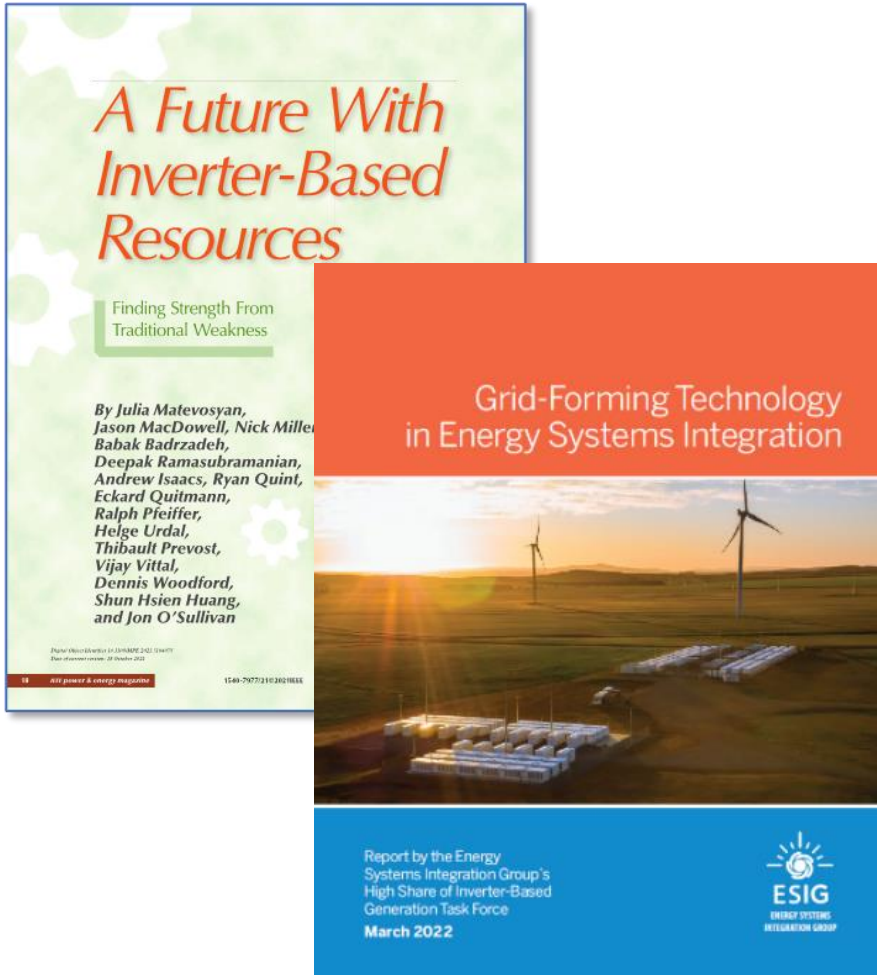
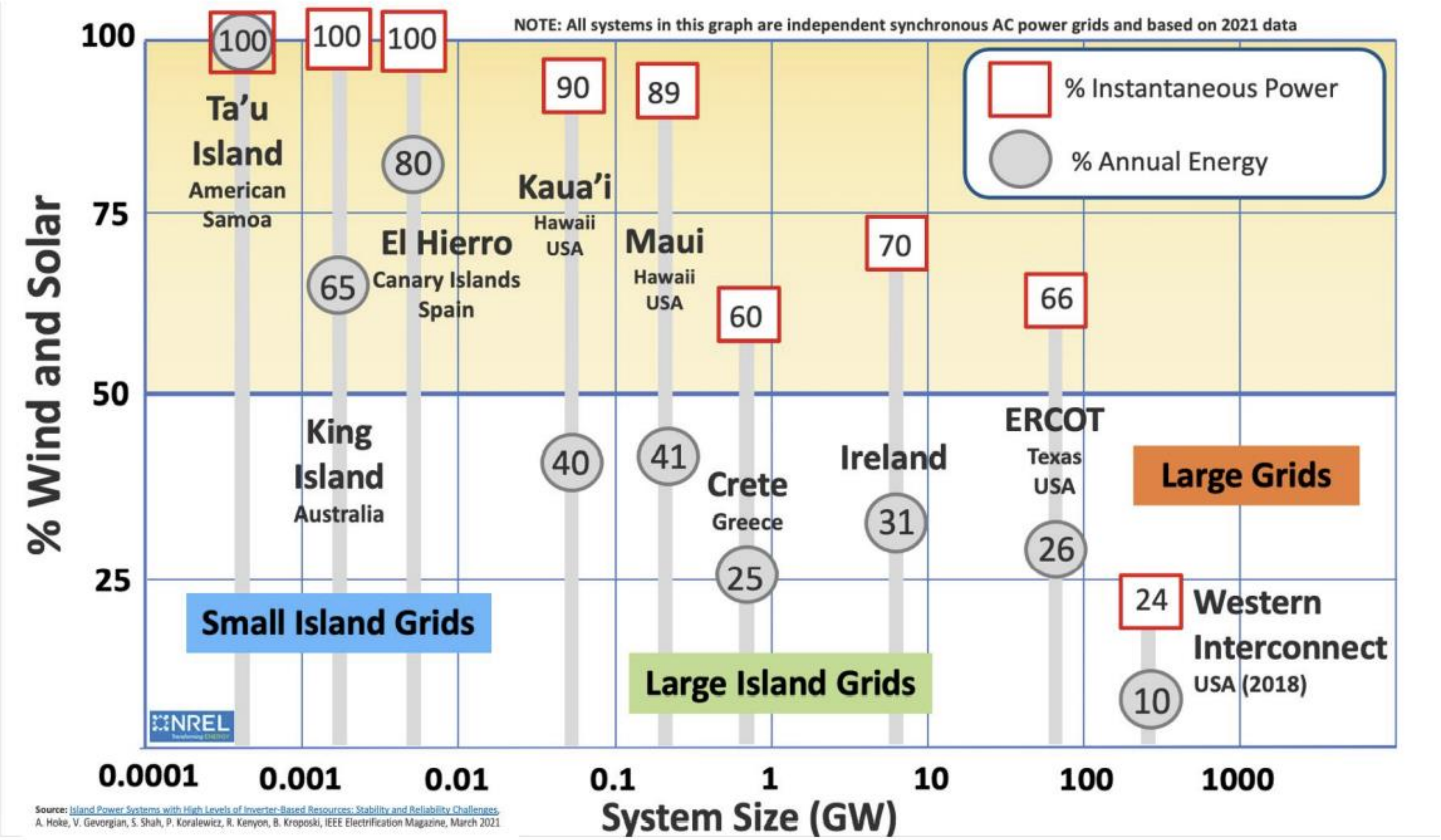
Grid Forming Technology in Energy Systems Integration, ESIG Report

- **Grid Forming vs Grid Following Inverter Based Resources**
  - Basic principles and overview of grid forming controls
- **System Needs**
  - What is changing with high shares of inverter-based resources?
  - Trade-off between system needs and resource needs.
- **System Services and Technical Requirements**
  - Breaking chicken-and-egg cycle
  - Global experiences with interconnection requirements and services
- **Advanced Characterization and Testing of Grid Forming Resources**
  - Tests applicable both to grid forming and grid following inverters
  - Tests applicable to grid forming inverters
  - Field Tests
- **Tools**
  - Stability tools, Analytical tools, Economics tools; Need for compatibility
- **Conclusions and Recommendations**

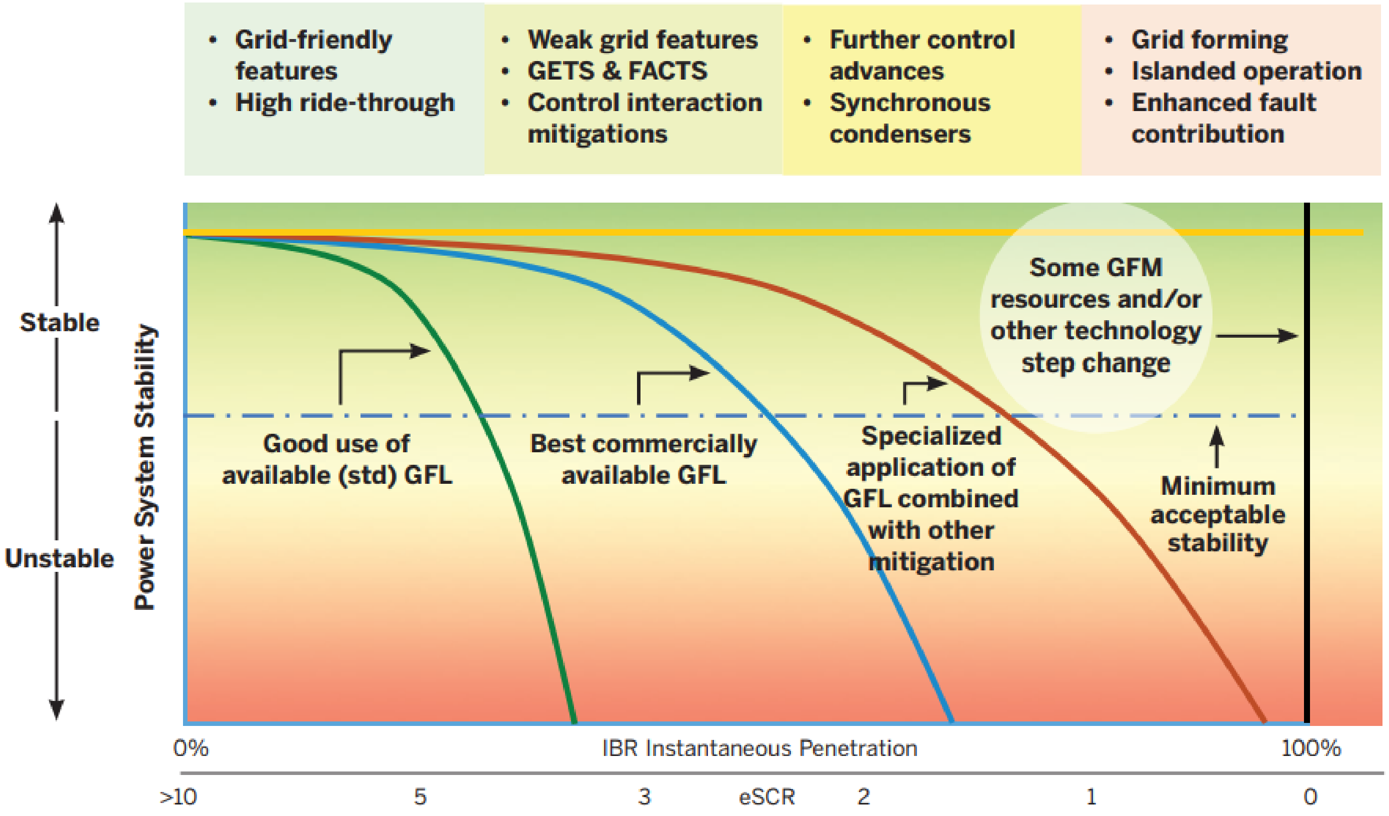


Where Are We Today?



Source: NREL

Technology Enabler to Promote the Shift to 100% Renewable Future

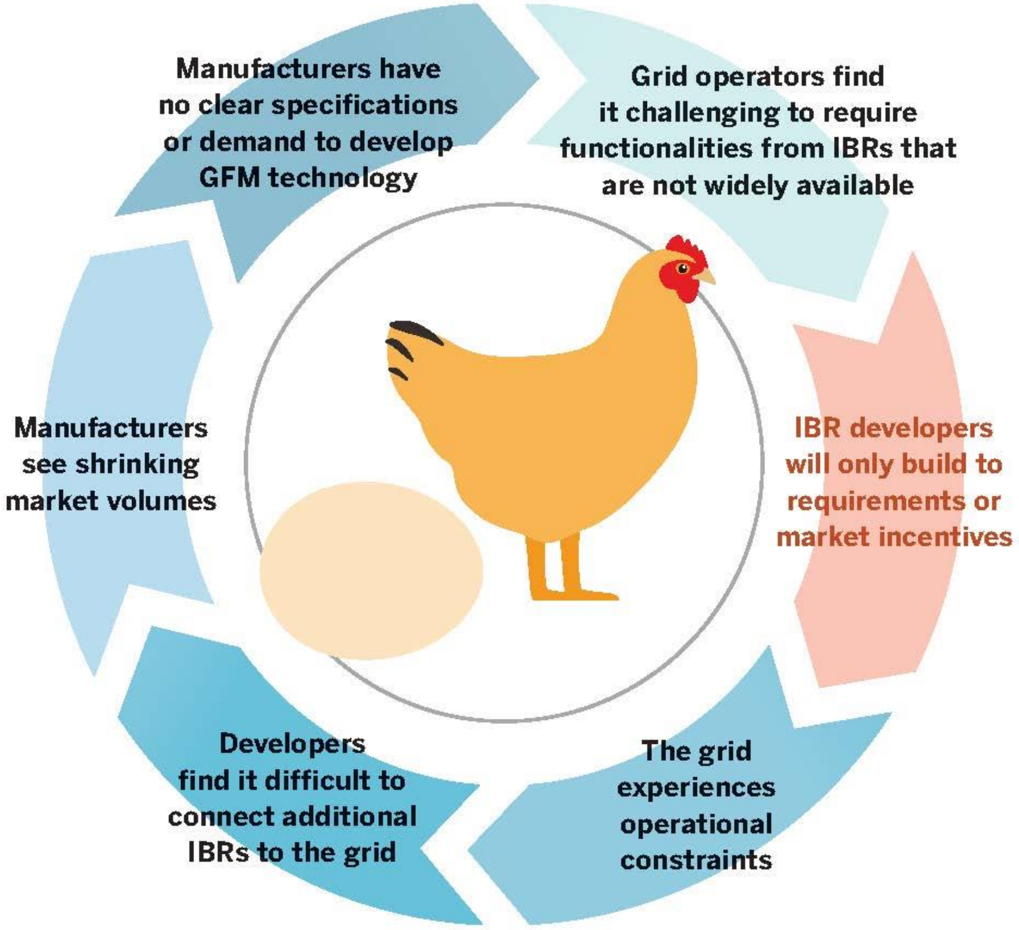


- Majority of the inverters today are "grid-following"
- They read the voltage and frequency of the grid, lock onto that, and inject power aligned with that signal.
- That signal comes from synchronous generators.
- The further wind and solar generation pockets are from synchronous generation, the weaker the grid.
- The signal is then easily perturbed by power injection from wind and solar resources, making it hard for inverters to lock onto it correctly.
- This may lead to local instability issues.

Grid Forming

- **Grid-Forming:** The primary objective of grid-forming controls for IBRs is to maintain an internal voltage phasor. When grid-forming controls are applied in bulk power system (BPS) connected IBRs, the voltage phasor is held constant in the sub-transient to transient time frames. This allows the IBR to immediately respond to changes in the external system and provide stability in the controls during challenging network conditions. This phasor must be controlled to maintain synchronism with other devices and control active and reactive currents to support the grid. When grid-forming controls are applied in non-BPS connected IBRs (for example black-start or microgrids), this synchronization functionality is removed or limited, and the voltage phasor may be held relatively constant over time. This allows the plant to operate in an electrical island and define the grid frequency.
- There are many variations of both grid-forming and grid-following converter controls. Both are subject to physical equipment constraints including voltage, current and energy limits, mechanical equipment constraints (on WTGs) as well as external power system limits.

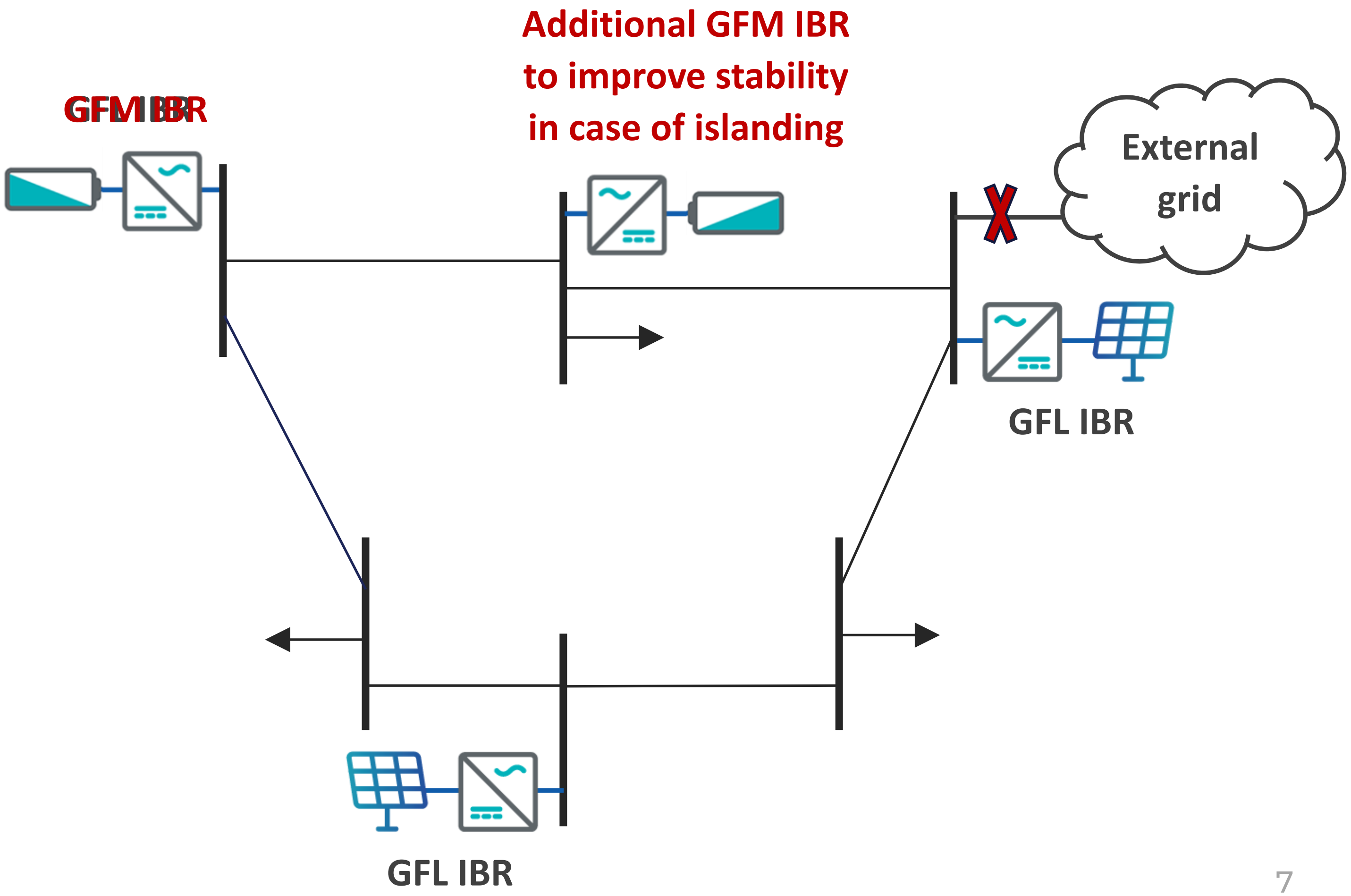
The Circular Problem of Requirements and Deployment of Advanced IBR Controls



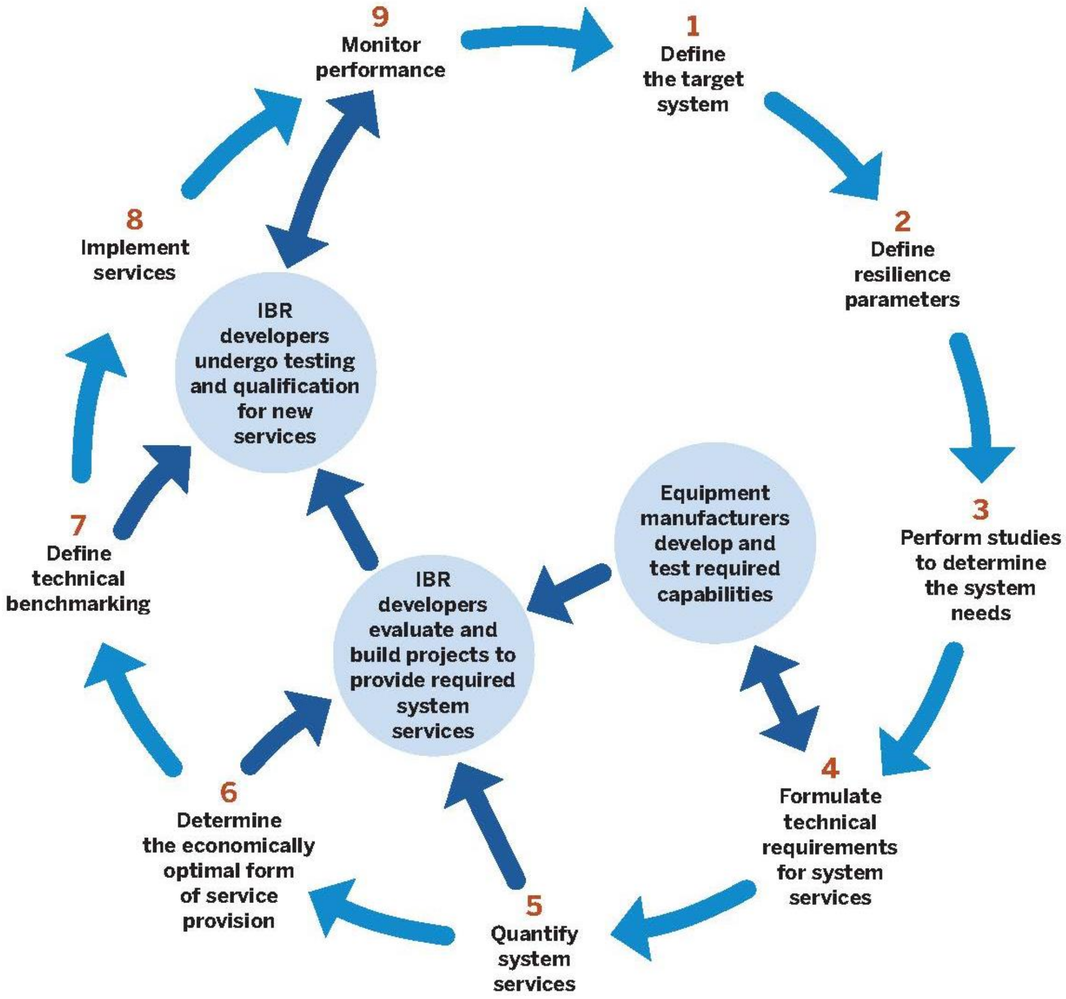
- Which comes first, the requirement for a capability or the capability itself?
- How do grid operators know what performance or capability is possible from new equipment, and therefore what they could conceivably require?
- How can they go about evaluating the costs and benefits of having such equipment on the grid?
- What drives manufacturers to invest in new technology without it being mandated or otherwise incentivized by the market?

Cost of Inaction

- The failure to find an exit from the circular problem could hinder our ability to meet energy transition targets and increase the costs of this transition.
- Around the world there are thousands of solar, wind, and battery resources waiting to connect to the grid.
- These resources, in the absence of clear requirements and market incentives for GFM functionality, will be built using today's grid following technology.
- This will increase systems' needs for additional reliability support from other sources and drive up costs.



Solving the Chicken-and-Egg Problem Through Adoption of a System Needs Perspective



Pilot Projects and First Interconnection Requirements for Grid-Forming Capability

- Battery energy storage systems (BESS) for microgrids and black start of simple cycle gas turbines (GE)
- BESS on St Eustatius island (SMA)
- Dersalloch Wind Farm in Scotland (Siemens Gamesa)
- Mackinac back-to-back Voltage Source Converter HVDC Flow Control Project (Hitachi ABB)
- Dalrymple BESS in South Australia (Hitachi ABB)
- Hornsdale BESS in South Australia (Tesla)
- More Grid Forming BESS underway in Australia
- Stability Pathfinder in Great Britain (National Grid ESO)
- First Approved (non-mandatory) Grid Forming Interconnection Requirements in Great Britain

For further information: ESIG Survey of Grid Forming Inverter Applications

Workshop Agenda Overview

Tuesday, June 7th

- **Session 1:** Defining Technical Requirements and Qualification of Services (NGESO, HECO, UNIFI)
- **Session 2:** Defining Target System, Desired Performance and System Needs Studies (Experience from AEMO)

Networking Reception 6:30 pm

Workshop Agenda Overview

Wednesday, June 8th

- **Session 3:** Grid Forming Capabilities and Challenges (GE, Hitachi Energy, SMA)
- **Session 4:** Incentivizing New Grid Services (NGESO, EirGrid, Vysus Group)
- **Session 5:** Performance Monitoring – GFM Projects and Pilots (RTE, Scottish Power Renewables, Aurecon)
- **Session 6:** Performance Benchmarking Modelling and Testing (AEMO, Vestas, Electranix, EPRI)

Thursday, June 9th

- **Session 7:** Research Roadmaps (UNIFI, RTE, CSIRO)
- **Session 8:** Closing Panel – What's Next? (GE, ESIG, NERC, HickoryLedge, SMA, NGESO)

Welcome!

- A warm welcome to real and virtual visitors from afar:
  - Australia
  - Germany
  - United Kingdom
  - Ireland
  - Finland
  - Italy
  - Canada
  - Texas
- Take the time to make some new friends!

- Looking forward to another great meeting!

ESIG High Share of IBR Task Force, Next Steps

Scope for 2022:

- Review existing requirements and specifications for grid forming capability
- Using G-PST Report System Needs and Services for Systems with High IBR Penetration as a starting point
- Develop high level technology-neutral specifications for new system services in power systems with high IBR
- Shape specification of new services with a small test system and test capabilities and limitations of grid forming inverters providing these services
- The report can serve as a guide to system operators that are only starting on this path

Global Power System Transformation Consortium advances action in 5 key areas

1. System Operator Research & Peer Learning

ESIG

Perform cutting edge applied research to create novel system operator solutions and globally disseminate and infuse new insights through peer learning

2. System Operator Technical Assistance

NREL Transforming ENERGY

Provide implementation support to scale established best practice engineering and operational solutions

3. Foundational Workforce Development

Imperial College London

Build the inclusive and diverse workforce of tomorrow through enhanced university curriculum and technical upskilling for utility and system operator staff

4. Localized Technology Adoption Support

IEEE Advancing Technology for Humanity

Adapt modern power system technologies to individual country contexts through testing programs and standards development activities

5. Open Data and Tools

Fraunhofer CINES, VTT

Support rigorous planning, operational analysis and enhanced real-time system monitoring through open data and tools

CORE TEAM – All Core Team members contribute to all activity pillars

REGIONAL LEADS – Coordinate regional peer learning networks and country-level TA delivery efforts for Africa, Asia, and Latin America and the Caribbean

INTERIM SECRETARIAT – Work program coordination, partnerships and support, outreach, etc.

Pillar 1: System Operator Research and Peer Learning

Research Agenda Group

9+ month consultation process with leading System Operators and global Research Institutes

Consensus Priority Research Program Areas

Inverter Design
Designing inverter capabilities for power systems

Analytical Tools and Methods
Generating new simulation methods for power system operation

Control Room of the Future
Enhancing real-time awareness and control over future power systems

Power System Planning
Creating new approaches for reliable planning of future power systems

Black Start
Ensuring resiliency through novel inverter-based system restart methods

All areas highly interrelated

Effective Coordination to Achieve Holistic Solutions

Quick Wins

- **Understand and apply known cutting-edge solutions from System Operator peers**
- **Translate existing state-of-the-art research results into application**
- **Commence coordinated research and piloting activities**

Transformative Solutions

Breakthrough technologies

Innovative engineering solutions

Paradigm shifts

2021 → **Today** → **Short-term** → **Longer-term**

Upcoming Meetings – 2022 and 2023

2022 Fall Technical Workshop
October 24-27, 2022
Minneapolis, MN

2023 Spring Technical Workshop and Annual Meeting
March 27–30, 2023
Tucson, AZ

2023 Meteorology and Markets Workshop
June 2023
Denver, CO

Grid –Forming Technology in Energy Systems Integration

THANK YOU & WELCOME