Grid Forming Technology in Energy Systems Integration

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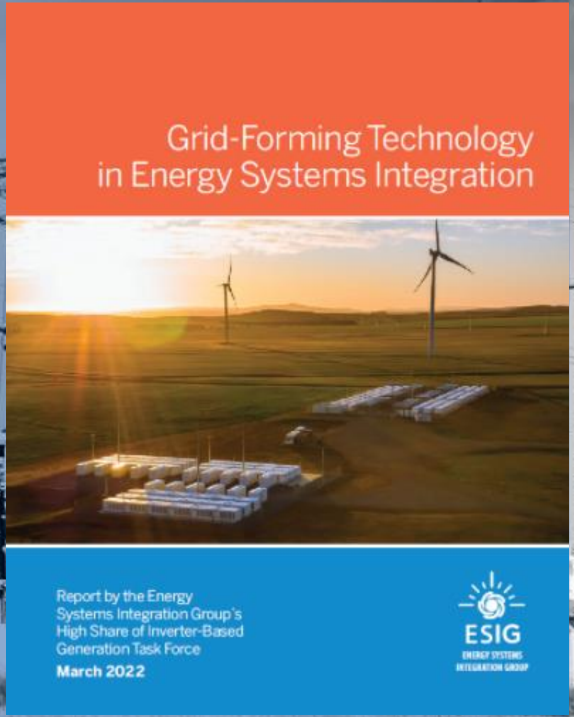
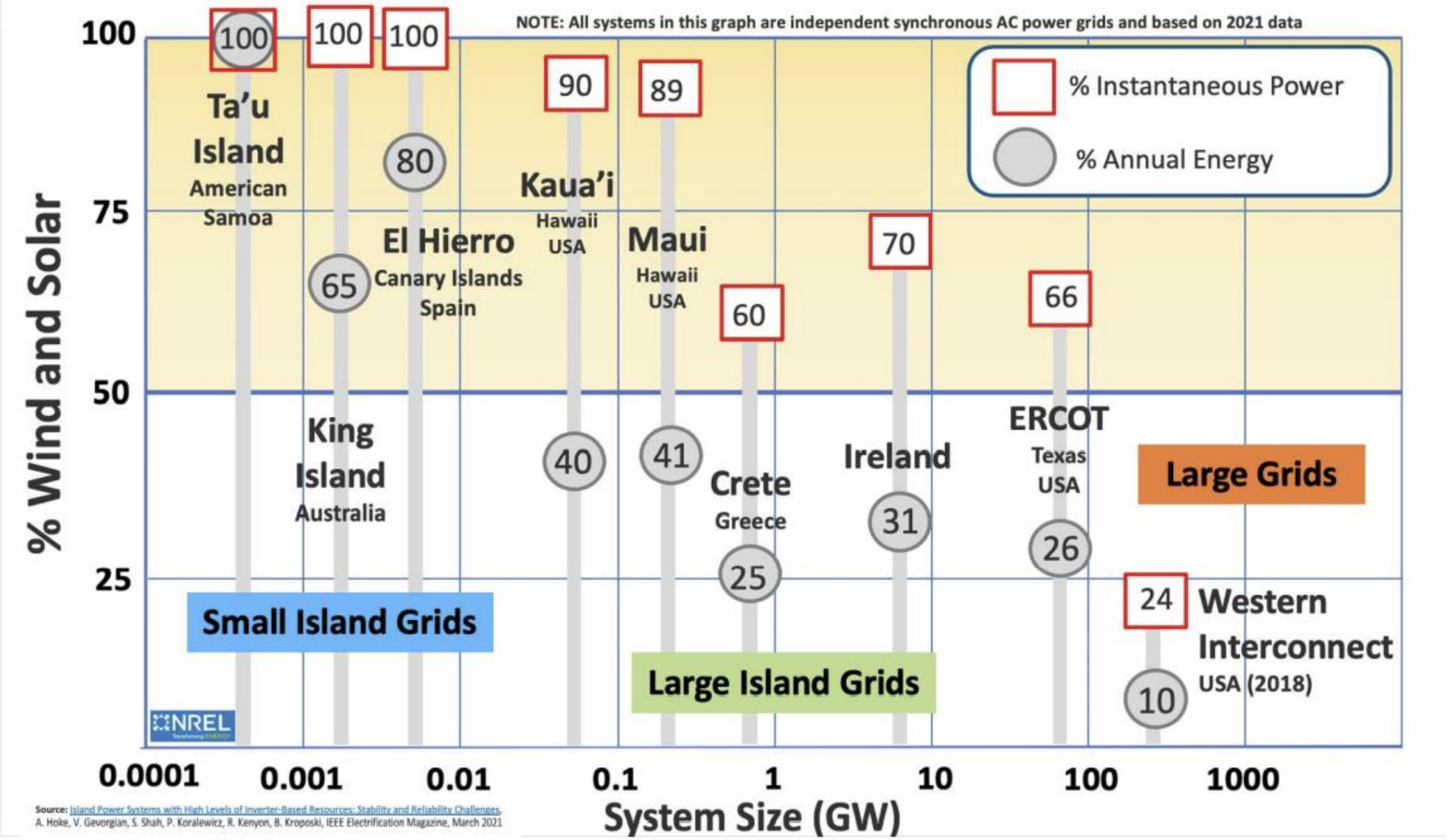
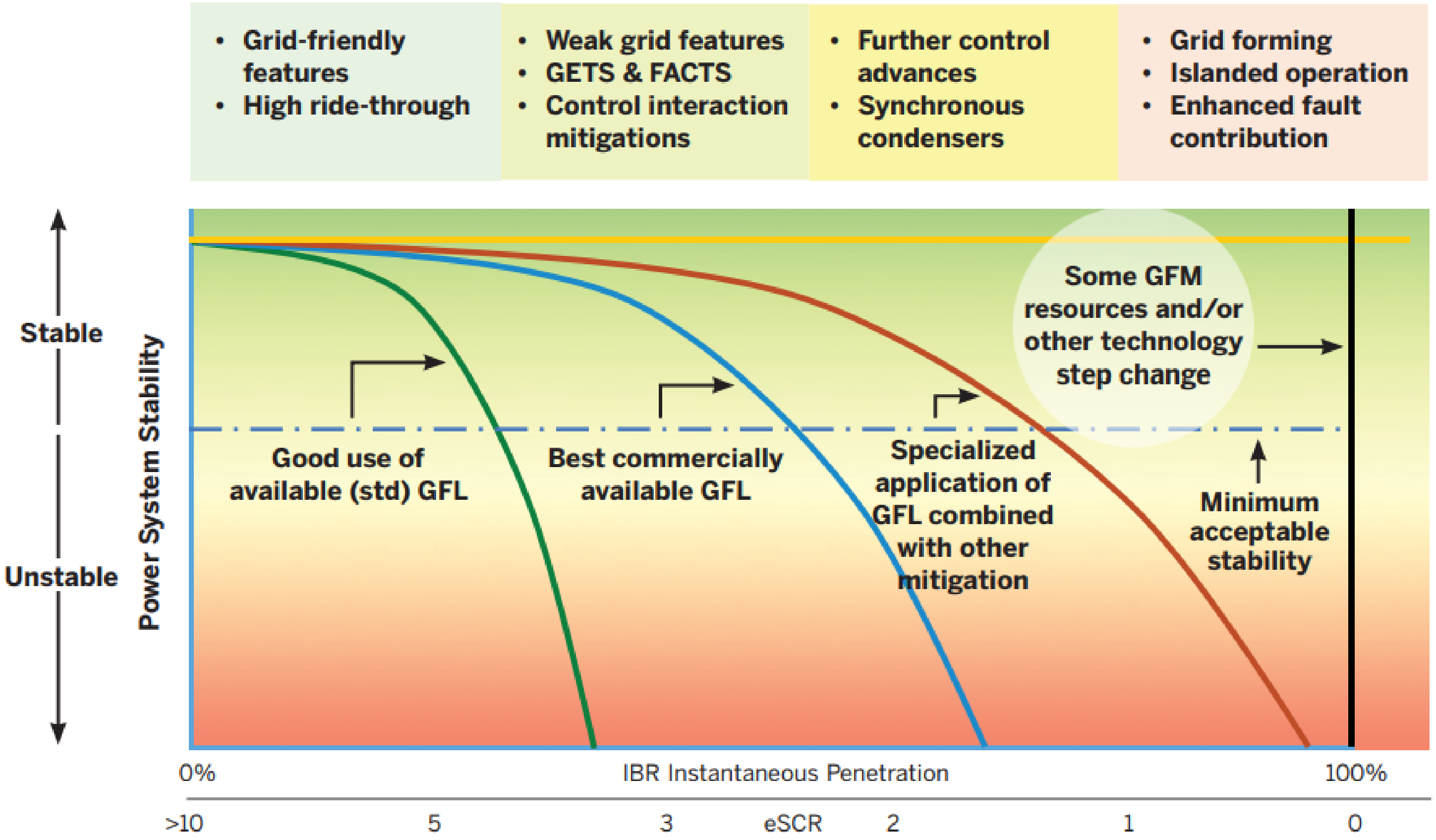


Where Are We Today?



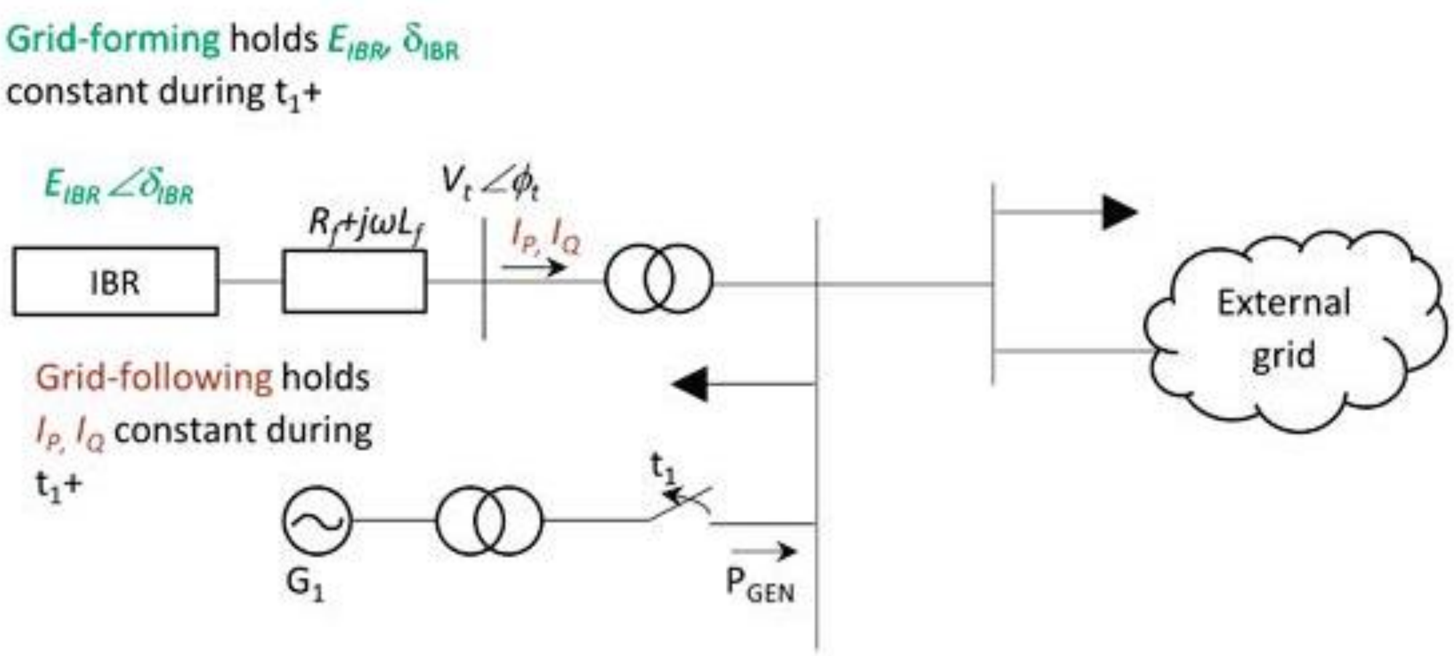
Source: NREL

Technology Enabler to Promote the Shift to 100% Renewable Future



Grid Following vs Grid Forming

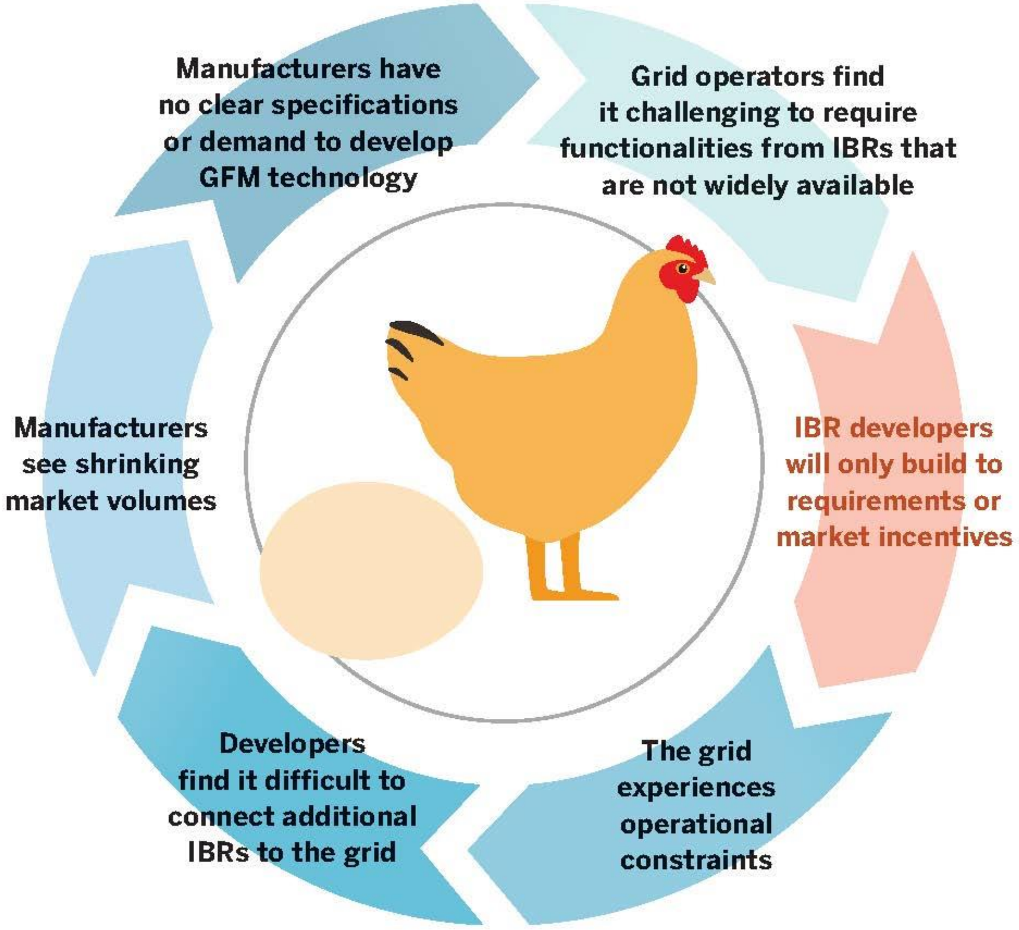
- A new class of inverters with advanced control -"grid forming" inverters.
- These advanced inverter controls can be designed to have stabilizing effect in weak grid areas and improve stability for existing grid following inverter-based resources.
- They can also provide other grid services.



Grid Following vs Grid Forming

Inverter Attribute	GFL Control	GFM Control
Reliance on grid voltage	Relies on well defined grid voltage	Actively maintains internal voltage magnitude and phase
Dynamic behavior	Controls current injected into the grid (appears as a constant current source in the transient timeframe)	Set voltage magnitude and frequency/phase (appears as a constant voltage source in the transient timeframe)
Reliance on PLL for synchronization	Needs PLL or equivalent fast control for synchronization	Does not need PLL for tight synch. of current controls. May use PLL to synch. overall plant response to the grid.
Ability to provide black start	Not usually possible	Possible if designed with sufficient energy buffer and overcurrent capability
Ability to operate in low grid strength conditions	Stable operation range can be enhanced with advanced controls but limited to a minimum level of system strength	Stable operation range can be achieved without minimum system strength requirement (long-distance high-power transfer issue still not resolved)
Field deployment and standards	Has been widely used commercially, standards exist	Deployed primarily on batteries in a few pilots, limited experience in interconnected power systems. Existing standards do not yet define required functionalities well.

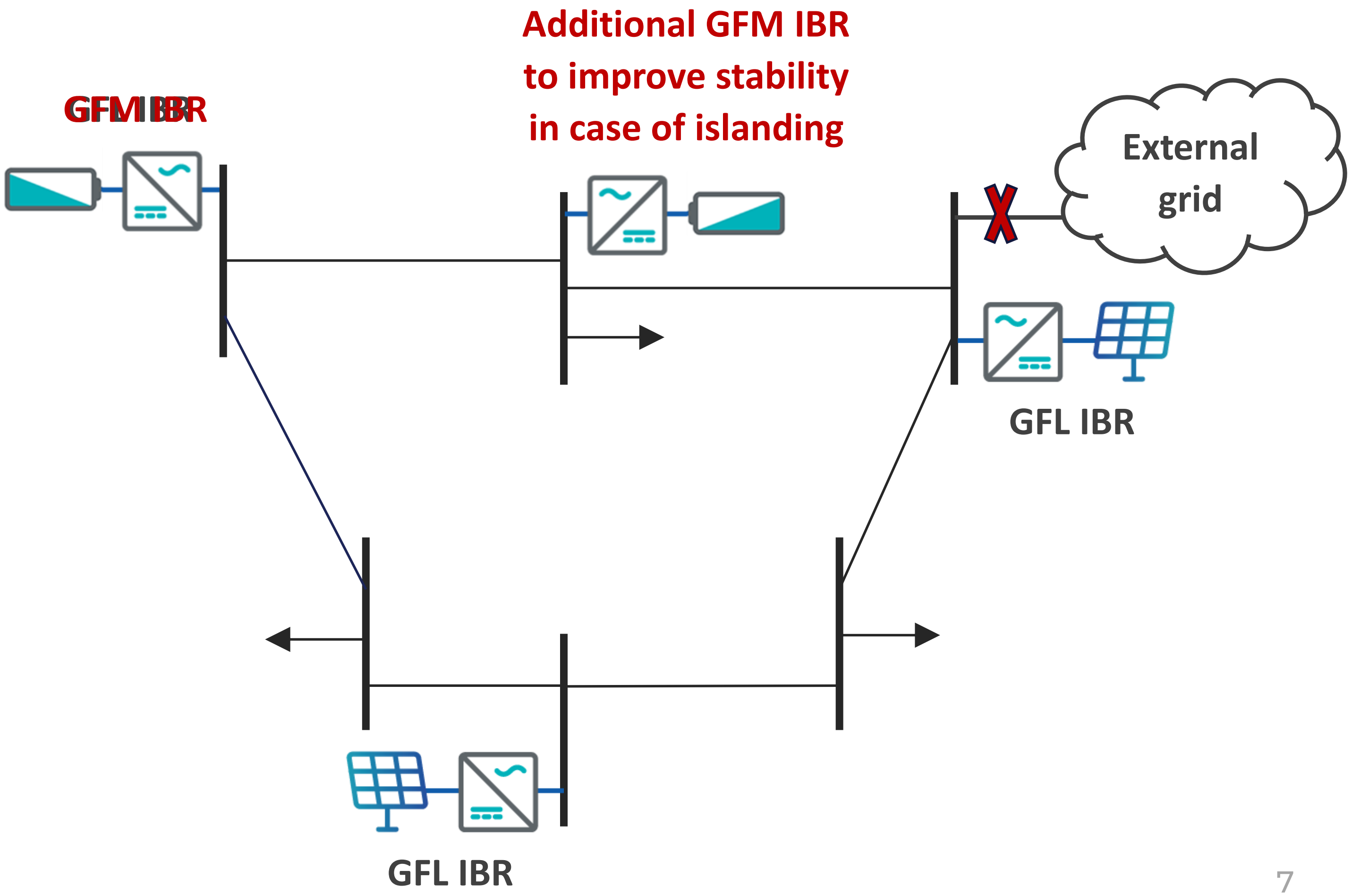
The Circular Problem of Requirements and Deployment of Advanced IBR Controls



- 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

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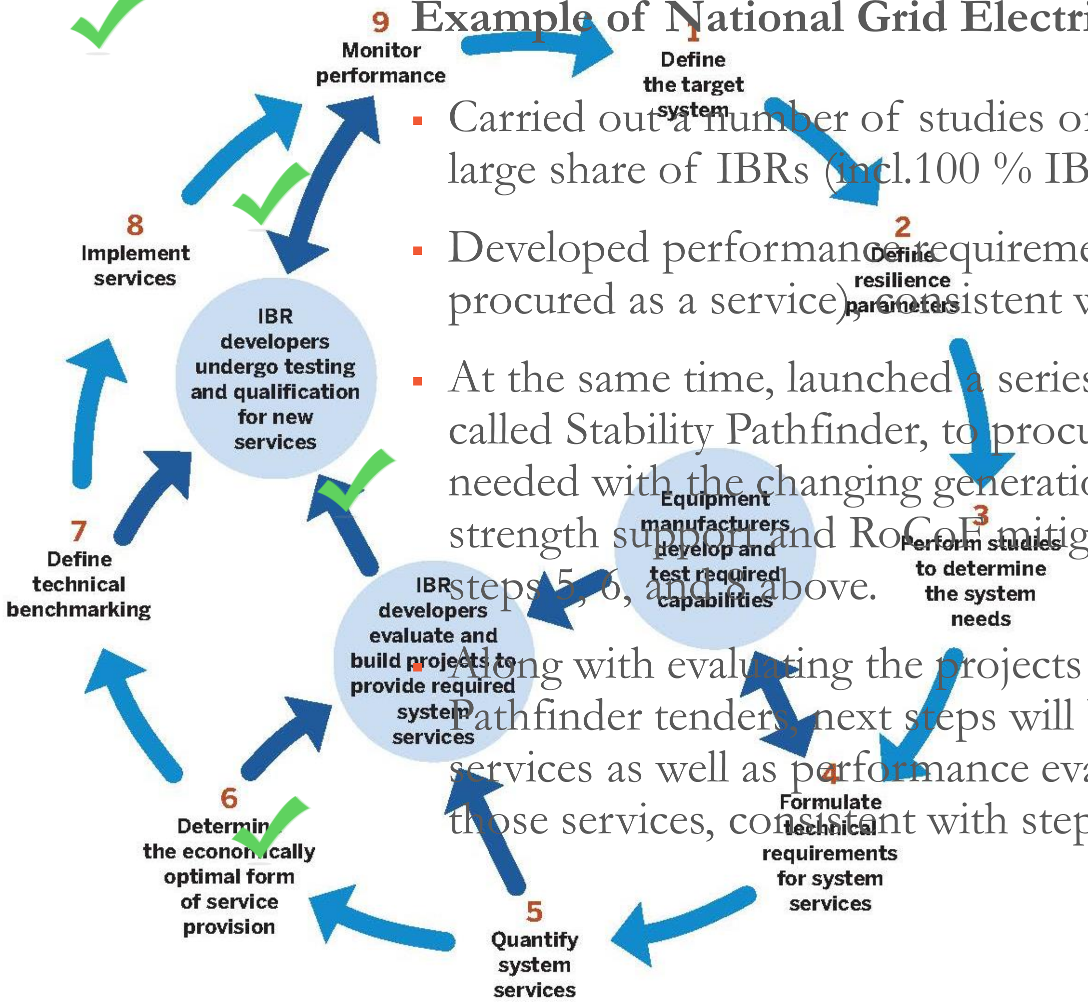
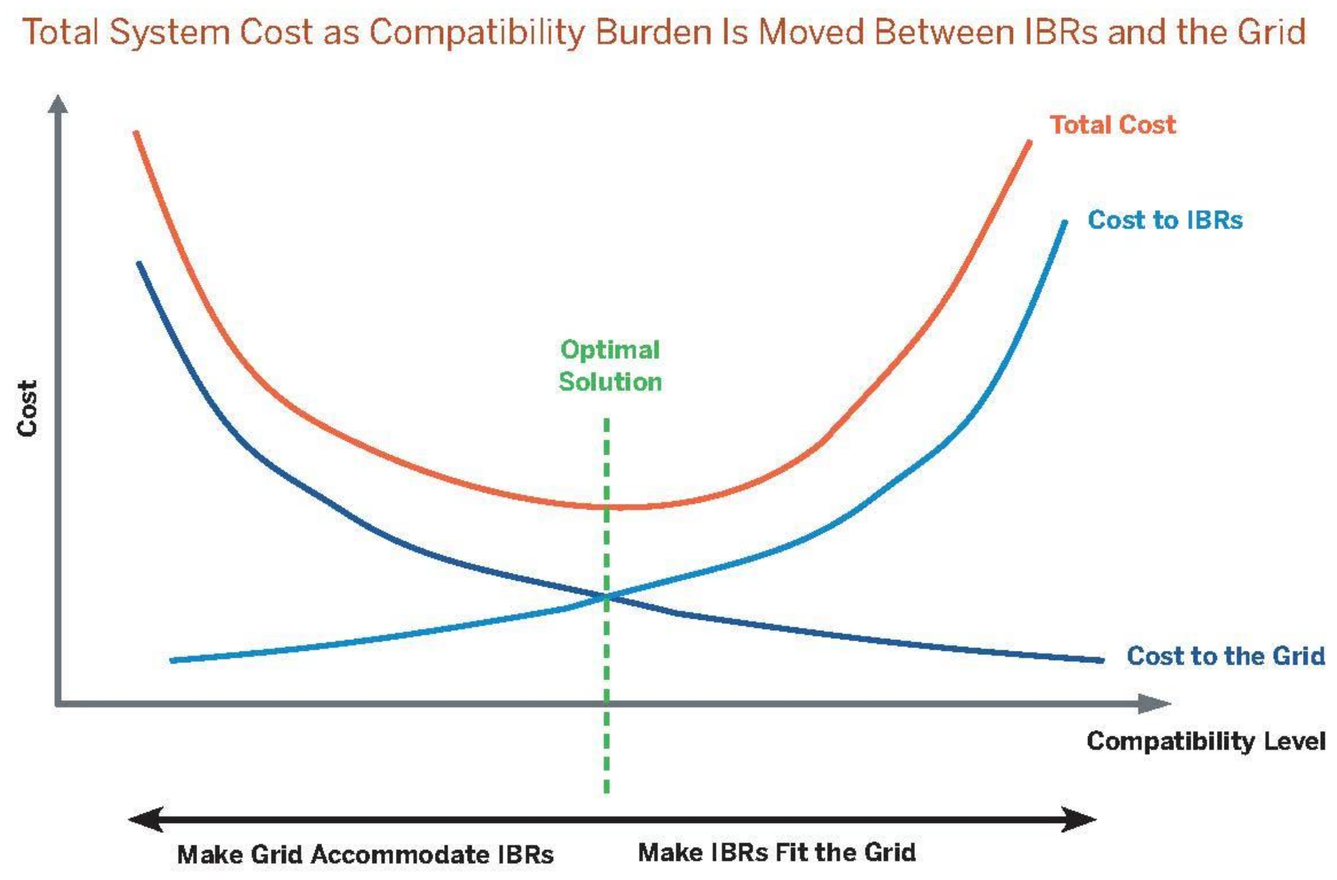
Example of National Grid Electricity System Operator:

- Carried out a number of studies of system performance with a large share of IBRs (incl.100 % IBR), steps 1-3.
- Developed performance requirements for GFM capability (to be procured as a service), consistent with steps 4 and 7.
- At the same time, launched a series of competitive tenders, called Stability Pathfinder, to procure new system services needed with the changing generation mix—specifically, system strength support and RoCoF mitigation. This is consistent with steps 5, 6, and 8 above.
- Along with evaluating the projects offering into Stability Pathfinder tenders, next steps will be to develop market-based services as well as performance evaluation requirements for those services, consistent with steps 8 and 9.

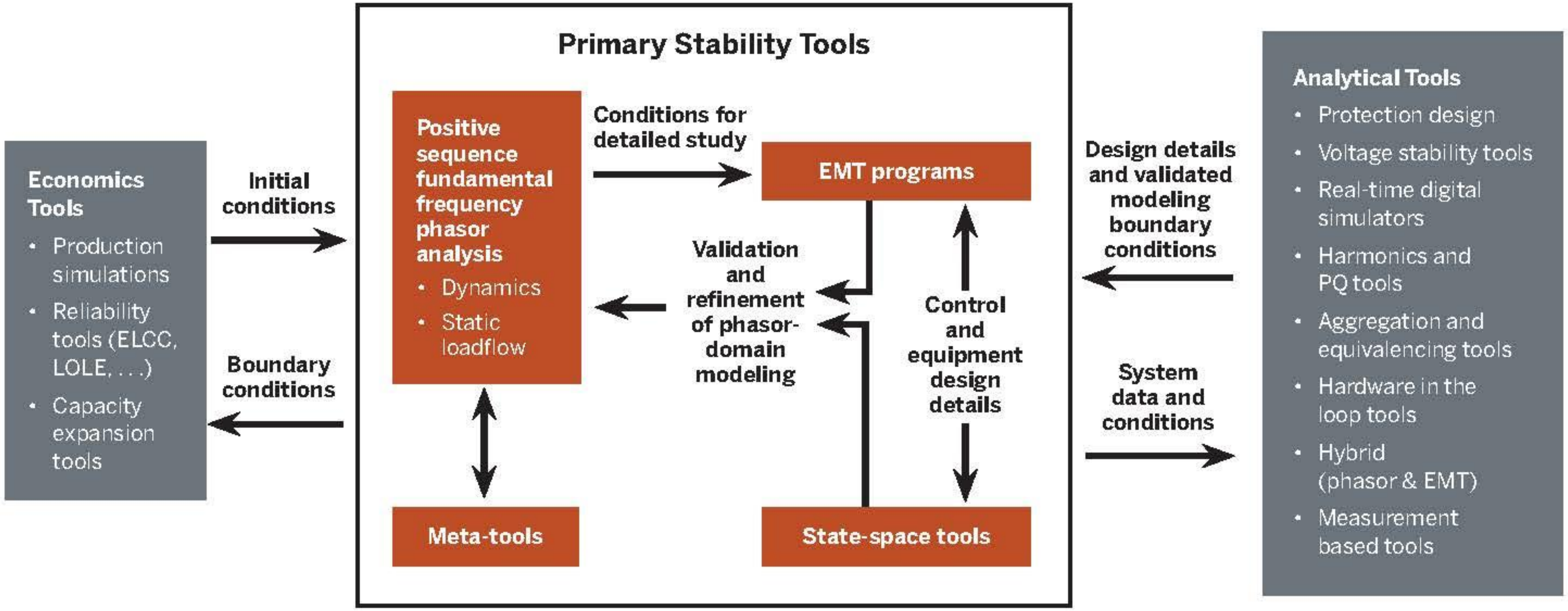


System Needs vs IBR Needs?



Role of Tools

Stability Simulation Environment



Source: HickoryLedge.

Conclusions and Recommendations

- GFM technology is one of the necessary enablers for higher IBR penetration.
- Not all GFM IBRs need to have all possible characteristics to provide all services. Services need to be approached from system needs perspective not a specific technology capability perspective.
- Step by step approach of defining and implementing new services is proposed.
- Early adopters such as, e.g., GB are breaking the circular problem through defining grid services based on system needs. This provides clarity for GFM IBR design and incentives for deployment.
- It is recommended that future adopters use higher-level functional requirements as a starting point, with more details on capability verification and performance testing provided in the form of technical guides.
- **GFM capability in batteries is a low hanging fruit. Not incentivizing it today will result in higher costs of supplemental stabilizing equipment in the future.**
- Further reinforcements of transmission system will be necessary to enable long-distance high-power transfer from remote areas rich with renewable resources
- With high shares of IBRs and new technologies there is a need for further development and tighter integration of study tools and processes.

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THANK YOU

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