Grid Forming Technology Implementation Council

Status and Outlook

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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

EPRI ELECTRIC POWER RESEARCH INSTITUTE

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

VTT

NREL Transforming ENERGY

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

olade · NREL Transforming ENERGY · EPRI Electric Power Research Institute · ESIG · IEEE Advancing Technology for Humanity · DTU · Fraunhofer CINES · CSIR · Imperial College London · CSIRO · VTT

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

ASEAN Centre for Energy (ACE) · olade Organización Latinoamericana de Energía · CSIR Touching lives through innovation

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

NREL Transforming ENERGY

GPST Goal Enablers & Implementation

Goals: Enable Operation of a 100% IBR Transmission System by 2025 or other regional goals

Enablers to achieve SO goals

- ✓ **Clear definition & adoption of new system needs & services framework**
- ✓ **Advanced techniques to define and ensure resource, energy and flexibility adequacy**
- ✓ **Deployment of advanced technology capabilities (e.g., GFM) to meet grid needs & provide services**
- ✓ **Refined stability tools, models, methods & metrics**
- ✓ **Advanced operational capabilities (e.g., control room of the future)**
- ✓ **DER architecture, operation & impact**

Implement via top projects

1. System Needs & Services Implementation Council
- NGESO Pathfinder project expansion

2. Resource Adequacy & Integrated Planning Implementation Council
- Next-gen RA & planning tools

3. Grid Forming Inverters: GFM Implementation Council
- GFM field test & demonstrations
- Cross-cutting standards development & technology adoption

4. Stability Tools, Models & Data Implementation Council
- Stability Tools for 100% IBR
- Improved accuracy of phasor and EMT tools & models
- Open-source tool development/data interoperability

5. CROTF Implementation Council
- Advanced operational capabilities

6. Distributed Energy Resources Implementation Council
- DER system architecture & tool development

KEY GFMIC INITIATIVES

PURPOSE - Break the chicken-egg cycle through deployment and commercialization of GFM technology by:

a) identifying GFM features/requirements by system operators
b) supporting technology demonstrations and deploying GFM resources from OEMs
c) GFM resource procurement by developers
d) Standardization, codes and interconnection requirements

METHOD - Collaboration with SOs, project developers, OEMs, software developers, standardizing institutions and other stakeholders on field tests, demonstrations, standards and codes, and dissemination

CONFIRMED & POSSIBLE PARTICIPANTS:

Developers

- ✓ Ørsted
- ✓ Enel
- ✓ Invenergy
- ✓ Zenobe
- ✓ Nextera
- Iberdrola
- EDF RE
- E.ON
- Acciona

System Operators

- ✓ NG ESO
- ✓ AEMO
- ✓ ERCOT
- ✓ Energinet
- ✓ Eirgrid
- ✓ FinGrid
- ✓ CAISO
- ✓ Amprion
- ✓ Elia
- ✓ 50 Hertz
- ✓ TenneT
- ✓ ENTSO-E
- ✓ XM
- ✓ CEN

OEMs

- ✓ GE
- ✓ Smartwires
- ✓ Siemens
- ✓ SGRE
- ✓ Hitachi Energy
- SMA
- Mitsubishi
- Toshiba
- Vestas
- Tesla

Software developers

- DigSilent
- GE
- Siemens PTI
- Manitoba Hydro
- EMTP
- Power World
- PowerTech Labs

GFM Implementation Council Tasks & Timeline

2023 - 2025

- Define GFM services
- Identify at least 5 GFM technology demonstrations and develop demo plan
- Document performance requirements ready to be codified and those that require further definition
- Create roadmap of requirements ready to be codified and outline studies/research needed for aspects that can’t
- Identify funding of research/studies for GFM aspects that can’t be codified
- Support development of GFM designs by manufacturers that can meet codified requirements
- Provide guidance to OEMs, software vendors and forward-thinking consultants to enable GFM technology deployment globally

2025 - 2027

- Full set of GFM equipment features will be deployable around the world
- GFM operating experience acquired by leading system operators will be shared globally

Goal: Selection of Initial GFM Demonstration Pilots

1. Immediate objective: Demonstrate GFM performance, capabilities, and models based on what we have today or will have soon via existing projects. Demonstrate performance of individual GFM capabilities.

2. Ultimate Objective: Conduct a series of field tests and model validation programs on 5 GFM projects connected in *GW-scale systems*. Demonstrate performance and interoperability across the grid with multiple GFM resources.

GFM demonstration projects:

AEMO
- 300MW existing or imminent BESS projects
- 8 new large GFM BESS projects, 250MW each, 2GW total (2025+)

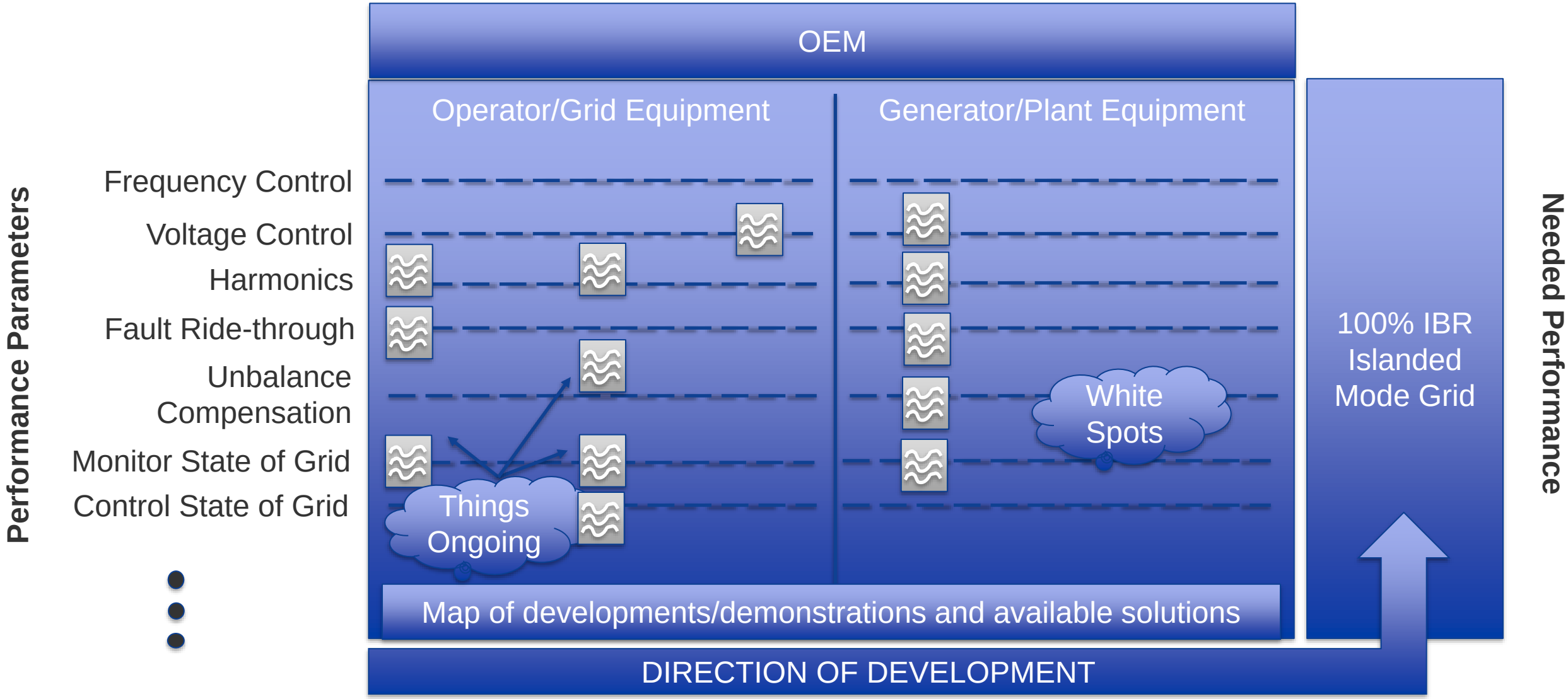
National Grid ESO
- 5 new GFM BESS projects under development (2024-2026)

ERCOT GFM demonstrations in West Texas
ELIA / 50Hz GFM field & lab demonstrations
ENERGINET GFM projects
ENTSO-E GFM requirements & programs
EPRI GFM programs and modeling
US DOE GFM demonstrations

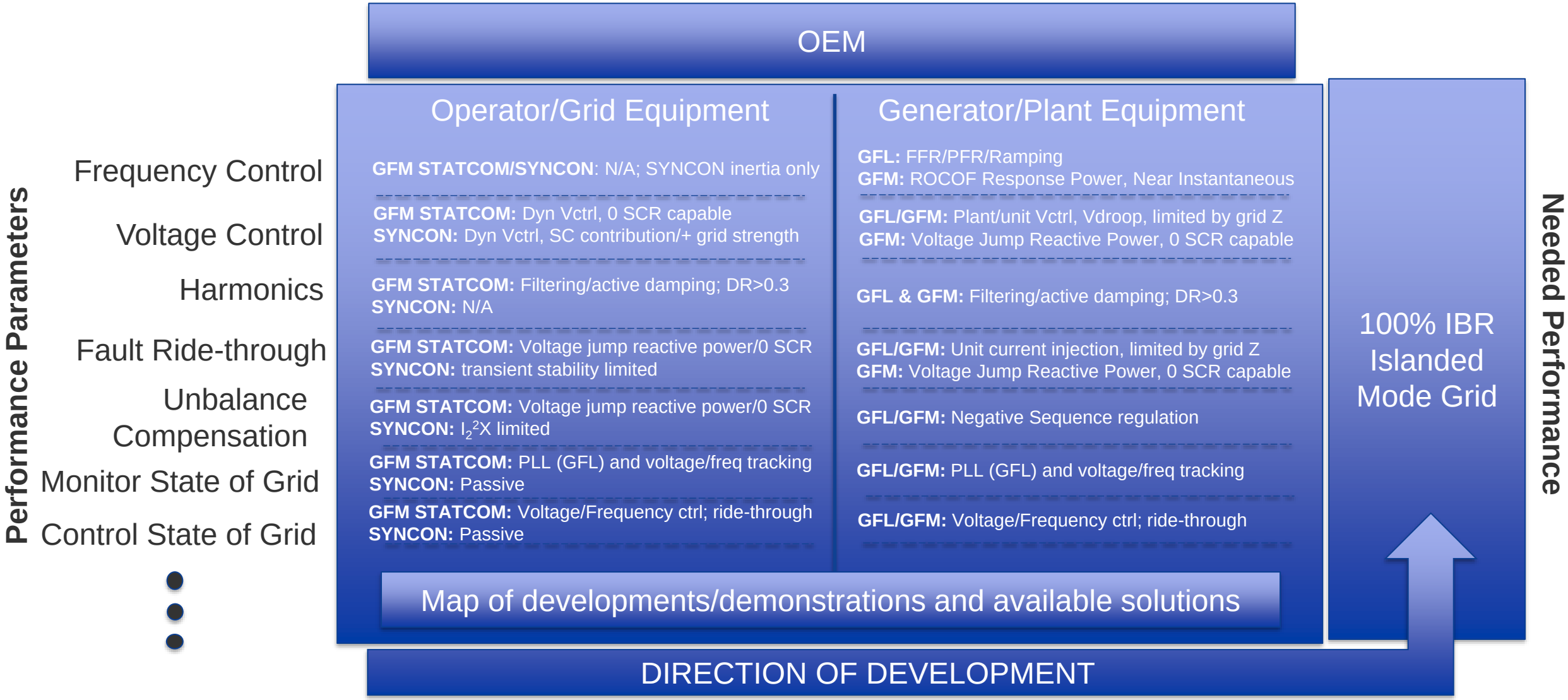
DEMONSTRATION PHASES

1. Utilize **existing project** commissioning, testing, monitoring and modeling data to demonstrate GFM performance.
2. Work with system operators, developers and OEMs on **imminent GFM projects** to implement a testing and monitoring plan.
3. Work with system operators, developers and OEMs to develop an extensive testing, monitoring and modeling program for enhanced demonstration of GFM **on new projects across the grid**.

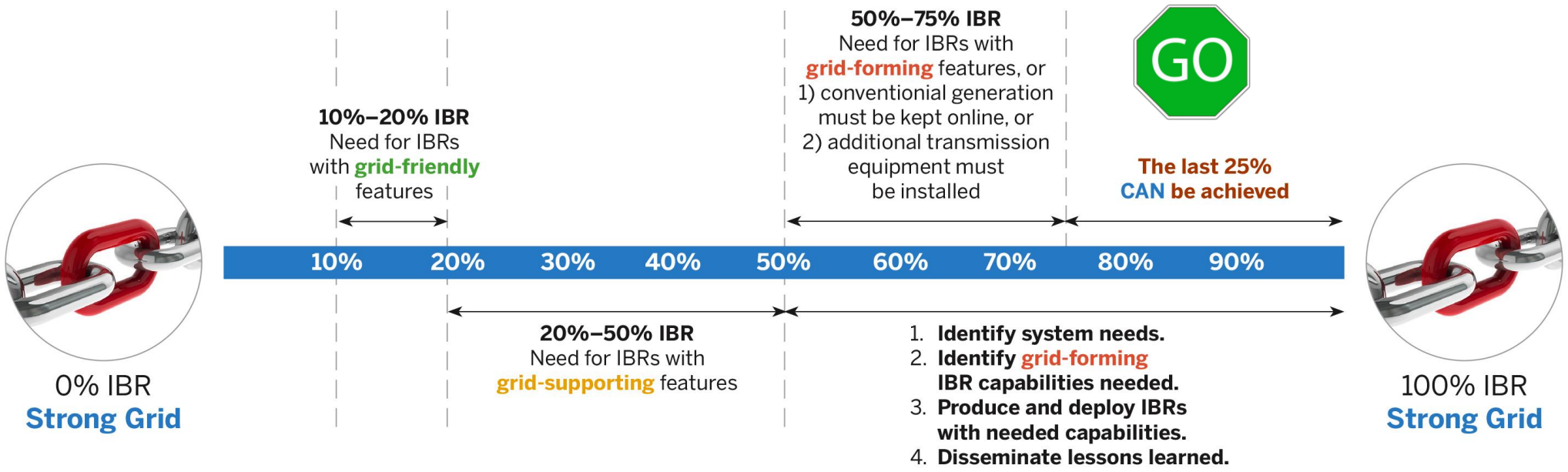
GFM Deployment Roadmap



GFM Deployment Roadmap



The way we can get to stable grid with 100%-IBR



Deploying grid-forming capabilities from IBRs themselves **is cheaper and faster** than adding new transmission assets, which would require additional investment and take much longer to build.

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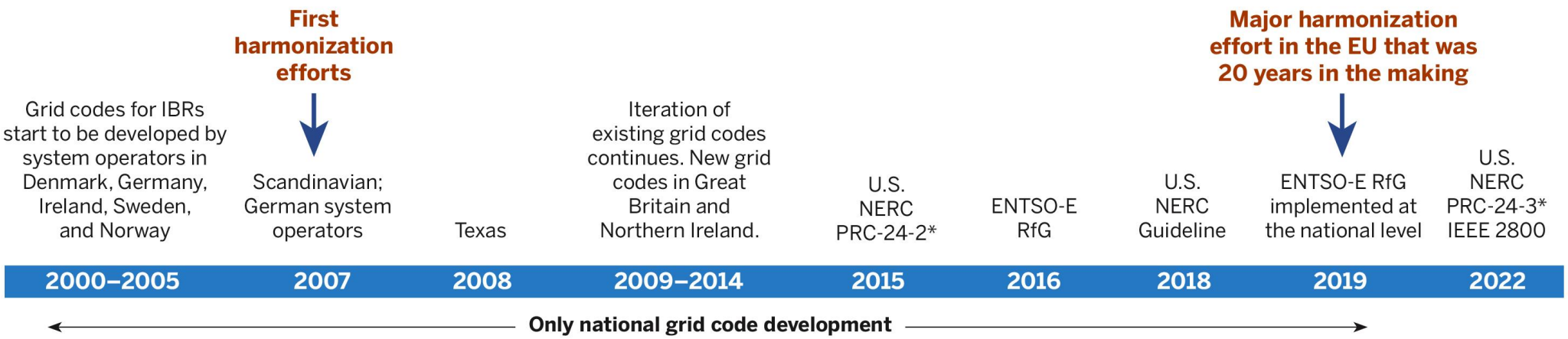
Timeline of Harmonization Efforts for IBR Grid Codes in Europe and the United States



- Grid codes specify the capabilities that IBRs must have in order to interconnect to the grid.
- Diversity in grid codes requires multiple product designs and increase equipment costs.
- Comprehensive harmonized grid code for IBRs took 20 years to develop in Europe.
- The U.S. still has no harmonized grid code for IBRs today.
- **We cannot take 20 years to develop and harmonize grid codes for grid-forming IBRs!**

*NERC PRC-024-2 only sets out a protective setting requirement and not a performance requirement to ensure ride-through capability

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Accelerating Pace of Change for GFM Technology through ESIG and G-PST

- **NREL:** Research Roadmap for Grid Forming Inverters (2020)
- **ENTSO-E:** High Penetration of Power Electronic Interfaced Power Sources and the Potential Contribution of Grid Forming Converters (2020)
- **NERC:** Grid Forming Technology Bulk Power System Reliability Considerations (2021)
- **NGESO:** GC0137 Minimum Specification Required for Provision of GB Grid Forming Capability (2021)
- **AEMO:** Application of Advanced Grid-Scale Inverters in the National Electricity Market (2021)
- **GPST:** System Needs and Services for Systems with High IBR Penetration (2021)
- **ESIG:** Grid Forming Technology in Energy Systems Integration (2022)
- **UNIFI:** Specifications for Grid-Forming Inverter-Based Resources – Version 1 (2022)
- **ARENA:** Australian Renewable Energy Agency Backs Eight Grid Scale Grid-Forming Batteries Worth $2.7 Billion (2022)
- **AEMO:** Transition to Fewer Synchronous Generators in South Australia (2023)
- **NGESO:** Great Britain Grid Forming Best Practice Guide (2023)
- **AEMO:** Voluntary Specification for Grid-Forming Inverters (2023)
- **FINGRID:** Specific Study Requirements for Grid Energy Storage Systems (focuses on grid forming requirements) (2023)

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Ongoing Global GFM Initiatives & Standardization

- **CIGRE JWG B4/C4.93** “Development of Grid Forming Converters for Secure and Reliable Operation of Future Electricity Systems“
- **IEC TC8/SC8A:** Proposal on Joint Working Group initiative for GFM standardization
- **CENELEC TC8X:** WG03 new work item on standardization of grid forming controls
- **IEEE P2988:** Recommended Practice for Use & Functions of Virtual Synchronous Machines
- **VDE-FNN** Grid Forming Guideline for HVDC and Power Park Modules
- **ACER / ENTSO-E RfG 2.0** (requirements for generators) and **INTEROPERA**: Grid forming requirements
- **Hawaii Grid Forming Specification**

GFMTC Demonstration Proposal

Framework of GFM capabilities and performance to be demonstrated & scaled

INPUTS

- Universal Interoperability of GFM Inverters (UNIFI) Specifications
- National Grid ESO GFM Requirements
- NERC Recommendations
- OSMOSE & VDE-FNN GFM Requirements
- HAWAII GFM Project Experience

ADD

- AEMO GFM Experience & Requirements
- Energinet GFM Experience & Requirements

GFM DEMONSTRATIONS VIA FIELD TESTS, MONITORING & MODELING

Performance under normal grid conditions

- Autonomously support the grid
- Provide positive damping
- Coordination of controls (P & Q sharing)
- Robust operation in low system strength grids
- Voltage balancing

Performance outside normal grid conditions

- Ride-through behavior
- Asymmetrical fault response
- Abnormal frequency response
- Response to phase jumps & voltage steps
- Intentional Islanding

Additional Behavior

- Black start and system restoration
- Regulating voltage harmonics
- Secondary voltage & Frequency Signal Response
- IBR short term rated current
- Constraints due to source ("*prime mover*")

Modeling & Documentation

- Model types, structure & parameterization
- Validation of models against field & factory tests
- Demo of GFM performance with validated models where field testing & monitoring is not available

Demonstration plans will be developed for each project
Planned $55M Funding Support ($5M/project + $5M PM support)
Perform demos, develop reports & disseminate knowledge globally

Build a Framework for GFM Requirements

- Document performance requirements ready to be codified and those that require further definition (per OSMOSE, GPST and ESIG reports)
  - Leverage existing GFM requirements already developed or being developed in National Grid, AEMO, ENTSOE, UNIFI, etc.
  - Leverage GFM test plans from Hawaii, NERC IRPS, German FNN-VDE requirements, UNIFI, etc.
  - Coordinate with Pillar IV on standards development
- Create roadmap of requirements ready to be codified and outline studies/research needed for aspects that can't
- Identify funding of research/studies for GFM aspects that can't yet be codified
- Identify and support development of GFM designs by manufacturers that can meet codified requirements
- Identify grid challenges that can't be resolved by GFM alone and articulate how requirements would need to be updated to address them

Actions and Next Steps

1. Accelerate GFMIC testing plans from 10 demonstration opportunities across the council.

- ✓ Single pilot tests
- ✓ Multi-GFM grid-wide tests

2. Develop detailed GFM demonstration plans :

- ✓ Simulation
- ✓ Testing
- ✓ Requirements/Standards deployment
- ✓ GFM Models
- ✓ Metrics
- ✓ Research & Innovation funding

3. Engage regulators in GFMIC discussions for developing a framework of baseline GFM requirements

High Priority Next Steps:

- ✓ Complete roadmap to identify white spots and actions to address them
- ✓ Accelerate GFM development & deployment through 10 demonstrations
- ✓ Create common framework for GFM codification and standardization for scalability
- ✓ Define expectations for the future that are realistic, implementable and at a workable pace for society

Thank you

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