Grid Transformation and Decarbonization

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

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My Perspective

Whether it was said by Bill Gates or others before him…

We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten.

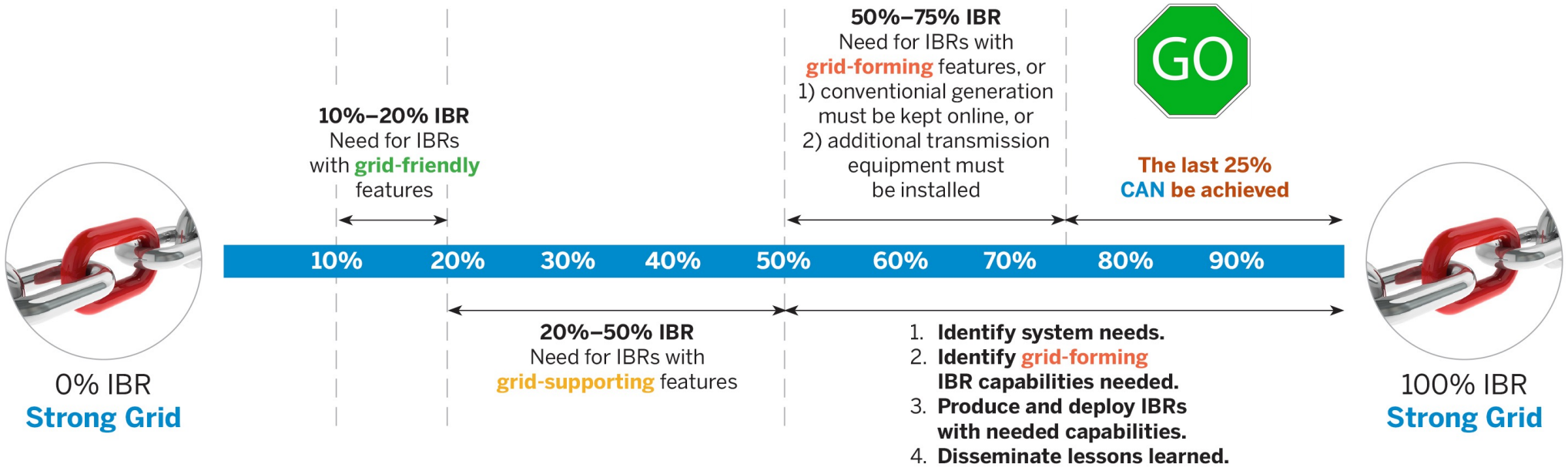
This is a time of great progress and rapid innovation

- Inverter capabilities and standardization
- Innovation (long-duration storage, “clean firm” options, hydrogen, more…)
- Collaboration and sharing

Organizations are convening, catalyzing and coordinating technical progress, including:

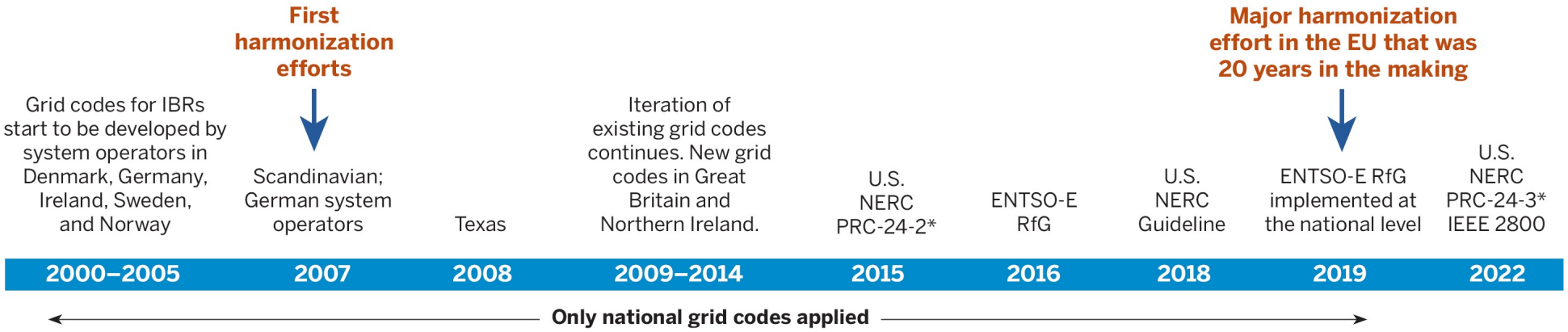
- Energy Systems Integration Group (https://esig.energy)
- Global Power System Transformation Consortium (https://globalpst.org)

Pathway to stable grid with 100% IBR



Deploying grid-forming capabilities in new inverter-based resources (IBRs) is the logical approach to stability and reliability

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



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

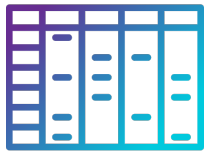
- Grid codes specify the capabilities that generators must have in order to interconnect to the grid.
- Diversity in grid codes requires multiple product designs and increase equipment costs.
- Comprehensive harmonized grid code for IBRs took 20 years to develop in Europe.
- The U.S. still has no harmonized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

Grid Forming Specs Landscape At Glance

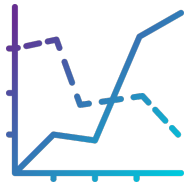
- **MIGRATE:** EU-funded project on the Massive Integration of Power Electronic Devices (2019)
- **HECO:** Model Energy Storage Power Purchase Agreement (2019)
- **NREL:** Research Roadmap for Grid Forming Inverters (2020)
- **ENTSO-E:** High Penetration of Power Electronic Interfaced Power Sources and the Potential Contribution of Grid Forming Converters (2020)
- **VDE FNN:** Guideline Grid forming behavior of HVDC systems and DC-connected PPMs (2020)
- **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)
- **HECO:** Model Energy Storage Power Purchase Agreement (2021)
- **OSMOSE:** EU-funded project (continuation of MIGRATE) that defined grid forming capability and new services (2022)
- **UNIFI:** Specifications for Grid-Forming Inverter-Based Resources – Version 1 (2022)
- **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)
- **NERC:** Grid Forming Functional Specifications for BPS-Connected Battery Energy Systems (2023)

Source: Adopted from UNIFI, GFM Inverter Technology Specifications: Review of Research Reports and Roadmaps

Resource Adequacy



- **Not all shortfalls are alike...**
  size, frequency, duration, and timing of events



- **Risk is shifting...**
  must look across entire years of operation

- **Weather...**
  Is changing, requires cross-disciplinary expertise, data, and updated assumptions

- **Resource sharing**
  sharing is critical, transmission is a capacity resource

For more information, see **ESIG, Redefining Resource Adequacy for Modern Power Systems,** 2021 Figure: Telos Energy (www.telos.energy)

Hybrid Resources

An “intelligent agent” approach for a system of technologies that offers energy and services at the grid point of interconnection (POI) like a conventional resource, but with more flexibility and fewer constraints through coordinated use of energy, storage, power electronics and software

Or said another way…

With sufficient energy, storage, electronics and software,
we can emulate any kind of electrical machine that we want or need

What's next?

Massive load expansion

- Green and blue hydrogen
- Carbon capture & storage
- Large "Flexible" Loads
- Long-duration storage
- Virtual power plants

Challenges

- Transmission
- Interconnection complexity
- Grid defection risk
- Legacy grid management and market software platforms
- Exponential increases:
  - innovation and analytics
  - number of participants
  - system complexity

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

THANK YOU

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