U.S. DEPARTMENT OF ENERGY

unifi consortium

universal interoperability for grid-forming inverters

UNIFI Consortium Overview

Ben Kroposki

UNIFI Organizational Director

March 2022

UNIFI is pronounced the same as unify

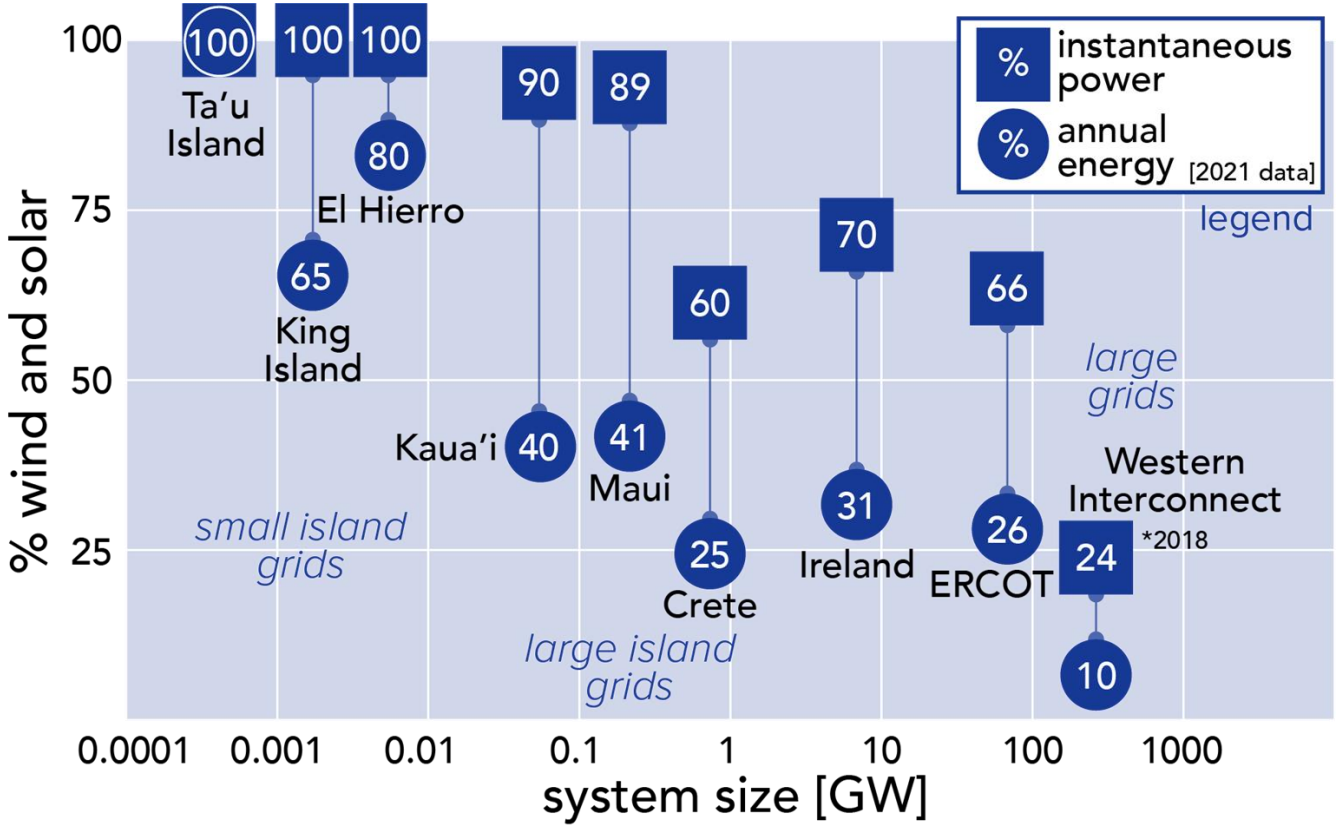
unifi consortium

universal interoperability for grid-forming inverters

Future power systems with any mix of machines and IBRs at any scale that are affordable, secure, reliable, clean, and resilient — **Vision**

Forum to address fundamental challenges in seamless integration of grid-forming (GFM) technologies into power systems of the future — **Purpose**

Conduct research and development, demo concepts at scale, author best practices and standards, train next-generation workforce — **Goal**



IBRs = inverter-based resources

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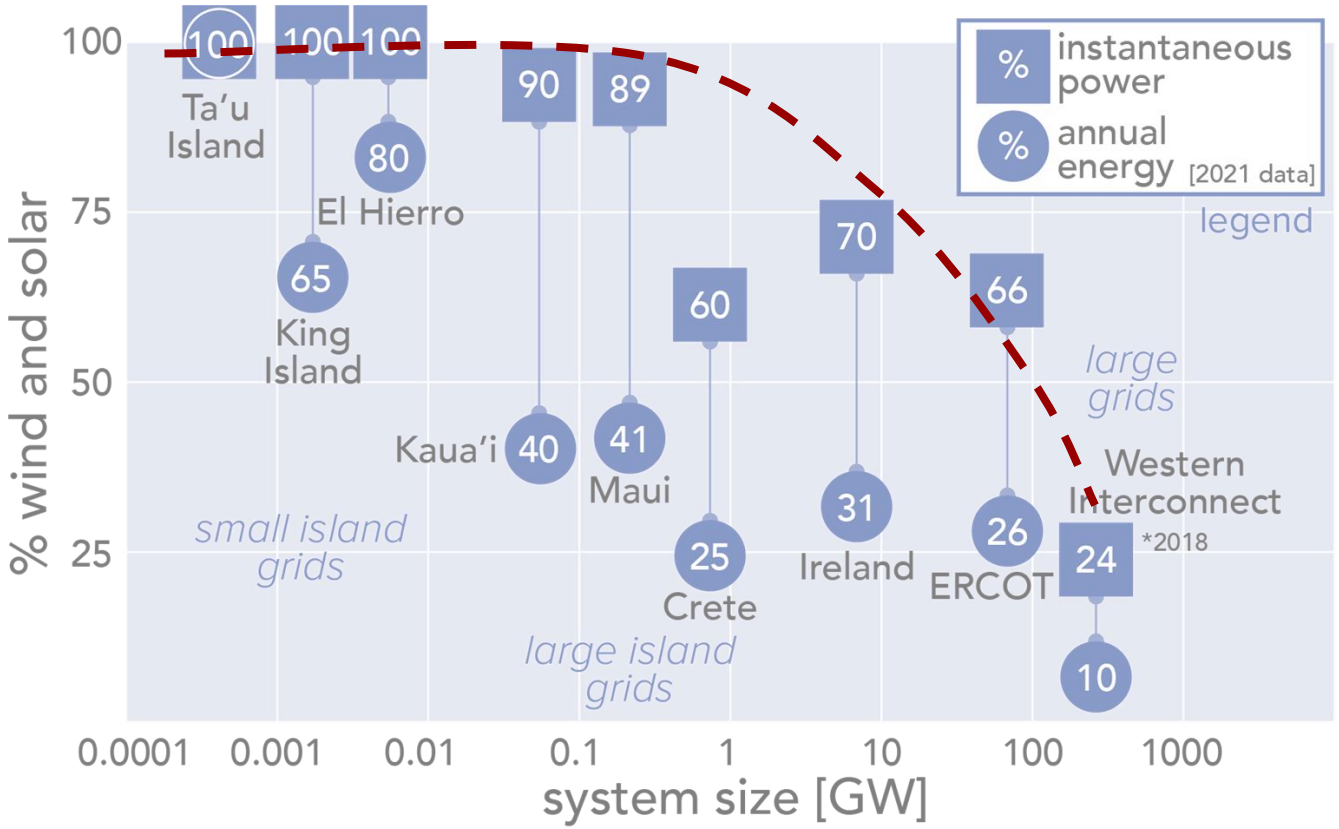

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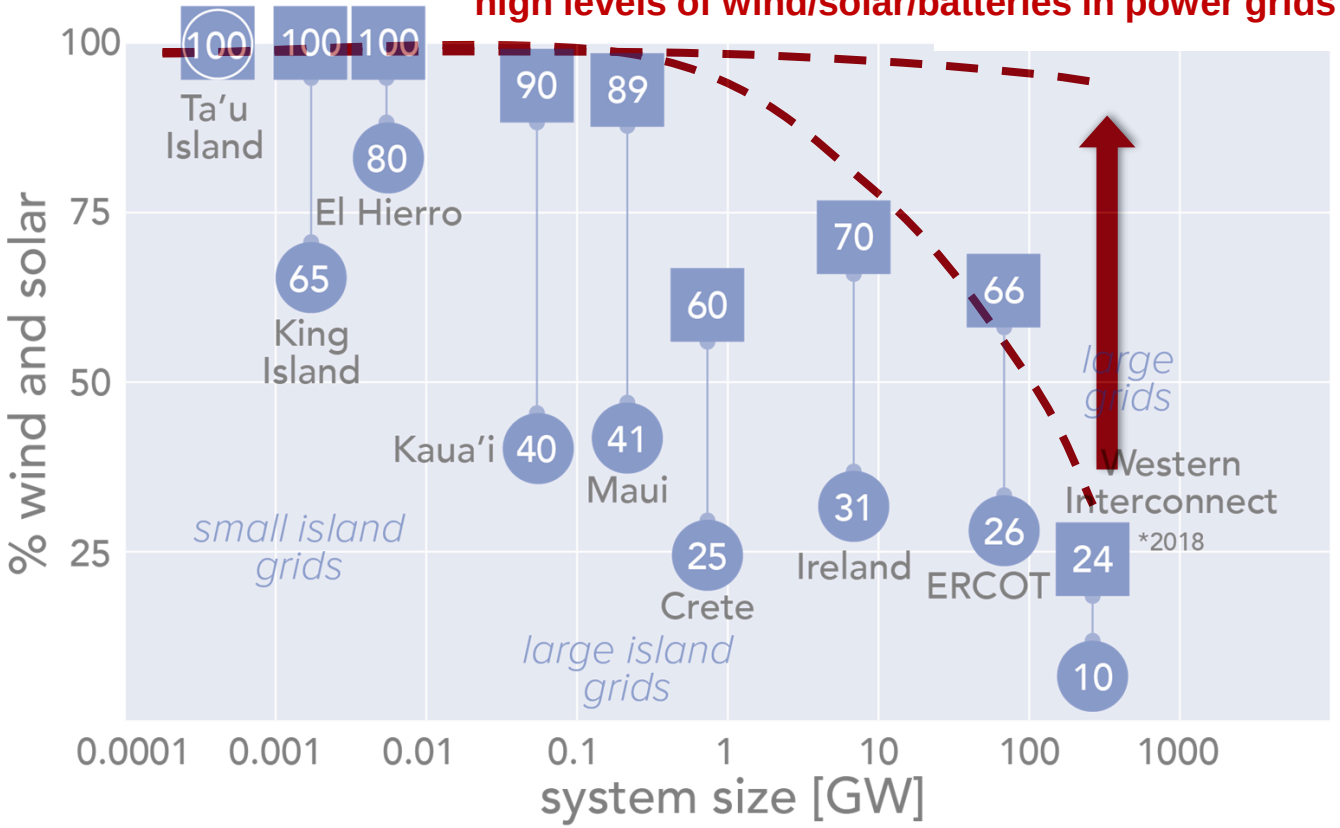
The most critical problem to solve to enable very high levels of wind/solar/batteries in power grids



Global Landscape

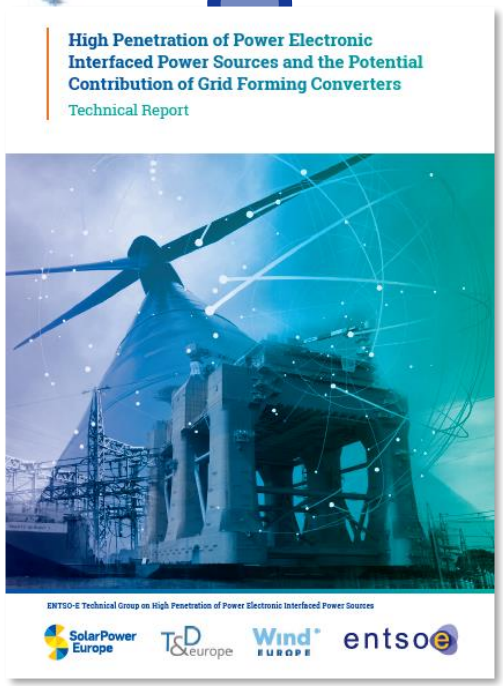
Grid codes and roadmaps around the world recognize the role for (and of) grid-forming (GFM) inverter-based resources (IBRs)

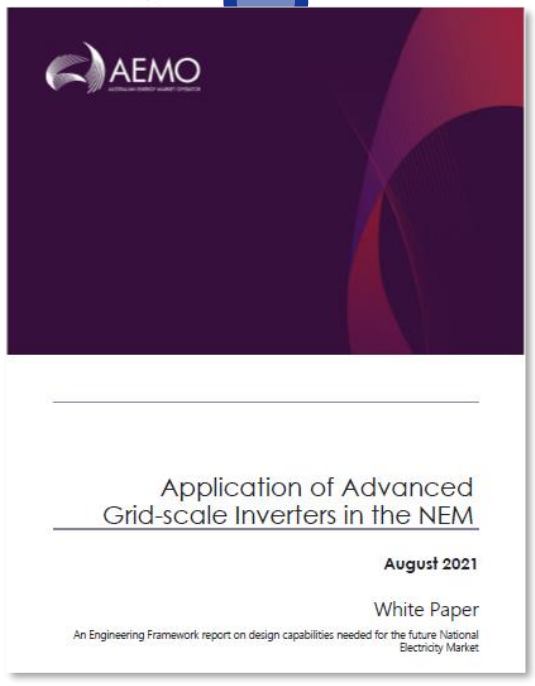
Challenges

- Poor definitions of capability and functionality across technologies; lack of standardization
- Limited-to-no consensus on expected performance from unit and system levels
- Vendors/Manufacturers and Utilities/Operators appear to be locked in circular death spirals

Solution (@ a snapshot)

- Interoperability drove interconnections in the past
- Interoperability will drive innovation into the future





What is UNIFI ?

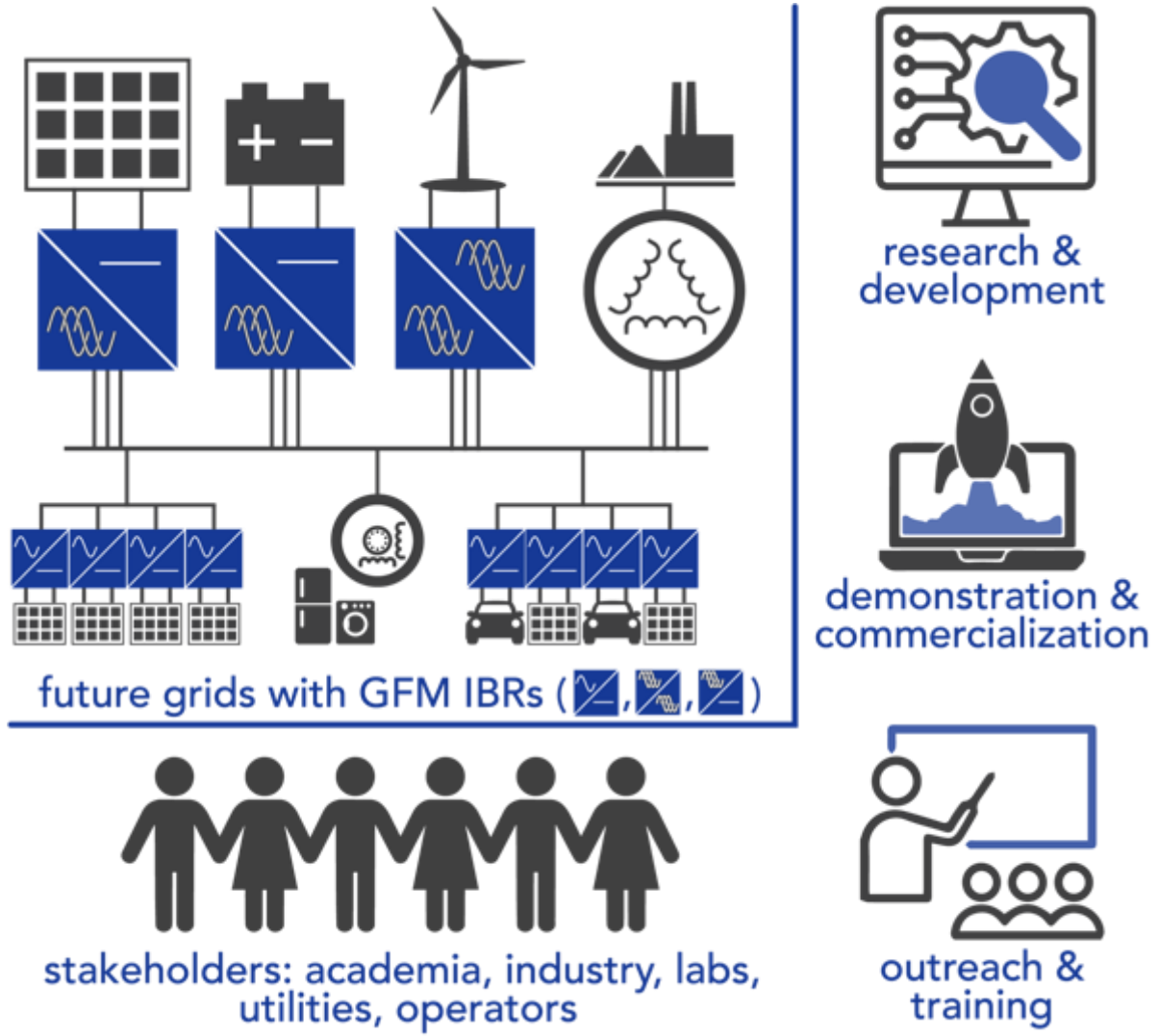
The **UNIFI Consortium** is a forum to address fundamental challenges in the seamless integration of grid-forming (GFM) inverter-based resources (IBR) into power systems of the future

Bringing the industry together to unify the integration and operation of inverter-based resources and synchronous machines

Three major focuses:

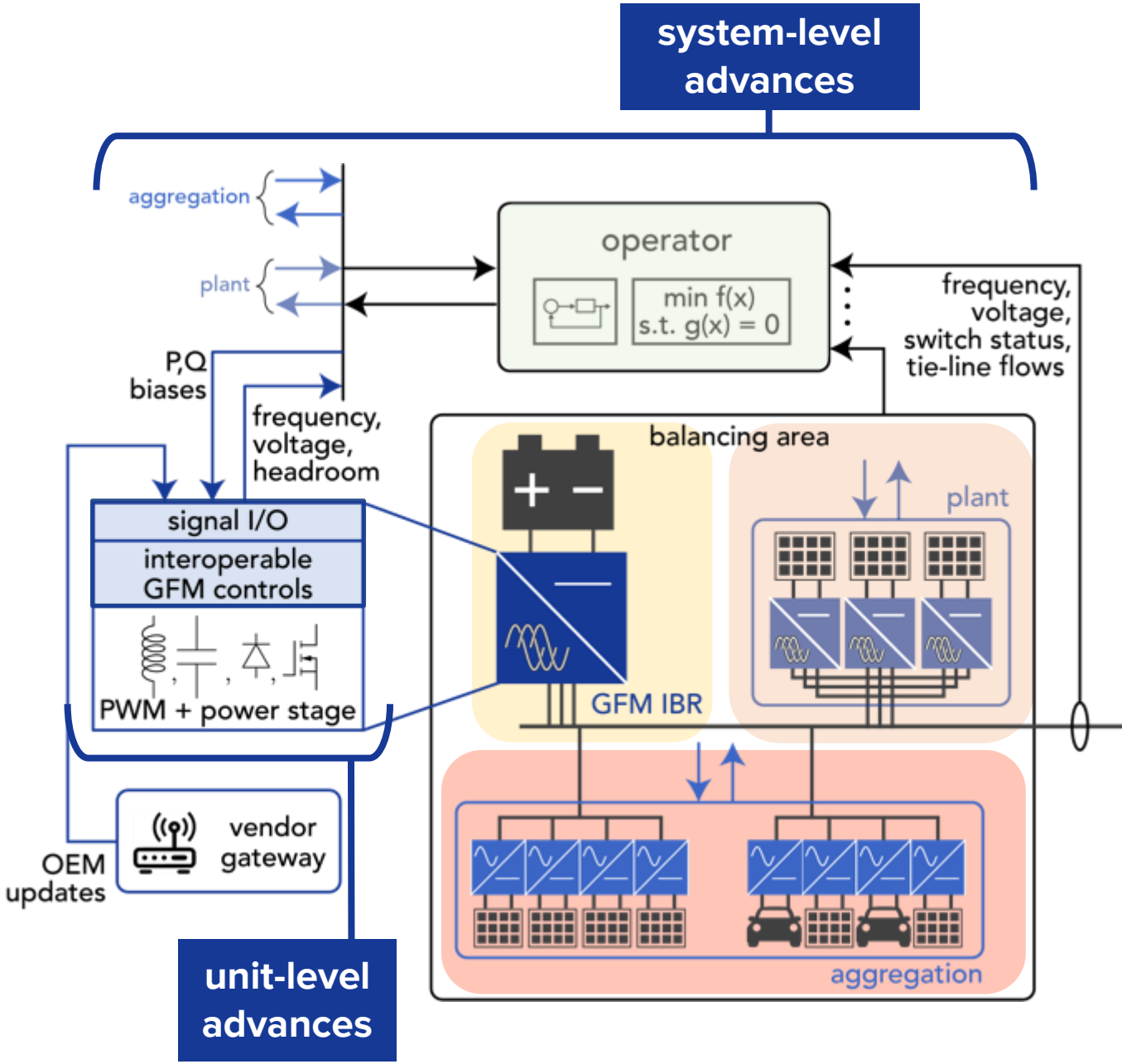
- Research & Development
- Demonstration & Commercialization
- Outreach & Training

DOE is funding a 5-year project to kick-start work – Plan to create a sustainable organization through memberships



Envisioned System Architecture

- GFM technologies: individual **GFM IBR**s (at sufficiently high capacity), **plants** (e.g., utility-scale PV/wind), or **aggregations** (e.g., heterogeneous units at distribution level)
- Unit-level functionality includes vendor-specific proprietary controls aided by a middle-layer (labelled **interoperable GFM controls**) that translates system-level control objectives
- Exchange standardized signals through suitable interface (**signal I/O**) in a cyber-secure manner with the system operator to regulate frequency & voltages via secondary control, and manage operations (e.g., black-start)
- Distributed optimization and control algorithms within and across control areas (**balancing area**s) may be required
- Will require both unit-level and system level advances



GFM = grid-forming inverter IBRs = inverter-based resources

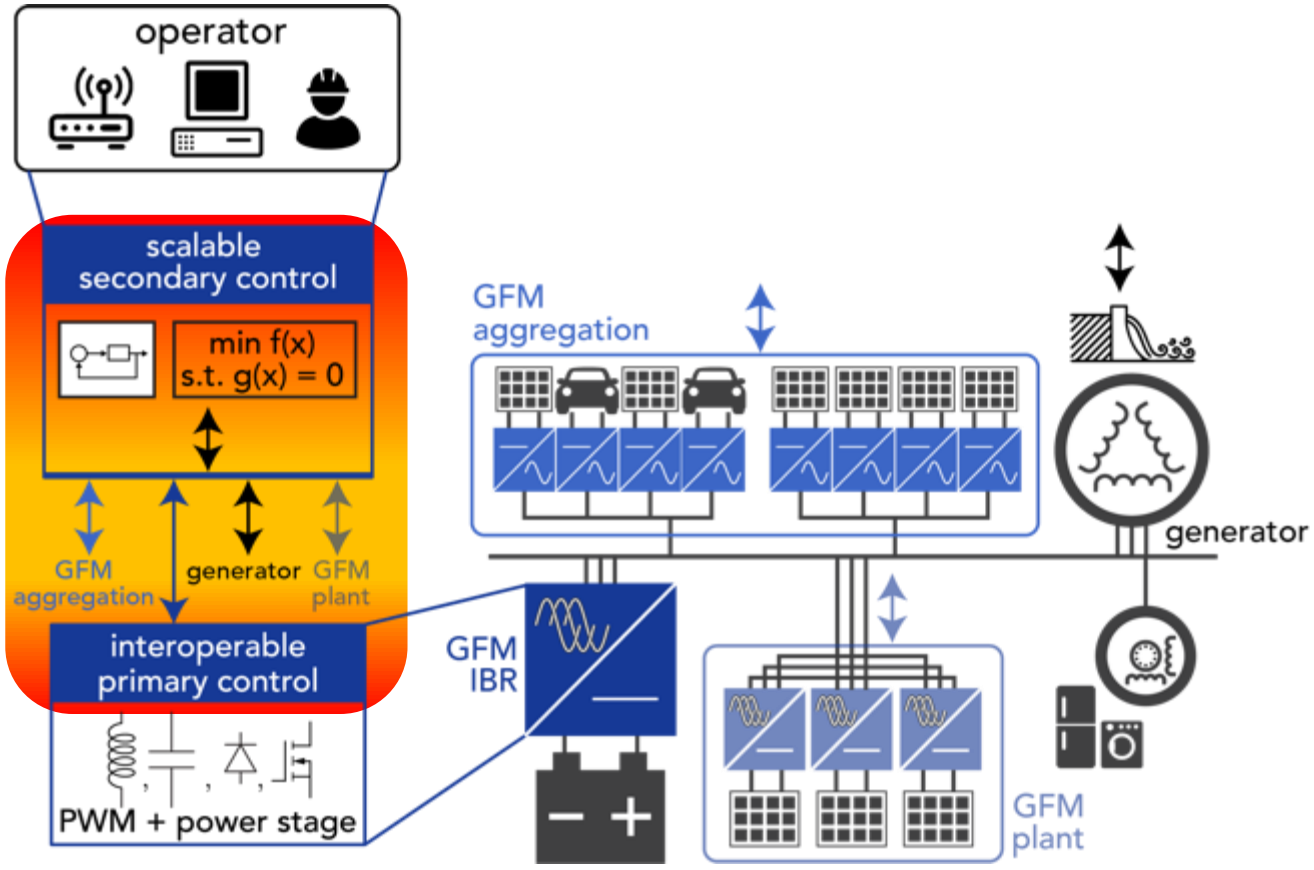
UNIFI Goals

Curate vendor- and technology-agnostic ***"UNIFI Specifications"*** that standardize performance and benchmark capabilities of GFM technologies across scales

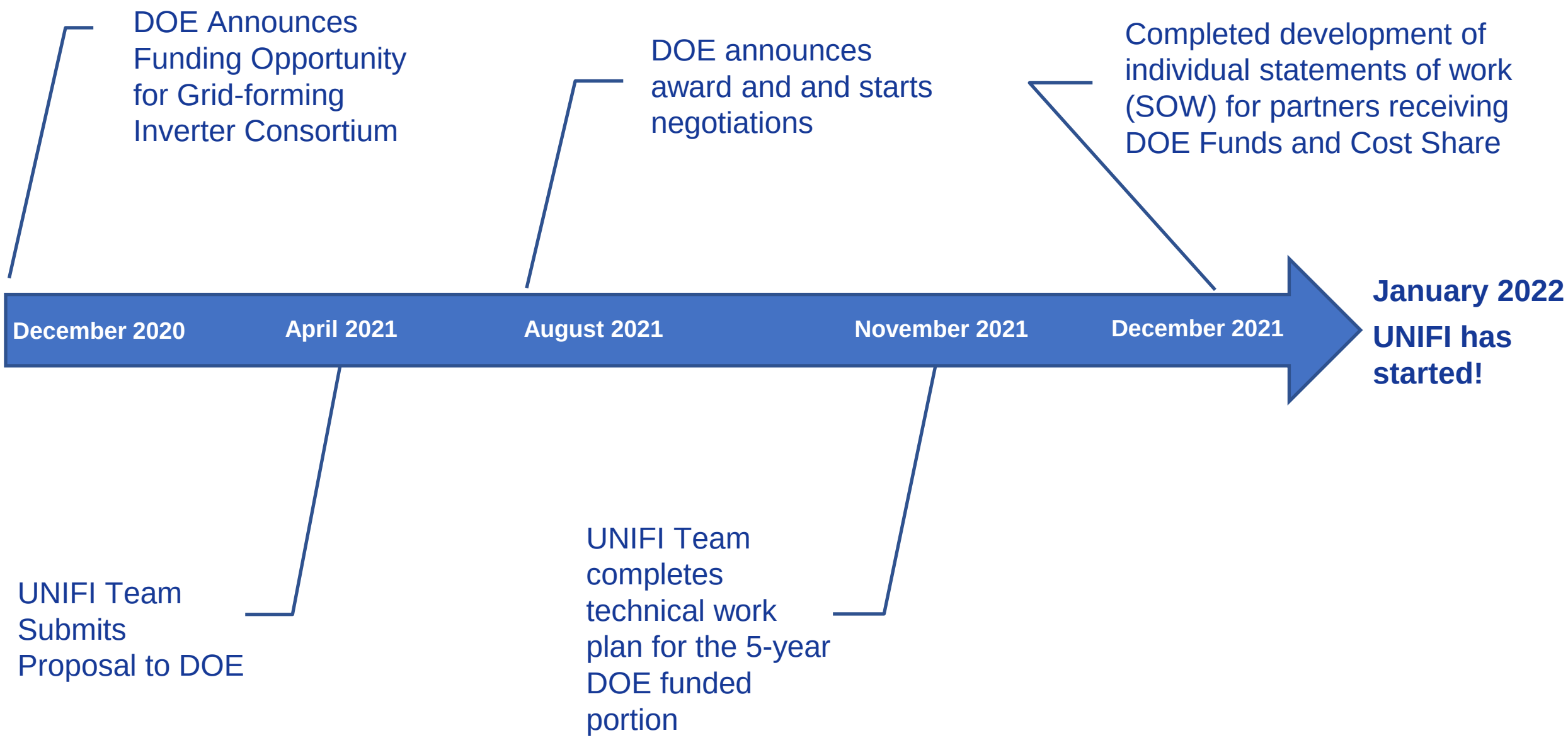
- ***Interoperability Guidelines (@ system level)*** - *that promote the coordinated and seamless operation of GFM technologies from multiple vendors while ensuring stable and reliable power grids*
- ***Functional Requirements (@ IBR level)*** – *that define GFM-IBR capabilities which are specified in a vendor-agnostic fashion to satisfy all system-level interoperability guidelines*

Convene continuous collaboration between inverter manufacturers (on one end) and system operators and utilities (on the other) to bridge gaps between power-systems and power-electronics industries

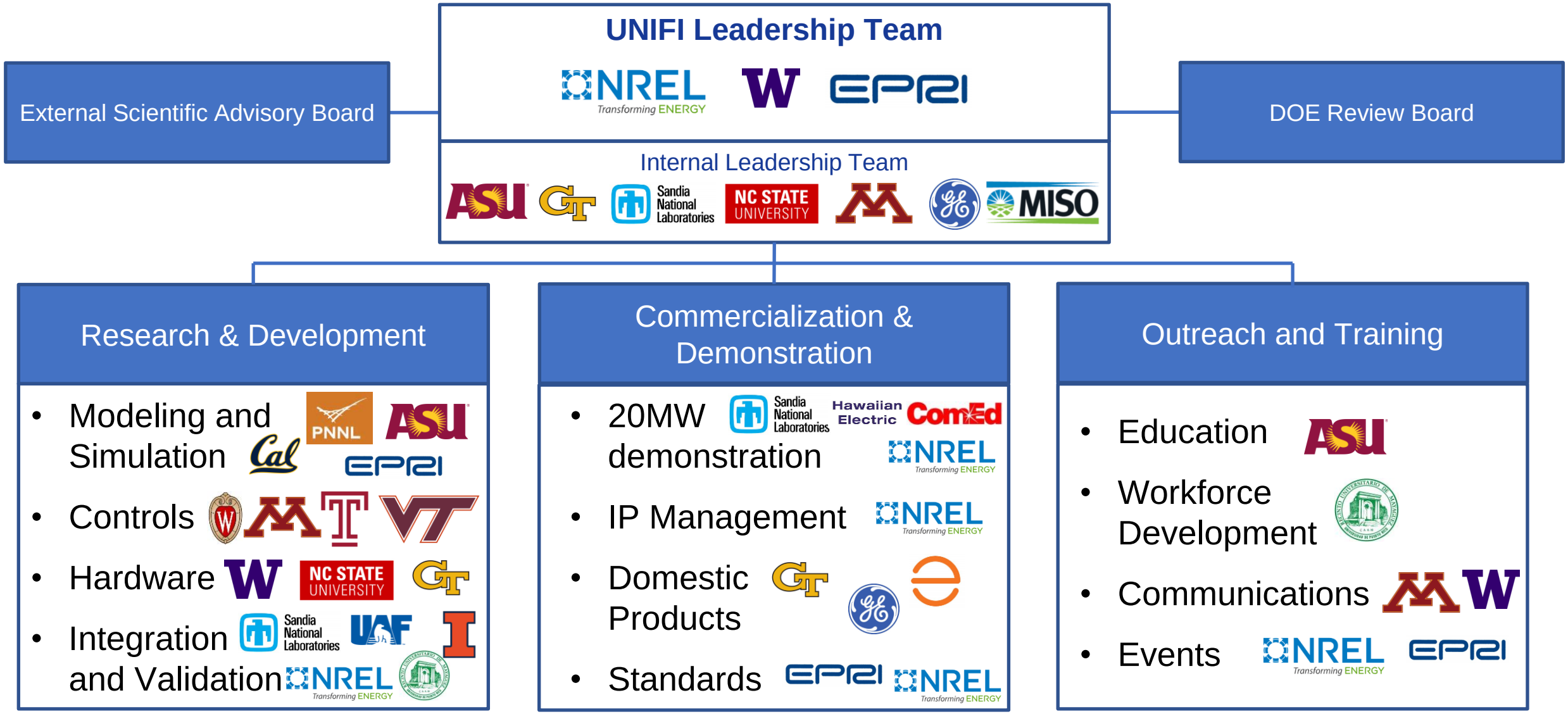
Cultivate inclusive culture and leverage member cooperation for sustained innovation



Timeline to Date



UNIFI Organizational Structure



UNIFI Working Groups (WG)

- UNIFI Specifications
  - Interoperability and Functional Requirements WG (defines interoperability, maintains rules, manages Core IP)
- Modeling and Simulation Area
  - GFM Model Development and Theoretical Innovations WG
  - Use Case, Software Testbed, and Interoperability
- Controls Area
  - Real-time Control and Dynamic Stability WG
  - Communication-coordinated Control and Cybersecurity WG
- Hardware Area
  - Open-source Code Development and Experiment Planning & Design WG
- Integration and Validation Area
  - Validation of UNIFI Specifications WG
  - 1MW Multi-vendor Experiment WG
- 20MW Demonstration Area
  - 20MW Demo Specifications WG
- Standards Area
  - Standards Coordination WG
- Education Area
  - Education WG
- Workforce Development Area
  - Seminar Series WG
  - Tutorials WG

UNIFI Members - Project Team

National Labs & Research Institutes

NREL Transforming ENERGY

EPRI

Berkeley Lab

PNNL

Sandia National Laboratories

Universities

unifi consortium

Industry

Utilities & System Operators

Additional Partners

- Participation confirmed through Letters of Support
- Representative of potential additional Consortium members, facility users, sponsors of directed R&D
- Emphasize strong ties with other relevant Consortia from inception to ensure unique positioning

Research & Development (R&D) Thrust

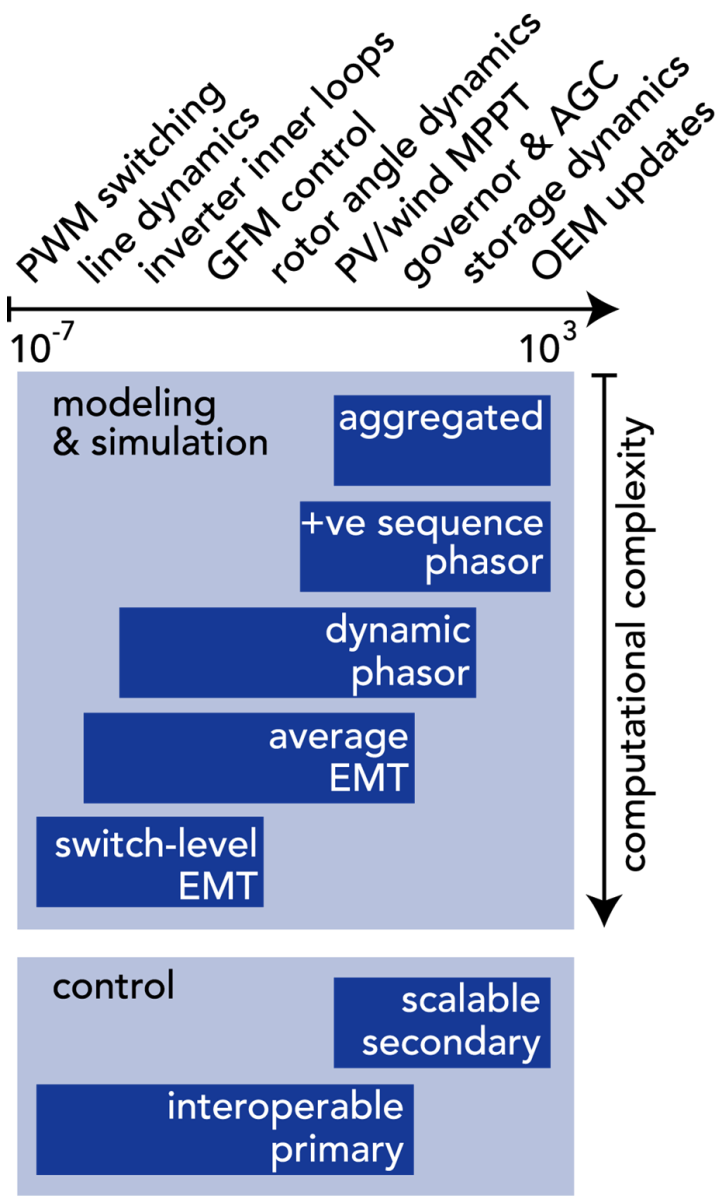
- **At-a-Glance:**
  - **Modeling & Simulation:** GFM-specific dynamics, bridge gaps to HIL
  - **Controls:** Unit- and system-level, Stability, Cybersecurity
  - **Hardware:** Anticipate industry needs, Develop open-source prototyping
  - **Integration & Validation:** Conduit to demonstrations, 1MW experiment at NREL

- **Features:**
  - Establish core technical capabilities in critical technical areas
  - Leadership provided by experts across academia, labs, industry
  - Emphasize interoperability across portfolio of solution sets

Modeling & Simulation Area

Snapshot of Innovations:

- Interoperability standards and application programming interfaces (APIs) to allow GFM models to be directly used by different software vendors
- Develop HIL-compatible software models:
  - Hybrid between virtual power stage model & controller in the loop
  - Integrated into commercial and open-source simulation tools
- Model interoperability tests on a virtual platform that provides a secure workspace for tool vendors and a means for utilities to participate and evaluate solutions
- UNIFI has partnerships and collaborations with **all** commercial power-system simulation-software vendors that cover timescales ranging from real-time through micro-/milli-second simulations:
  - EMT simulation (PSCAD, EMTP, HYPERSIM, PLECS)
  - Positive-sequence simulation (PSLF, PSS/E, TSAT, PowerWorld)
  - Real-time simulation (Opal-RT and Typhoon HIL)

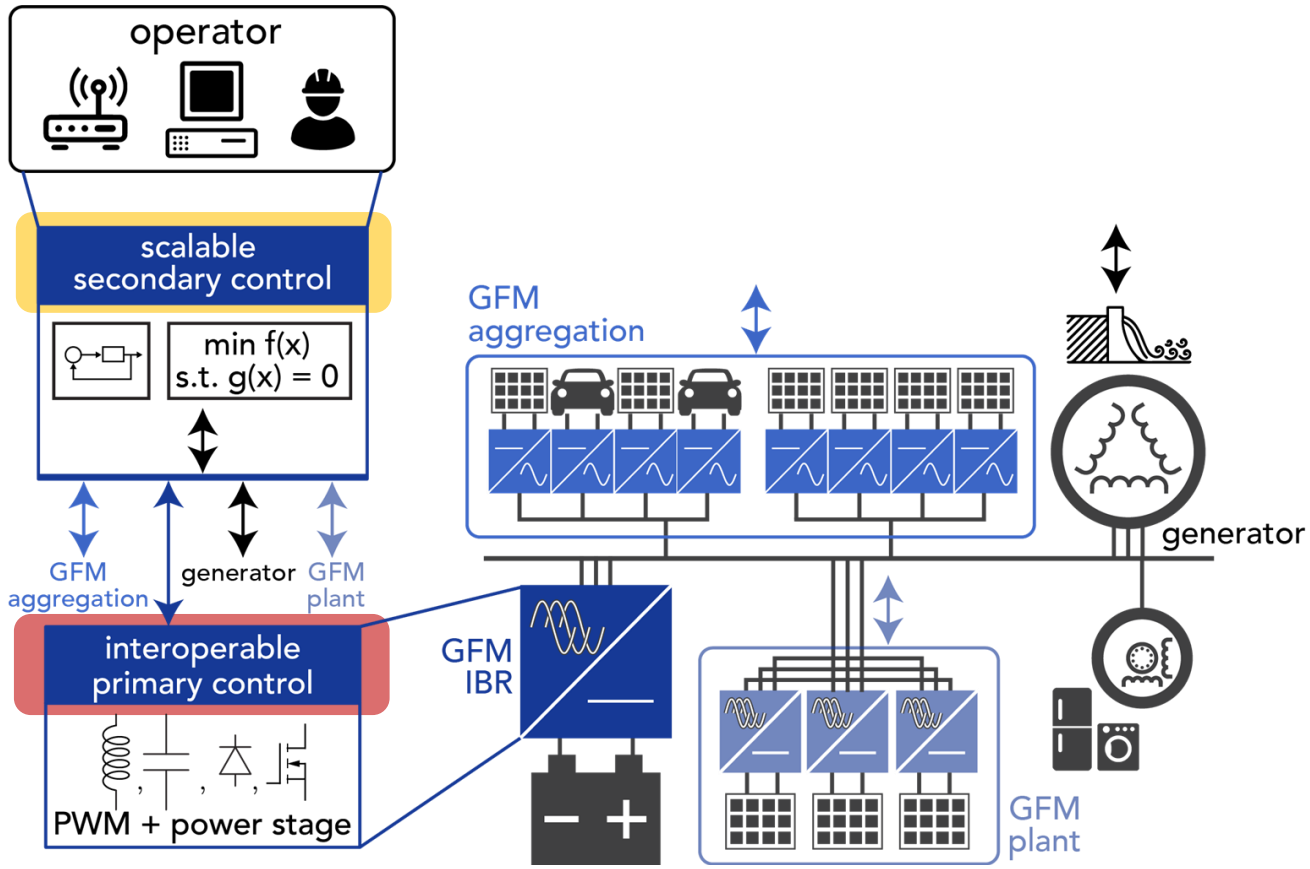


Controls Area

Snapshot of Innovations:

- **Interoperable GFM primary-control architecture:**
  - Compatible with generation and storage technologies via vendor-agnostic middle-layer that translates system-level control signals
  - Coordinates energy transfer within hybrid IBR-plants, large-scale PV, and wind energy conversion systems while managing IBR-level source-side and inverter limits

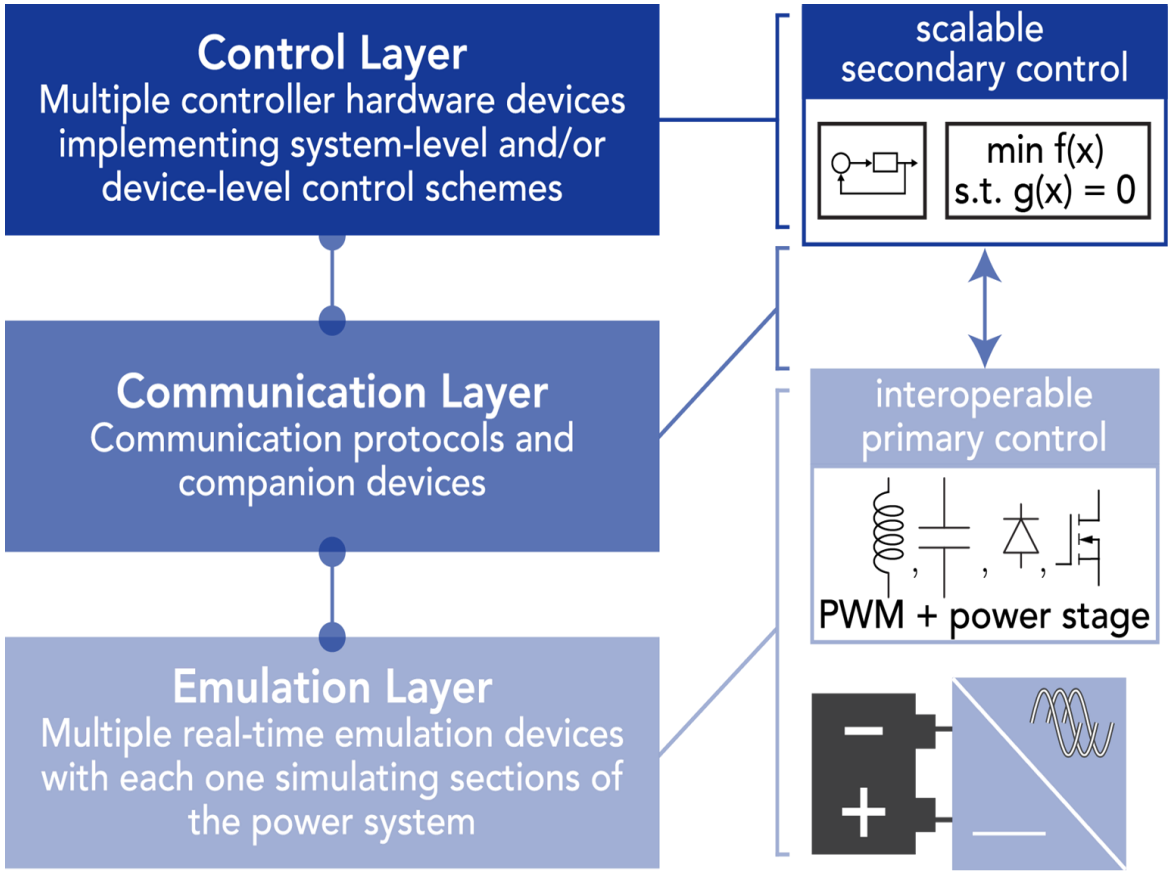
- **Scalable secondary-control architecture:**
  - Generalize area control error (ACE) beyond frequency (to include, e.g., voltage magnitude, phase imbalance)
  - Coordinate and prioritize between different balancing areas while accounting for IBR limits

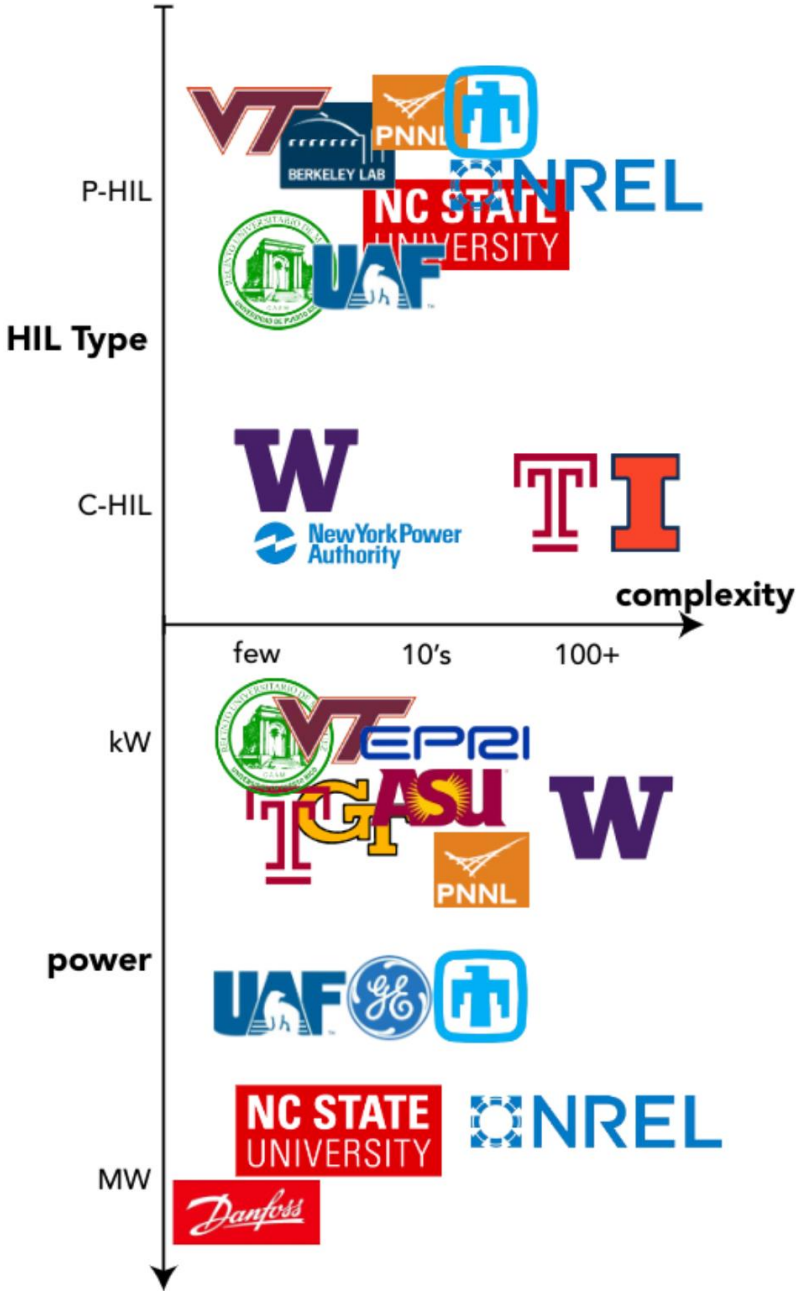


Integration & Validation Area

Snapshot of Innovations:

- Federate and standardize testing and characterization facilities across partnering institutions
- Use cases → testing, evaluation, communication protocols → certification-type testing environment → user facilities for fee





Integration & Validation Area

1 MW Experiment – at NREL in Year 3

- Create a hardware testbed that all vendors that follow the UNIFI Specifications for interoperability should be able to plug and play with other vendors
- Includes various physical sizes (250W-1MW)
- Three-phase, single-phase generation & loads
- Multiple source-side resources (PV, energy storage, wind (if possible))
- 50%, 75%, 90%, and 100% power contribution from GFM IBRs
- Connections to multiple laboratories: integrated testing and validation approach to realize multiple 1MW demos

Demonstration & Commercialization (D&C) Thrust

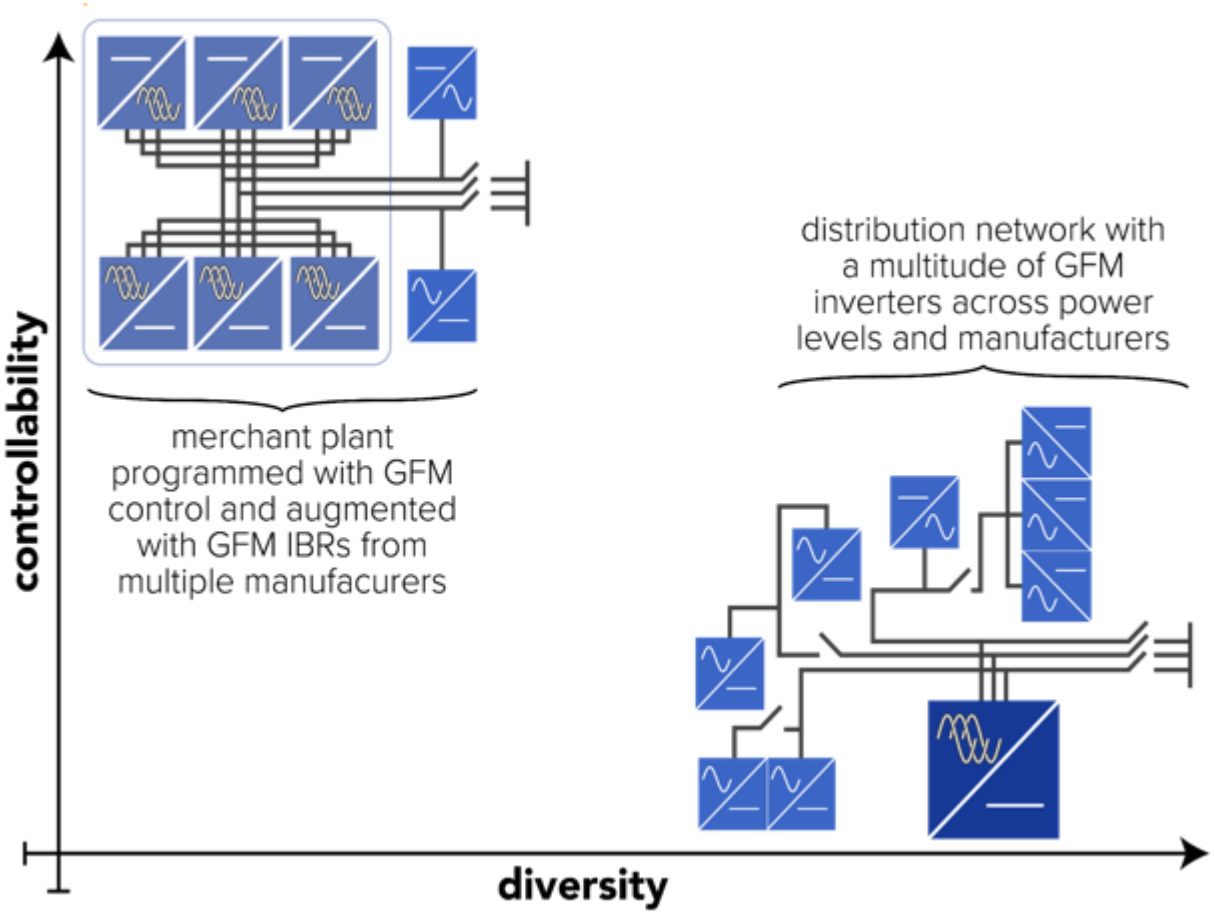
- At-a-Glance:
  - **20+MW Demo:** flagship UNIFI outcome
  - **IP Management:** collaborative IP to focus on interoperability
  - **Domestic Products:** position US as world leader in PV, wind, and storage
  - **Standards:** align with technology cycles via emphasis on interoperability

- Features:
  - Conduit to transition R&D to commercial products and applications
  - Leadership by experts who have built startups and led acquisitions
  - Testing grounds to evaluate broad impact across industries
  - Extensive experience with standards development organizations

20+MW Demonstration

Large-scale Plant Integration

[Barilla Solar, TX]



Distribution Networks with high PV integration

[Chicago, IL]

[Oahu, HI]

- Examining a range of possible sites that trade off controllability and diversity of resources and IBR size
- Also looking for demonstrating much larger than 20MW sizes and at possibly at multiple sites
- Demonstrate a full range of GFM services and validate *Interoperability Guidelines & Functional Requirements*
- Would like to examine unique objectives if possible such as energy justice (collocate with underserved communities)

20+MW Demonstration

We are looking for sites that include some or all of the following:

- a mix of three-phase/single-phase resources
- a mix of GFM IBRs, GFL IBRs, and machines
- devices that have a wide range of power ratings (from 250W to MW)
- solutions from multiple vendors a plurality of source-side energy sources (PV, energy storage, wind)
- plant-level controls and SCADA as required
- range of load types and sizes (resistive/inductive, single-/three-phase)

Would like to validate the UNIFI system interoperability guidelines and functional requirements

- interoperable and scalable primary and secondary control
- frequency and voltage control
- power sharing among units
- black-start
- transient operation during balanced and unbalanced faults
- operations to achieve up to 100% power contribution from IBRs during medium- and high-demand periods

Let us know if you have potential demonstration sites

Prior Work

Demonstration of Essential Reliability Services by a 300-MW Solar Photovoltaic Power Plant

Clyde Loutan, Peter Klauer, Sirajul Chowdhury, and Stephen Hall
California Independent System Operator

Mahesh Morjaria, Vladimir Chadliev, Nick Milam, and Christopher Milan
First Solar

Vahan Gevorgian
National Renewable Energy Laboratory

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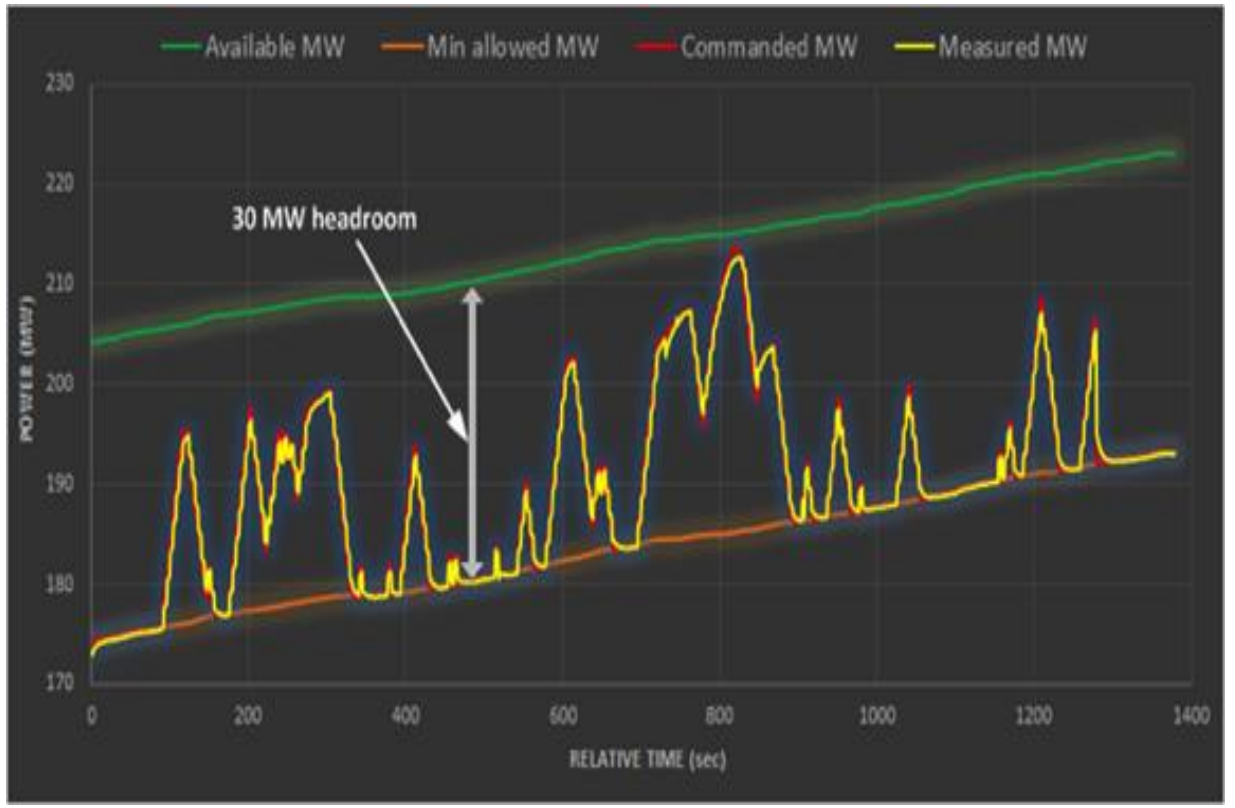


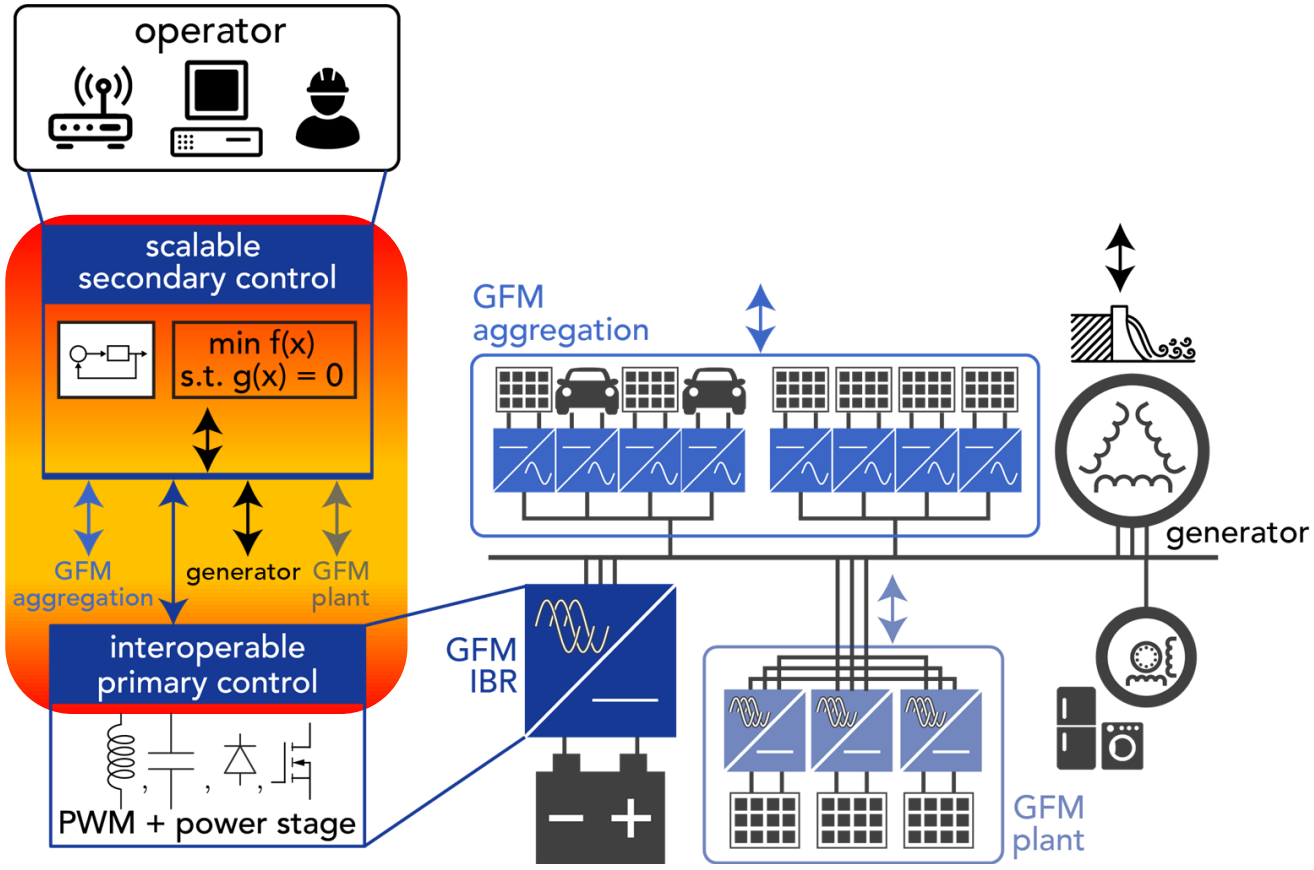
NREL/FirstSolar/CAISO experiment: 300-MW plant following Automatic Generator Control (AGC) signal

Source: C. Loutan, P. Klauer, S. Chowdhury, S. Hall, M. Morjaria, V. Chadliev, N. Milam, C. Milan, V. Gevorgian, *Demonstration of Essential Reliability Services by a 300-MW Solar Photovoltaic Power Plant*, http://www.nrel.gov/docs/fy17osti/67799.pdf

IP Management and Product Development

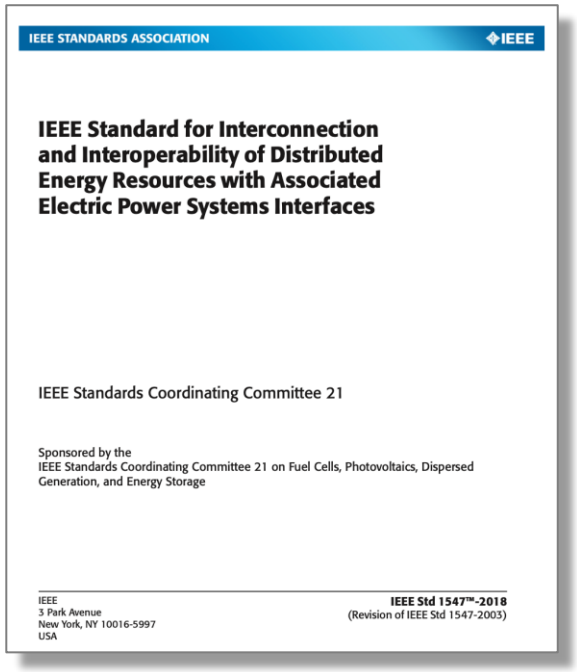
- UNIFI plans to work with members to determine and develop *"Core Stack"* IP that will enable GFM technologies to meet the Interoperability Guidelines and Functional Requirements

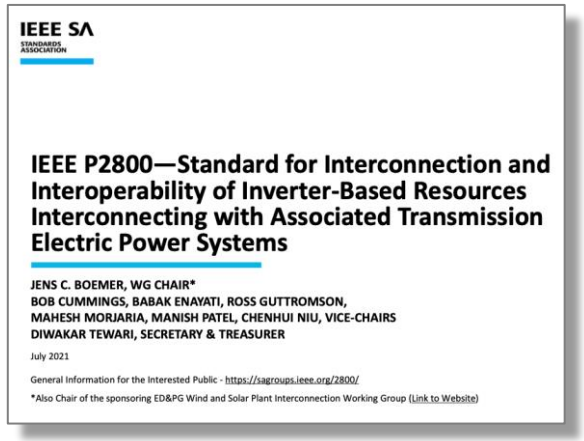
- Ensure that members have ability to meet UNIFI Specifications



Standards

- Current standards for interconnecting IBR to power systems do not specifically address GFM technologies
  - IEEE 1547 - Distribution
  - IEEE P2800 - Transmission
- Conducting a gap analysis on existing IEEE 1547 and 2800 standards along with development of technical minimum capabilities for GFM devices
- UNIFI will focus on developing specification for GFM technologies
- Working closely with Standard Development Organizations, UNFI will bring expertise on GFM to future updates of these standards





Outreach & Training (O&T) Thrust

- At-a-Glance:
  - **Education:** certificate program, summer program, half-day certification for teachers
  - **Workforce development:** short courses & tutorials, safety-certification courses
  - **Communication:** website and e-newsletter(s)
  - **Events:** annual meetings, webinars

- **Features:**
  - Cultivate inclusive culture with focus on diversity going beyond academic minority serving institutions (MSI)
  - Leverage institutional resources for free exchange of people and ideas

IEEE PES Power & Energy Society®

2022 IEEE Power & Energy Society General Meeting (GM)

17 – 21 July 2022 | Denver, Colorado

https://pes-gm.org

Outreach & Training (O&T) Thrust

Industry-led training events

Interoperability Events

Workshops (in person!)

Leverage Institutional partnerships

UNIFI Seminar Series

15 seminars every Spring and Fall for the next 5 years – Mondays at 4-5pmET/1-2pmPT

Register for Spring 2022: https://nrel.zoomgov.com/meeting/register/vJIsf-iuqT8pH3JW9MffrITPmAsfXgzZ_q8

Moving forward

How to get involved with UNIFI?

- UNIFI has a membership structure over the next few months to allow organization that are not part of the original project to join.

Benefits of Membership

- Access to Working Groups
- Participate in the development of GFM interoperability specifications
- Access to experts in GFM
- Access to educational and workforce development material

For more information on Memberships Contact: Ben Kroposki (benjamin.kroposki@nrel.gov) or Iqbal Hussain (ihusain2@ncsu.edu)

Membership Levels & Benefits

Benefits	Full Member ($50,000/yr)	Startup Member[a] ($5,000/yr)	Non-profit Member ($3,000/yr)	Associate Member ($10,000/yr)	Affiliate Member ($3,000)[b]
Voting member (points)	**50**	**5**	**3**	**10**	**0**
Early access to UNIFI Specifications	✓	✓	✓	✓	✓
Access to UNIFI core-stack IP (note: access may not be free)	✓	✓	✓	✓	✓
Participation in UNIFI events (workshops, trainings, job fairs, etc.)	✓	✓	✓	*limited*	*limited*
Development of UNIFI Specifications (based on votes)	✓	✓	✓	✓	
Participation in UNIFI working groups	✓	✓	✓	*limited*	
Access to education and workforce-development material	✓	✓	✓	*limited*	
Access to demonstrations	✓	✓	✓		
Access to member-provided or other new funding	✓	✓	*limited*		
Decide on member-funded projects (based on votes)	✓	✓			

- Structure in place for Years 1-5 of Consortium; subject to adjustment per bylaws
- *limited* defined per the bylaws
- [a] Startup members must have less than 50 employees and be less than 5 years old
- [b] One & only fee for 5 years

Why should you join?

- Seat at the table alongside other vendors, utilities, system operators
- Participate in (and drive) cutting-edge R&D through UNIFI working groups
- UNIFI specifications (interoperability guidelines + functional requirements) will leapfrog traditional standardization
- Access to core stack IP that is key to interoperability of GFM technologies across scales
- Participate in 1MW and 20MW demos
- Network with wide student pool across universities that will enter workforce
- UNIFI events (training, job fairs, workshops) will be key to educate on novel technology area
- Access to educational and training material in up-and-coming technology space

Where can I find out more information?

- UNIFI Website is underdevelopment
- UNIFI website will provide more information and access to specifications and material for members as well as public information
- We will also send out info on LinkedIn
  - Check for the the “**UNIFI Consortium”** Group

For more information

- Benjamin Kroposki
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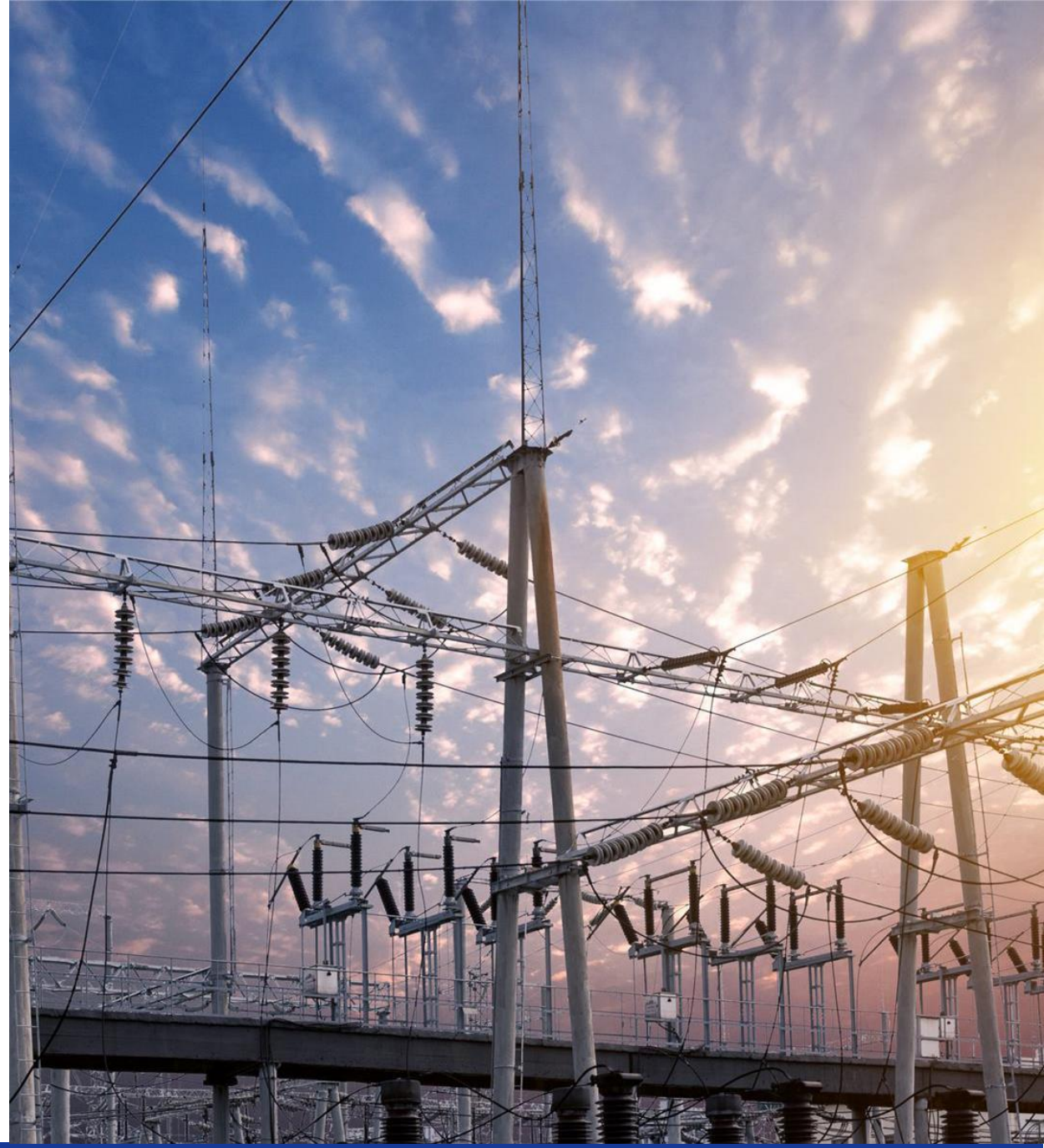
  - Director, Power Systems Engineering Center, NREL
  - benjamin.kroposki@nrel.gov
- Iqbal Husain
  - UNIFI Sustainability Officer
  - Professor, NCSU
  - iqbal_husain@ncsu.edu
- UNIFI LinkedIn group



Thank you