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The Need for Grid-forming (GFM) Inverters in Future Power Systems

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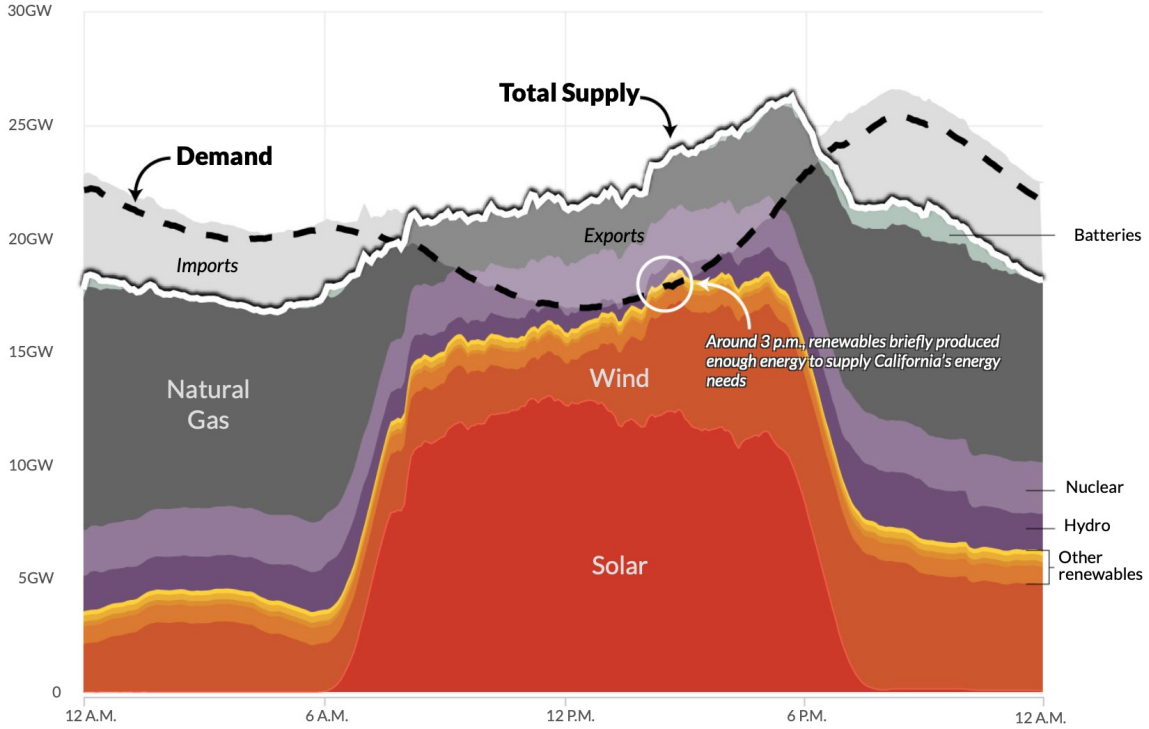
In 2022, 33% of annual electricity in CA was from wind and solar

- 19% Utility Solar (17.5GW)
- 8% Distributed Solar (14.5GW)
- 7% Wind (6.2GW)
- Source: EIA - https://www.eia.gov/state/analysis.php?sid=CA

Renewable energy breaks record in California

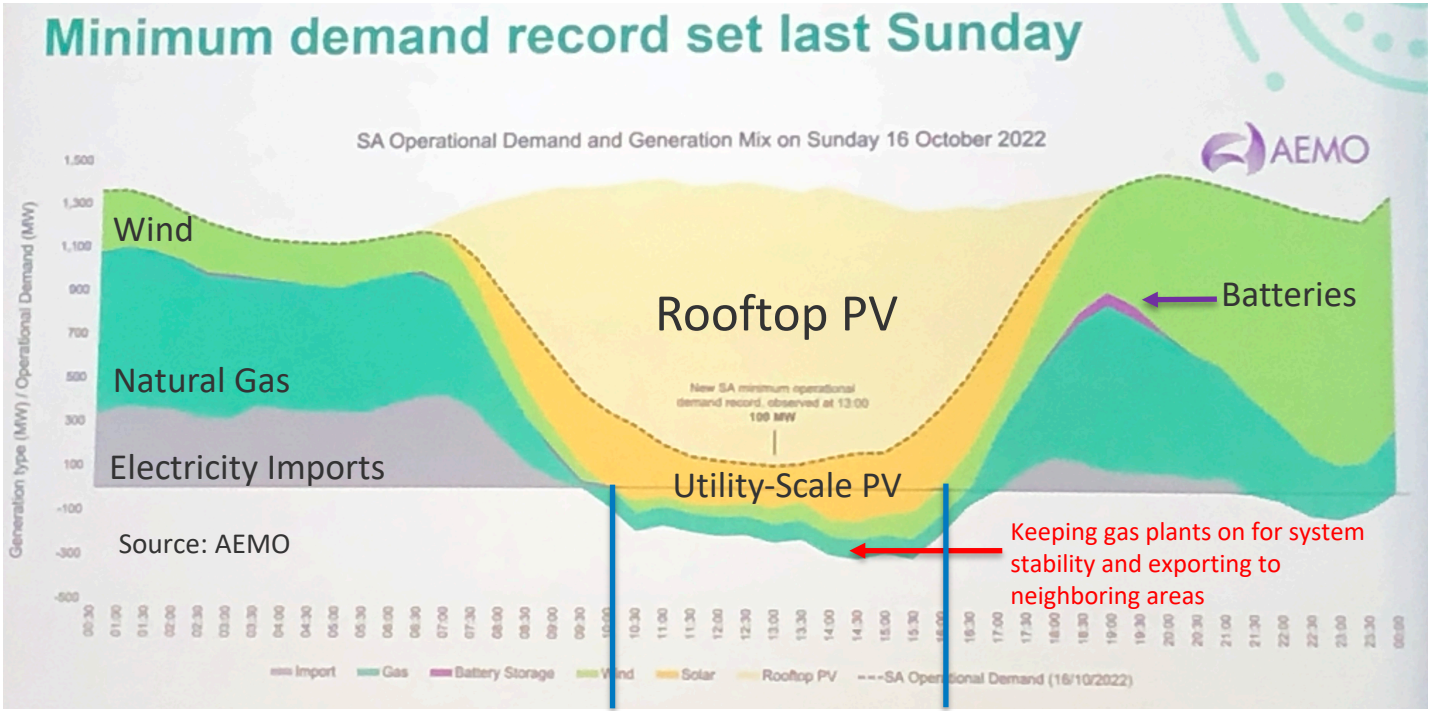
On April 30, 2022, solar, wind and other renewables provided enough electricity to meet the needs within California's Independent System Operator, which supplies about 80% of the state. More power was being generated



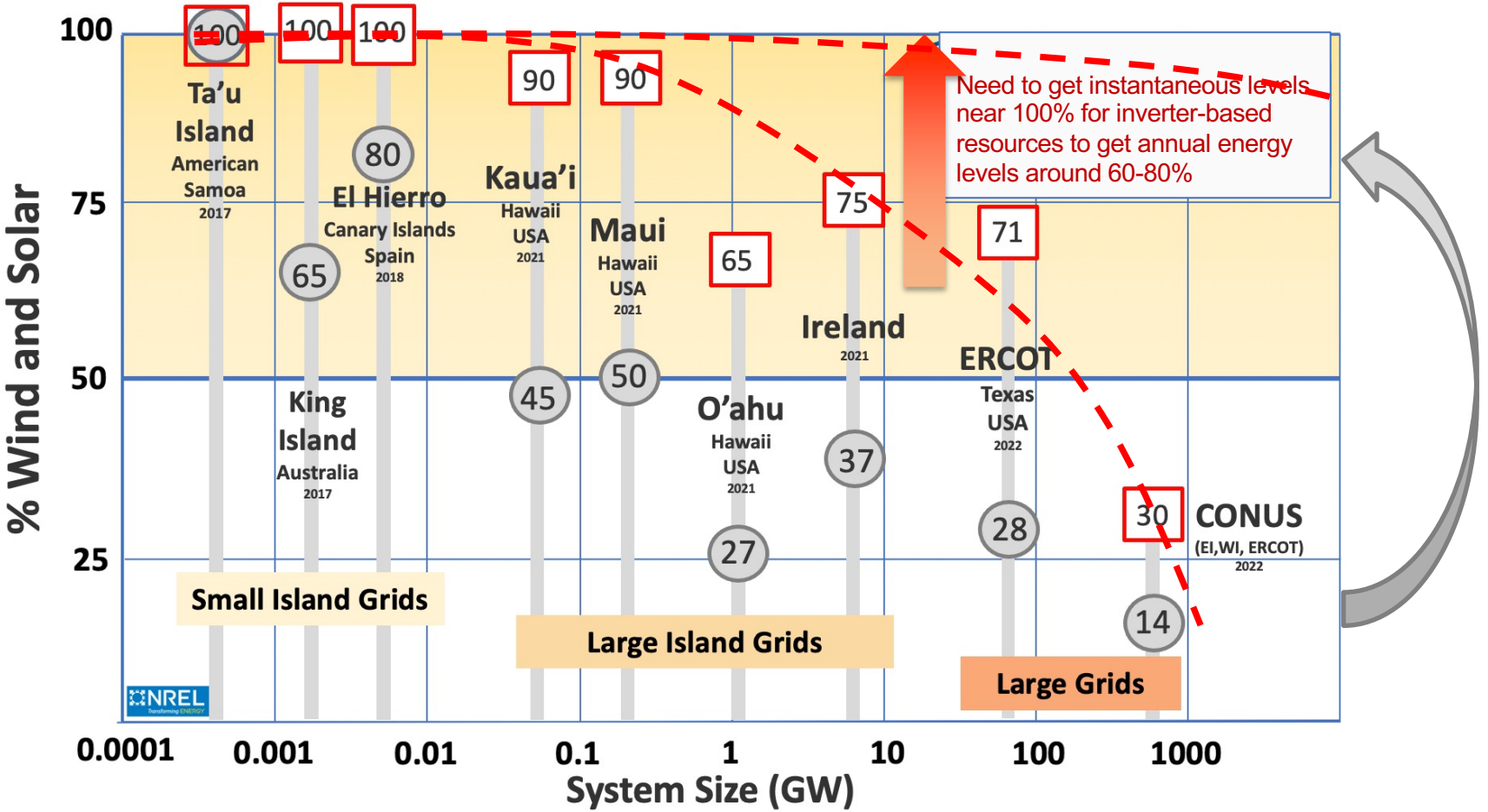
Source: NPR - https://www.npr.org/2022/05/07/1097376890/for-a-brief-moment-calif-fully-powered-itself-with-renewable-energy

A peek into the future – South Australia
Parts of large grids already operating at 100% IBR, but…

Source: AEMO



To get closer to 100% IBR, you need grid-forming (GFM)



Source: Updated from Island Power Systems with High Levels of Inverter-Based Resources: Stability and Reliability Challenges, A. Hoke, V. Gevorgian, S. Shah, P. Koralewicz, R. Kenyon, B. Kroposki, IEEE Electrification Magazine, March 2021

Technical Challenges with Higher Inverter-based Resources

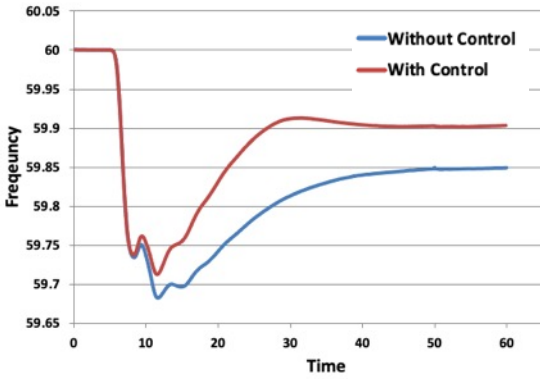
Challenges:

- Frequency Stability (Lower System Inertia)
- Voltage Stability and Regulation
- System Protection
- Grid Forming capability
- Black Start capability
- Control system interactions and resonances
- Cybersecurity

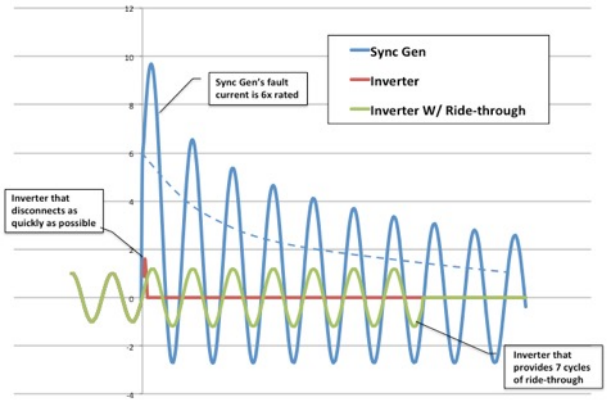
Source: B. Kroposki et al., "Achieving a 100% Renewable Grid – Operating Electric Power Systems with Extremely High Levels of Variable Renewable Energy," http://ieeexplore.ieee.org/document/7866938/

Source: Blackstart of Power Grids with Inverter- Based Resources, H. Jain, G. Seo, E. Lockhart, V. Gevorgian, B. Kroposki, 2020 IEEE Power and Energy General Meeting: https://www.nrel.gov/docs/fy20osti/75327.pdf

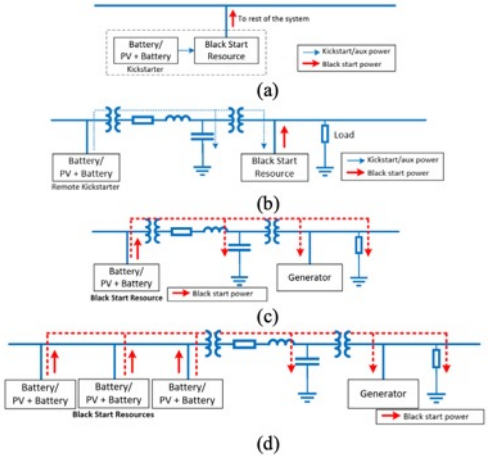
Stability



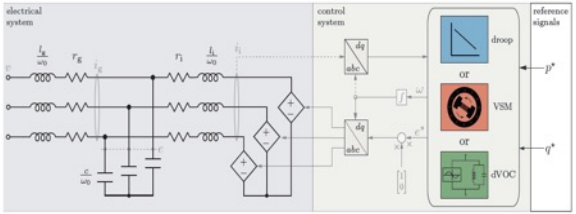
Protection



Grid-forming/Blackstart

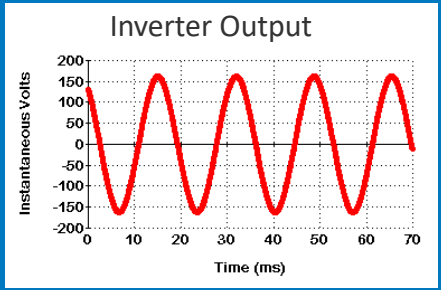


Control system interactions and resonances



Power System Oscillations

Grid Following (GFL) vs. Grid Forming (GFM)



- Assumes grid is already formed - Needs a grid to synchronize to
- Cannot make its own voltage sinewave
- Acts as a current source

- Can make its own voltage sinewave and acts as a voltage source
- Can synchronize to other sources
- Can blackstart the grid

Source: Lin, Yashen, Joseph H. Eto, Brian B. Johnson, Jack D. Flicker, Robert H. Lasseter, Hugo N. Villegas Pico, Gab-Su Seo, Brian J. Pierre, and Abraham Ellis. 2020. **Research Roadmap on Grid-Forming Inverters**. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5D00-73476. https://www.nrel.gov/docs/fy21osti/73476.pdf.

Benefits to Using Grid-forming (GFM) IBR

- Can maintain system voltage
- Very fast response to disturbances
- Blackstart capability
- Enable higher levels of wind and solar to be integrated in grids
- Improved system reliability and resilience
- Added economic value from providing essential grid reliability services

unifi consortium

universal interoperability for grid-forming inverters

Co-led by NREL, University of Texas-Austin, and EPRI

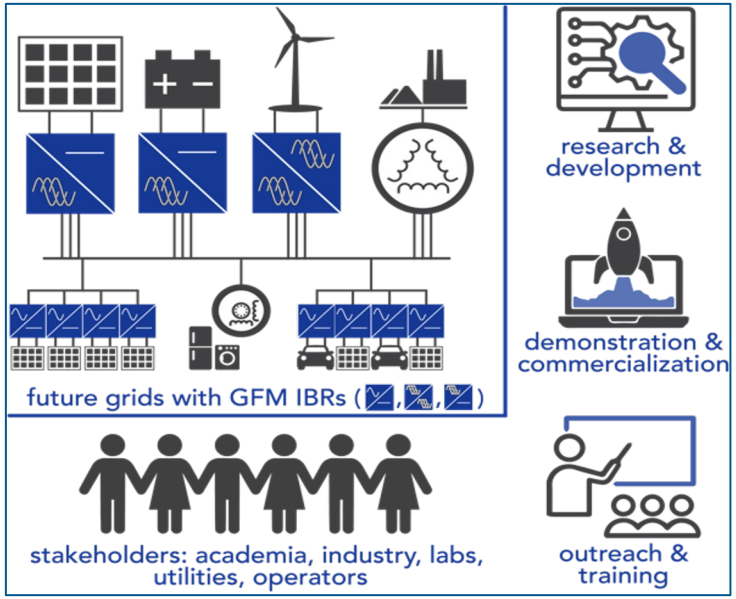
U.S. DEPARTMENT OF ENERGY

The **UNIFI Consortium** is a forum to address fundamental challenges to the seamless integration of grid-forming (GFM) technologies 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** (Modeling, Controls, Hardware, Integration & Validation)
- **Demonstration & Commercialization** (Large Demonstrations, IP Management, Products, Standards)
- **Outreach & Training** (Education, Workforce Development, Communications, Events)



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For More Information: https://sites.google.com/view/unifi-consortium/home

UNIFI GFM IBR Specifications – Version 1

- Defines a set of UNIFI Specifications for GFM IBRs that provides requirements from both:
  - Power system-level (grid) requirements
  - Inverter-level requirements
- Provide vendor-agnostic operation of GFM IBRs at any scale in electric power systems.
- Provide uniform technical requirements for the interconnection, integration, and interoperability of GFM IBRs of any size in electric power systems of any scale.
  - Performance Requirements for Operation Within Normal Grid Operating Conditions
  - Performance Requirements for Operation Outside Normal Conditions
  - Additional GFM Capabilities and Considerations (GFM+)

Find out more information

Website

https://sites.google.com/view/unifi-consortium

LinkedIn

- join the UNIFI Group

YouTube

- visit the UNIFI Channel that hosts the Weekly Seminar Series every Fall and Spring

Summary

- Start using Grid-forming (GFM) Inverters on utility scale wind, PV, and battery systems (not just microgrids)
- Start using UNIFI GFM Specs
- GFM is commercially available for battery energy storage systems – coming soon for wind and PV
- Do it now before you need to retrofit GWs of inverters (remember the 50.2Hz issue in Germany?)