



Power HIL evaluation of inverter controls for 100% inverter-based bulk power systems

A power electronics grid integration case study

Andy Hoke

Power Electronic Grid Interface (PEGI) Platform
Workshop

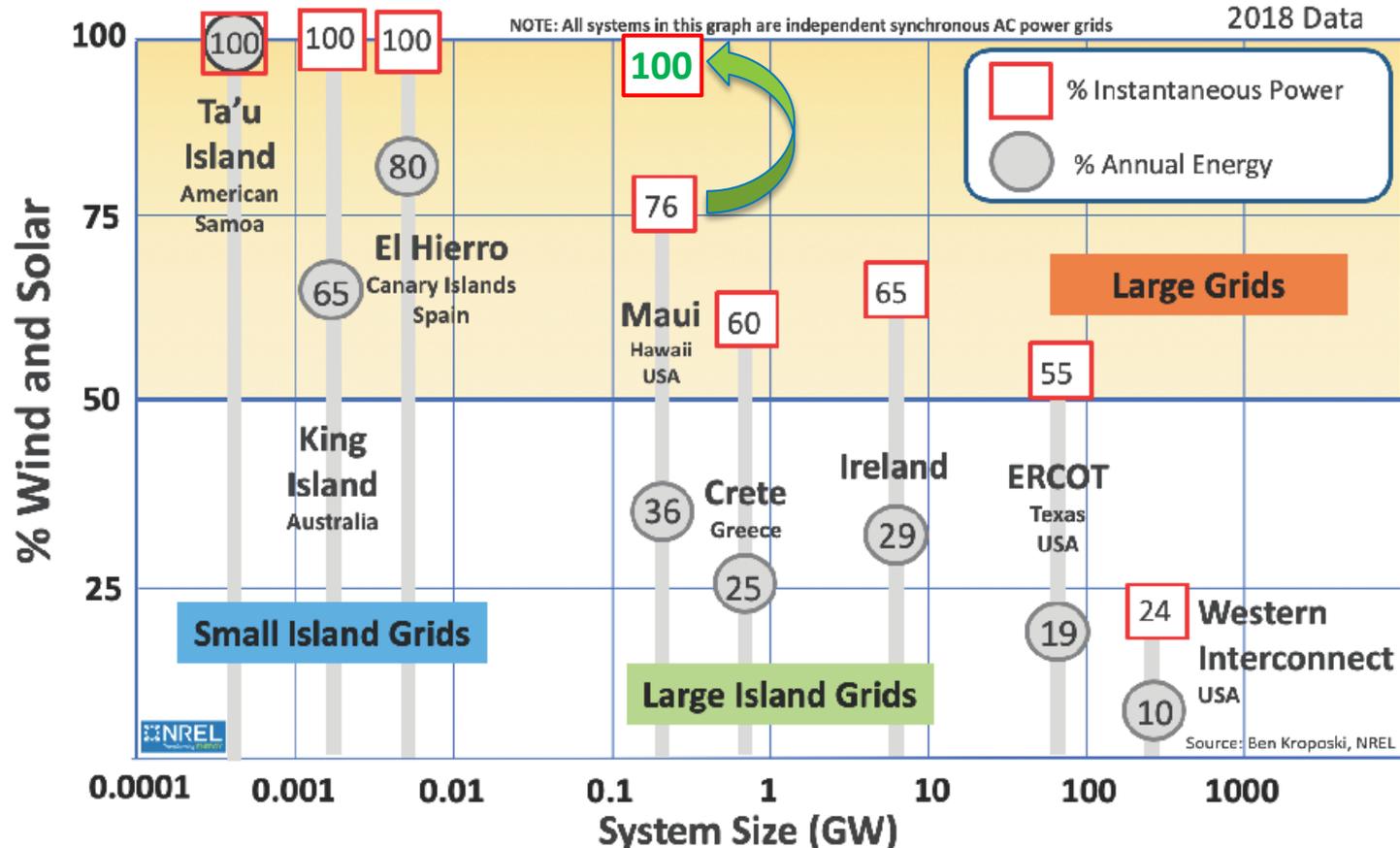
October 13, 2020

Motivation

- As PV and wind generation reaches roughly 1/3 to 2/3 of annual energy production, peak instantaneous IBR generation can reach 80-100% of load
 - Inverter-based resource (IBR) = PV, wind, BESS, etc
- At these very high instantaneous levels of inverter-based generation, the dominant physics of grid operations change
 - “Very high” \approx instantaneous IBR generation is 80-100% of load
- At very high IBR levels, **synchronous inertia and generator magnetic flux** that stabilize grid frequency and voltage **need to be supplemented/replaced with well-designed power electronic inverter controls**
- Similar inverter controls are widely used for small islands and off-grid microgrids*, but RD&D is needed to adapt them for larger systems
 - “Larger systems” = systems large enough to have a transmission system
- The PEGI platform is designed to test such controls in scenarios that mimic real grid dynamics

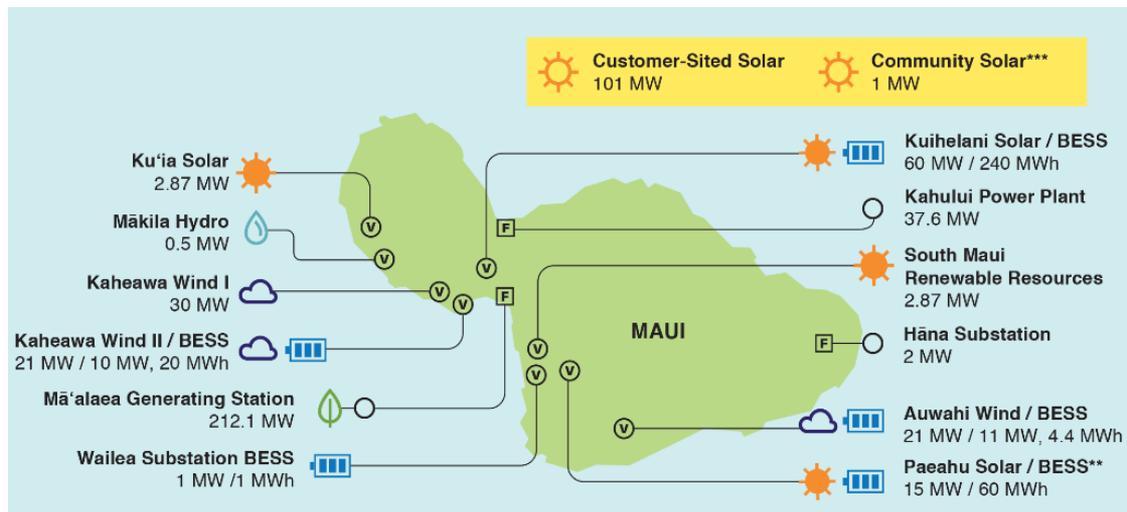
*Plenty of room for improvement in microgrid island transitions and co-operation with larger power system.

Wind and Solar in Synchronous AC Power Systems as a Percentage of Instantaneous Power and Annual Energy



Background

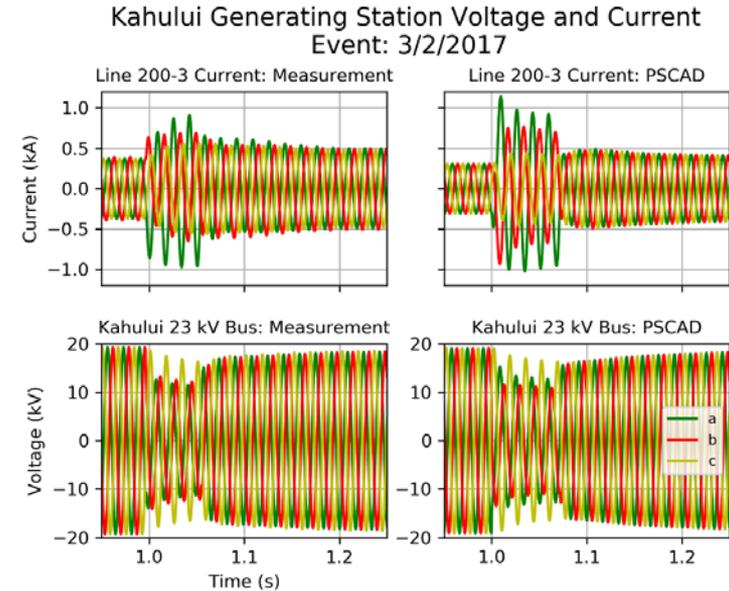
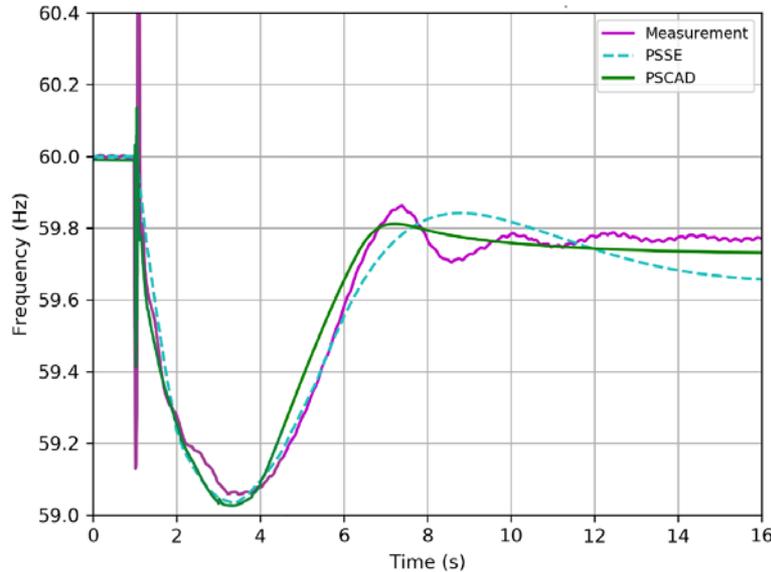
- Hawaiian Electric expects Maui to be the first large island to operate with 100% inverter-based resources
 - 2018 peak: ~80% IBR
- 100% IBR expected to occur for certain hours by 2023
- Maui would be the first interconnected power system of its size (200 MW peak) with highly distributed utility-scale generation and 69 kV voltage levels to reach this milestone
- Grid-forming controls required for Stage 2 PV-BESS plants (~2023 interconnection)
- Technical hurdles need to be overcome to ensure grid stability on the shortest time scales
- Currently performing EMT study (PSCAD)
- Next step: Power HIL at Flatirons



Maui PSCAD study

- Developed EMT (PSCAD) model of Maui, parallelized on 28 cores*
- Validated against HECO field event data and PSSE model [1]
- Simulating faults, contingencies under various grid and IBR configurations

**3/2/2017 Event:
Line-ground fault
induces
generation trip**



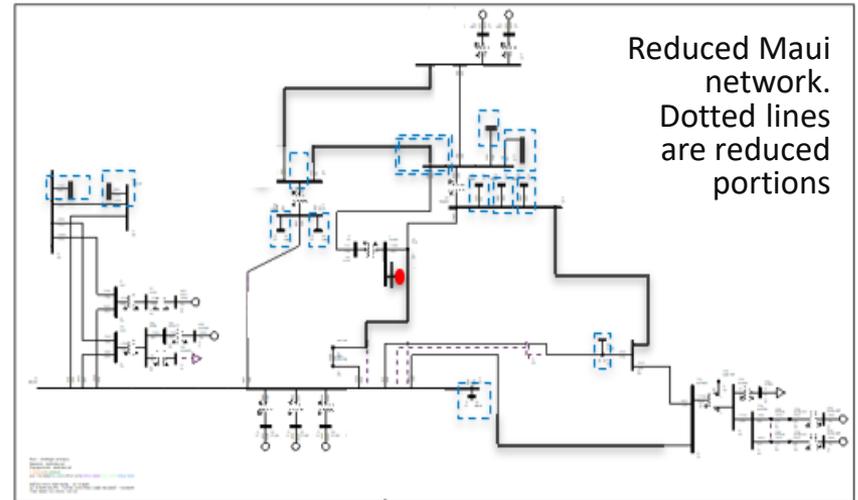
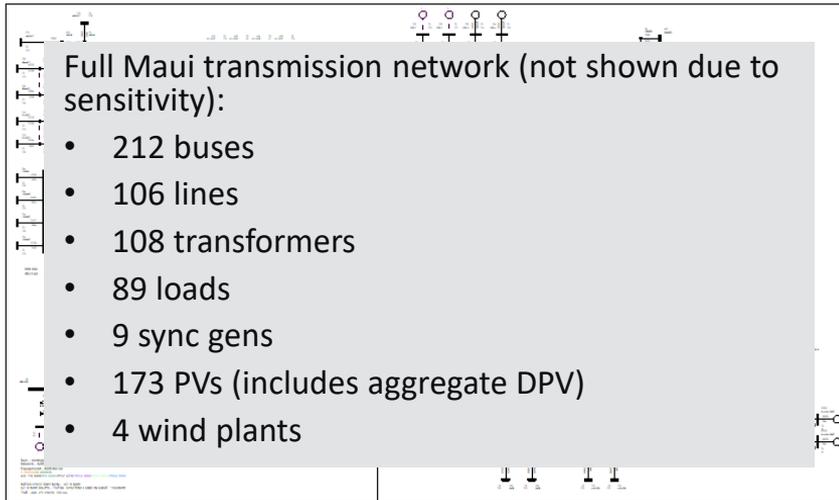
*Thank you to
Electranix for
providing E-
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Why power HIL?

- When models of hardware devices (e.g. inverters, controllers) are not available or not validated, HIL testing can be used to link the physical device to a real-time simulation of the rest of the system
- Advantages
 - Provides additional confidence in hardware performance
 - Can be used to validate models
 - Particularly valuable to *de-risk field deployments of new technologies*
- Disadvantages
 - May require model reduction for real-time simulation
 - Can introduce additional dynamics, especially on very short time-scales
 - Requires specialized hardware and software

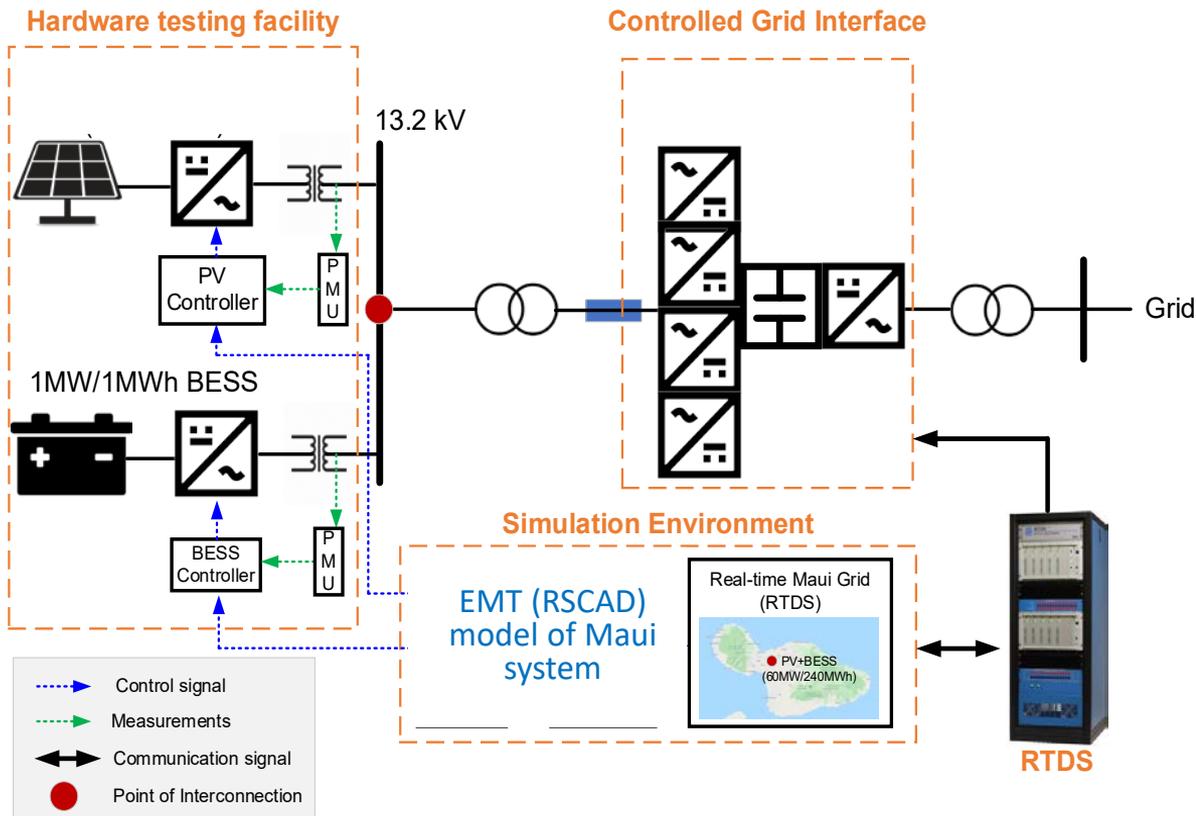
Maui PHIL study

- Maui project will use MW-scale power HIL to confirm findings of EMT study
- Connect MW-scale PV/BESS inverters at Flatirons campus to real-time simulation of Maui network
 - Include scaled replica of one of the actual hybrid power plants to be constructed on Maui
 - Test contingency events, faults
- Maui dynamic model converted to RSCAD
 - Reduced transmission network model using single-port and two-port equivalent networks:



Maui PHIL study

Scaled down hardware PV and storage plants, including grid-forming and grid-following inverters

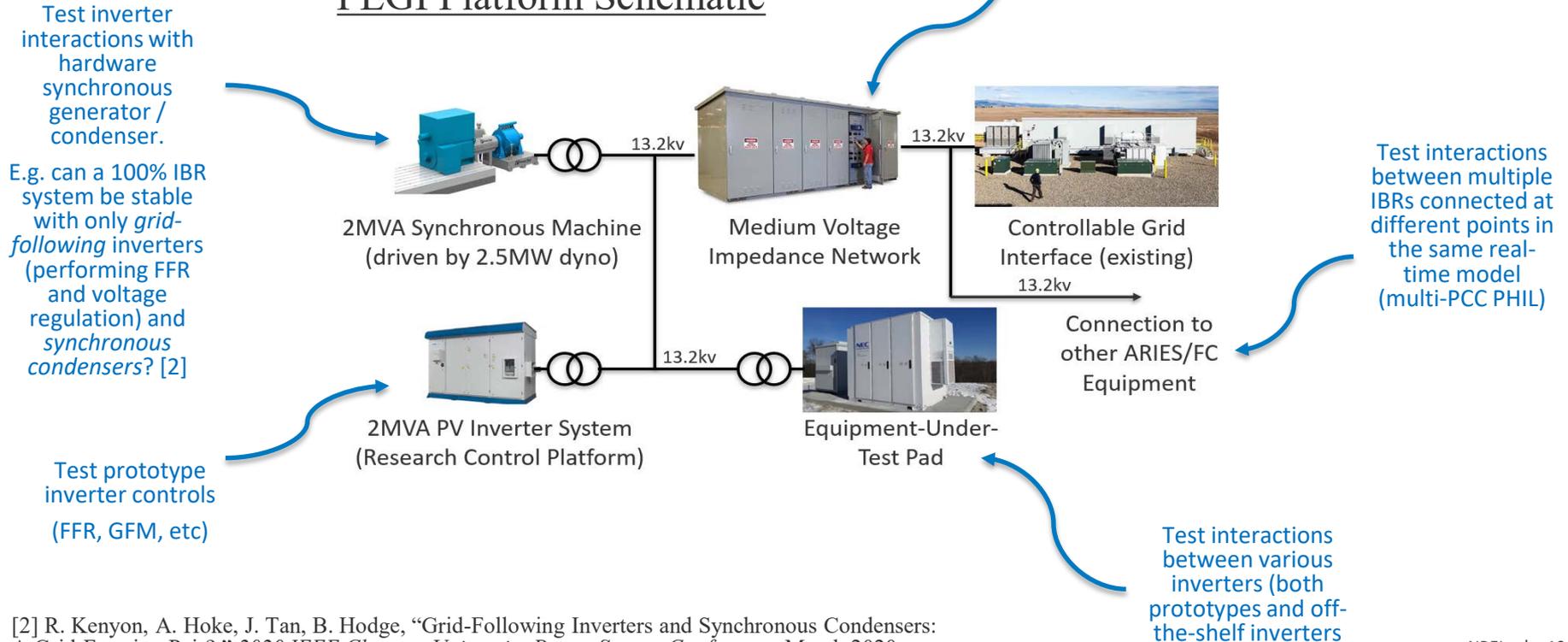


Questions we hope to answer

- Can an inertialess or very low inertia system offer the same system stability as the present system (or better)?
- How should inverters be controlled?
 - Fast droop controls? Other forms of fast frequency response?
 - Voltage and reactive power control?
 - Grid-forming mode (i.e. fast voltage control without PLL?)
 - Do these answers depend on system inertia or other factors?
- How will behind-the-meter generation interact with IBR controls?
 - Rooftop PV can be >70% of instantaneous generation on Maui
 - Behind-the-meter hydro may be online or off at any time
- Are additional technologies needed? Synchronous condensers?
- What constraints should be placed on IBR controls to ensure they are stable, both with and without other generation present in the system?
- Are current models sufficient to answer these questions?

Beyond Maui PHIL study: What could PEGI do?

PEGI Platform Schematic



[2] R. Kenyon, A. Hoke, J. Tan, B. Hodge, "Grid-Following Inverters and Synchronous Condensers: A Grid-Forming Pair?," 2020 IEEE Clemson University Power System Conference, March 2020

Challenges/ Opportunities

- Like a computer simulation, a power HIL test is only as good as the real time model
- PEGI/ARIES provide greater flexibility in linking MW-scale power to real-time models
- Real-time models (both of grid and of connected devices) should be validated. For PEGI applications, this will typically mean EMT models
- Path to confidently operating grids with 80-100% IBRs includes four key components (hopefully disseminated as widely as possible)
 - Technology development and maturation
 - EMT simulations of key scenarios
 - Selective use of power HIL to confirm performance and stability
 - Field deployments

Questions?

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