Hawaiʻi Natural Energy Institute Research Highlights

Energy Policy & Analysis

Integrated Stability and Cost Production Analysis

OBJECTIVE AND SIGNIFICANCE: As the Hawaiʻi grids transition to high penetrations of solar plus storage to meet generation needs, conventional stability tools that utilize a limited number of snapshots of operations expected to show worst-case conditions (i.e. an evening peak load) cannot capture the range of grid conditions that are important to evaluate on high percentage-renewable grids.

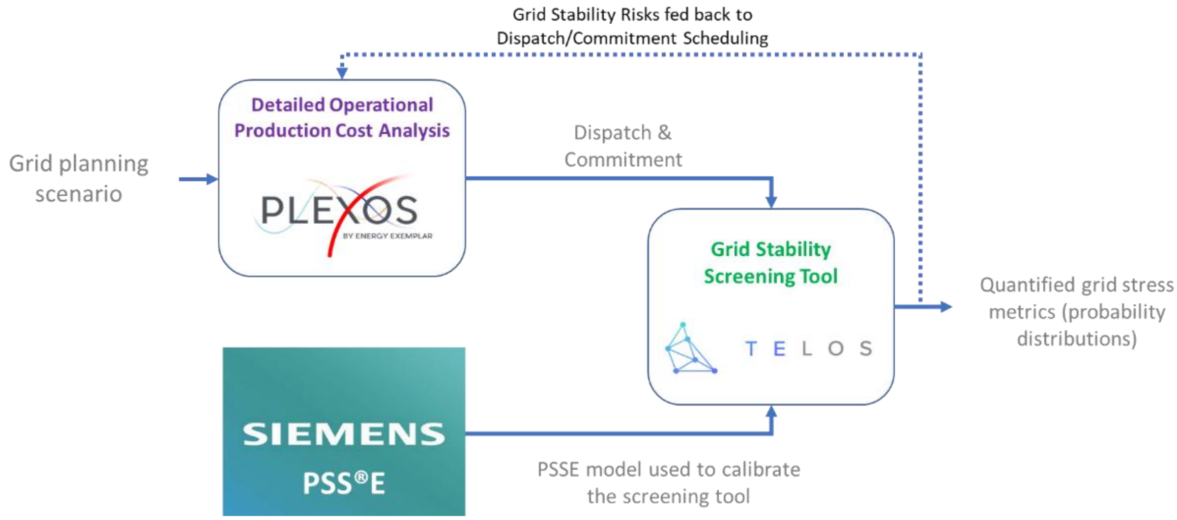
The objective of this activity, conducted in collaboration with Telos Energy, was to develop a new tool to evaluate grid stability over the entire range of operations expected throughout the course of a year. Evaluating grid risk at every hour of the year enables grid planners to understand both the magnitude and duration of risk to the grid, which gives valuable context for informing mitigation decisions. A second objective of this activity was to integrate both stability and cost production into one tool, with a significant improvement over traditional tools that cannot co-optimize production cost and grid stability.

KEY RESULTS: The HNEI team has successfully developed a new screening tool that quantifies the stability risk to the grid using a probabilistic approach across all 8760 hours of grid operation instead of just at preselected conditions of expected risk. This technique yields probability distributions of the frequency excursions for grid events such as loss-of-generation. This new tool provides a more comprehensive means for assessing stability of the Hawaiʻi grids as conventional thermal generation is retired and replaced by variable renewables systems. The accuracy of this new tool was calibrated using the full dynamic model of the Oʻahu grid and validated against the typical transmission planning snapshots as described below.

BACKGROUND: Typical utility grid planning processes only evaluate a limited number of grid conditions for dynamic stability, sometimes as few as two or three "worst-case" snapshots (i.e. summer peak, spring light-load conditions) from each planning scenario. This traditional approach provides limited information for today's modern grids with high penetrations of variable renewable resources and storage because (1) the "worst-case" periods are shifting and no longer obvious and (2) this approach provides no indication of how often the grid is exposed to the "worst-case" conditions, which is critical in understand how to best mitigate issues that arise.

To overcome these limitations, the HNEI team developed and validated a new tool to evaluate the stability and performance of the grid probabilistically across all 8760 hours of the study year for each scenario. This enables a comprehensive, yet easy-to-understand view of how system risk changes as the grid evolves.

PROJECT STATUS/RESULTS: The new tool enables an analysis that is both broad and deep by combining the wide range of realistic grid operating conditions over the course of an entire year (from PLEXOS) with the detailed dynamic behavior of the grid during major grid events (from PSSE). The core of the tool



Hawaiʻi Natural Energy Institute | School of Ocean & Earth Science & Technology
University of Hawaiʻi at Mānoa, 1680 East-West Road, POST 109 • Honolulu, HI 96822
Phone: (808) 956-8890 • Fax: (808) 956-2336 • www.hnei.hawaii.edu

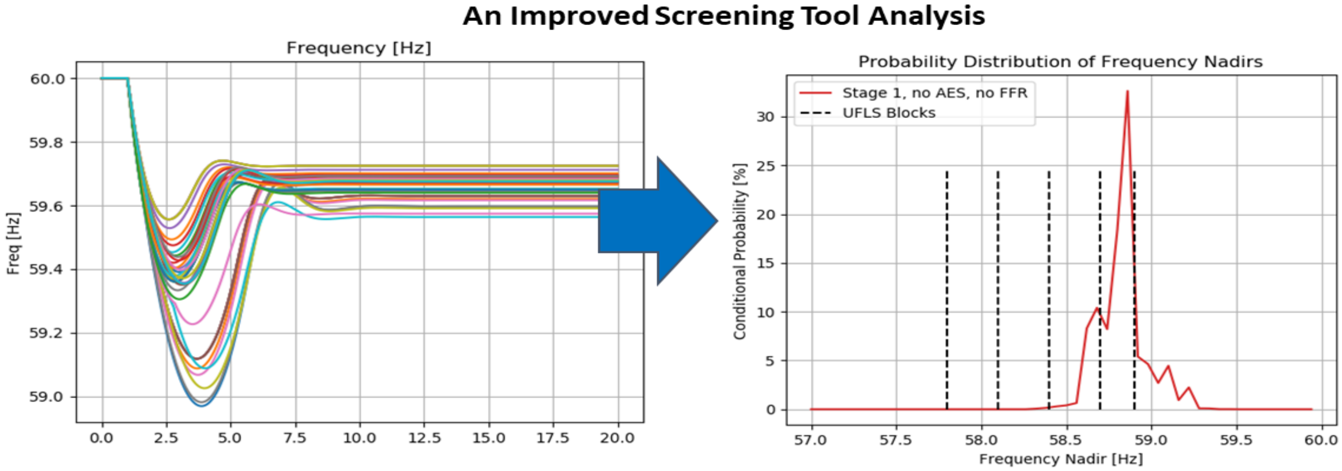
is a simplified dynamic model of the island power system. This simplified model is then calibrated using the detailed dynamic model from PSSE. This calibrated, grid-specific model then uses inputs from the production cost tool (PLEXOS), such as the total thermal generation online, renewable generation, and energy storage reserves to estimate the grid frequency excursion for each hour of the simulation assuming loss of the largest single generator on the grid. This methodology is shown schematically in the figure on the previous page.

The output of the tool, the frequency nadir, is captured to show the stress on the grid and the impact to customers. The frequency nadir is the minimum frequency that is reached after the loss of generation event. Lower values of frequency nadir indicate higher levels of grid stress and greater likelihood of a blackout or the need for load shedding or blackout. To quantify customer impact, the probability of load disconnection due to the under-frequency load-shedding scheme on the grid is reported. To more easily visualize these results, the frequency nadir and load-shedding metrics are presented as probability distributions that show the probability of reaching a certain level of grid stress (frequency nadir and load-shedding) over the course of a year for a given mix of generation resources. This is shown in the figure below, where the frequency nadir from 8,760 individual dynamic simulations can be represented as a single probability distribution curve. By running multiple future resource mixes that consider different penetrations of solar + storage, the probability distributions can be plotted to show the trends in dynamic stability as the grid becomes increasingly renewable.

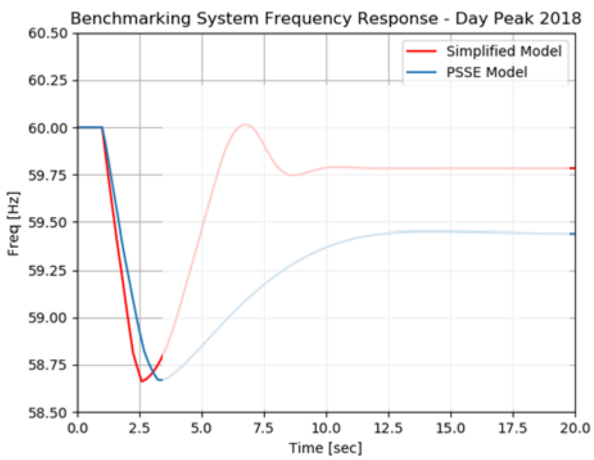
As indicated in the schematic, this new tool is fully integrated with PLEXOS allowing the results of the dynamic stability simulations to be fed back to PLEXOS, where the scenarios and/or the grid operations can be adjusted to achieve desired levels of grid stability, such as a maximum value of load-shedding or a minimum allowable frequency nadir. This is fundamentally different than traditional techniques where system cost is optimized first without regard to stability, then adjustments to the grid that are needed for grid stability reasons are made second, which leads to a suboptimal resource mix. Based on the desired stability objectives, operational parameters such as generation commitment decisions, generation retirement and replacement scenarios, battery scheduling and utilization, and demand response assumptions can all be adjusted individually or in combination.

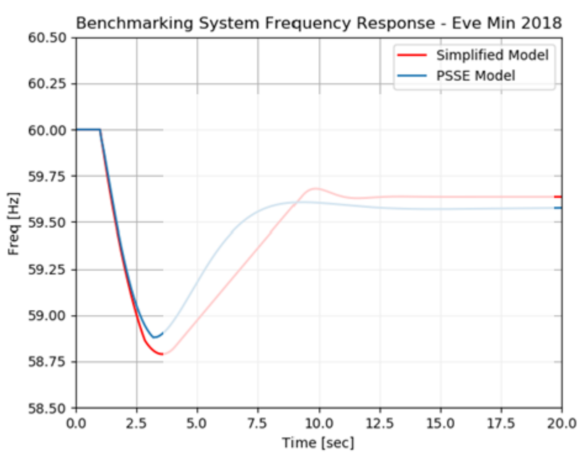
This tool has been applied to the island of Oʻahu to assess grid stability with high solar + storage integration and evaluate the risk of customer disconnection and grid black-out for near-term scenarios including the retirement of AES and the installation of Stage 1 PV+BESS projects. The results are detailed in the project summary "**Oʻahu Grid Stability with High Solar + Storage Integration**". The tool has been benchmarked against the full dynamic model of Oʻahu as represented in PSSE for four different grid conditions, including the maximum and minimum loads during daytime and nighttime periods (see figures on following page). In each case, the largest single generator is suddenly disconnected and the grid frequency is over-plotted. The focus of the validation is on matching the

An Improved Screening Tool Analysis



frequency nadir, which is considered the most important grid stress metric for loss-of-generation events and directly corresponds with load-shedding on O‘ahu. It is acknowledged that the dynamic response of the grid predicted by the tool after the frequency nadir occurs is often not accurate. This is because the response of the grid after the nadir is dependent on many other dynamics (thermal generator governor dynamics) that are not modeled. These post-nadir dynamics are not modeled because they are not significant factors in the response of the grid prior to the nadir. It is the period of time prior to the nadir that is the focus of this analysis because this period is most critical for the survivability of the grid and most indicative of grid stress and customer impact.





The loss-of-generation events are only one type of challenging grid event that grid operators and planners must assess. Other challenging events including short-circuit (fault) events, particularly with low grid strength, which occurs when there are high levels of generation from inverter-based resources and few conventional plants online. This method and analysis tool can be adapted to evaluate these risks as well, which is expected to be critically important for O‘ahu, Maui, and Hawai‘i in the near future.

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Contact: Richard Rocheleau, rochelea@hawaii.edu

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