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# Integrating High Levels of Wind in Island Systems: Lessons from Hawaii

Nicholas Miller [1], Devon Manz [1], Harjeet Johal [1], Sebastian Achilles [1], Leon Roose[2], James P. Griffin[3]
[1]General Electric Company, Schenectady, NY, USA, e-mail: nicholas.miller@ge.com
[2]Hawaiian Electric Company, Honolulu, HI, USA
[3]University of Hawaii, Hawaii Natural Energy Institute, Honolulu, HI, USA

*Abstract*- **Variability of power generation from intermittent resources such as wind and solar plants presents an operational challenge for grid operators. The economic incentives and technical challenges that accompany large amounts of variable generation in island power systems are often much greater. The Hawaiian Electric Company and its subsidiaries, the Maui Electric Company and the Hawaii Electric Light Company have considerable experience in planning and operating power systems with relatively high levels of wind power. The islands of Hawaii and Maui operate power systems with high levels of wind power (more than 10% by energy) and have experienced and addressed challenges associated with the variability and uncertainty of wind power. The island of Maui is anticipating further wind plant deployments in the near future. Recent analyses of possible near-term deployment of large amounts of wind power on the Oahu power system (500MW of wind power; approximately 1200MW peak and 520MW minimum annual load) has shown the potential for this system to accept almost 25% of its energy from wind and solar power. This paper will identify some of the wind integration challenges and highlight the benefits of a variety of strategies that are expected to improve system economics and operational reliability, including proposed modifications to the baseload thermal fleet (deeper turndown, higher ramp rates, and tuned droop characteristics), advanced wind turbine grid support features, new operating strategies, wind forecasting and refinements to the up and down reserve requirements. This paper will present the key findings in the context of useful insights and lessons learned that are relevant to other island power systems considering very high levels of wind power.**

***Index Terms*** **— wind energy, power systems, power generation dispatch, power system stability, power system control**

## I. INTRODUCTION

In 2008 the Hawaiian Electric Company (HECO) and the State of Hawaii signed the Energy Agreement. The Energy Agreement is part of the State's energy policy and documents a course of action to reduce Hawaii's dependence on imported fossil fuels and develop indigenous renewable energy sources. To that end, the Energy Agreement commits Hawaiian Electric to facilitate the integration of substantial amounts of wind and other renewable energy into its grid and to enable electricity consumers to manage their electricity use more effectively. In this agreement, the renewable portfolio standard (RPS) goals were modified to require 40% of the islands electricity be generated from renewable energy by 2030 (10% by 2010, 15% by 2015, and 25% by 2020), which is one of the highest standards in the nation.

The General Electric Company, the Hawaii Natural Energy Institute, and the Hawaiian Electric Company set forth to develop detailed, state-of-the-art power systems models of the Oahu grid spanning many timescales of power system operation from seconds to one year. The Oahu power system was modeled in GE Multi-Area Production Simulation (GE MAPS™) and GE Positive Sequence Load Flow (GE PSLF™). In addition to these tools, new tools were developed to assess the sub-hourly system performance; a critical timeframe on island power systems with high levels of wind power. Additional tools were used to assess the ramp rate and reserve adequacy of the Oahu system (GE Interhour Reserve Adequacy Tool) as well as the system frequency performance during specific, challenging events (GE Automatic Generation Control Model). All together, these tools were used to identify system performance and characteristics, such as unit commitment and dispatch, amount of wind energy curtailed, total variable cost, thermal unit ramp rate adequacy, frequency performance during challenging system events, transient frequency performance for relevant high wind contingencies, etc. Following this assessment a number of potential strategies were considered to improve system operation, reliability and economics. In parallel with this effort, the Hawaiian Electric Company performed a number of internal studies ranging from capability assessments of steam generator improvements, EMS/AGC, fast-start generation, load control as an operational resource, wind resource modeling, and wind forecasting potential. The results of these assessments were used in this study. Also in parallel, a number of large studies were undertaken including a technical undersea HVDC cable feasibility assessment and a variety of other systems studies. The results presented incorporate the conclusions and recommendations of many of these studies.

## II. SYSTEM DESCRIPTION

A model of the Oahu power system was developed for the scenario year of 2014. The system peak load for this year is projected as 1243MW and the minimum load as 513MW,