U.S. DEPARTMENT OF ENERGY

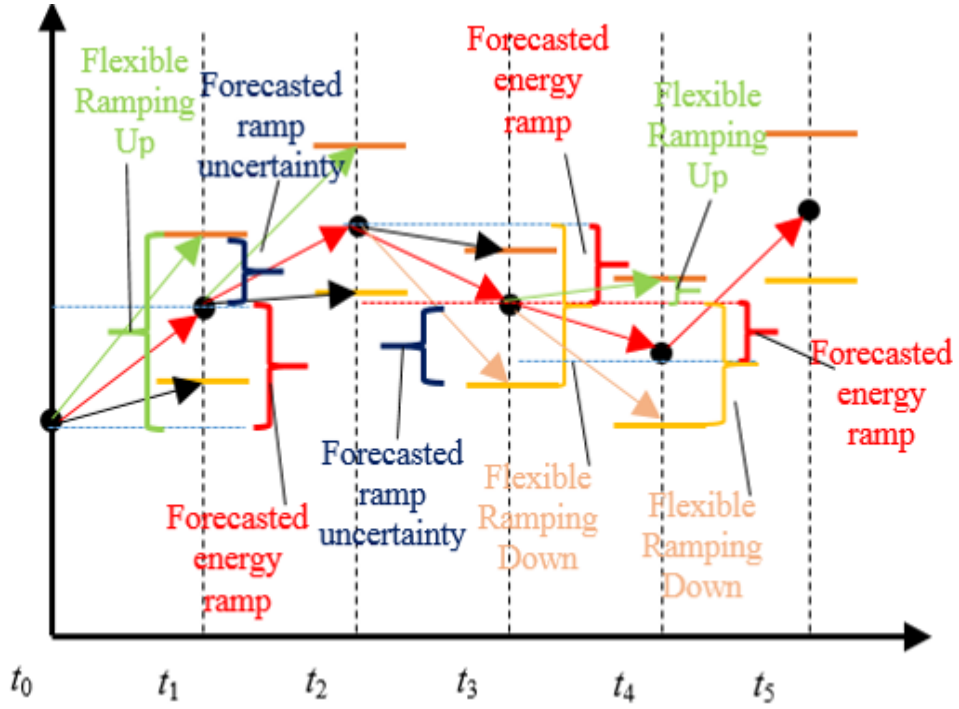
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Providing Ramping Service with Wind to Enhance Power System Operational Flexibility

Project ID #M7

Bri-Mathias Hodge

NREL



FY17–FY18 Wind Office Project Organization

"Enabling Wind Energy Options Nationwide"

Technology Development	Market Acceleration & Deployment
Atmosphere to Electrons	Stakeholder Engagement, Workforce Development, and Human-Use Considerations
Offshore Wind	Environmental Research
Distributed Wind	Grid Integration
Testing Infrastructure	Regulatory and Siting
Standards Support and International Engagement	
Advanced Components, Reliability, and Manufacturing	

Analysis and Modeling (cross-cutting)

Project Overview

M7: Providing Ramping Service with Wind to Enhance Power System Operational Flexibility

Project Summary

The aim of the wind-friendly flexible ramping product is to transform a natural characteristic of wind power, specifically ramping, into an advantageous one. Through efficient management of wind ramps with probabilistic wind ramps forecasting, the dispatchability of wind power can be improved with wind providing the flexible ramping product in the multi-timescale markets.

Project Objective & Impact

This project aims to develop an innovative, integrated, and transformative approach to mitigate the impact of net-load ramping by providing a flexible ramping product from wind power. The project will significantly contribute to the reduction of wind integration costs by making wind power dispatchable and allowing the efficient management of wind ramping characteristics.

Project Attributes

Project Principal Investigator

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Project Duration

April 2016 to March 2019

Technical Merit and Relevance

A wind-friendly ramping product can provide an attractive approach to guarantee the needed operational flexibility and bring substantial economic benefits to the system.

California ISO (CAISO): *In August 2011, the California ISO Board of Governors approved the flexible ramping constraint interim compensation methodology.*

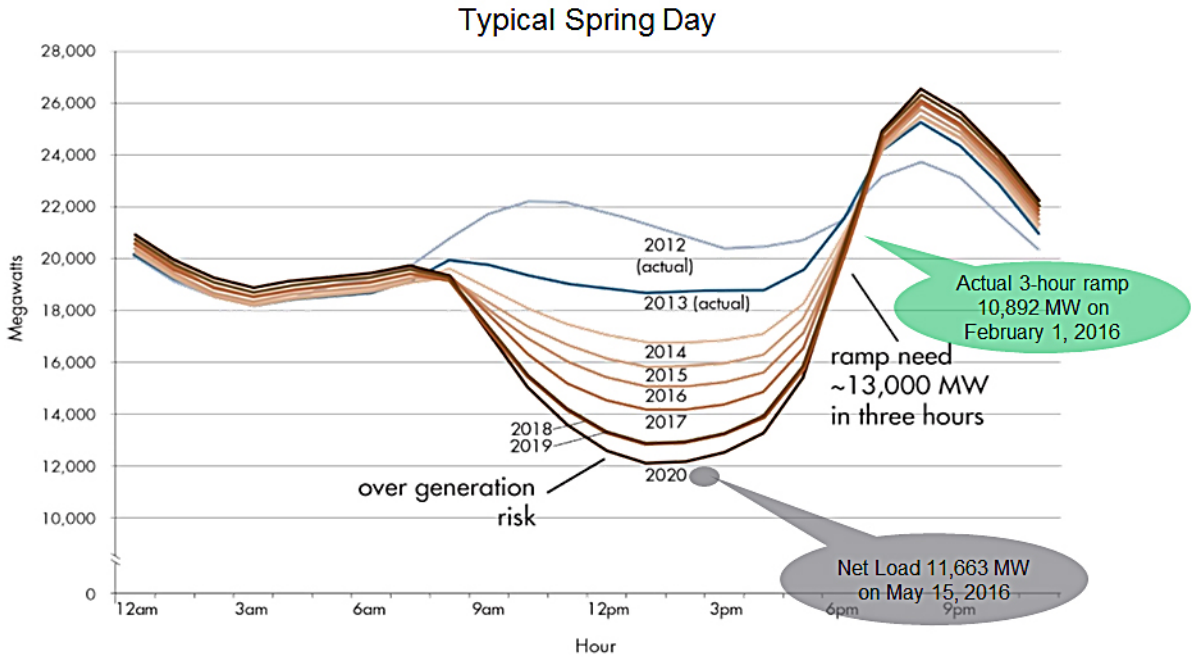

Figure 1. "Duck" curve in CAISO[1]

[1] "Duck Curve" California ISO, https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

Approach and Methodology

In this project, a data-driven approach is being used to perform the probabilistic wind ramps forecast. Then, the wind-ramping products (WRPs) are obtained from this probabilistic forecast. Finally, the WRPs are integrated into multi-timescale electricity market simulation.

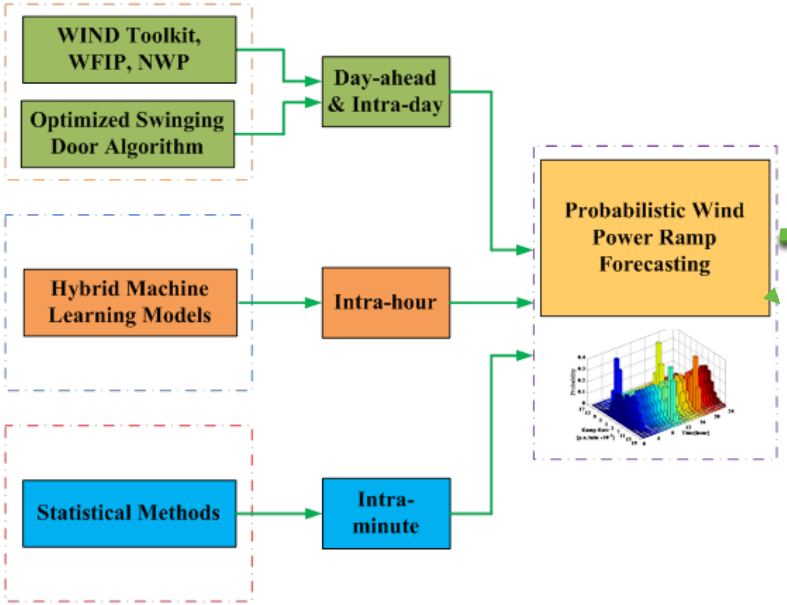

Figure 2. Probabilistic wind power ramp forecasting

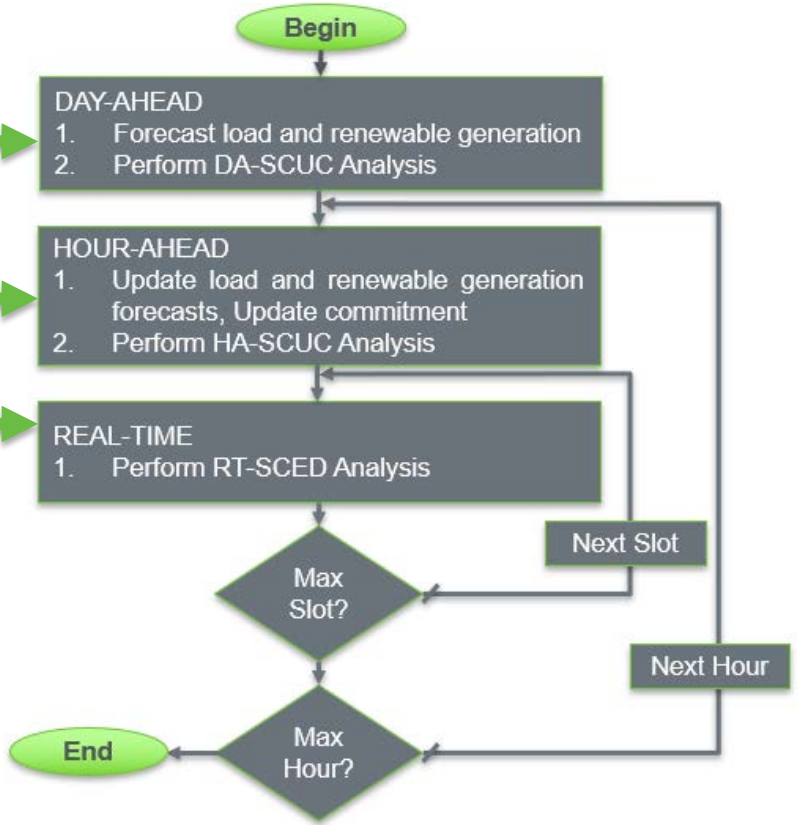

Figure 3. Open Source Sequential Multitimescale Electricity Market Simulation Tool (OpenSMEMS)

Accomplishments and Progress

Test system:

- The 2000-bus system tested is a simplified ERCOT system shown in Figure 4.

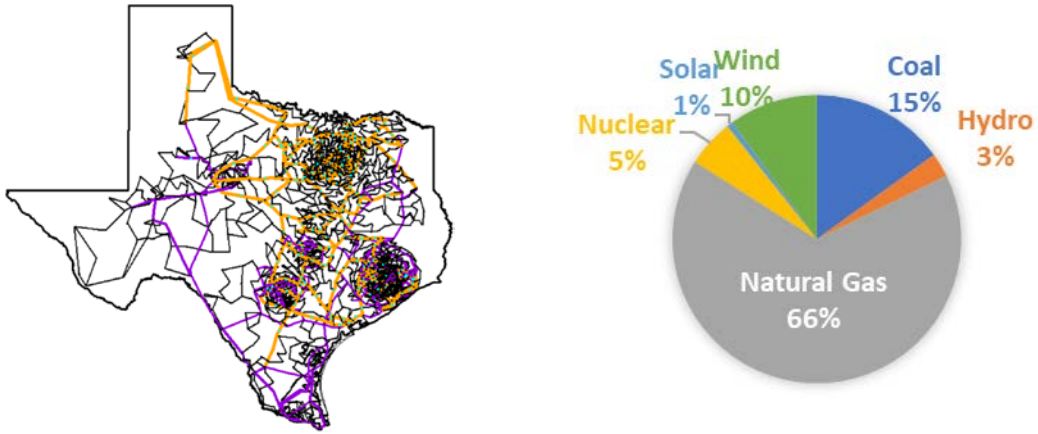

Figure 4. TAMU ERCOT 2000-bus system map and generation mix

Case studies:

- Impact of a wind-ramping product at different wind power penetrations on system ramp procurement costs
- Impact of wind power penetration on real-time operation costs

Accomplishments and Progress

Impact of wind ramping projects at different wind power penetrations on system ramp procurement costs

Input data

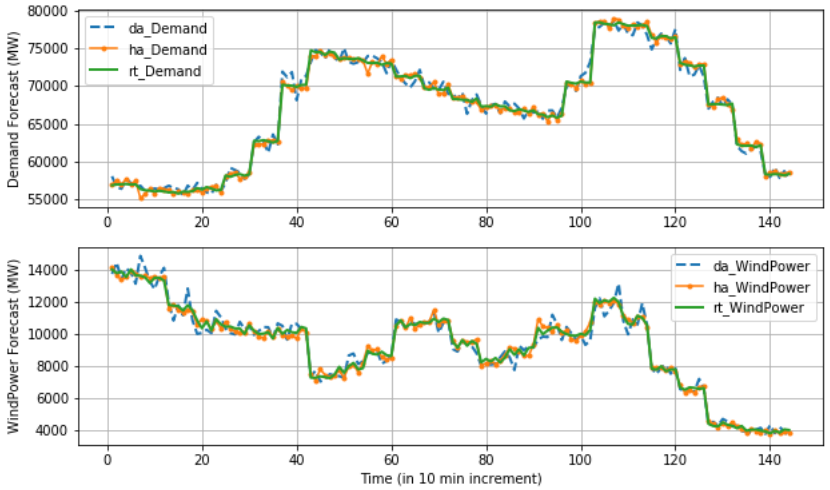

Figure 5. Load and wind power input profiles in day-ahead (da), hour ahead (ha), and real-time (rt) markets. The wind power penetration is 25% in this study.

System ramp cost with and without wind providing ramping product

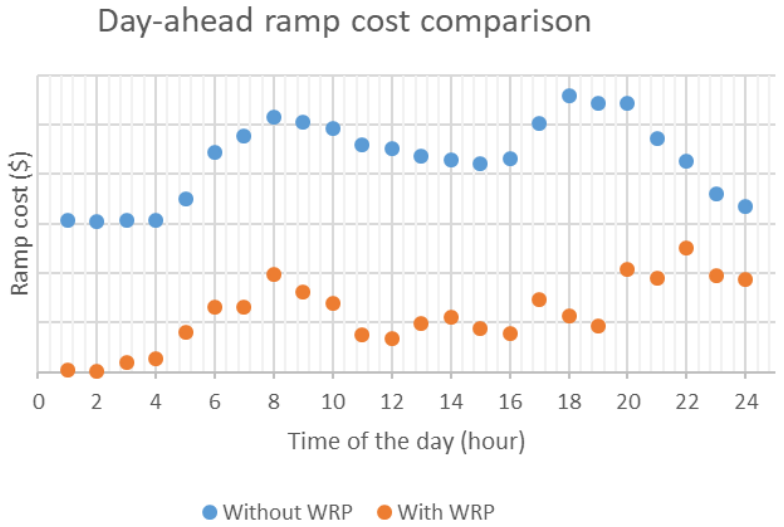

Figure 6. Day-ahead ramp cost reduction rate when wind power plants provide flexible ramping product

✓ **Regardless of the time, allowing wind to provide flexible ramping products results in higher cost savings that increase with wind penetration levels**

Accomplishments and Progress

Impact of wind ramping product on system dispatch

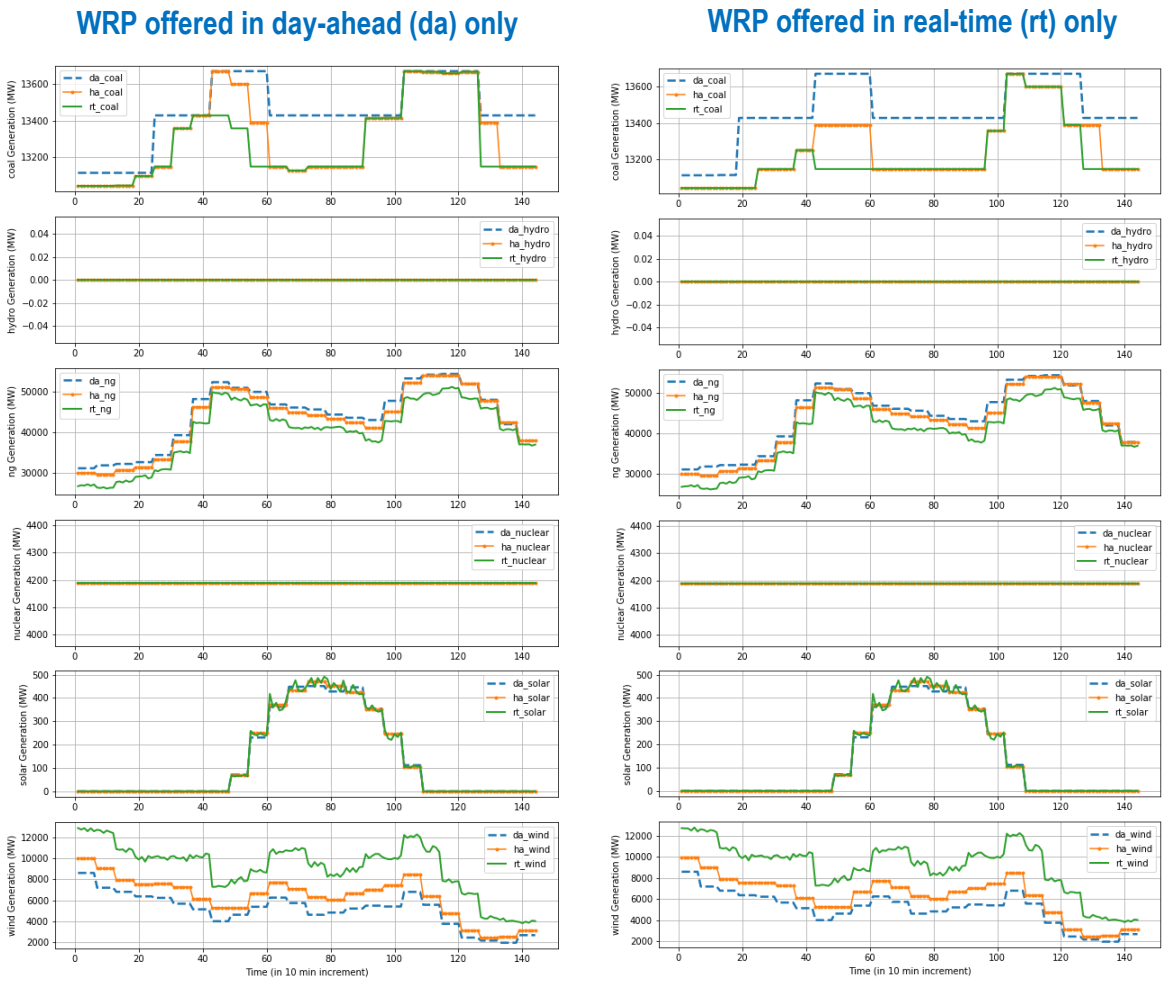

Figure 7. TAMU 2000-bus system generation mix for day-ahead and real-time WRP offer options

- The system generation dispatch mix differs according to whether wind offers a ramping products in day-ahead or real-time market
- For the TAMU 2000-bus system, the most notable displacement occurs with coal generation based on cost minimization objectives
- Wind-ramping products result in higher cost savings that increase with wind penetration levels

Accomplishments and Progress

	FY 2017	FY 2018
Quarter One	Developed new techniques for short-term (e.g., 5-minute) wind power ramp forecasting.	OpenSMEMS tool was developed to align the market constructs with CAISO and MISO practices of co-optimizing energy, reserves, and ramping product.
Quarter Two	Assessed wind ramping forecast at different forecasts horizons. Quantitatively evaluated the performance of developed deterministic and probabilistic wind ramp forecasting methods at mid- and short-term forecasting horizons.	Integrated probabilistic wind forecasts into markets. Probabilistic wind (and the resulting net-load forecasts) were developed to estimate the uncertainties in the ramping product requirements in the market.
Quarter Three	Designed the wind-friendly flexible ramping product. Developed a multi-timescale unit commitment and economic dispatch model, including a wind flexible ramping product.	Including the sequential day-ahead Security Constrained Unit Commitment (SCUC), real-time SCUC, and real-time Security Constrained Economic Dispatch (SCED) in OpenSMEMS to model multi-timescale market simulations.
Quarter Four	Enhanced the Open source Sequential Multi-timescale Electricity Market Simulation (OpenSMEMS) electricity market simulation tool (formerly known as the GridLAB-ISO tool).	Completed comprehensive modeling and assessment of the wind-ramping product in the simplified TEXAS 2000-Bus system using the OpenSMEMS tool, under different penetrations of variable renewables.

All milestones were completed.

- **FY17**: Develop deterministic and probabilistic wind ramping forecast at different time horizons.
- **FY18:** Develop open-source sequential multi-timescale electricity market simulation tool with a wind-ramping product. Two conference papers submitted to IEEE PES General Meeting won Best Conference Paper awards.

Communication, Coordination, and Commercialization

The project team has, or has presented plans to, disseminate the results of project research to relevant audiences:

- Presented the probabilistic ramping forecast and wind-ramping product at IEEE PES General Meeting 2018 and won two Best Conference Paper awards
  - Xin Fang, Bri-Mathias Hodge, Venkat Krishnan, Fangxing Li. "Potential of Wind Power to Provide Flexible Ramping Products and Operating Reserve," IEEE PES General Meeting, Portland, OR, Aug. 16–20, 2018. **Best Conference Paper**.
  - B. Huang, V. Krishnan, B.-M. Hodge, "Analyzing the Impacts of Variable Renewable Resources on California Net-Load Ramp Events," IEEE PES General Meeting, Portland, OR, Aug. 16–20, 2018. **Best Conference Paper**.
- Published six journal papers about the wind-ramping forecast and wind-ramping product on *IEEE Transactions on Power Systems, IEEE Transactions on Sustainable Energy, IEEE Transactions on Smart Grid,* and *Applied Energy.*
- Partnering with ERCOT to discuss the wind providing ramping in ERCOT's system
- Released OpenSMEMS to the public to make other researchers study the impact of a wind-providing ramping product.