ENERGY TRANSITIONS INITIATIVE
U.S. Department of Energy

Partnership Project

City and Borough of Sitka, Alaska
Modeling and Controls Assistance and Renewable Energy Resource Assessment

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National Renewable Energy Laboratory, Golden, CO, USA

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Executive Summary

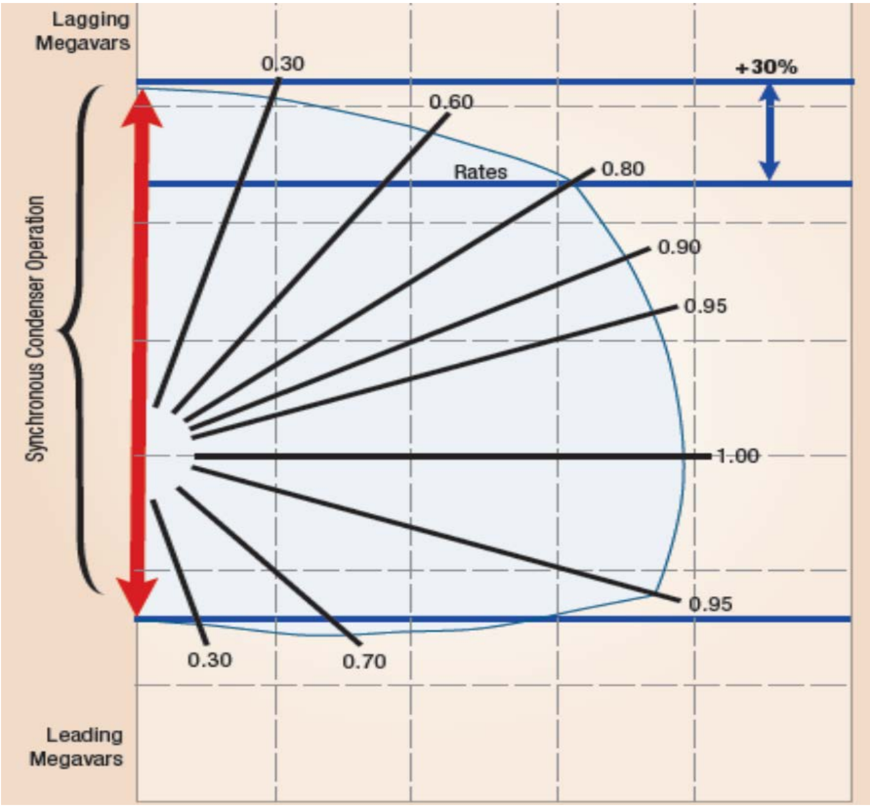
- This project develops the dynamic modeling of hydro plants and wind generation.
- A dynamic penetration of renewables was evaluated under various conditions.
- The impact of altering hydro generation control to synchronous condenser control was evaluated.
- While the existing hydro generations are sufficient to address voltage instability, a detailed study of the active-reactive capability limits of hydro generation operation should be conducted to uptake at various wind penetration levels.

Project Timeline

- In Fiscal Year 2022:
  - NREL conducted dynamic modeling of the Sitka system.
  - NREL previously evaluated the high penetration of renewables in the Sitka network.
- In FY23:
  - NREL carried out an initial analysis to examine the conversion of generators to synchronous condensers and its impact.
  - NREL collected practical governor and exciter parameter data to complete the analysis.
  - NREL constructed and validated a synchronous condenser model using the exciter data.
  - NREL reevaluated renewable penetration with the synchronous condenser in place.

Synchronous Condenser

- Synchronous condensers have $10,000–$60,000 per megavolt ampere of reactive power (MVAR) capital cost and high operational cost.
- Synchronous condenser operation has thermal and stability limitations.
- The over-excited reactive capability of the synchronous condenser zone is more prominent than its under-excited reactive power capability.
- Converting existing synchronous generators to condensers may require the following changes:
  - Installation/modification of start-up frequency converter (SFC)
  - Installation/modification of transformers for SFC
  - Installation/modification of medium-voltage (MV) switchgear
  - Modification of generator protection and synchronizer
  - Modification of excitation equipment
  - Installation/modification of electrical installation (cabling) and modification works.

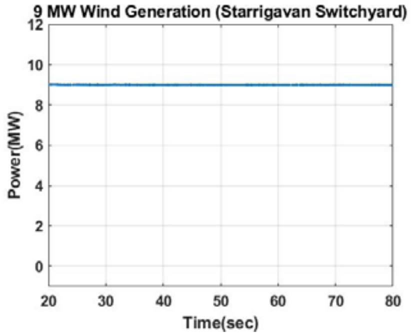


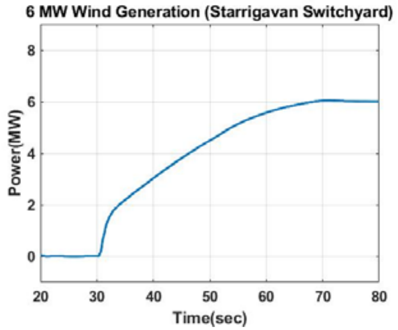
Synchronous condenser reactive power capacity

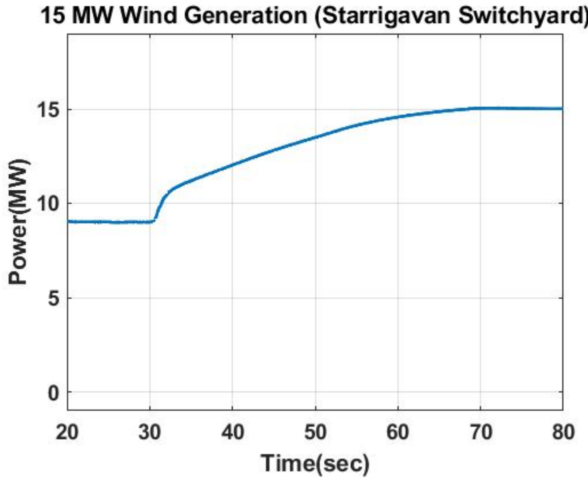
(By Dr. James M Fogarty, and Ryan M LeClair, GE Energy "Converting Existing Synchronous Generators into Synchronous Condensers")

15 MW Wind Turbine Installation at Starrigavan

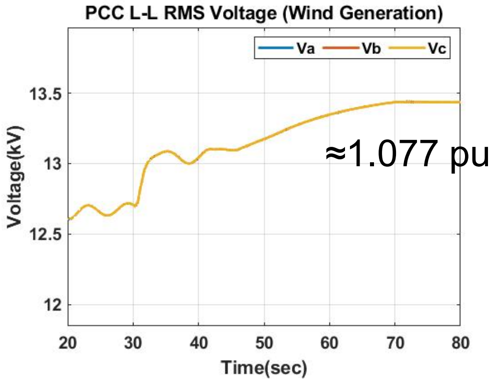
Scenario: Load 15 MW, Wind ramp up from 9 to 15 MW, and synchronous generators ramping, and power factor limited to 0.95 lead/lag, theoretical synchronous generation parameters.

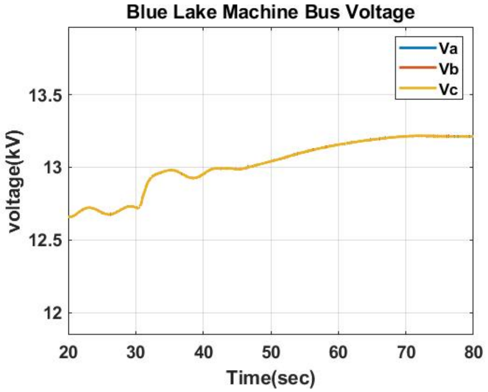


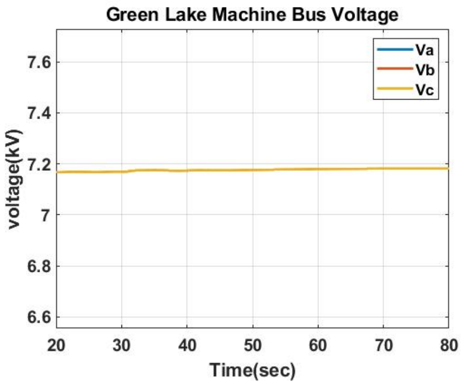


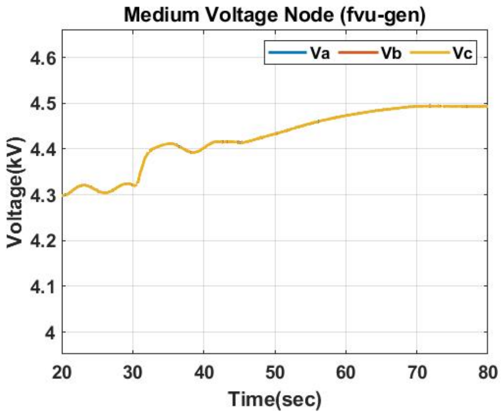


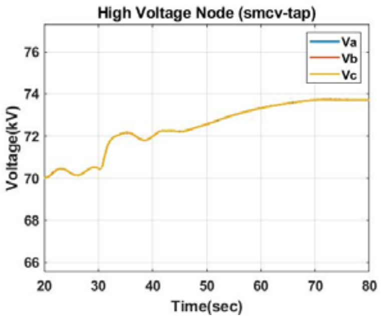
Total Wind Power: Step from 9 MW to 15 MW

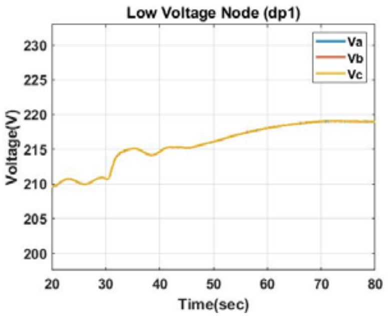


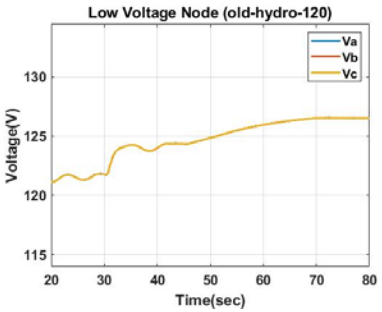






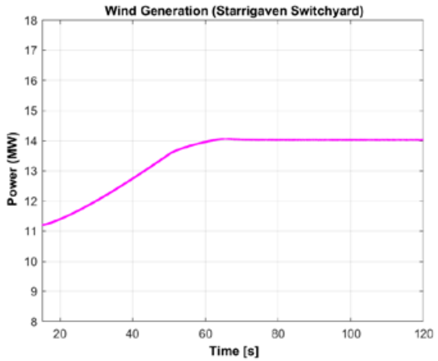


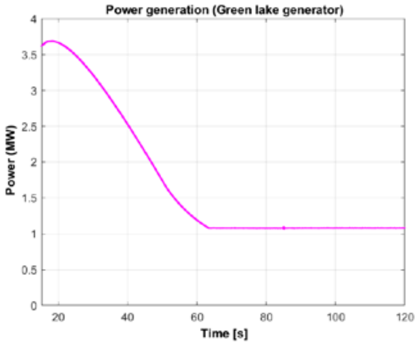


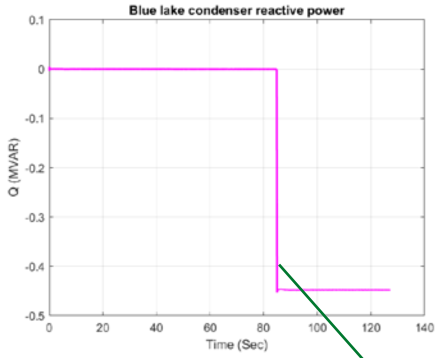


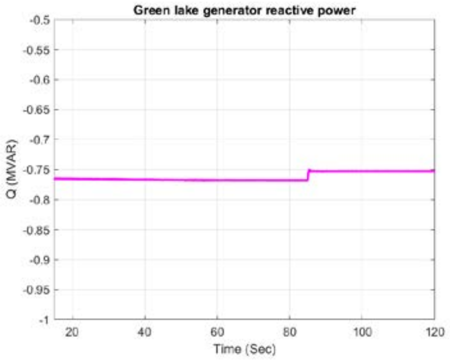
15 MW Wind Turbine Installation at Starrigavan and Blue Lake Synchronous Condenser

Scenario: Load 15 MW, Wind ramp up from 12 to 14 MW, and Blue Lake synchronous condenser, practical Sitka synchronous machine parameters.



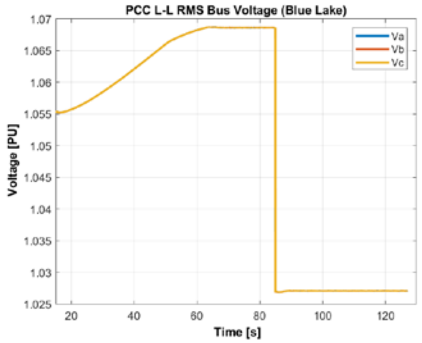


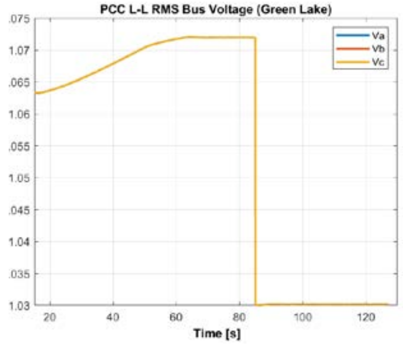


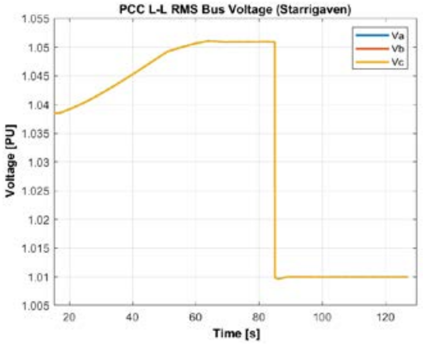


Synchronous condenser operation

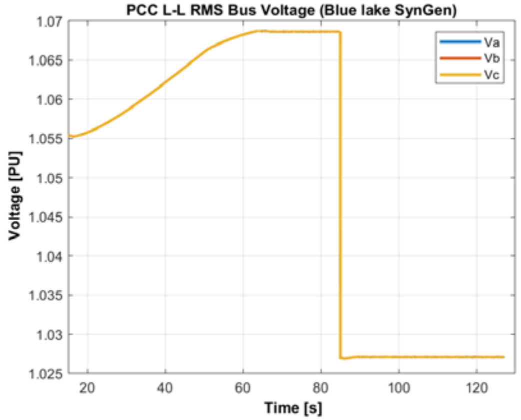
Bus Voltage Stability Limit should be ±5%

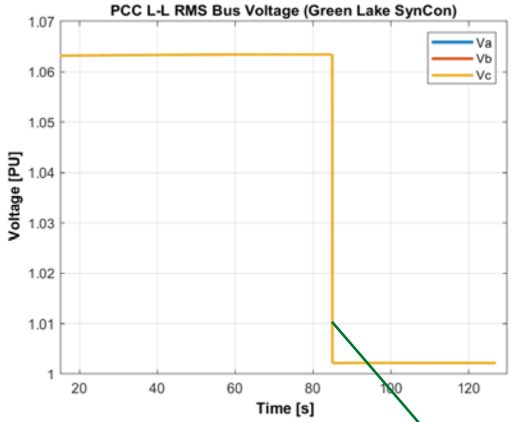






PCC voltage at wind generation locations

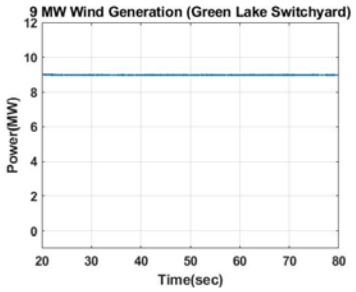


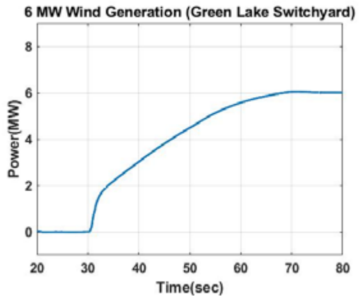


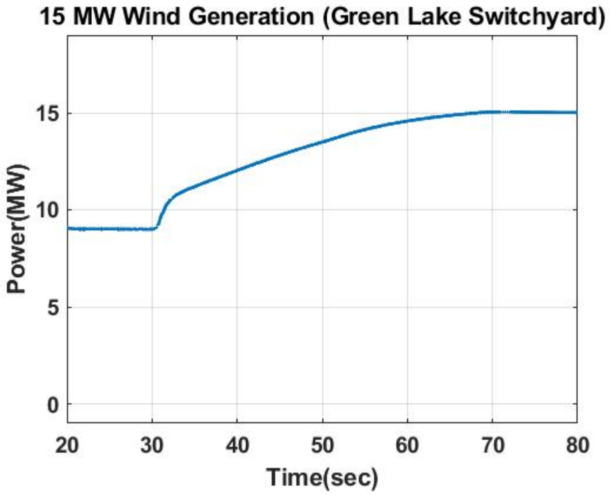
Synchronous condenser voltage correction

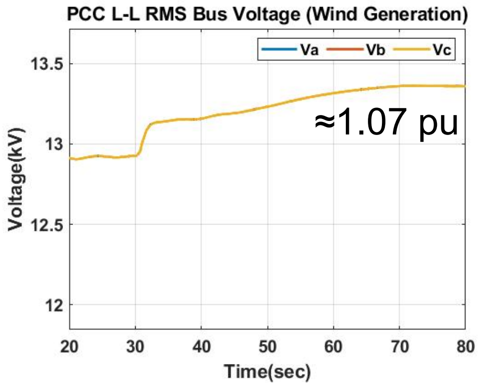
15 MW Wind Turbine Installation at Green Lake

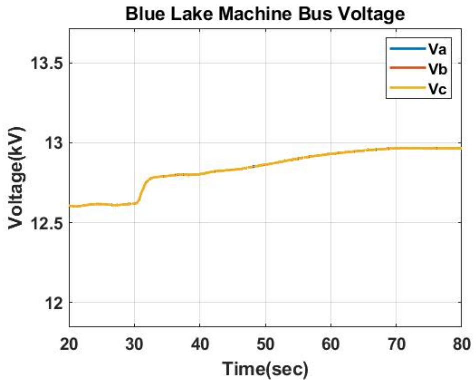
Scenario: Load 15 MW, Wind ramp up from 9 to 15 MW, and synchronous generators ramping, and power factor limited to 0.95 lead/lag, theoretical synchronous machine parameters.

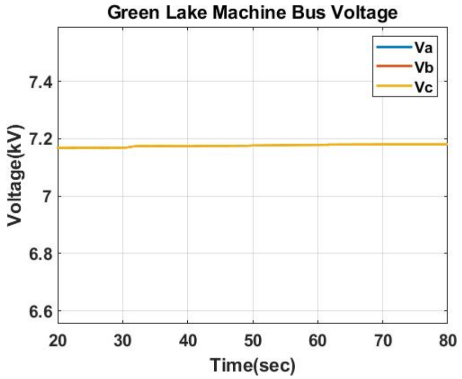


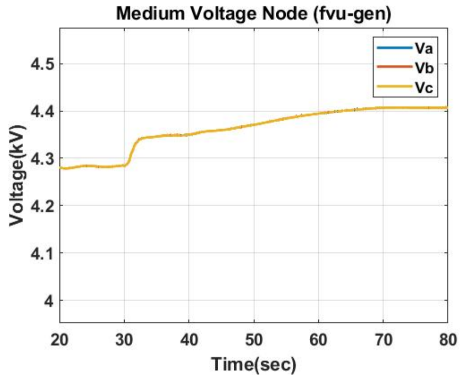


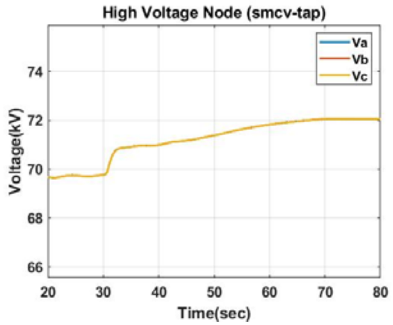


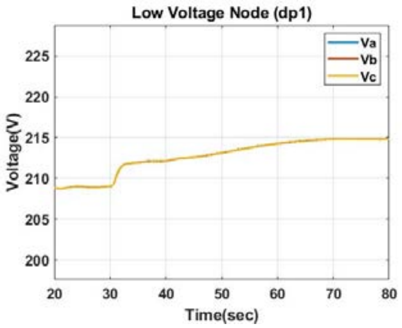


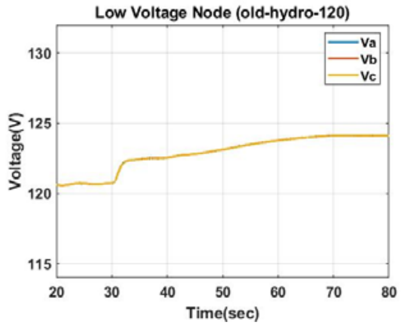












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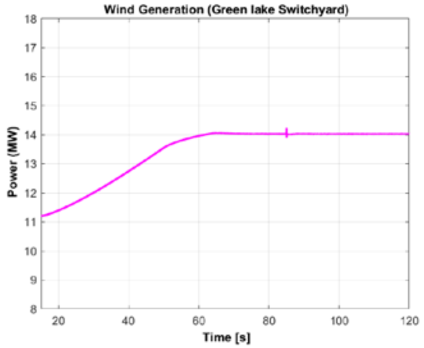
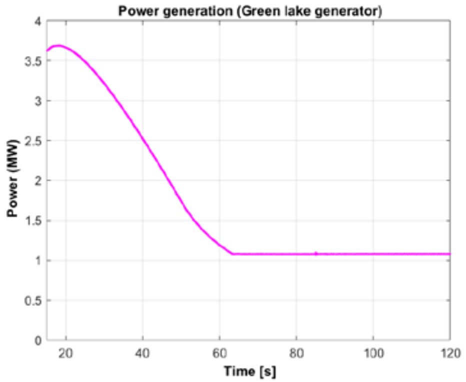
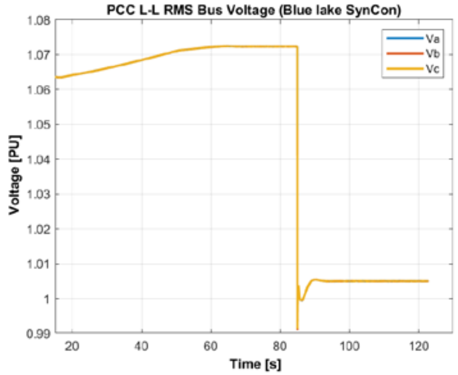
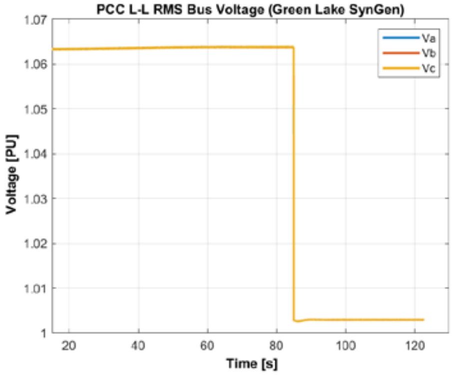
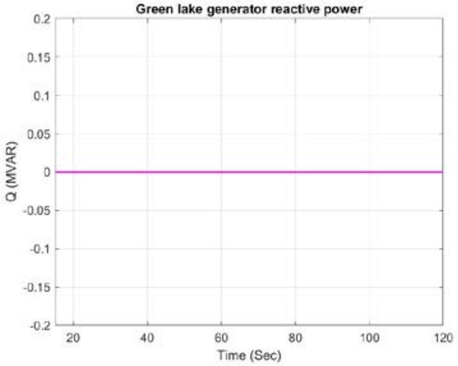
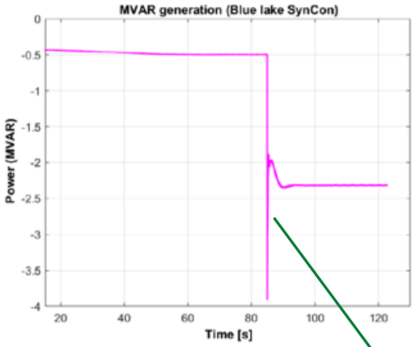


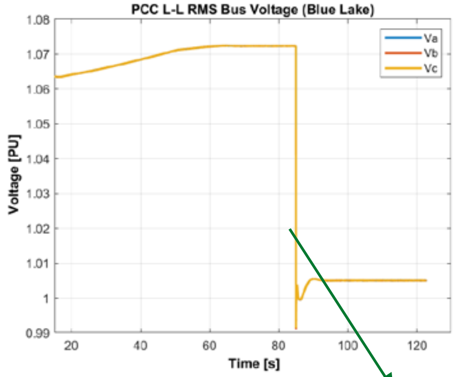


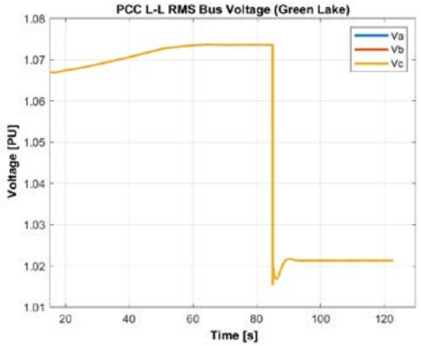


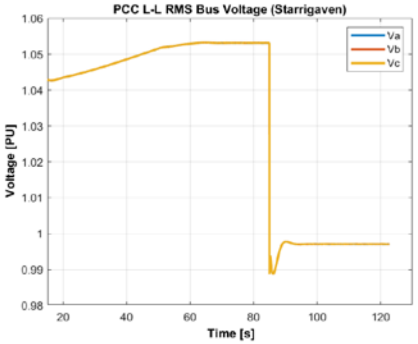










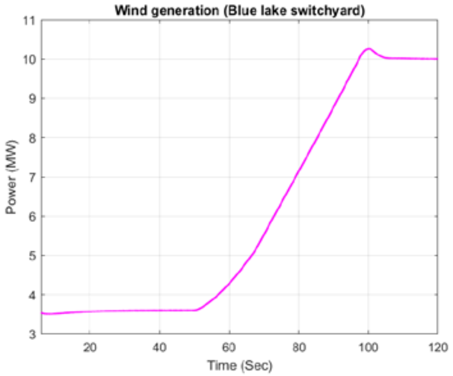


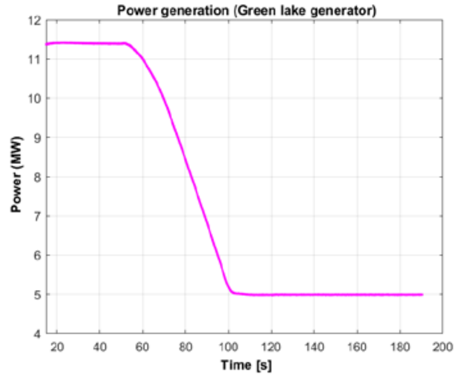
Synchronous condenser operation

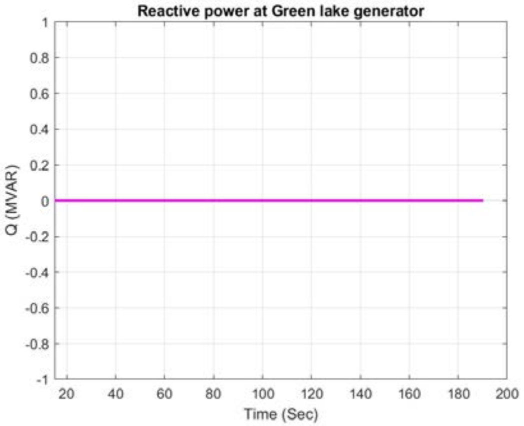
Synchronous condenser voltage correction

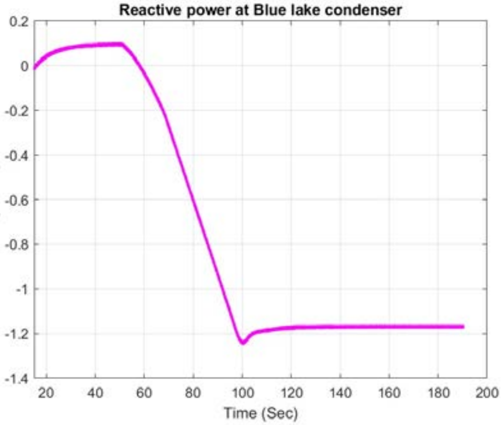
15 MW Wind Turbine Installation at Blue Lake and Blue Lake Synchronous Condenser

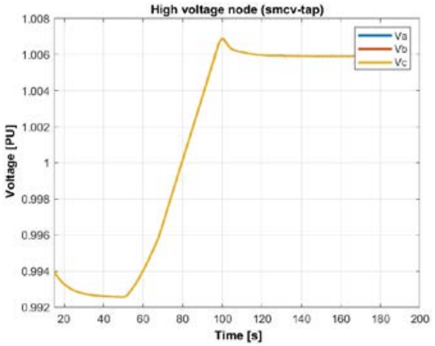
Scenario: Load 15 MW, Wind ramp at Blue Lake ramp, and Blue Lake synchronous condenser, practical Sitka synchronous machine parameters.

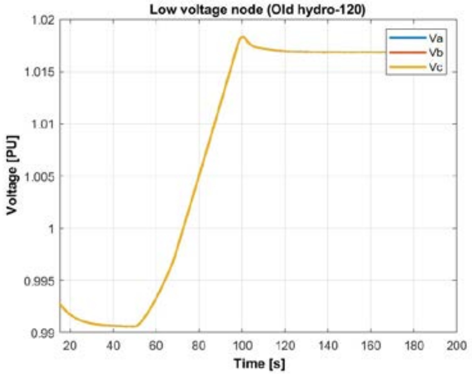


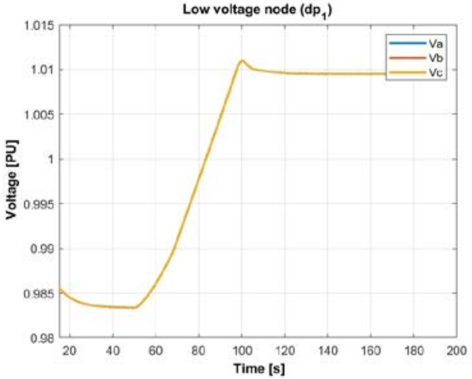


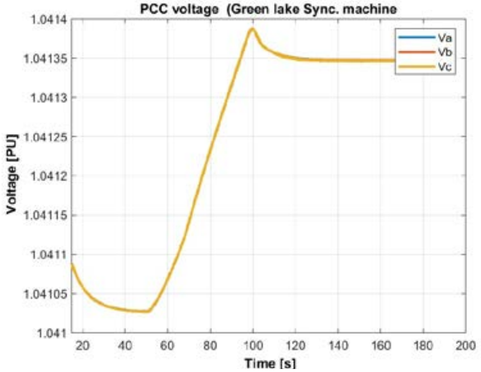


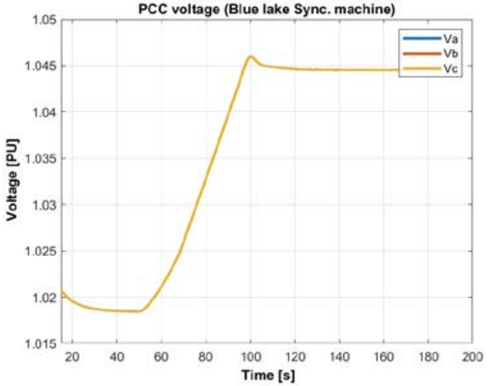


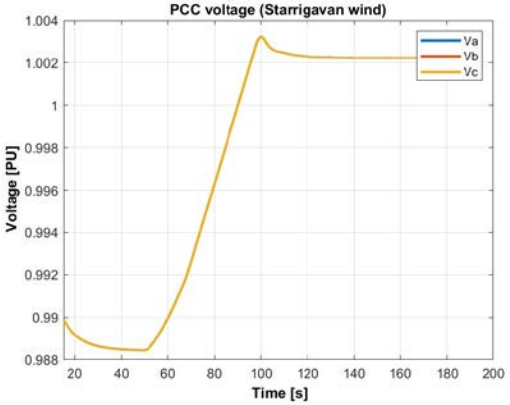












15 MW Wind Turbine Installation at Blue Lake and Blue Lake Synchronous Generator

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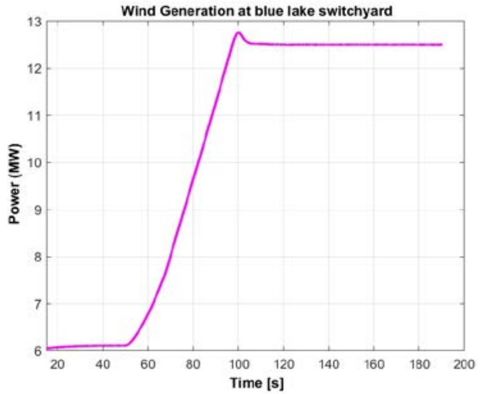

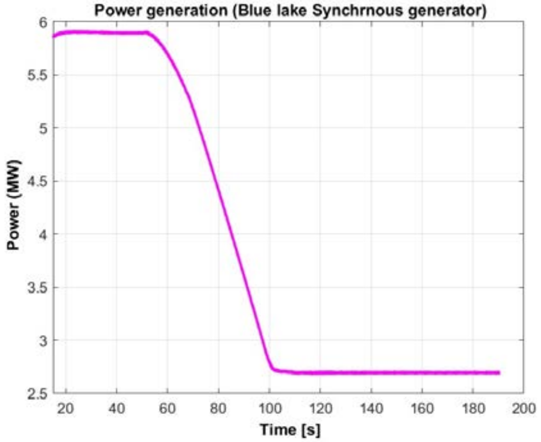

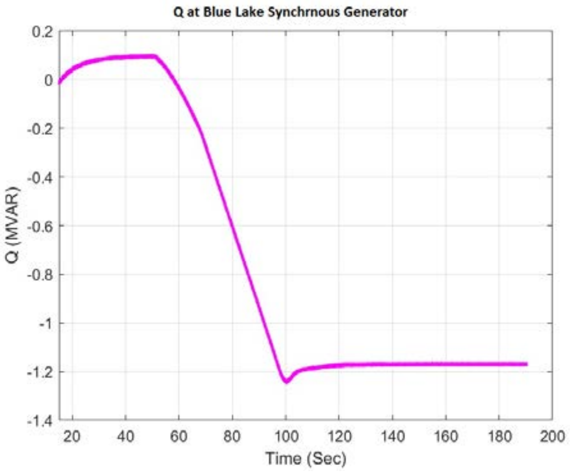

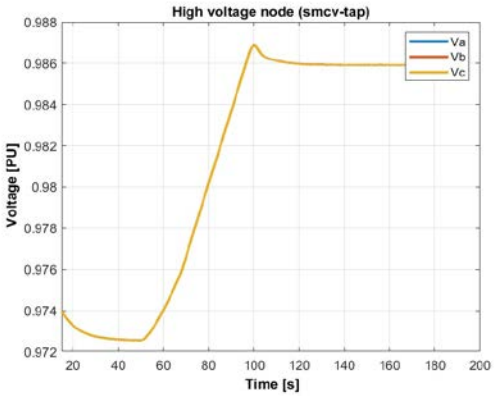

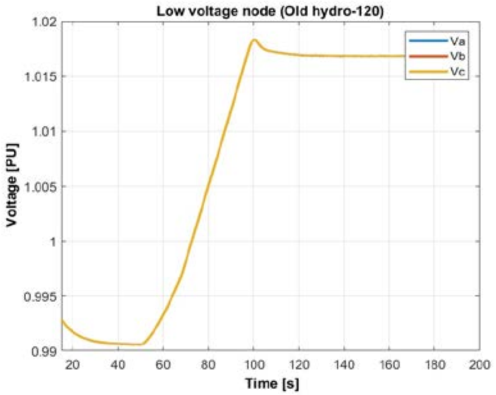

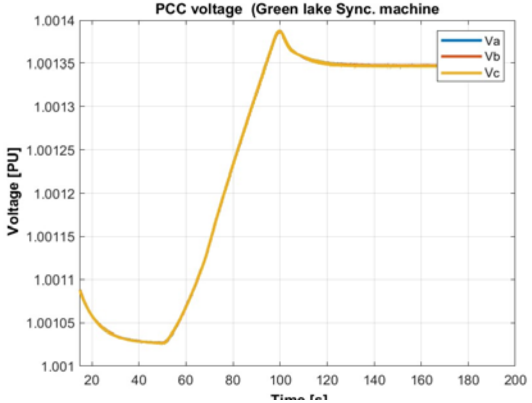

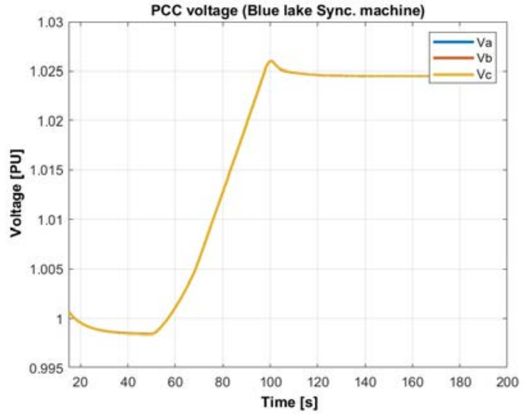

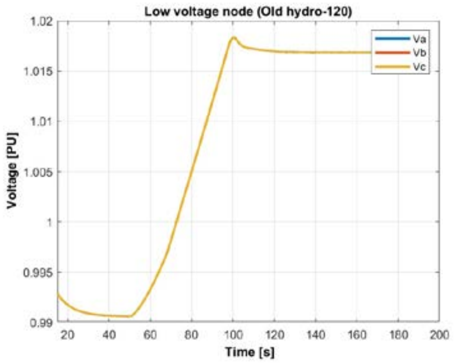

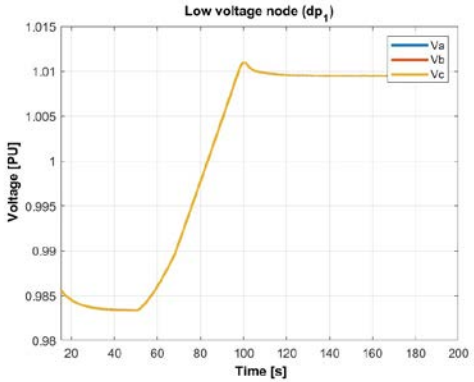

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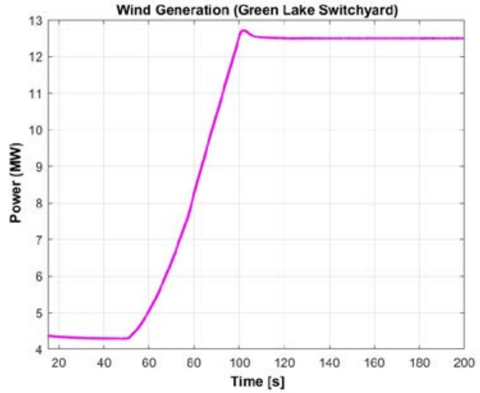

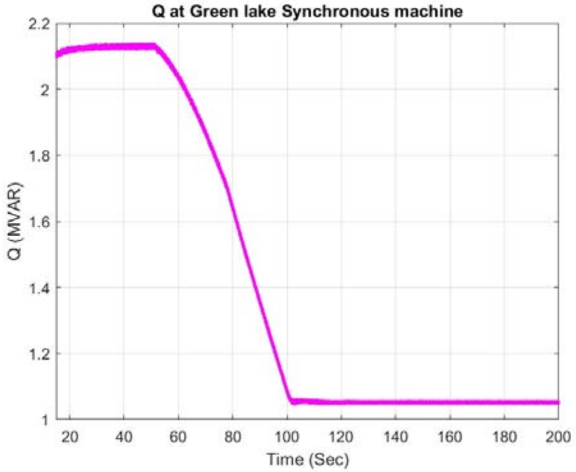

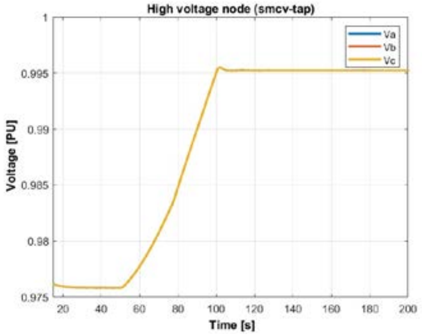

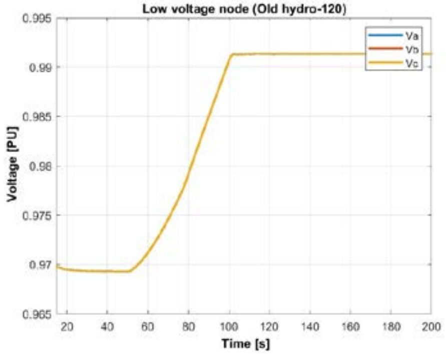

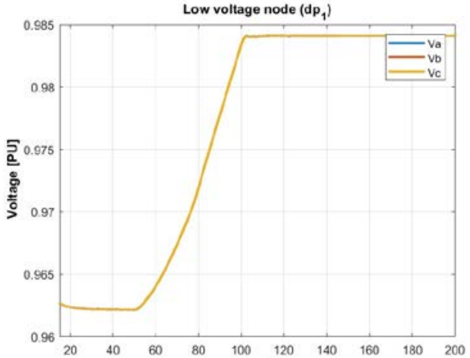

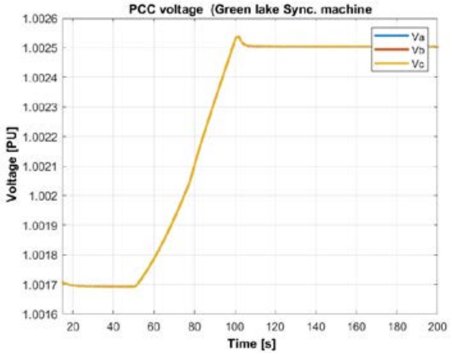

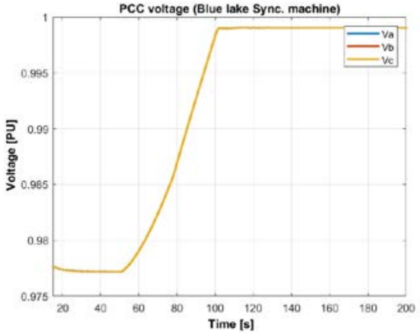

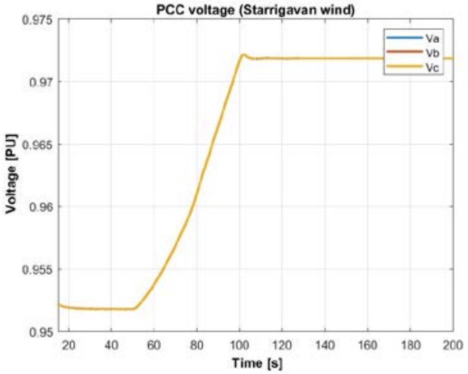

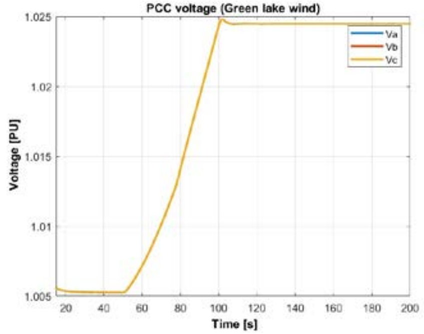

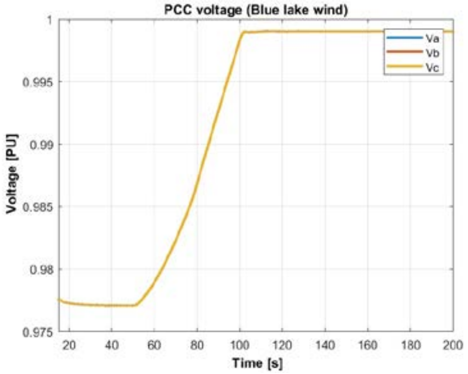

Observations

- When the tighter power factor limit (ranging from 0.95 lag to 0.95 lead) is applied to the Blue Lake and Green Lake synchronous generators, voltage instability becomes prominent.
- The synchronous condenser can effectively correct voltage violations.
- The application of a synchronous condenser results in a significant injection of reactive power, which corrects voltage issues.
- With a more lenient reactive power limit (ranging from 0.9 lag to 0.9 lead) for synchronous generators at Blue Lake and Green Lake, voltage instability challenges can be mitigated.

Summary

- NREL built a dynamic model to evaluate grid stability and control impacts with the addition of renewable generation in the dynamic Opal RT model.
- All practical synchronous generator parameters submitted by Sitka in June 2023 were considered in the dynamic Opal RT model.
- Typically, the percentage of renewable generation in relation to load can inform about steady-state voltage limits. Here, NREL developed case studies that focus on the dynamic voltage stability and requisite controls in the real time Opal RT model.
- NREL focused on synchronous condenser modeling and its coordination in this work.
- Typical synchronous condensers have a limited overcurrent capability. Converting existing synchronous generators into condensers can provide only a limited percentage of reactive power support.

Summary Continued

- Based on the initial evaluation, there is no need for transitioning from synchronous generators to condensers for stability and control with additional wind generation.
- Higher wind penetration is possible with substantial reactive power support from Blue Lake and Green Lake synchronous generation (more lenient reactive power limit 0.9 lag to 0.9 lead).
- Upgrades to controls of synchronous generation may be needed for stability and control with additional wind generation.
- Multiple scenarios, including feeder thermal limits and stability considerations, should be studied for peak loads of 15 MW or higher.

Thank You

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