INL/CON-22-67182-Revision-0

Variable Resource Resilience: How Systems Experience Increased Resilience from Variable and Hybrid Resources

May 2022

Changing the World's Energy Future

Megan Jordan Culler, Stephen Arthur Bukowski, Jake P Gentle, Sarah Barrows

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

Variable Resource Resilience:

How Systems Experience Increased Resilience from Variable and Hybrid Resources

M. CULLER[1], S. BUKOWSKI[1], S. BARROWS[2], J. GENTLE[1]
1 Idaho National Laboratory, Idaho Falls, ID
2 Pacific Northwest National Laboratory, Richland, WA

DEFINING RESILIENCE

While the concept of resilience is not new, its application to the electric grid is neither standardized nor well-defined.

After a review of industry, government, and academic sources on the subject, INL defines resilience of an electric energy delivery system (EEDS) as:

"a characteristic of the people, assets, and processes that make up the EEDS and its ability to **identify, prepare for**, and **adapt** to disruptive events (in the form of changing conditions) and **recover rapidly** from any disturbance to an **acceptable state** of operation." [1]

RESILIENCE FRAMEWORK FOR EEDS

- INL developed a resilience framework for EEDS to enable consideration of resilience throughout system lifecycle. [2]
- The framework emphasizes selection of resilience goals, metrics, and prioritized hazards based on system qualities.
- Resilience hazards can be assessed against other business risks.
- Understanding the resilience benefits of variable and hybrid resources allows them to be properly factored in to cost/benefit analyses.

MIRACL

Microgrids, Infrastructure Resilience, and Advanced Controls Launchpad

MIRACL is a multi-laboratory program funded by the DOE Wind Energy Technologies Office (WETO). The project examines resilience, advanced controls, valuation, and cybersecurity for distributed wind.

The authors would like to acknowledge Patrick Gilman and Bret Barker of DOE WETO for their support of MIRACL.

MIRACL Partners:

Idaho National Laboratory (INL)
Pacific Northwest National Laboratory (PNNL)
National Renewable Energy Laboratory (NREL)
Sandia National Laboratories

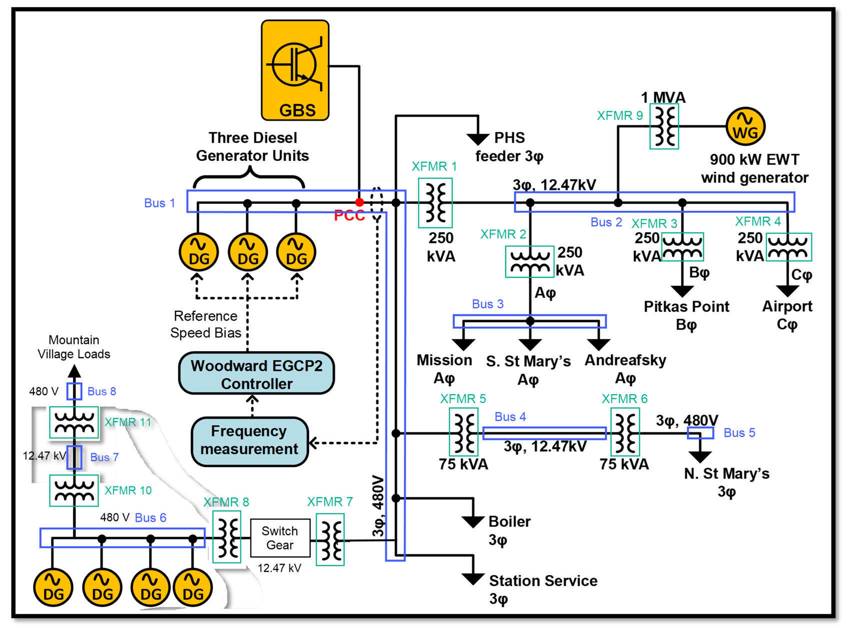
CASE STUDY – ST. MARY'S, AK [3]

System Description

- 900 kW wind turbine installed in 2019
- Over 2000 kW diesel generation capacity
- Transmission intertie between St. Mary's and Mt. Village came online in 2020
- Peak load (combined system): 1072 kW

Resilience Goals

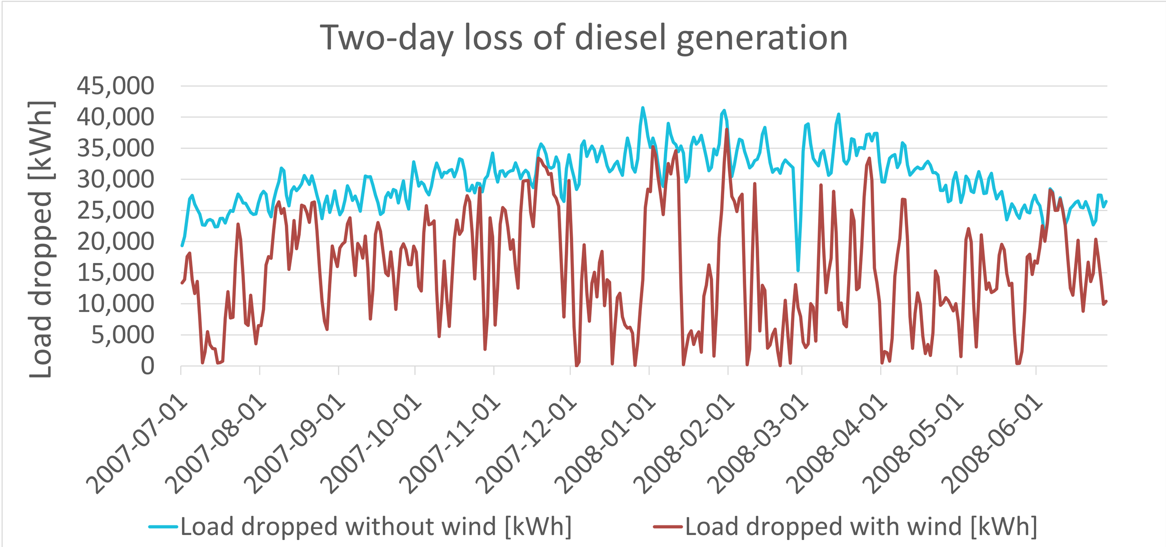
1. Reduce dependency on diesel
   - Prior to wind turbine install, only fuel source was diesel generators, dependent on annual fuel shipments by barge
2. Improve power quality
   - System is small and electrically isolated, lacking stability of a bulk power system



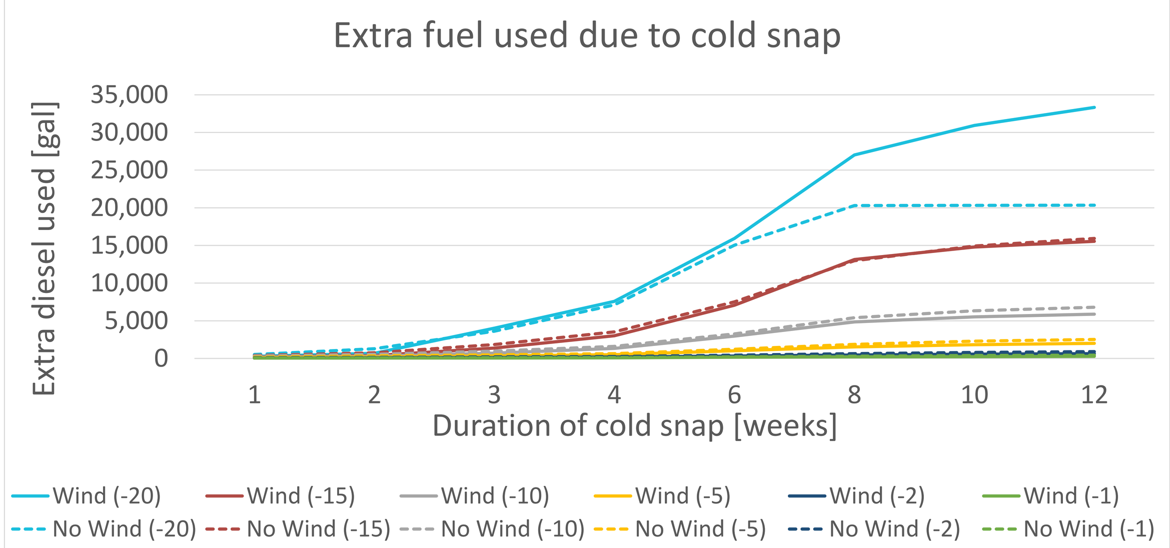
Electrical description of combined St. Mary's / Mt. Village system).

Hazards

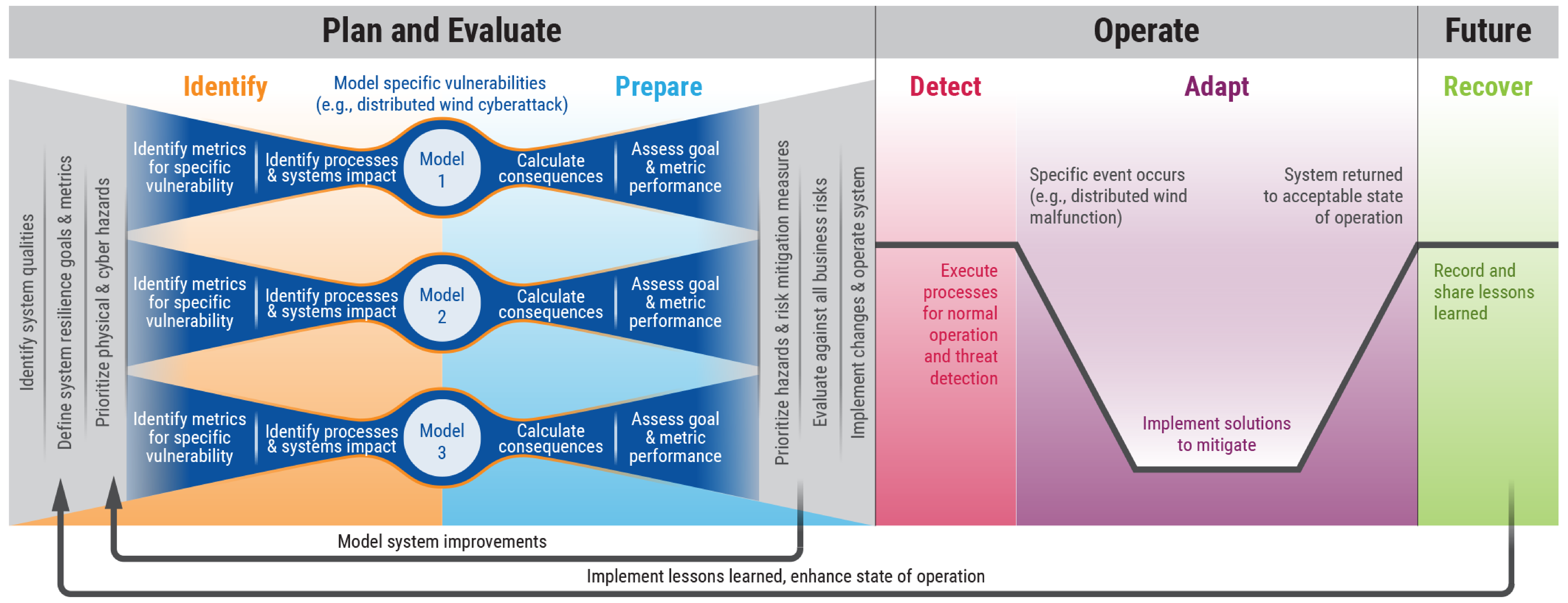
- Fuel shortage
  - "Forecasted" shortages (delayed fuel shipment) & "Immediate" shortages (failure of storage tank or pipe) analyzed.
  - 2-day and 2-week immediate shortages analyzed.
  - The presence of the wind turbine **always** decreases the amount of fuel used, and the duration or severity of outages, if any. This analysis assumes the system (loads, physical components) can tolerate the variability of wind generation.
- Extreme winters
  - Temperature drops of varying severity (-1°C to -20°C) and duration (1 week to 12 weeks) analyzed.
  - Temperature drops correlated to increases in load.
  - Wind that was curtailed in base case instead used to help serve excess load.
  - Exception: extreme cold dropped temp below turbine's operating point.
- Communications outage for turbine
  - No direct system impacts due to comms hazard alone, but lost visibility could increase severity of other hazards (i.e., undetected issues could cause longer turbine downtimes).



A two-day diesel generator outage resulted in less load dropped with wind installed compared to without wind. On average, the wind turbine could theoretically serve an extra 14,643 kWh of load during the hazard, saving up to $447,592 for the community and up to $4,241 for the utility for each outage occurrence.



Except in the most extreme scenario, which has temperatures below the wind turbine's operating limit, the wind turbine saves excess fuel consumption during the hazard. The fuel savings from having wind installed were maximized for mid-severity cold snaps (-10° compared to a normal year) for long durations.



INL Resilience Framework for EEDS: The steps in the Plan and Evaluate stage were followed for the St. Mary's case study.

RESILIENCE METRICS FOR VARIABLE RESOURCES

Choosing appropriate resilience metrics for the system and the hazards it faces is a critical step to unlocking resilience value.

The table below describes metrics that can be used to demonstrate the resilience value of variable resources, including wind, solar, storage, and hybrid resources and the resilience hazards or goals that are appropriate to evaluate with these metrics.

Metric	Goal
Fuel displaced [gal]	Reduce dependency on fossil fuels or fuel imports
Lost load avoided [kWh]	Serve as much load as possible during a hazard
Duration of outage [h]	Reduce interruptions to service during a hazard
Time until load first dropped [h]	Maintain service to a load that cannot tolerate interruptions
Critical load served [kWh]	Ensure community or facility can operate at minimum levels with critical services
CO2 output [tons]	Reduce dependency on fossil fuel plants as more are retired or experience high price fluctuations

KEY TAKEAWAYS

- Resilience goals, metrics, and hazards represent a "uniqueness quality" for different systems, stakeholders, and environment and need to be customized to the system.
- Variable resources can mitigate hazards and improve resilience primarily by servicing local load.
- Variable resources can maximize their resilience value through the use of advanced controls. including inverter functions (grid-forming, voltage and frequency support) and accurate forecasting.
- Coupling storage with distributed wind and other carriable resources can increase flexibility and resource diversity to enhance resiliency.

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CONTACT

Megan.Culler@inl.gov