What is a Microgrid?

A microgrid is a small-scale energy distribution system with control capability, allowing it to disconnect from the traditional grid and operate autonomously. Generally, a microgrid can be operated connected to larger power networks, or as a remote islanded grid. In Alaska, however, microgrids typically cannot be connected to the greater transmission grid because of geographical remoteness, and, therefore, they are not designed with that operational capability.

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Case Study: Geothermal Integration Study for the Wind-Diesel Microgrid of Nome, Alaska

This project simulated Nome's grid using a time-dependent energy balance model based on two years of data. Four scenarios were run with several diesel fleets of various-sized generators for geothermal capacities between 0 and 5.2 MW. This data preceded the installation of the majority of Nome's wind turbines, thus a model was developed to estimate the wind power contribution. Diesel generators fulfilled the load following requirements while their minimum optimal loading requirements were respected and geothermal and wind production was prioritized to minimize the diversion of renewable resources.

Model Results

Major results of this study showed that there is a critical point at which significant amounts of geothermal energy would need to be diverted in order to maintain the minimum optimal loading for the current fleet of diesel generators and that this critical point is close to the base load for the Nome grid. However, adding diversity to the diesel fleet postpones the point at which significant wind and geothermal energy needs to be diverted because fleets with more generating options were better able to match the capacity required to supply spinning reserve while maintaining their minimum optimal loading. However, as the switching of diesels comes with a warm-up, cool-down, and minimum operation time penalty, excessive switching, more than four to six times per day, is not desirable.

Total Annual Demand	35,300 (MWh)
Total Wind Energy	4,110
Scenario 1	
Diesel displaced	15,300
Wind diverted	1,252
Geothermal diverted	1.42
Scenario 2	
Diesel displaced	15,500
Wind diverted	1,017
Geothermal diverted	1.36
Scenario 3	
Diesel displaced	15,800
Wind diverted	691
Geothermal diverted	1.29
Scenario 4	
Diesel displaced	15,900
Wind diverted	575
Geothermal diverted	1.21

In conclusion, adding geothermal power will reduce overall diesel consumption. At 2 MW geothermal, for example, 3.8% of diesel was displaced and 8.2% of the wind power was diverted. Even so, the value of the displaced diesel generation was still greater than the displaced renewable generation. The addition of energy storage or dispatchable loads may increase utilization of the wind resource, but those options were not a part of this analysis.

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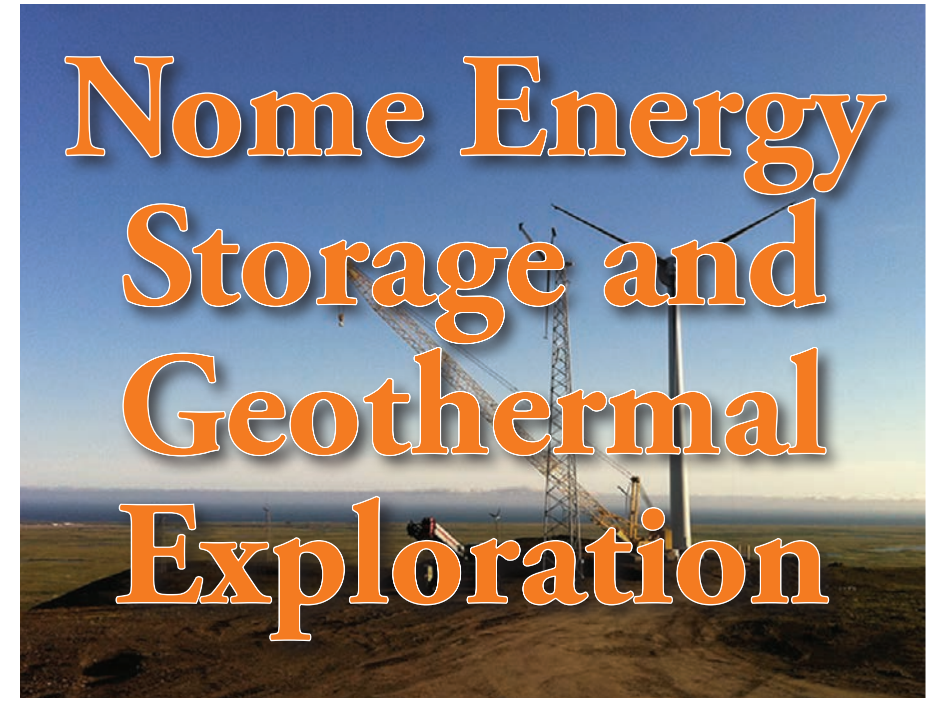
Nome Energy Storage and Geothermal Exploration



Wind turbines near Nome, Alaska

The community of Nome, Alaska is exploring options for developing geothermal power and energy storage systems to increase its penetration of renewable resources and to reduce electricity costs. As a remote and islanded microgrid, Nome relies on diesel as a primary fuel source for power generation. This research briefing highlights two case studies of how ACEP is working with communities to develop strategies to reduce reliance on diesel generation by developing local renewable energy resources, as well as energy storage.

Background

Nome is a community of approximately 3,600 permanent residents located in western Alaska on Seward Peninsula, which juts out into the Bering Sea. Due to its remote location, Nome generates power locally to serve the community using an integrated wind-diesel microgrid with a 4 MW average load and powered by 5.2 MW of diesel generation and 2.7 MW of installed wind power capacity. There is a potential geothermal resource, Pilgrim Hot Springs, located 37 miles away, and the community of Nome is exploring the possibility of purchasing power produced from this resource to provide up to 2 MW of baseload geothermal power to its grid.

On behalf of the City of Nome and Nome Joint Utility Services, ACEP was asked to: (1) understand how Nome can maximize the use of its existing wind generation and minimize diverted energy through the use of energy storage and (2) understand the optimal amount of geothermal energy Nome should purchase without necessitating investment in additional equipment, given its existing wind farm and diesel fleet.

Nome, Alaska

Pilgrim Hot Springs, near Nome, Alaska

The Alaska Center for Energy and Power (ACEP) based at the University of Alaska is dedicated to applied energy research and testing focused on lowering the cost of energy throughout Alaska and developing economic opportunities for the state, its residents, and its industries.

Alaska's remote communities, spread across the state's geographically diverse regions, are home to more than 250 microgrids. These communities are isolated from one another and from the state's major population centers and rely heavily on electricity produced by diesel generators. The cost of electricity in rural Alaska is four to ten times higher than the national average. As a consequence, the State of Alaska has invested heavily in energy efficiency, weatherization, and renewable energy systems. Today, more than 70 of Alaska's isolated microgrids incorporate renewable energy, including small hydro, wind, geothermal, biomass, and solar projects.

Nome, with an existing wind farm and the potential for adding geothermal energy, is an example of a community that is taking advantage of local resources and available state funding to reduce reliance on imported diesel fuel. This research briefing includes two case studies from Nome that show how a rural community is exploring additional renewable integration and energy storage systems to further reduce diesel consumption.

Energy Storage

In isolated grids, diesel generators have two functions: to provide electric energy and to help with grid stabilization. Diesel generators are kept online for spinning reserve so that added capacity is always available to buffer sudden reductions of renewable energy production or increases in demand. However, providing spinning reserve capacity with diesel generators necessitates operation at reduced load factors, which reduces the efficiency of the diesel plant. This diminishes the cost-effectiveness of the renewable energy system and limits the maximum penetration of renewable energy into the grid.

An alternative way to stabilize these grids and allow for a higher share of renewable energy is through the use of an electric energy storage system (EESS). Its basic function is to store energy when there is a surplus available and to release energy when there is a deficit. In islanded grids, EESS can replace online generators in providing spinning reserve, for just long enough to bring diesel generators online. High power density and a nearly unlimited life cycle make kinetic energy storage systems (KESS) well suited for this application. KESS would allow the grid to meet the same demand with a lower capacity of diesel generators, leading to an ultimate reduction in diesel fuel consumption.

Power Systems Integration

Power Systems Integration (PSI) is the process of integrating diverse energy sources into a coherent system. In particular, the rising demand for clean, renewable energy has propelled research on how to integrate renewable energy resources into the existing electric grid. Renewable energy technology is only useful if it can be harnessed and incorporated into the existing power system, so power system integration is both a challenge and necessity.

Power Systems Integration Lab: Testing New Technology at the UAF Lab

With hundreds of remote communities whose reliance on diesel power results in some of the highest energy costs in the nation, Alaska has a strong interest in improving performance of both new and existing systems. To address this need, ACEP has established the Power Systems Integration Lab for development and testing of hardware and software components within an integrated grid system.

The Power Systems Integration Lab operates on the same scale as a village power system and can be modified for a wide range of islanded microgrid and distributed generation scenarios as well as for the performance of individual components. The lab enables research and development and testing of grid components and control approaches without risking outages to customers, as would be the case in field tests. Thus, it enables integration of earlier development stages into a typical system, which can accelerate technological advancement and provide confidence of readiness prior to initial field deployments.

Power Systems Integration Lab. UAF photo by Todd Paris

The 5,000 square foot lab offers unique capabilities, both in terms of equipment and employees, who have years of experience working in remote village power plants in rural Alaska, and the depth and breadth of knowledge required to provide an environment conducive to on-the-fly problem solving and selection of effective research and development trajectories. Partnering with industry, government and academia, the PSI Lab provides a controlled environment for a broad range of product development and testing in a setting which can closely replicate real-world environments. The PSI lab was especially designed to further the integration of intermittent generating sources and auxiliary equipment required, e.g., energy storage, with conventional power generation. ACEP has no vested interest in any specific technology.

Technicians from Hatch testing flywheel performance. Photo by Max Frey

Case Study: Development of Kinetic Energy Storage Systems for Islanded Grids

This project used the specification, design and assessment methodology to size a kinetic energy storage system (KESS) for the islanded grid of Nome. In order to optimize grid stability and to reduce actual energy costs, the operational strategy of the EESS had to be carefully analyzed to meet the characteristics of the specific grid. Based on a data-driven time-series energy balance model developed by the Alaska Center for Energy and Power, technology neutral requirements were derived in the "specification" step. In the "design" phase, a KESS was developed to meet these requirements. An operational strategy was determined and in the "assessment" step, the KESS was simulated and analyzed to ensure its functionality and economic feasibility.

Project Results

An outer-rotor flywheel developed at TU Darmstadt, Germany, was optimized for adapting power and capacity to the requirements of the application. The resulting storage system consisted of seven KESS, and it provided 959 kW of total power with a combined capacity of 58 kWh.

The simulations showed that the KESS was an efficient way to provide spinning reserve capacity in high wind periods; the storage system reduced the diesel consumption by 745 to 960 gallons per week during those periods. In lower wind periods, the diesel savings were 320 to 585 gallons per week. In very low wind periods, the KESS did not affect the generator scheduling and, consequently, did not lead to a reduction of the diesel consumption during these weeks; in some cases, the energy demand of the storage system led to a slight increase in diesel consumption. Load smoothing was implemented into the operational strategy of the storage system as a secondary function, relieving the diesel generators from high dynamic load changes.

Flywheel developed at TU Darmstadt, Germany. Photo by Max Frey