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Alaska boasts 149 small remote communities, over 120 of which operate on independent micro-grids, and most of the Alaska villages have a peak operating load of less than 200 kW. Using wind energy to offset electricity produced by diesel in these communities requires a sophisticated integration of energy dispatch, electronic switchgears, storage, controls, and distribution to create a functional and efficient hybrid system. Alaskan customers of these electrical hybrid systems can suffer system shortcomings including blackouts and sometimes increased costs to pay for these systems. The Alaska-sponsored PCE (power cost equalization) program provides subsidies to many remote and high energy cost communities to help equalize energy services with the more urban areas of the state. Because PCE is essentially a diesel subsidy to the local utility, wind and other renewable energy projects can work at cross-purposes to PCE depending on the resulting fuel and generation mix.

Some customers are trying to solve their energy issues by installing private wind projects and possibly disconnecting from the grid. Loss of customers from the grid adds a burden to the remaining customers and centralized utility since the grid and the entire associated electrical infrastructure, i.e., the fixed costs of providing electrical service to a community, must be maintained in an already marginal and high cost environment; these costs are absorbed by the remaining customers. The variability in wind, the associated integration problems and the need to lower energy costs in remote communities beg for a better use of fickle wind energy resources.

Hybrid systems with energy storage can offer a level of stability and higher penetration of intermittent renewable energy than systems without energy storage. Such storage can be in several forms including hot water and electrical storage. In Alaska, some hybrid systems using wind and hydro along with diesel are seeing great success such as on Kodiak Island, Alaska. Though still young in its deployment in the field, the use of electrical energy storage (EES) systems, if properly designed and installed, can also increase grid reliability and reduce maintenance costs on diesel engines and wind turbines. The Editorial, "Electrical Energy Storage for the Grid: A Battery of Choices" (B. Dunn, et al., Science, 18 November 2011, p.

928) describes use of electrical energy storage as supportive of deploying renewable energy projects. The village of Kokhanok, a remote settlement of 200 people located in remote Alaska, operates on one of these micro-grids with two reconditioned Vestas V-17 turbines rated at 90kW each on 85' lattice towers. A synchronous condenser and grid forming inverter were installed, along with 336 kWh of nominal battery storage. Lead-acid battery banks were used in Kokhanok because they were less expensive up front, but the extended life of lithium batteries and the added expense of shipping lead-acid batteries from a remote site would favor the use of lithium batteries in some wind-diesel hybrid projects. The integration of these various system components is still ongoing, and not yet perfected, but holds tremendous promise for high penetration wind-diesel systems and over time, even "diesel off" operation.

For future projects in other remote Alaska communities, the higher energy density lithium ion batteries are attractive because shipping costs are so high and more energy can be stored per unit of weight with lithium ion. Based on electric vehicles' technology development, lithium ion battery packs can weigh about 40 pounds each and are additive so that many can be tied together for charging and increase grid reliability while individual modules can be used to power equipment, 4 wheelers, boats, etc.

Although some success comes from energy storage, another solution is to use the wind energy in real-time to help offset the primary energy use in most Alaska villages, that of space heating. The Alaska Energy Authority has determined that about 55% of the energy used in Alaska villages is for heating homes and buildings. Using wind energy for space heating and heating domestic hot water can reduce integration and efficiency challenges associated with hybrid electrical systems and storage, especially in high penetration systems. A variety of techniques for using renewable wind energy can be deployed in homes and other buildings including heating insulated concrete slabs/floors with hot water or resistance coils; the mass acts like a heat storage device that can release its stored heat to the building even when the wind turbine is not producing energy. The costs of using concrete floors can be cost effective when compared more sophisticated systems.

When properly constructed and integrated into the overall system, heating floors in cold climates has some promising applications because of its thermal storage and slow release characteristics. For example, a newly poured concrete foundation could be poured on polystyrene board isolating the floor from heat-loss to the ground, and embedding PTEX piping or resistive heating in the concrete. Once connected to the wind-produced energy source, the concrete floor would become warm when the wind blows (and the turbine is operating) and begin cooling when the wind is calm. But the floor would retain its heat in the mass of the floor for long periods. If the wind resource is especially good, the wind system can be sized accordingly to allow for very high penetration into the conventional diesel grid and, by using heat production and thermal storage, high electrical integration and storage costs can be avoided by direct conversion to heat and thermal mass instead of just electricity for the grid.

A wind/thermal system for the government facilities at Cold Bay and King Salmon, Alaska are models of low to medium penetration with coincident thermal energy generation wind due to the locations having strong wind resource and the opportunity to optimize system economics through a significant offset of heating fuel consumption and electric energy. In the low to medium penetration design, it is anticipated total wind generating capacity may meet the facility's peak power demand and heating fuel requirements. Through such a configuration, the wind turbines will provide a significant heating fuel off-set by supplementing the thermal requirements, converting wind electric energy to thermal energy. The primary building blocks of the Cold Bay and King Salmon hybrid wind systems include the wind generation equipment, microprocessor based sensors that simultaneously monitor instantaneous load and wind speed, specialized controls that allow for seamless operation between the electric utility and, thermal electric nodes and hot water storage tanks with associated thermal energy delivery infrastructure as electric boiler system and energy storage.

In the typical Alaska village micro-grid connect wind energy system, the electric utility must continue to supply energy regardless of wind speed and wind energy contribution. Here, the wind generator(s) run in constant parallel with the utility, which serves to reduce the electric load at the facility. This configuration produces no cogenerated by-product such as hot water, as there is no excess energy. By integrating wind turbine generating capacity to achieve energy conservation as an aggregate of all energy, as well as the simultaneous production of a beneficial thermal, our conceptual design produces far greater total energy avoidance in terms of fuel savings and superior long term total system operating efficiencies. Accordingly, this design is focused on the low to mid penetration model with thermal electric integrating thermal storage nodes as its first priority use for wind generated energy. Secondarily, excess wind generated energy will be used to off-set electric energy consumption.

Russia has over 100,000 villages, and the Department of Renewable Energy of the Russian National Electric Utility has identified seventeen specific regions (out of 89 total) in Russia where it believes wind power development is particularly viable: Murmansk, Arkhangelsk, Karelia, Leningrad, Kaliningrad, Astrakhan, Volgograd, Krasnodar, Stavropol, Kalmykia, Dagestan, Komi, Magadan, Maritime, Kamchatka, Sakhalin, and Khabarovsk (E. Martinot. 1999. Renewable energy in Russia: markets, development and technology transfer. Renewable and Sustainable Energy Reviews; 3: 49-75). Use of wind energy is not new to Russia; The Danish government made Russia a gift of two *Micon* wind turbine generators rated at 250 kW each mounted in the village of Nikolskoye (Bering Island, Kamchatka Region). The wind turbine generators have been part of a diesel-wind hybrid system for years and saving up to 40% of diesel fuel usage. Heat is provided to the community by a central heating system that burns coal in the fall, winter and spring. Even this community, with its two large wind turbines, would benefit from a wind-powered home and building system as discussed above and could perhaps reduce coal use with effective application and integration of wind power into the hybrid system.

In 1997-1999 the US Department of Energy and the Russian Ministry of Fuel and Energy worked together on hybrid wind-diesel power systems; the National Renewable Energy Laboratory (NREL) supplied technical assistance to the project and the U.S. Agency for International Development (USAID), provided funding for the equipment and supplies. It may be time to re-establish a US-Russia wind energy program using new technologies and the strategies discussed above to provide electricity and heating to remote Russia (Gevorgian, V., K. Touryan, P. Bezrukikh, P. Bezrukikh Jr., and V. Karghiev. 1999. Wind-Diesel Hybrid Systems for Russia's Northern Territories. NREL/CP-500-27114).