"Camp Raven Renewable Energy System"

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Systems Overview

From late April through mid-August, Camp Raven serves as a training facility for the New York Air National Guard (NYANG), the primary logistical aircraft support provider for the United States Polar Programs. The camp also provides a limited amount of scientific support to arctic researchers with two year-round autonomous instrument stations. A quickly deployable, off-grid, photovoltaic (PV)/wind hybrid system has been created to power the site during the summer when it is staffed by two individuals.

Location

Raven is located on the Greenland ice cap just below the Arctic Circle (66º 29.789' N, 46º 17.095' W).

Power Requirements/Instruments Powered by System

The critical camp load is the communications equipment, consisting of one HF radio, two VHF radios (air and ground bands), an Iridium satellite telephone, and an Inmarsat Telex system. There are also numerous handheld radios that must be recharged, and two laptop computers are on fairly continuously throughout the day. One of these computers has an Internet link through the Iridium phone. All other camp loads are fairly minimal.

Above: The power systems array outside the staff berthing & office.

Left: A Hercules C-130 touches down on Raven's skiway.

The load table below details all of the equipment used at Raven and the power requirements. These values are not representative of an average day; these values represent the maximum amount of energy used on a busy flight day.

Raven Camp Load Table

DC Instruments	Watts	Hours/Day	Daily Wattage Hrs.
Enermaxer DC dump load*	1,800.00	10.00	18,000.00
Engel fridge/freezer	31.20	12.00	374.40
ICOM HF radio receiver	340.00	1.00	340.00
ICOM HF radio transmitter	22.00	8.00	176.00
Ground band radio transmitter	5.00	24.00	120.00
Telex transmitter	9.50	12.00	114.00
Telex receiver	80.00	1.00	80.00
Air band radio transmitter	9.00	8.00	72.00
Air band radio receiver	36.00	1.00	36.00
Ground band radio receiver	25.00	1.00	25.00
		Total DC	**19,337.40**

AC Instruments	Watts	Hours/Day	Daily Wattage Hrs.
Electric heater**	1,500.00	2.00	3,000.00
IBM Thinkpad computer	72.00	12.00	864.00
Gateway Solo computer	50.00	12.00	600.00
Microwave	1,480.00	0.10	148.00
Boom box stereo	18.00	6.00	108.00
Iridium phone transmit	5.00	12.00	60.00
3 compact fluorescent lights	15.00	4.00	60.00
DeWalt charger	240.00	0.25	60.00
2 radio charger transmitters	3.00	12.00	36.00
2 radio charger receivers	28.00	1.00	28.00
Iridium phone receiver	24.00	1.00	24.00
2 radio charger transmitters	2.00	12.00	24.00
Davis Weather Station	1.80	12.00	21.60
Makita charger	35.00	0.50	17.50
2 radio charger receivers	35.00	0.50	17.50
Coffee grinder	120.00	0.01	1.20
		Total AC	**5,067.30**
		Grand total	**24,404.70**

* Used only when winds are high and temperatures are low.
** Rarely used—only when winds are high, the sun is out, and temperatures are low.

Environmental Data

Factor	Parameter
Wind speed (summer season)	Average: 15 knots (16.5 mph, 7.4 m/s) High: >50 knots (>55 mph, >24.5 m/s)
Solar insolation	Summer maximum is >350W/m2. Annual mean is approximately 130W/m2.

Solution

Because wind is a persistent feature at the site, it was chosen as the primary renewable energy source. The wind generator is a Bergey 1500 model, capable of generating 1.5 KW of three-phase AC electricity. This is routed through a three-pole, double-throw, safety transfer switch and a three-phase breaker disconnect. Both of these switches are mounted at the base of the wind tower. The primary purpose of the transfer switch is to provide a means of shorting the windings of the generator, thus effectively slowing or locking the blades of the turbine. This is essential for the seasonal disassembly of the wind generator.

Amy Dahl doing some home improvement at Camp Raven.

At the base of the tower, the input from the wind turbine feeds to the middle set of contacts in the transfer switch. These contacts are continuously energized when the turbine is spinning. The bottom set of contacts shorts the windings together, whereas the top set connects to the breaker/disconnect. The purpose of the breaker/disconnect is to provide a simple method of disconnecting the wind generator from the rest of the system, as well as providing for overcurrent protection.

The wind generator is mounted on top of a square, reinforced tower. The tower is 16 in (41 cm) on each side and is fairly robust. It is also guyed with steel cable at two elevations on the tower, which run down to dead-men anchors—4 ft (1.2 m) long sections of pressure-treated 4 x 4 in (10 x 10 cm) lumber—placed deep in the snow. The present height of the tower is approximately 26 ft (8 m)—about 10 ft (3 m) less than when it was extended in 2001. Therefore, the accumulation of snow in the immediate camp area is about 5 ft (1.5 m) per year, or nearly 1.67 times the accumulation in the general area.

The three-phase AC electricity created by the wind generator is delivered to the main Weather-Port tent structure via a 6/4 (#6, 4 conductor) SO cable. The cable was buried this year in an attempt to facilitate set-up and alleviate problems with snow removal around camp. Extra cable is coiled on the tower, as well as on a 4 x 4 in (10 x 10 cm) post that marks the southeast corner of the main Weather-Port structure. The extra wire allows for further extension as the snow continues to accumulate.

Once inside the structure, the three-phase AC output is converted to DC by the Bergey VCS 1.5 system controller. This device is essentially a sophisticated rectifier/regulator. The nominal system voltage is 24 VDC, but the maximum voltage delivered to the battery bank has been set at 27.3 VDC, as required by the sealed gel-cell batteries.

The wind-electric system is augmented by a small PV component, which allows for battery charging on the relatively rare days when there is little or no wind. By mid-May, useable solar energy is available for 340º. At summer solstice, there is 24-hour-a-day sun. A very simple tripod arrangement is used to gain near maximum insolation over the course of the day. Three 4 x 4 in (10 x 10 cm) posts are set in an equilateral triangle about midway between the wind turbine tower and the main Weather-Port (and battery bank). The three Solarex SX120U panels are mounted facing outward from the triangle at a 90º angle to the snow surface. This arrangement takes great advantage of the reflected light from the snow. Indeed, even on overcast days, there is so much reflected light between the surface and the clouds that the PV panels continue to produce at nearly the maximum rated output.

The 24-volt panels are wired in parallel inside a Xantrex TCB6 PV combiner box. 6/4 SO cord carries the output to the Xantrex C40 charge controller mounted on the power panel inside the Weather-Port. This PV system is designed to provide a modest solar input over the entire course of the day rather than the maximum output over a few hours. Although it is possible to use a 360º tracking array, the simplicity and robust nature of this arrangement seems to make more sense for this location.

The battery bank consists of twelve 12-volt, 100-amphour (amp) batteries wired in a series/parallel configuration. The result is a 24-volt, 600 amp-hour bank. These relatively small gel-cell batteries were chosen to facilitate transportation by air and because the battery bank must be assembled on site each season (carrying the batteries by hand).

The DC electricity from the batteries is converted to AC electricity by a Xantrex DR 2424 inverter. This unit is capable of producing 2.4 KW at 117 volts continuously and can surge to nearly double that figure. This is more than enough energy for any loads at camp. The inverter can also operate as a three-stage battery charger. When AC electricity is applied to the inverter's AC input via a Honda 3.5 KW generator, the inverter automatically switches to charger mode while simultaneously energizing a 30-amp bypass relay. This allows the generator to power any loads thereby maximizing the running efficiency and allowing uninterrupted battery charging.

A 20 ft (6 m) long 12/2 SO cord hangs from a pole beside the Weather-Port. It plugs into the generator with a 30-amp twist-lock plug. Two 20-amp breakers mounted on the power panel provide overcurrent protection to the AC loads inside the structure.

As many loads as possible are run on DC to increase efficiency. The Xantrex DC disconnect box is set up to operate as a DC load center. A 250-amp breaker provides the main disconnect from the batteries. Two 60-amp breakers serve as disconnects for the solar array and a 24 VDC circuit for communications equipment.

An 80-amp breaker in the DC disconnect box is for a DC diversion load. When wind speeds are high, temperatures inside the Weather-Port tend to be low. By throwing the breaker, excess energy is routed to a Xantrex C60 set up in diversion mode. From there, it feeds an Enermaxer 1,800-watt diversion load. This is basically an electric space heater controlled by the Xantrex C60. If battery voltage gets too low, the C60 will reduce output to the Enermaxer. A Xantrex system meter allows for monitoring of the system voltage, the amps in and out, and the state of charge of the battery bank.

The power panel is set up as a complete unit. The protective plywood box serves as the base when the panel is set up for use and allows for easy transport when not in use. The system only requires six cable connections on site. The only downside is that it is rather heavy, requiring two people to carry.

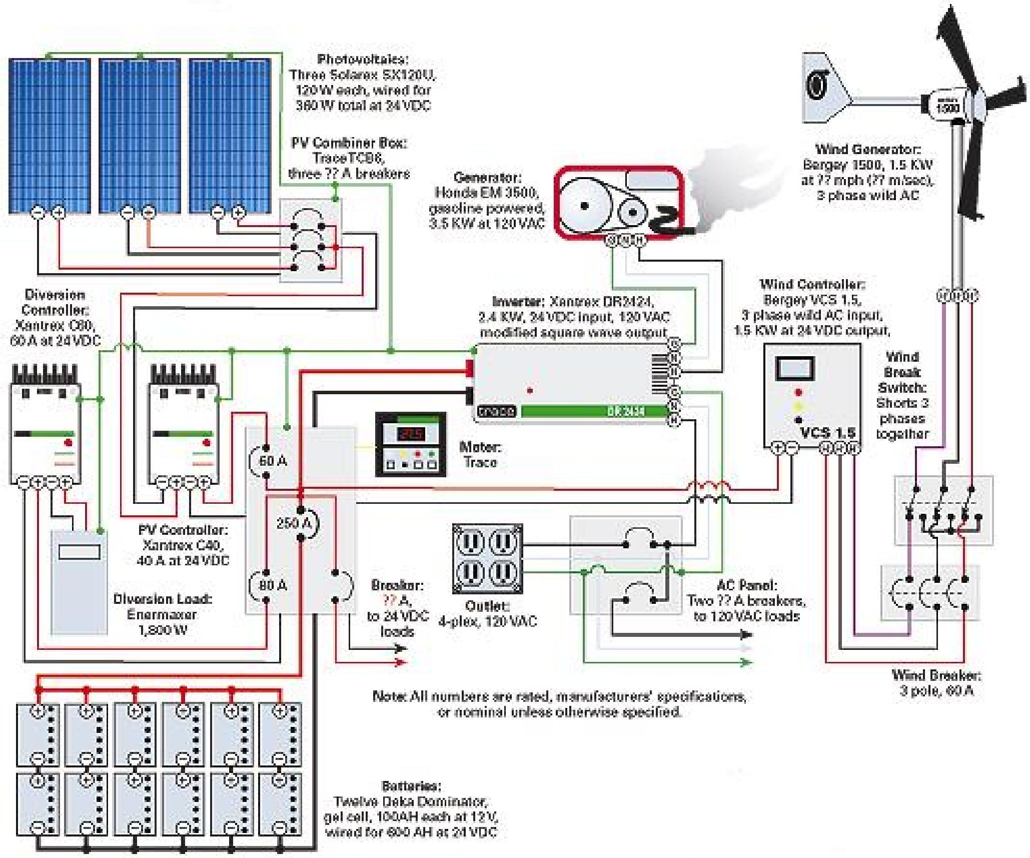
Tracy Dahl drilling a 4 x 4 post for solar panels.

Renewable Energy System Specifications

System Overview	
System type	Off-grid PV/wind hybrid
Location	Camp Raven, Greenland
Solar resource	12 average annual peak sun hours per day
Production	200 total AC KWH per month average
Wind Turbine	
Turbine	Bergey 1500
Rotor diameter	10 ft (3 m)
Average KWH per month	174 at 12 mph (5.35 m/s)
Peak KW rating and wind speed	1.5 KW at 28 mph (12.5 m/s)
Wind turbine controller	Bergey VCS 1.5
Tower	32-ft Rohn, guyed lattice
Photovoltaics	
Modules	3 Solarex SX120U, 120 W STC, 24 VDC nominal
Array	360 W STC, 24 VDC nominal
Array combiner box	Xantrex TCB6 with 10 A fuses
Array disconnect	Xantrex DC250 enclosure with two 60 A breakers
Array installation	Custom ground mount; east, south, and west facing; 90º tilt angle
Balance of System	
Inverter	Xantrex DR2424, 24 VDC nominal input,120 VAC nominal input
PV charge controller	Xantrex C40, PWM
Wind charge controller for diversion load regulation	Xantrex C60, PWM
System performance metering	Xantrex TM500 meter
Engine generator	Honda EM3500, 3.5 KW, 120/240 VAC nominal, average annual run time approximately 100 hours
Energy Storage	
Batteries	12 Deca Dominator gel-cell 12 VDC nominal, 100 AH at the 20-hour rate
Battery pack	24 VDC nominal, 600 AH total
Battery/inverter disconnect	Xantrex DC250, 250 A breaker

Successes

Although the electrical system at Camp Raven has the ability to use a backup generator, we have not had to do so for the last three years. The generator is sometimes used to operate electric block heaters on equipment or for power tools away from the main camp, but it has not been necessary to use it for basic camp infrastructure functions. Basically, the renewable energy system generates plenty of energy to meet the needs of the camp, as long as we recognize the limitations of the system.



Lessons Learned

PV arrays: From past experience, conventional arrays, angled perpendicular to the sun, tend to act like large wings. Indeed, structures weighing several tons can move by several meters due to the force of the wind. It speaks to the quality of the array mount, but it is a rather disconcerting experience for the occupants of the structure. Hence, if mounted on a nonpermanent structure, PV arrays are laid out perpendicular to the surface, as they are at Raven, or flat.

Generator: When temperatures dip below 5°F (–15°C), the crankcase breather of the generator freezes up. This causes the engine crankcase to become pressurized, ultimately blowing out one of the crankshaft oil seals. Consequently, the generator is now run inside its own specially built, sled-mounted, vented enclosure for operation at these temperatures.

Bergey controller: Two years ago, there was a problem with fuses blowing out in the crowbar circuit of the VCS 1.5 controller for the Bergey. After conferring with the Bergey technical support people, they determined the source of the problem and advised on recalibrating the set points for the type of batteries used in the Raven system. The faulty unit was replaced with a new one, and the defective unit was rebuilt at the factory as a backup. There have been no problems since that time.

Further Reading

Adapted from an article titled “Polar Power”, published in issue #99 of *Home Power* magazine.

Ed., Ross, Michael; Royer, Jimmy, (1999) *Photovoltaics in Cold Climates,* James & James

Gipe, Paul, (2004) *Wind Power: Renewable Energy for Home, Farm, and Business,* Chelsea Green

Bergey Wind Power: www.bergey.com