Final Technical Report
Kotzebue Wind Power Project
Volume I

Grant Identification Number

DE-FG36-97GO10199

October 2007

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Acknowledgements

This material is based upon work supported by the Department of Energy under Award Number DE-FG36-97GO10199.

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Abstract

The Kotzebue Wind Power Project is a joint undertaking of the U.S. Department of Energy (DOE); Kotzebue Electric Association (KEA); and the Alaska Energy Authority (AEA). The goal of the project is to develop, construct, and operate a wind power plant interconnected to a small isolated utility grid in an arctic climate in Northwest Alaska.

The primary objective of KEA's wind energy program is to bring more affordable electricity and jobs to remote Alaskan communities. DOE funding has allowed KEA to develop a multi-faceted approach to meet these objectives that includes wind project planning and development, technology transfer, and community outreach.

The first wind turbines were installed in the summer of 1997 and the newest turbines were installed in the spring of 2007. The total installed capacity of the KEA wind power project is 1.16 MW with a total of 17 turbines rated between 65 kW and 100 kW. The operation of the wind power plant has resulted in a wind penetration on the utility system in excess of 35% during periods of low loads.

This document and referenced attachments are presented as the final technical report for the U.S. Department of Energy (DOE) grant agreement DE-FG36-97GO10199. Interim deliverables previously submitted are also referenced within this document and where reasonable to do so, specific sections are incorporated in the report or attached as appendices.

Project Description

The Kotzebue Electric Association (KEA) wind power plant consists of small, commercial-scale wind turbines with a total nameplate rating of approximately 1.2 MW. The project consists of 15 AOC 15/50 66 kW wind turbines manufactured by Atlantic Orient Corporation (AOC) of Norwich, Vermont; one NW 100 wind turbine rated at 100 kW and manufactured by Distributed Energy Systems (formerly Northern Power Systems) of Waitsfield, Vermont; and one refurbished V-15 wind turbine rated at 65 kW and manufactured by Vestas of Denmark. The AOC turbines and the Vestas turbine are installed on 24.4-m (80-ft) lattice towers on piling foundations, resulting in a hub height of approximately 26.5 m (87 ft). The AOC 15/50 and the V-15 are both three-bladed, downwind turbines with a 15-m (49-ft) rotor diameter. The NW 100 is installed on a 23.4-m (77-ft) tower and is also mounted on a pile foundation. The resulting hub height is approximately 26.5 m (87 ft).

KEA's project site is located on the tip of the Baldwin Peninsula, approximately 42 km (26 mi) north of the Arctic Circle on the northwest coast of Alaska near the town of Kotzebue. With a population of approximately 3,000 residents, Kotzebue is the largest community in Northwest Alaska and serves as the economic, governmental, medical, communication, and transportation hub for the 11 communities in the Northwest Arctic Borough, an area roughly the size of Indiana. Kotzebue can be accessed only by air or water. Daily jet service is available from Anchorage, and small aircraft carry passengers and supplies from Kotzebue to the surrounding villages. Figure 1 shows the location of Kotzebue on the Alaska state map.

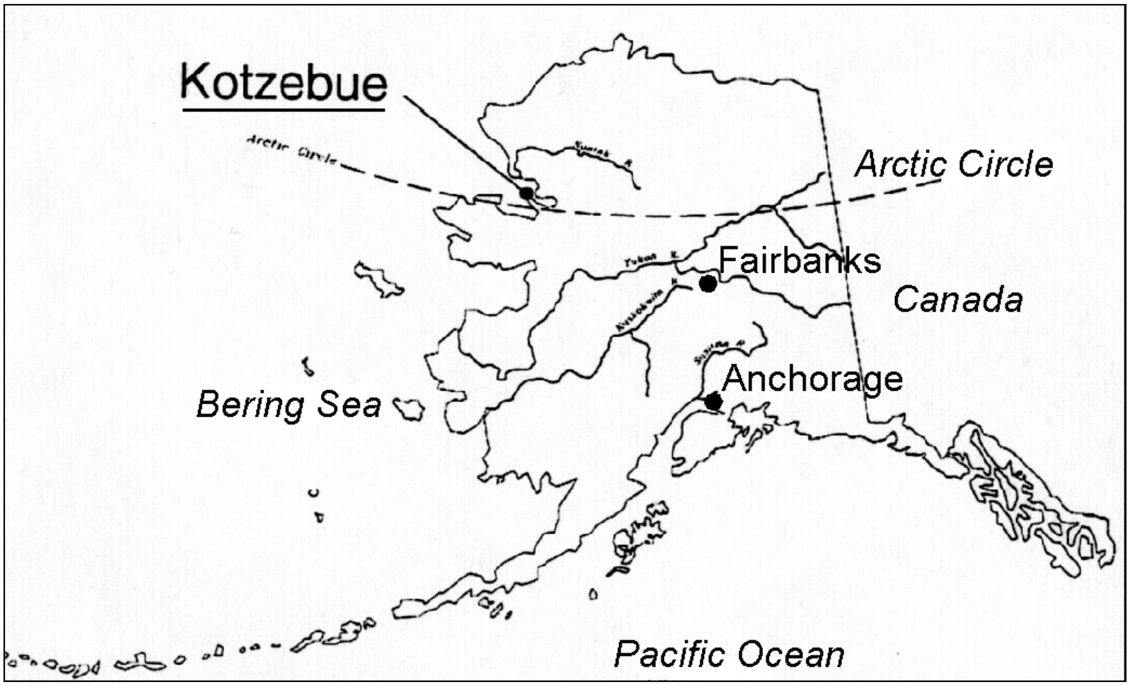


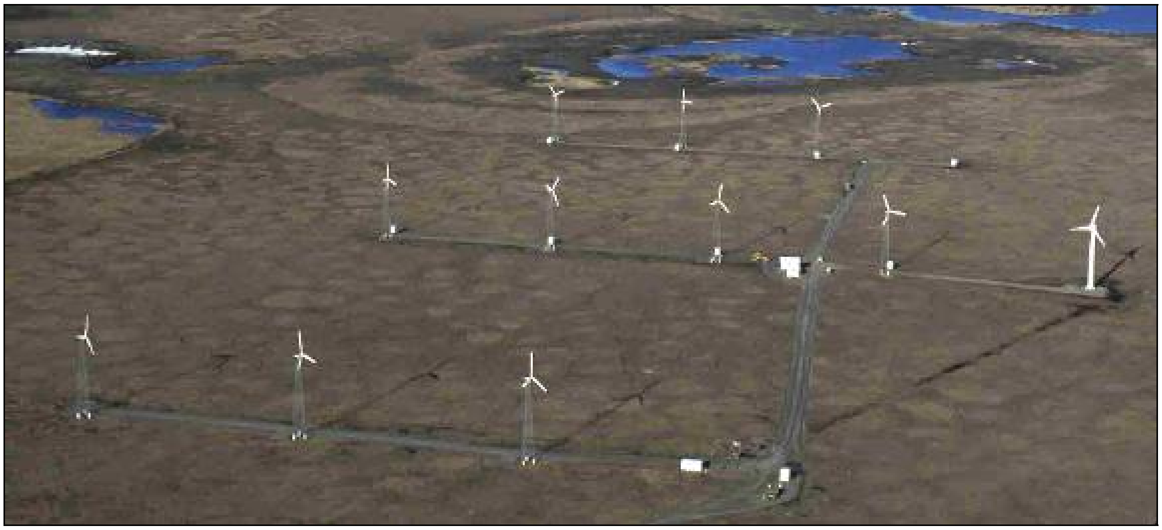
Figure 1. Alaska State Map

The climate in Kotzebue is characterized by long, cold winters and short, cool summers. The Kotzebue Sound and area rivers begin to freeze in early October, and spring breakup generally occurs in late May or early June.

The 148-acre KEA wind project site is located approximately 7.2 km (4.5 mi) south of the town of Kotzebue. The land is owned by the Kikiktagruk Inupiat Corporation and leased to KEA for an initial period of ten years, with an extension option of four additional ten-year periods. The wind project is situated on a relatively flat plain of treeless tundra that is well exposed to both the prevailing easterly winter winds and the prevailing westerly summer winds.

The initial ten-turbine project was installed in multiple phases at a single site over a period of approximately two years. The phases are defined by their funding sources. Phase 1 consists of the first three turbines, installed in July 1997 and commissioned in September 1997. All seven of the Phase 2 and 3 turbines were installed in the spring of 1999 and commissioned in June 1999.

Two additional AOC turbines were ordered in late 2000 and specified as Turbines 11 and 12. Although the turbine nacelles were delivered to Kotzebue in November 2001, turbine towers, blades, and controllers were not available until the fall of 2002. Initially, the NW 100 was expected to be installed after the two AOCs and was designated as Turbine 14. The NW 100 installation was completed in May 2002. The installation of two additional AOC 15/50s was completed in the spring of 2003. Since this time, KEA has installed a refurbished Vestas V-15 and is completing the installation of three additional AOCs which brings the installed wind capacity to 1.155 MW. Additional expansion of the wind project is anticipated in the future. An aerial photograph of the first 10 AOCs and the NW-100 is shown in Figure 2.



(photo courtesy of Brad Reeve, KEA)

Figure 2. KEA Wind Power Plant

Grant Agreement Tasks and Deliverables

Due to the length of this grant agreement, numerous circumstances have changed and evolved differently from what was initially anticipated. Of particular note are the availability and cost of wind turbine equipment appropriate to the KEA environment. As a result, it was necessary to eliminate, combine, and/or modify a few of the tasks. Any task with material changes from the initial scope of work will be explained under each task.

After the initial grant agreement was funded, KEA was incorporated into the Turbine Verification Program (TVP) as an associate project. The purpose of KEA's involvement in the TVP was to document the development, construction, and operation of a commercial utility-scale wind power project and to share this information with other organizations interested in wind energy as well as to obtain technical support through the National Renewable Energy Laboratory (NREL). The TVP was a joint program of the DOE and the Electric Power Research Institute (EPRI).

KEA was involved in the TVP from 1997 through 2003. During this time, EPRI published five reports under the program that document the development of the KEA Wind Power Project and the first four years of project operations. Through the preparation of these reports, several of the DOE Grant deliverables have previously been satisfied. A copy of the Project Development Report, published in December 1999, was provided to DOE in 2000. In November 2003, the first three annual operating reports were submitted to DOE. The TVP concluded in December 2003 and in March 2004, KEA submitted the fourth and final annual operating report. These reports can be obtained from http://epri.com by searching for "Kotzebue Wind."

Throughout this document, these TVP reports will be referenced where they have met specific DOE deliverables. In some cases, summaries of or excerpts from sections of these reports will be provided.

This document does not include financial documentation. The financial reporting requirements have been fulfilled throughout the course of the contract period including the submission of annual audit reports from KEA's accountants.

Following is a brief description of each task and the associated deliverables. The deliverables for each of the 20 tasks are either provided below, referenced as an attachment to this document, referenced as an earlier submittal, or an explanation of a task modification is provided.

In November 2001, KEA submitted a Statement of Work (SOW) modification request and supporting documentation to DOE. The SOW modification request is included as Appendix A. The requested task modifications were approved in December 2001. Task modifications that affect the deliverables for a task are discussed in the task-by-task descriptions.

Task 1: Project Management

The project manager will thoroughly plan the various tasks and will provide oversight and direction to each task to ensure accomplishment of objectives and milestones, and timely submission of deliverables. The project manager will serve as the interface with DOE.

The required deliverables for the Project Management task have been fulfilled by the previous submission of the TVP Project Development and Annual Operating Reports referenced above. As required by the SOW, these reports included the operating data, economic data, and a detailed description of the evolution to define system design, system investment, and the maintenance and operation requirements of the wind power project in Kotzebue.

Task 2: Meteorological Characterization

KEA shall define and implement a meteorological program to ensure that the required resource assessment data are collected and analyzed. Data shall be collected using the exiting NRG system at the wind site.

The deliverable for this task was submitted to DOE on June 12, 2002. The submittal letter and the report are included in Appendix B.

Task 3: System Design

KEA shall perform detailed designs of the electrical and civil engineering aspects of the project. The electrical engineering designs shall include the diesel/wind turbine control system with updating of certain equipment to electronic computer control. The control system activities will include the engineering, installation, initial testing, and monitoring of the System Master Controller and the Windsite Master Controller. Definition of the required interface/communications with existing KEA equipment will also be performed. Civil engineering shall include field layout, foundations, field wiring, and power/control wiring between the wind and diesel sites.

This task was included in the November 2001 SOW Modification to include system design work performed on the Wales, Alaska, High-Penetration Wind Project. Through KEA's work on the Wales project, they gained knowledge and experience that directly facilitates the continuing expansion of the KEA Wind Project.

Deliverable: A full set of as-built drawings shall be provided at the end of the project, along with documentation of all significant analyses.

The as-built drawings for the Wales wind project are included as Appendix C. Associated with Tasks 16 & 17, KEA Plant SCADA, comprehensive as-built drawings of the entire KEA power system were generated which include the wind project. These drawings have been formatted to meet DOE's requirement and are referenced under Task 16 & 17. All other significant analyses are referenced throughout the report and are contained in this final report or the annual TVP reports previously referenced.

Task 4: Turbine Procurement

Per the specifications defined by the system design, KEA shall purchase and receive the wind turbines to achieve the project schedule. After the SOW Modification, this task includes the purchase of nine AOC 15/50s and one Northwind 100 (NW 100). This represents a reduction of two AOC turbines from the original SOW with a modified budget that reflects this decrease in turbine procurement.

Project expansion scheduling was affected by turbine manufacturing delays. These delays were significant and were largely due to the bankruptcy and restructuring of Atlantic Orient Corporation, the manufacturer of the AOC 15/50. There has been very limited availability of any commercially available wind turbines in the 50-100 kW range.

KEA recently completed the installation of Turbines 15, 16, and 17. The total turbine count includes 15 AOCs, one NW 100, and one refurbished V-15. Nine of the AOCs and the NW 100 were procured under this task. (The refurbished V-15 was procured and installed under Task 19.) Installation photographs of Turbine 17 are shown in Figure 3 and Figure 4.

Figure 3. Assembling Turbine 17 Tower

Figure 4. Preparing Turbine 17 Nacelle for Installation

Task 5: Balance of System Procurement

KEA shall procure all necessary equipment for the balance of the system (except turbines and towers). This shall include the diesel control system upgrade, a hybrid power supervisory control and data acquisition system (SCADA), and electrical equipment such as transformers. No specific deliverables were identified with this task.

The budget for this task was reduced due to fewer turbine installations and because the SCADA system was provided to KEA as a TVP participant.

Task 6: Turbine Installation

KEA shall install wind turbines in an environmentally acceptable manner per the design and manufacturer's specifications.

Installation of all turbines described in Task 4 has been completed.

Task 7: Balance of System Installation

KEA shall install all supporting equipment to enable the turbines to perform per project requirements.

As part of this task, KEA installed a System Control and Data Acquisition (SCADA) system. The SecondWind SCADA system was commissioned in September 1999 as Turbines 4 to 10 (AOC turbines) were being commissioned. The SCADA system was upgrade in September 2002 to incorporate the NW 100 turbine and to prepare for connecting two additional AOCs that were scheduled for installation in the spring of 2003.

Deliverables also include the installation of "pioneer floating road" to provide year-round access to the wind site. The 0.7 mile access road was completed between May and July 1998. A photograph and a description of the construction process was included in the *Project Development Experience at the Kotzebue Wind Power Project, EPRI TR-113918, December 1999*.

The final project under this task, which was added in the SOW Modification, was the extension of the site road to gain year-round road access along the turbine rows. This task was completed in the summer of 2002.

Task 8: System Commissioning

KEA shall conduct a formal commissioning process to ensure safe and reliable operation of each group of wind turbines.

The commissioning of the AOC wind turbines is documented in the first TVP report, *Project Development Experience at the Kotzebue Wind Power Project, EPRI TR-113918, December 1999*. The commissioning of the NW 100 is documented in the fourth EPRI report, *Kotzebue Electric Association Wind Power Project Third-Year Operating Experience: 2001-2002, EPRI 1004206, December 2002*. No specific deliverables are called out for this task.

Task 9: System Operation

KEA shall operate all available wind turbines to maximize electricity production within prudent ranges to protect overall hybrid power system integrity. Detailed operational logs and data shall be collected, analyzed, interpreted, and documented in appropriate annual and final reports.

Extensive analysis was performed on operations and maintenance data which were collected during the first four years of project operations. These analyses were summarized and presented in reports published under the TVP program and were previously submitted to DOE as deliverables under this grant agreement.

Task 10: Turbine Test Bed Operations

KEA shall develop a portion of the Kotzebue wind test site to characterize the suitability of wind turbines for cold weather operation. Three turbine test sites shall be selected within the wind site turbine layout and matrix. The first turbines which are planned to be characterized include the AOC 15/50 (in conjunction with the DOE Turbine Development Program), the Advanced Wind Turbine Company AWT-27 or AWT-26, and the Northwind 100 turbine. KEA shall work with the turbine vendors to establish test and operations matrices to determine performance over a wide range of conditions. Detailed logs of installation, operation, and maintenance characteristics shall be maintained.

Deliverable: The test turbine characterizations shall be documented as a separate report(s) or, upon KEA/DOE agreement, as appropriate chapters in the final project summary report.

In addition to the general analysis of day-to-day operations and maintenance at the Kotzebue wind project, KEA conducted analyses of the turbine pitch settings and turbine power performance. These tests were conducted in cooperation with the TVP and the results were included in the *Kotzebue Electric Association Wind Power Project First-Year Operating Experience 1999-2000, EPRI 1000957, December 2000* and *Kotzebue Electric Association Wind Power Project Fourth-Year Operating Experience 2002-2003, EPRI 1004805, December 2003*. Following are excerpts from these reports which describe the methodology and results of the power performance tests for the AOC and NW 100 turbines and the pitch settings analysis of the AOC turbines. Note that the captioned and referenced tables and figures are a part of the excerpts only.

From the *Kotzebue Electric Association Wind Power Project First-Year Operating Experience 1999-2000:*

Turbine Power Performance Test

As part of its technical support, TVP conducted a third-party evaluation of the power performance characteristics of a AOC 15/50 wind turbine installed at Kotzebue. Wind speed and concurrent power were collected from calibrated power transducers and meteorological sensors and processed according to the International Electrotechnical Commission (IEC) Standard 61400-12, *Wind Turbine Power Performance Measurement*. The test provides a measured power curve for comparison against the manufacturer's predicted power curve and enables baseline production projections for evaluating performance. The test also enabled the TVP to gain experience with the IEC power performance measurement standard and to provide feedback to the IEC working group responsible for developing the Standard.

As previously discussed, the Second Wind SCADA system was installed and commissioned in late 1999. This system was used to collect data for the performance testing. The test data collection period ran from November 8, 1999 to May 31, 2000. A post-test recalibration of the primary anemometer was performed on June 28, 2000.

In accordance with the Standard, test data were considered valid only from a certain direction sector determined to be free from obstructions. This sector was identified through a defined site assessment process that excluded any direction sectors in which the met tower or test turbine (Turbine 8) would be affected by the wake of nearby turbines. Figure 4-14 shows the location of the site reference met tower, the turbines relative to the surrounding terrain, and the valid measurement sector (32.5º clockwise to 225º).

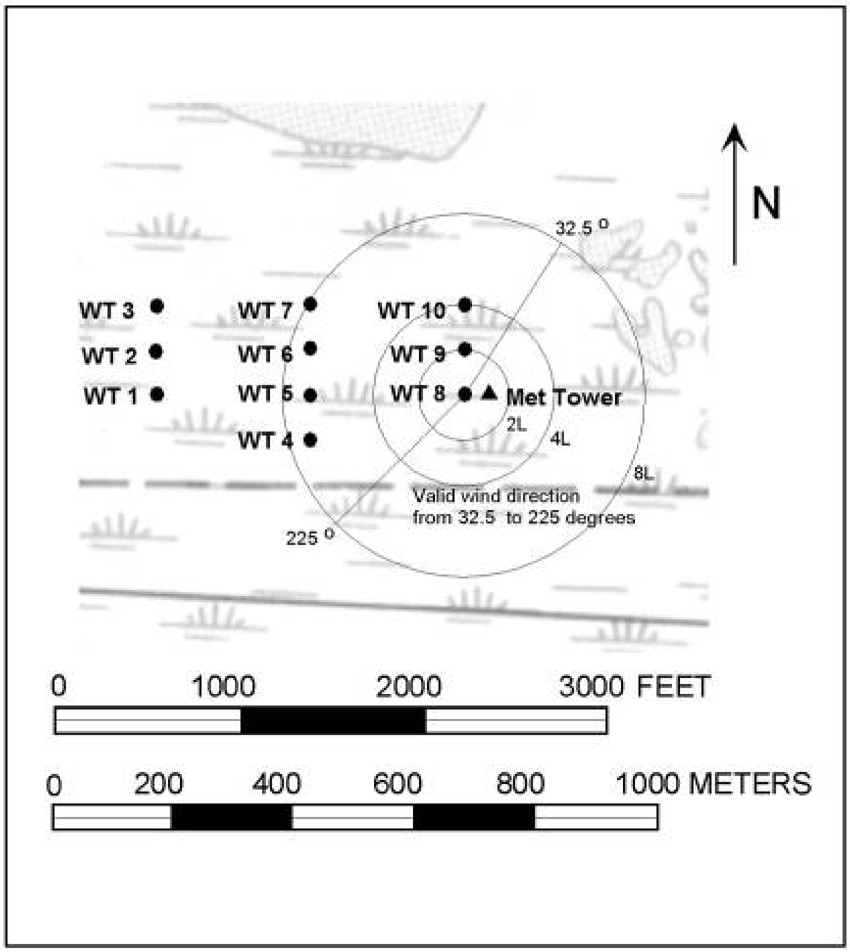


Figure 4-14. KEA Topographic Site Map Used for Power Performance Test

Test Methodology

According to the IEC Standard, the test site must be evaluated by three criteria to determine which data must be excluded from the database: topographic variations, neighboring and operating wind turbines, and other significant obstacles. If the topography of the site meets the criteria given in the IEC Standard, then the wind speed at the meteorological mast is assumed to be identical to the wind speed at the wind turbine. If the topographic variations exceed the criteria, then an experimental calibration of the test site is required to determine corrections to the wind speed. The neighboring wind turbines were evaluated to determine whether they disturb the free stream wind velocity. There were no other significant obstacles. Direction sectors found to have free stream wind disturbance by the adjacent turbines, using the criteria set forth in the IEC Standard, were excluded from the database. Due to the flat terrain at the KEA site and the absence of obstacles, a site calibration was not required.

During the test period of November 8, 1999 through May 31, 2000, 2198.3 hours of valid data were collected while the wind was from the valid wind direction (32.5º to 225º), icing conditions were not apparent, and the turbine was available. The highest bin filled with at least three valid 10-minute average data points (with wind speed normalized to sea-level density) was the 17.0 m/s bin. According to the Standard, data should have been collected up to a wind speed equal to 1.5 times the wind speed at which the turbine reaches 85% of its rated power. As previously discussed, the AOC turbine is rated at 66 kW based on the TVP definition. For the AOC 15/50, the data collection requirement would be up to 19.0 m/s according to the power curve provided by the manufacturer.

Test Results

Test results indicate that the AOC 15/50 at sea level density does not meet the cut-in wind speed of 4.6 m/s and reaches a peak power output of approximately 68 kW at approximately 14.5 m/s. This is 36% above the manufacturer's nominal rated power of 50 kW and 3% above the manufacturer's specified sustained peak power level of 66 kW. At site density (1.361 kg/m3) the peak output is 75.5 kW @ 14.5 m/s.

Consistent with the slow-start problem previously discussed in this report, the body of the curve in low to moderate winds (5 to 11 m/s) was below the manufacturers estimate. The problem is severe enough and frequent enough to reduce average power levels at these wind speeds by 10% to 30%.

The results of the power performance test were adjusted to sea-level and are shown in Figures 4-15 through 4-17. The error bars shown on the power curves represent the combined uncertainty calculated in accordance with IEC 61400-12, based on error introduced by the standard deviation of the measured data points and the uncertainty in the sensors and data acquisition system. No error bars are shown for the data points with less than three 10-minute samples in the bin.

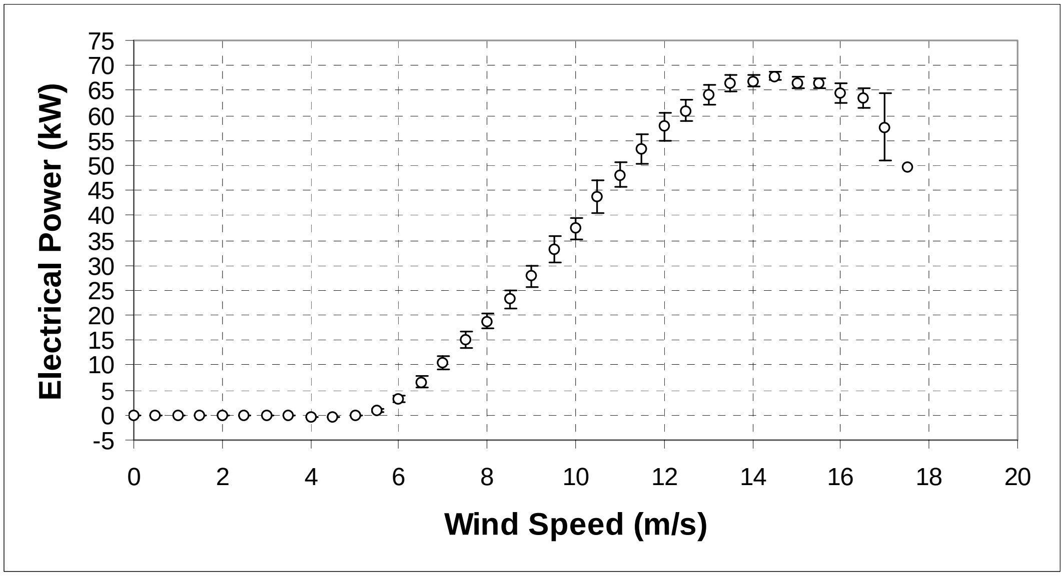


Figure 4-15. Power Curve at Sea-Level Density, 1.225 kg/m^3

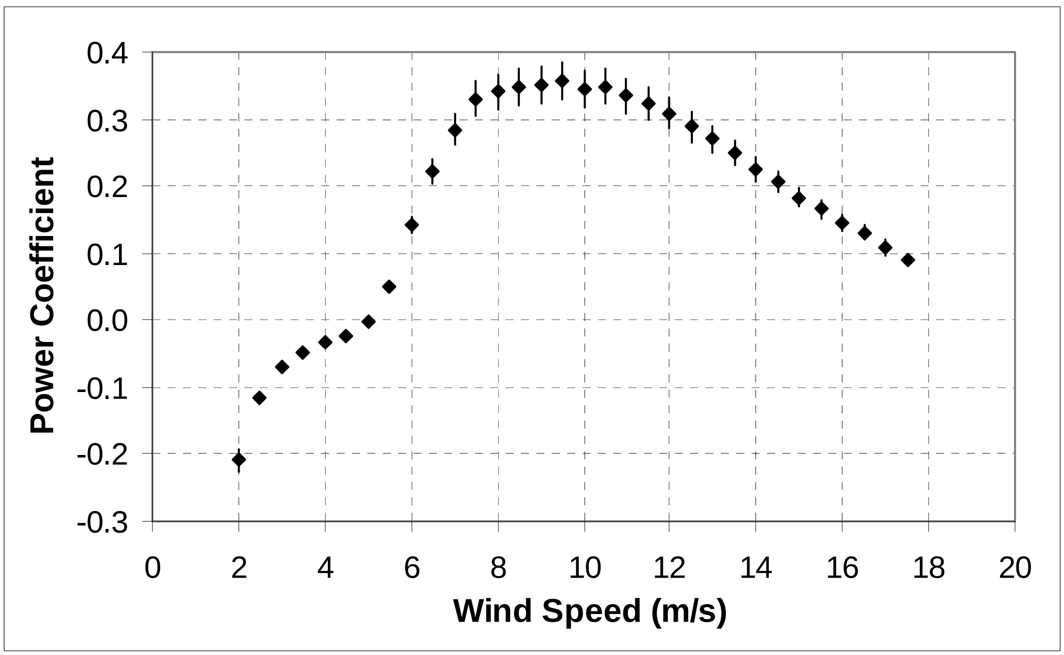


Figure 4-16. Power Coefficient at Sea-Level Density, 1.225 kg/m^3

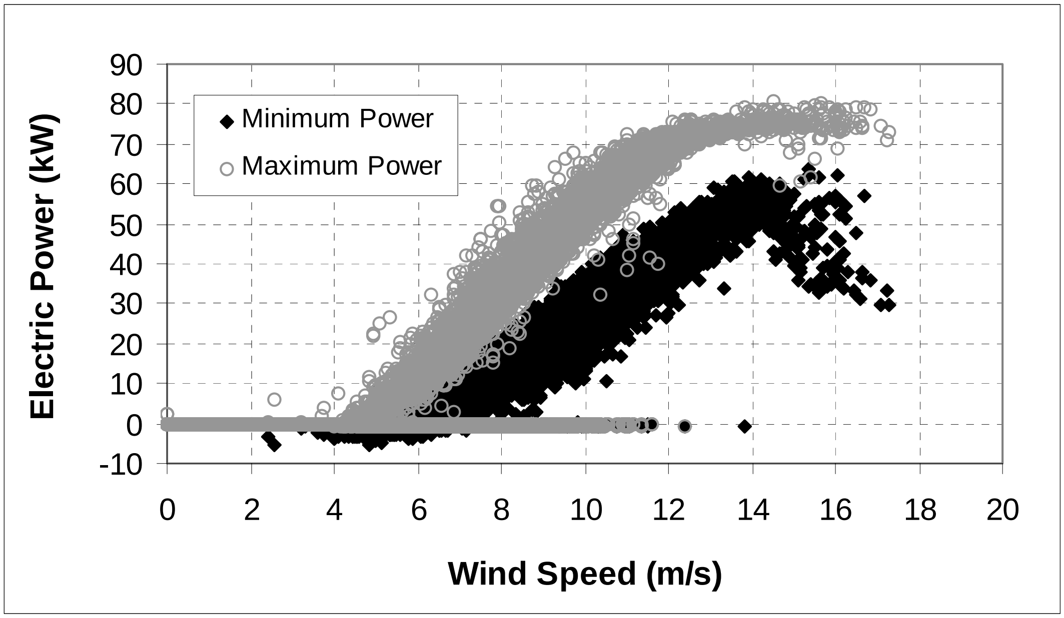


Figure 4-17. Maximum and Minimum Power Measured at the AOC

The gross annual energy production (AEP) results are presented in Tables 4-7 and 4-8 for the measured and extrapolated power curves along with the associated uncertainties. The measured AEP only includes wind speeds bins for which there are three or more data points. The extrapolated AEP assumes that the power at higher wind speed is equal to the power of the last filled wind speed bin. Wherever the energy production from the measured curve is 95% or greater than the energy for the extrapolated curve, the data is considered complete. When the measured energy is less than 95% of the extrapolated energy, the results are labeled incomplete.

Table 4-7. Annual Energy Production at Sea-Level Density, 1.225 kg/m^3

Rayleigh Mean Hub Height Wind Speed (m/s)	AEP-Measured (from measured power curve)		Uncertainty of AEP-Measured		AEP-Extrapolated (from extrapolated power curve) (MWh/yr)
	(MWh/yr)	Status	(MWh/yr)	(%)	
4	18.2	Complete	2.6	14.15	18.2
5	50.9	Complete	5.1	10.15	51.0
6	94.9	Complete	7.5	7.9%	95.6
7	140.6	Complete	9.4	6.7%	144.8
8	179.7	Incomplete	10.5	5.8%	191.9
9	207.9	Incomplete	11.0	5.3%	232.7
10	224.8	Incomplete	11.1	5.0%	264.8
11	232.0	Incomplete	10.9	4.7%	287.6

Turbine Pitch Settings

During the first two years of evaluation, power curve issues were noted for some of the AOC turbines at KEA. First, most turbines would generate power at levels significantly in excess of the 66 kW rated capacity during periods of high air density. This produced immediate problems such as blown fuses and also generated concern that long-term problems such as reduced gearbox life and reduced overall efficiency would occur. Second, although the turbines were intended to be configured with identical pitch angles, it was clear that there were significant differences between the power curves of some turbines, indicating dissimilar pitch settings.

Based on these observations and the results of the repitching of Turbine 8 in September 2000, the TVP performed an evaluation of the available performance data to identify an optimal pitch setting for the turbines that would result in the highest expected annual energy production while limiting the peak power production to levels that would not be expected to have an adverse effect on the turbine component life.

Initial reviews of the data indicated that, to a large extent, these goals were mutually exclusive; i.e., pitching the turbines to reduce overproduction would likely have a negative impact on annual energy production. Consequently, the data were reanalyzed with the turbine component life as the main goal, and the extent to which meeting this goal would impact turbine production was evaluated. A target level of a 2-second peak production of 85 kW at a worst-case air density of 1.41 kg/m^3 (based on the highest observed air density during the winter of 2002) was established as the point at which no long-term effects on component life or blown fuses would be likely to occur. Worst-case peak power levels for each of the turbines were compared with the peaks of sea-level power curves, and it was determined that setting the pitch such that the turbines would not generate power in excess of the target level would reduce the peak of the sea-level power curve to approximately 60-64 kW; i.e., only a 2-6 kW reduction from the TVP rated capacity of 66 kW.

Based on the apparently small impact on the desired power curve, KEA and GEC concluded that repitching the turbines to reduce peak power would be beneficial. Current turbine pitch settings were measured in August 2002 and an optimal setting that is expected to meet the target peak power level was determined. The impact on energy production will vary by turbine due to the wide variety of current pitch settings. Based on preliminary analyses, the overall annual energy production is not expected to decrease by more than 10% as a result of repitching the turbines to the recommended pitch setting.

During the August 2002 testing, Turbine 5 was pitched to a less aggressive pitch. The turbine had experienced several outages related to high power output. Although KEA has not performed additional blade pitching since August 2002, they have been observing the average and peak output of the turbines to evaluate the pitch adjustments that have been made to date. KEA has decided the low output and slow start-up experienced at Turbine 8 indicates an overly conservative blade pitch setting and intends to repitch the turbine to a somewhat less conservative setting. KEA is not currently planning a project-wide repitching activity.

From the *Kotzebue Electric Association Wind Power Project Fourth-Year Operating Experience 2002-2003:*

Turbine Power Performance Test

As part of its technical support, TVP conducted a third-party evaluation of the power performance characteristics of the AOC 15/50 wind turbines installed at Kotzebue during the first operating year and of the NW 100 wind turbine installed at Kotzebue during the fourth operating year. Wind speed and concurrent power were collected from calibrated power transducers and meteorological sensors, and processed according to the International Electrotechnical Commission (IEC) Standard 61400-12, *Wind Turbine Power Performance Measurement*. The test provides a measured power curve for comparison against the manufacturer's predicted power curve and enables baseline production projections for evaluating performance. The test methodology and test results for the NW 100 power performance test are presented below. The results of the AOC power performance test were provided in the first-year operating report published in 2000.

As previously discussed, the NW 100 was connected to the Second Wind SCADA system in September 2002. This system was used to collect data for the performance test. The test data collection period ran from April 4, 2003, to May 15, 2003.

In accordance with the Standard, test data were considered valid only from a certain direction sector determined to be free from wind-flow obstructions. This sector was identified through a defined site assessment process that excluded any direction sectors in which the met tower or the NW 100 would be affected by the wake of nearby turbines. Figure 4-18 shows the location of the site reference met tower, the turbines relative to the surrounding terrain, and the valid measurement sector (71° clockwise to 223°).

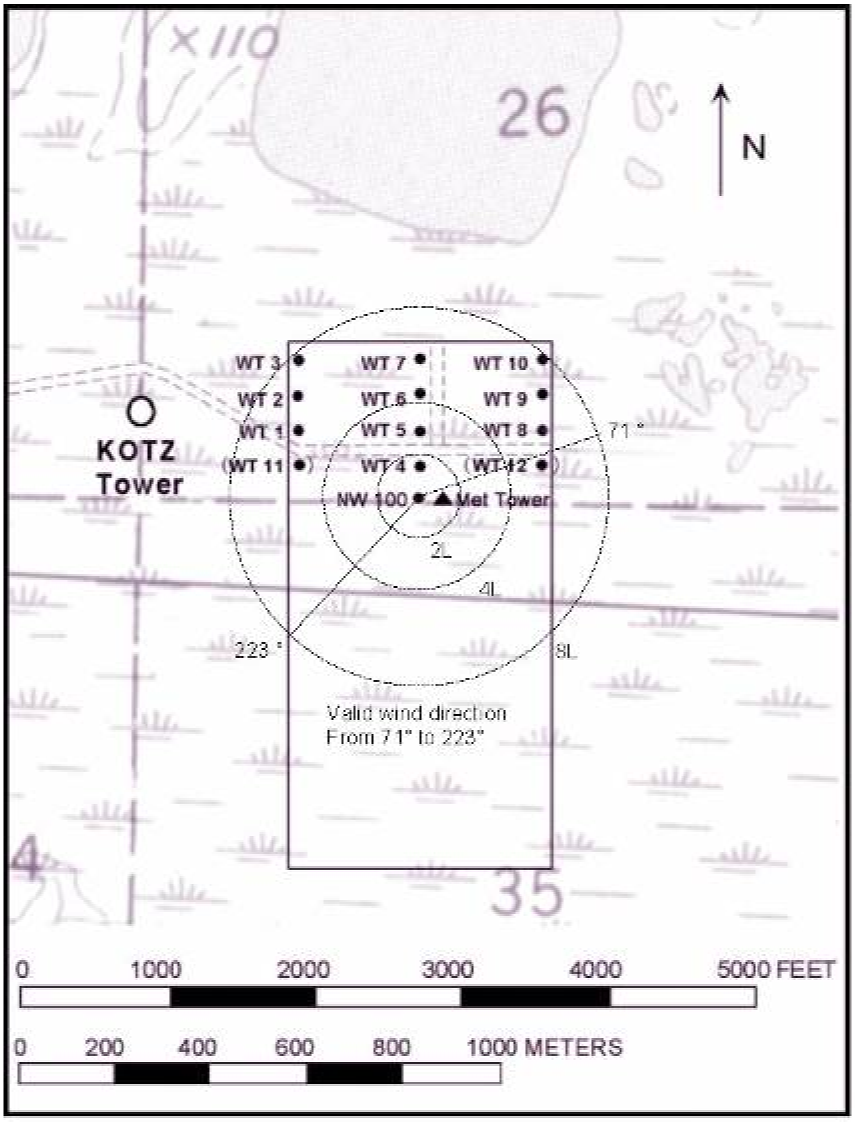


Figure 4-18. Valid Measurement Sectors for NW 100 Power Performance Test

Test Methodology

According to the IEC Standard, the test site must be evaluated by three criteria to determine which data must be excluded from the database: topographic variations, neighboring and operating wind turbines, and other significant obstacles. If the topography of the site meets the criteria given in the IEC Standard, then the wind speed at the meteorological mast is assumed to be identical to the wind speed at the wind turbine. If the topographical variations exceed the criteria, then an experimental calibration of the test site is required to determine corrections to the wind speed. The neighboring wind turbines were evaluated to determine whether they disturb the free-stream wind velocity. There were no other significant obstacles. Direction sectors found to have free-stream wind disturbance by the adjacent turbines, using the criteria set forth in the IEC Standard, were excluded from the database. Due to the flat terrain at the KEA site, and the absence of obstacles, a site calibration was not required.

During the test period of April 4 through May 15, 2,755 10-minute records of valid data were collected while the wind was from the valid wind direction (71° to 223°), icing conditions were not apparent, and the turbine was available. The highest bin filled with at least three valid 10-minute average data points (with wind speed normalized to sea-level density) was the 19.0 m/s bin. According to the Standard, data should be collected up to a wind speed equal to 1.5 times the wind speed at which the turbine reaches 85% of its rated power. The NPS turbine is rated at 100 kW. For the NW 100, the data collection requirement would be up to 17.0 m/s according to the power curve provided by the manufacturer.

The Standard also provides the option of completing a post-test calibration of the primary anemometer, or performing an in situ calibration. The latter option was chosen for this test. It entails installing a secondary calibrated anemometer very near the hub-height anemometer at the start of the test. The secondary anemometer is used to identify any changes in the primary anemometer calibration over time. No change was found during this test.

Test Results

The results of the power performance test were conducted at sea level and are shown in Figures 4-19 to 4-21. The error bars shown on the power curves represent the combined uncertainty calculated in accordance with IEC 61400-12, based on the error introduced by the standard deviation of the measured data points and the uncertainty in the sensors and data acquisition system. No error bars are shown for data points with less than three 10-minute samples in the bin.

Test results indicate that the NW 100, at sea-level density, does limit peak production to 100 kW by fixing the rotor speed; thus, acting very similar to a stall-controlled machine. The performance tests show that the NW 100 maximum output is reached at approximately 16 m/s. Also, rotor speed varied by less than 9% between wind speeds of 4.5 m/s and 19 m/s.

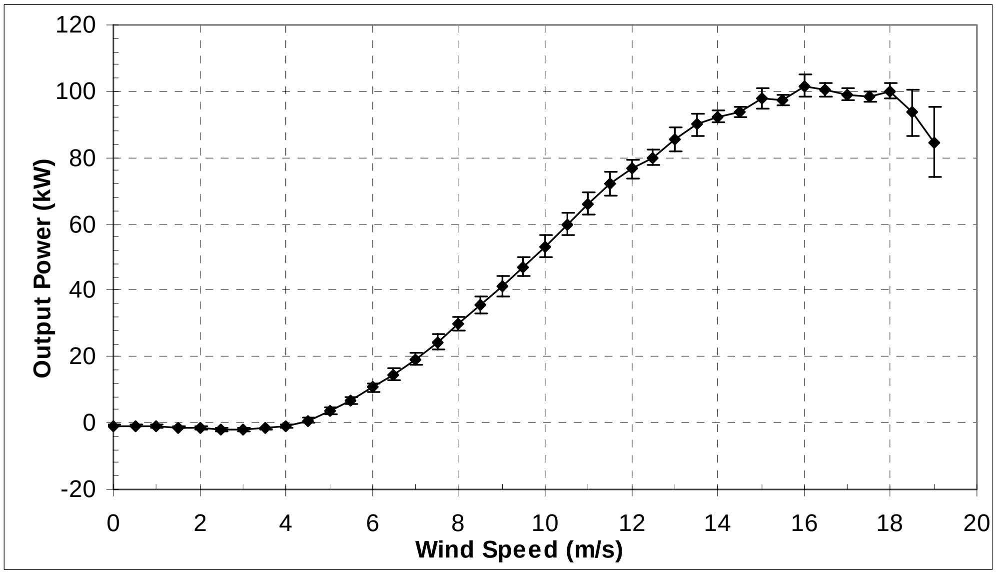


Figure 4-19. Power Curve at Sea-Level Density, 1.225 kg/m^3

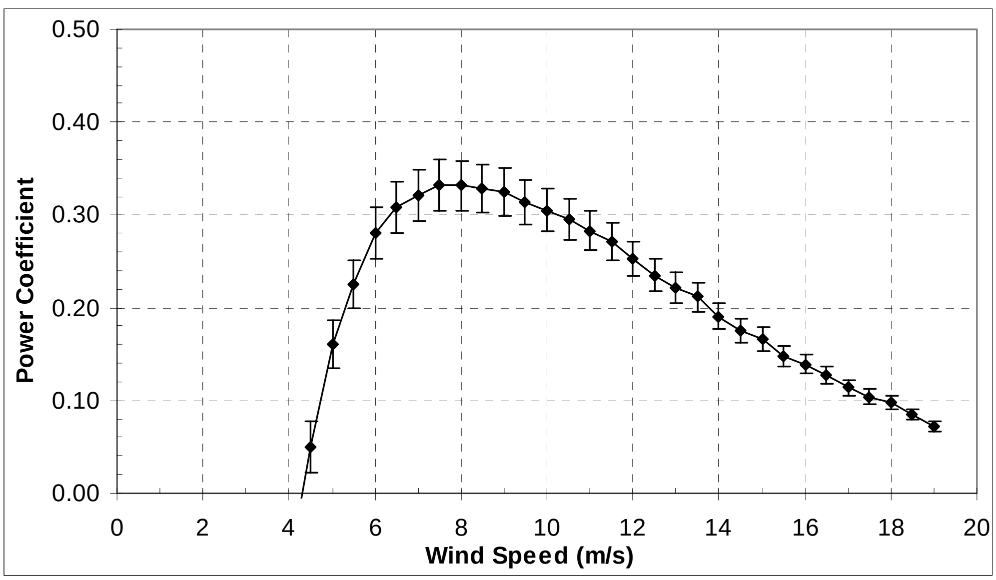


Figure 4-20. Power Coefficient at Sea-Level Density, 1.225 kg/m^3

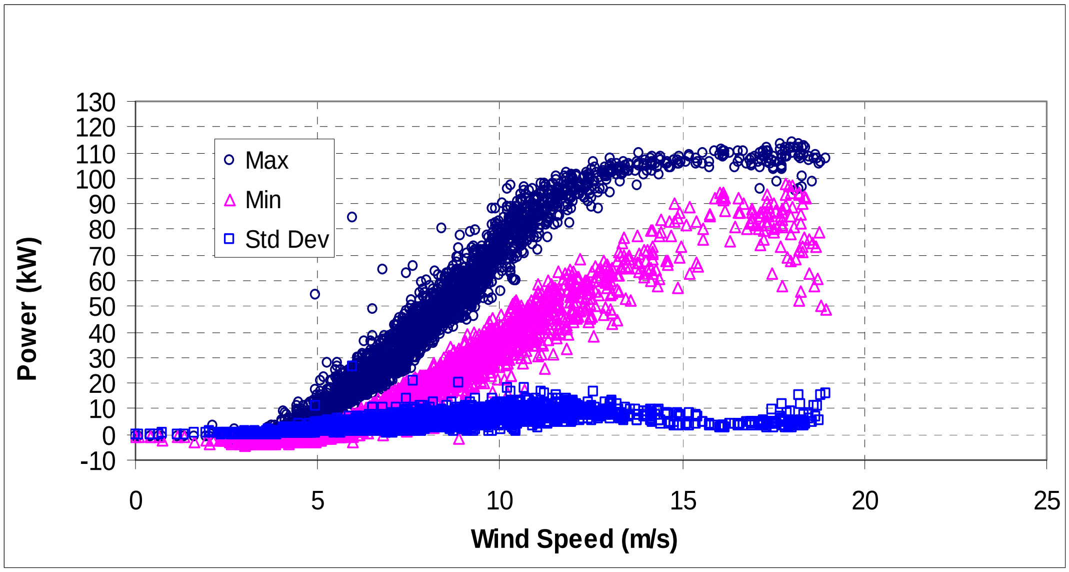


Figure 4-21. Maximum, Minimum, and Standard Deviation of Power Measured at the NW 100

The gross annual energy production (AEP) results are presented in Table 4-6 for the measured and extrapolated power curves along with the associated uncertainties. The measured AEP only includes wind speed bins for which there are three or more data points. The extrapolated AEP assumes that the power at higher wind speeds is equal to the power of the last filled wind speed bin. Wherever the energy production from the measured curve is 95% or greater than the energy for the extrapolated energy, the results are labeled "incomplete."

Table 4-6. Annual Energy Production at Sea-Level Density, 1.225 kg/m^3

Rayleigh Mean Hub-Height Wind Speed (m/s)	AEP Measured		AEP Uncertainty		AEP Extrapolated (MWh/yr)
	(MWh/yr)	Status	(MWh/yr)	(%)	
4	38	Complete	7.8	20.3%	38
5	93	Complete	10.6	11.4%	93
6	160	Complete	13.2	8.3%	160
7	229	Complete	15.3	6.7%	231
8	290	Complete	16.8	5.8%	299
9	339	Incomplete	17.7	5.2%	360
10	372	Incomplete	18.1	4.9%	410
11	390	Incomplete	18.1	4.6%	449

Task 11: Educational Outreach

KEA has a prominent role in working with the University of Alaska and local colleges to provide video education leading to an associate of arts degree in power plant operation, maintenance and installation. KEA shall develop appropriate video modules to extend the curriculum to include wind energy. This shall be included as part of the regular program. It is anticipated that KEA power plant operations will be among the first to complete the wind energy modules.

Deliverables: A summary report will describe the educational outreach with the report due in mid-1998, detailing the program to be implemented in the fall of 1998.

Modification Comments: Budget increase of $25,000. Under this task KEA has accomplished a significant amount of educational and community outreach through the development of high-quality brochures and pamphlets. KEA has also added a wind-energy component to their website that provides information to the public and can be viewed at http://www.kea.coop/wind/.

Site tours have been provided to local school groups, the news media, public policy officials, and utility and technical groups with specific need for information about the project. KEA held a well-attended project dedication ceremony involving local and state dignitaries in August 1999.

The original task included the development of a curriculum for training power plant operators in wind plant operation. Although preliminary work has been done with the University of Alaska (U of A) and the Alaska Technical Center, the necessary components for developing this program are not in place. In spite of their commitment, KEA anticipates that the development of this program will ultimately be driven by need as wind projects are installed in other villages in northwest Alaska. KEA would like to include this work in a later program budget.

A wind technician training program has never been initiated by the U of A or the Alaska Technical Center and therefore KEA has not developed a related curriculum. However, KEA has developed an education workbook about wind energy for elementary-level education. A copy of the workbook is included as Appendix D and has also been uploaded as separate document to the DOE website.

Task 12: TVP Integration

KEA will integrate the KEA wind farm into the DOE Turbine Verification Program, with the objective of collecting, analyzing and evaluating the wind turbine economic and performance data in such a way that the merits of wind energy will be available to other utilities who seek to use wind energy.

For several years, the majority of KEA's technical analysis and information dissemination was performed as part of the TVP program. This included monthly performance reporting that tracked the production, availability, and maintenance activities of the KEA wind project as well as routine interaction with the TVP support contractor and other utilities. The TVP provided statistics for all of the TVP projects, including KEA, in its quarterly TVP Bulletin.

KEA continues to be actively involved with the Utility Wind Interest Group (UWIG). Brad Reeve served as UWIG President for several years. Participation in UWIG activities provided

KEA with opportunities to interact on a regular basis with other utilities from around the country that are using or considering wind energy as part of their energy mix.

As the President of UWIG, Mr. Reeve was instrumental in planning the annual TVP Workshop, which was held in conjunction with the fall UWIG meeting. In 2001 the TVP/UWIG Workshop was held in Abilene, Texas, and included a tour of the new 150 MW Trent Mesa wind project. The 2002 workshop was held in Nebraska City, Nebraska, and highlighted integration impacts of utility-scale wind projects and TVP operating experience.

Task 13: Wind Site Improvements

There are two items included in this task. The first is for improvements of the 4600' feet of existing roadway. This includes the addition of 1' of gravel on the roadway, re-grading of the entire surface, and compaction to improve drainage.

The remaining part of this task is for the addition of spur roads that will provide access to the NW 100, installed in May 2002 and two AOC 15/50s that were installed in the spring of 2003.

All of the work included in this task was performed on the existing 148-acre project site. This work and affected area were covered in the original Environmental Assessment report prepared by the DOE Golden Field Office in May 1998.

Task 14: Turbine Improvements

Consistent with the program objectives, KEA is committed to turbine performance improvement. KEA has identified several areas of turbine improvement that will either increase the reliability or production of the turbines installed in Kotzebue or similar turbines installed in similar environments.

A description of the ten items originally included in this task is listed below. Information related to the completion of the task or an explanation of why the task was not performed is included.

1. *Design and build a piece of equipment which will be used to change the gearbox oil on the AOC 15-50. KEA will design the unit and have a company in Anchorage manufacture it.* This task was not undertaken.

2. *The panel-mount fused disconnects on WTG 4-10 are underrated. They should have 125A fuses, but due to the frame size of the disconnect, only 100A fuses can fit. The installation of these larger disconnects will increase power output from the turbine.* This task was performed on 2 turbines. KEA then decided it would be more appropriate to resolve this issue by replacing the turbine meter. All turbine meters were replaced.

3. *Remove AOC produced current sensor and install new, commercially available model. The sensors provided by AOC have a high failure rate.* Task completed.

4. *Install Uninterruptible Power Supply (UPS) to provide control power for AOC turbines.* UPS was determined to be unreliable and KEA decided this task was unnecessary.

5. *Update PLC software and standardize on all turbines. This will include the development and implementation of a turbine free-wheeling routine which will minimize braking cycles and maximize turbine output.* This task was completed in June 2006 during the power plant upgrade. Additional description is included under Task 16 & 17.

6. *Establish optimal, year-round blade pitch for KEA's site and accurately repitch all turbines.* After completion of the turbine pitch setting test, KEA determined it was appropriate to repitch a limited number of turbines. Turbine 5 was pitched to a less aggressive pitch. The turbine had experienced several outages related to high power output. KEA decided the low output and slow start-up experienced at Turbine 8 indicated an overly conservative blade pitch setting and repitched the turbine to a somewhat less conservative setting. KEA decided against a project-wide repitching activity.

7. *Procure and install vents and fans for the AOC controllers to resolve overheating problem.* The vents and fans were procured and installation is partially complete.

8. *Design and fabricate work platforms for the AOC turbines to increase climber safety.* The work platforms were designed and fabricated and are particularly helpful in performing work on the turbines tip brakes. A photograph of the platform in use is provided in Figure 5.

9. *KEA will add 20 yards of gravel to foundation piling at each of the existing 10 turbines plus the 3 new turbines which will provide greater thermal protection.* A photograph showing the added gravel is provided in Figure 6.

10. *Second Wind is developing a SCADA call-out feature that will notify the plant operator by phone when turbine goes off line due to a fault. This will improve response time and increase project availability.* Development of the call-out feature was completed and implemented in the SecondWind SCADA system, but this SCADA system was replaced as part of the power plant upgrade.

Figure 5. AOC Work Platform

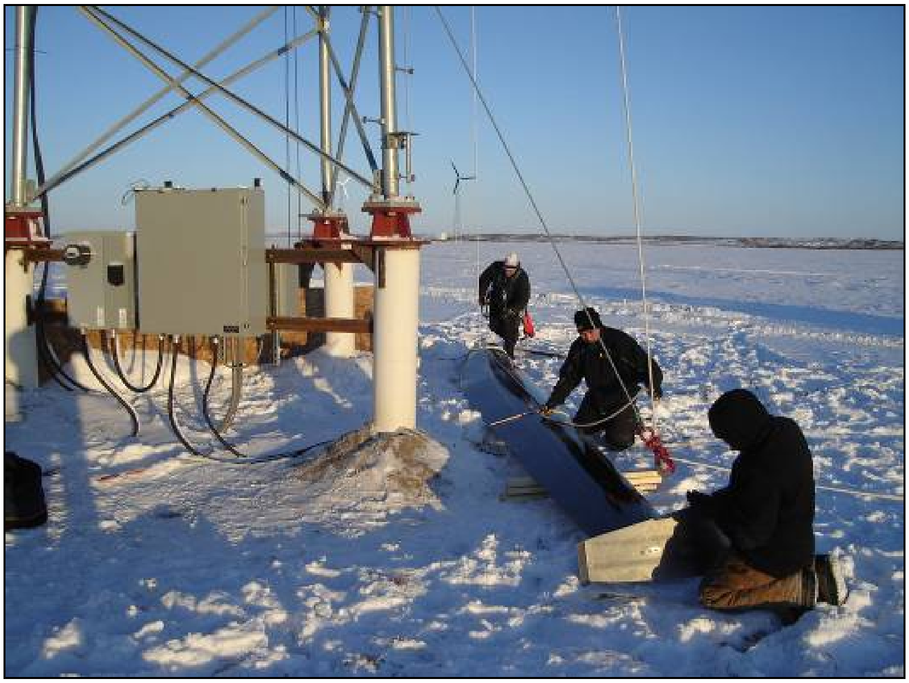


Figure 6. Gravel Around Foundation Pilings for Added Thermal Protection

Task 15: Educational Outreach

KEA is committed to providing educational outreach activities for the general public in Alaska and for operators who will be trained to operate the hybrid wind/diesel power plants. Task 3 is divided into two subtasks. In the first subtask, KEA will work with a safety consultant to develop an instructional video and related testing procedures to train wind project operators on OSHA-compliant training and safety requirements. The wind site manager will be certified as a tower climbing instructor.

In the second subtask, KEA will provide support to the Alaska Technical Center in Kotzebue in developing their Renewable Energy Program. In addition to general wind energy consultation, KEA will assist with the instrumentation and installation of a 3-kW solar panel provided by British Petroleum. This demonstration solar project will be monitored by the U of A-Fairbanks Energy Center to advance renewable energy education.

KEA determined that developing an instructional video in Kotzebue was not feasible. Matt Bergan, primary wind technician at KEA, attended the Tower Climbing Safety and Rescue Training program in Monroe, Wisconsin. The training was held in January 2002. Since that time, KEA has conducted training of several KEA workers for the safe maintenance of the Kotzebue wind turbines as well as training a maintenance technician at the wind project in Selawik, Alaska.

The solar panels were installed at the Alaska Technical Center in September 2004. Photographs of the solar panels are included as Figure 7 and Figure 8. Although the energy generated by the solar panels is being used by the center, the energy production is not currently being monitored.

Figure 7. Installing Solar Panels at the Alaska Technical Center

Figure 8. Completed Installation of Solar Panels at the Alaska Technical Center

Task 16 & 17: KEA Plant SCADA Phase 1 & 2

Task 16 & 17 as Envisioned and Described in the Statement of Work

Phase 1 of the Supervisory Control and Data Acquisition (SCADA) system design and installation will include the installation of all equipment and software that establishes control of the power plant in either a manual mode through physical controls at the engine or other control panels. It will also include the capacity to allow the control interface to dispatch the engine/generators, wind turbines and local and remote secondary energy loads that regulate the electric system as a complete operational system.

Discussions with Lloyd Controls provided a budgetary estimate of $560,000 for the cost of design, manufacturer and installation of a SCADA system for the Phase 1 KEA plant upgrade. Lloyd Controls had recently completed a SCADA system installation similar to that required by KEA.

Phase 2 of the SCADA system design and installation will be comprised of instrumentation changes to one of their three larger units (Unit 9) and all three of their smaller units (Units 7, 11 and 12). Unit 9 will be instrumented with pressure transducers, temperature transducers and limit switches. The governor will be changed to an electronic system and all control and instrumentation points will be brought out to a new mechanical panel suitable to intertie to the SCADA system. Units 7, 11 and 12 have an electronic governor readily adaptable to the SCADA, but these units will need to be instrumented with electrical pressure transducers, temperature transducers and limits switches.

Phase 2 of the SCADA will also include the actual remote secondary energy loads and a system of controlling the frequency and other electric characteristics of the KEA system. These systems will include components such as the synchronous condenser, a boiler system capable of providing replacement heat that is currently provided by the engine/generators, and the communications infrastructure to receive data and control the equipment while keeping the electric system stable.

Sustainable Automation, LLC, provided a budgetary estimate of $200,000 for the cost of design, manufacture and installation of a wind-diesel supervisory controller for the Phase 2 KEA plant upgrade. Steve Drouilhet, principal of Sustainable Automation, was responsible for design and implementation of the Wales, Alaska, wind-diesel control system. With a potential wind penetration of greater than 100%, the Wales system is significantly more complex than the system required for the KEA plant.

The total estimated cost of this task has been allocated to equipment, KEA labor, and the prime contractor as outlined in the Budget Explanation Form GO-PF20. With the exception of some wiring, all equipment and supplies for these tasks are included in the subcontractor's costs.

Task 16 & 17 as Combined and Implemented

The SCADA project was taken out for bid as an engineer-procure-construct (EPC) project. The project bid included scope to design and install new switchgear in the power plant; however, the switchgear purchase and installation was funded with a loan from the Rural Utility Service (RUS), a division of the United States Department of Agriculture.

The SCADA architecture, preliminary engineering, and major components were selected by KEA for implementation. The project bid required the contractor to finalize the preliminary design documents, procure all materials needed to construct the SCADA system, install and commission the system, service the system, and train KEA personnel to operate and maintain the system.

Because Kotzebue has a stand-alone power plant and high-penetration wind in the system, many special provisions were required to be built into the system in order to ensure adequate reliability. A Special Provisions document prepared by the contractor who worked with KEA to design and install the SCADA system is included in Appendix E.

Following is a chronological description of the preliminary engineering, bid development and selection, and the implementation of the KEA power plant upgrade. Although funded under an RUS loan, the switchgear installation was integral to the power plant upgrade and is therefore included in this description.

In the description below, several references are made to the old section of the power plant and the newer section of the plant. The old section of the plant was installed in 1953 and consists of three Caterpillar diesel generators. The newer section of the plant, installed in 1972, houses the three EMD diesel generators.

Chronological Description of KEA Power Plant Upgrade

1. Prior to June 2004 Thompson Engineering and KEA prepared the *Phase I Preliminary Engineering – Request for Quotation*. This document provided information about the existing KEA system equipment, including the diesel plant, wind plant, substation, fuel system, and radiator systems.

   The Request for Quotation, which included numerous charts, tables, and drawings and a verbal narrative of the existing KEA systems, described the current and proposed operations under the SCADA system which bidders would design.

2. For the initial part of the project, KEA requested that Electric Power Systems, Inc. (EPS) of Anchorage, Alaska, identify alternatives that would achieve KEA’s SCADA requirements and identify and evaluate advantages and disadvantages of each alternative. KEA reviewed the evaluation and recommendations from EPS and selected a SCADA system alternative. KEA identifies this portion of the process as Phase I of the project.

   Based on KEA’s system selection, EPS prepared the bid document, *High Penetration Wind SCADA System Engineer, Procure & Construct Project.* This bid document, which is provided in Appendix F, was completed and released on August 24, 2005.

3. On October 13, 2005, proposals were received on the Phase II project from EPS and Powercorp. EPS was awarded the contract based on cost and qualifications.

4. Separately, KEA requested that EPS prepare a Request for Proposals (RFP) for the replacement of the KEA plant switchgear. The switchgear RFP was funded separately and completed after the SCADA proposal because the switchgear was funded separately with RUS loan funds. EPS was tasked with this project to ensure an effective interface of the new switchgear with the plant SCADA. The Switchgear Equipment RFP was issued on January 11, 2006, and bids were opened until January 27, 2006.

5. In early February 2006, Myers Power Products, Inc. (Myers) was awarded the contract to construct the new switchgear. To expedite the project, KEA agreed to have its shipping contractor pick up the switchgear at the Meyers factory in California on May 29, 2006. The switchgear was trucked from the Myers factory to Seattle, shipped to Anchorage, and then air freighted to Kotzebue.

   During June 2006, SCADA programmable logic controllers (PLCs) for the diesel engines were constructed by EPS in Anchorage. The PLCs, shown in Figure 9, were completed, tested, and air freighted to Kotzebue.

Figure 9. Diesel Engine PLC Panels from EPS

6. Early in 2006, KEA began making space in the old section of the plant for new switchgear. At the time, a combination lathe room and small parts storage room was located in the area planned for the new switchgear. In addition, the station service equipment that provides power to the low-voltage systems in the old section of the plant was located on a wall of the area.

7. In March 2006, KEA began relocating the electrical panels and transformers. Relocation had to be performed one circuit at a time to keep the old section of the plant operational. A portable backup generator was set up outside the power plant and is shown in Figure 10. The backup generator was critical to implementing the power plant upgrade without loss of power to the town. The generator was used several times. Once the electrical equipment was relocated, the interior walls of the room were removed to make space for the new switchgear. Figure 11 shows the old switchgear being removed from the old section of the plant and where the interior wall was removed.

Figure 10. Backup Generator Set Up During SCADA Installation

Figure 11. Removal of Old Switchgear from Old Section of Plant

8. In June 2006, a crew from Entegrity Wind (the company that purchased AOC), KEA, and Thompson Engineering removed the PLC controls from the AOC turbines and installed the new orbital controls and peripherals. The PLC controllers were replaced in order to standardize the controls for each unit and to standardize the input and outputs to the new SCADA system.

9. In early July 2006, new switchgear and new SCADA PLC engine panels arrived in Kotzebue. As shown in Figure 12, the equipment was staged near the power plant at the KEA office parking lot.

10. On July 5, 2006, a hole was opened in the northeast wall of the old section of the KEA power plant. The old section of the plant was shut down and disconnected from the newer section of the plant. As shown in Figure 13, pieces of the plant switchgear were removed through the plant wall. The remaining switchgear was removed through the west overhead plant door.

11. As seen in Figure 14, the new switchgear for the old section of the plant was moved inside in sections through the hole in the plant wall. As shown in Figure 15, the new switchgear was set in place and leveled. After interconnecting the switchgear, the KEA and EPS crews separated to perform different tasks.

    As shown in Figure 16, KEA's crew installed cable trays for the engine generator power leads and rerouted sections of cable tray for the bus tie interconnect between the two sections of the plant. KEA's crew also removed numerous control cables between the two plants from a second cable tray to make room for new cables. EPS's crews installed the instrumentation modifications on the Caterpillar generators in the old section of the plant as well as the SCADA PLC control panels and new switchgear.

Figure 12. Staging For Switchgear and SCADA Equipment

Figure 13. Removal of Old Switchgear from Old Section of Power Plant

Figure 14. Installing New Switchgear in Old Section of Power Plant

Figure 15. New Switchgear in Place and Leveled

Figure 16. Installing Cable Trays in the Power Plant

12. The original bus tie cables between the two sections of the plant (750 mcm, aluminum installed in 1972) were temporarily rerouted to the new switchgear in the old section of the plant for use during the changeover of switchgear in the new section of the plant.

13. The EPS crew installed the first SCADA PC server in the existing KEA control room. Power for this unit is backed up through an inverter off of the KEA DC bus. The EPS crew installed the fiber optic control lines in the old section of the plant between this server, the KEA switchgear, and the SCADA PLC engine controls.

    A second server was installed in the old office building also powered through an inverter off the new plant 125 volt DC bus. The third redundant server was installed at the KEA wind site and was powered through a large UPS (uninterruptible power supply).

    In addition to the actual servers there are two interactive terminals which serve as visual and control screens. One is located in the newer section of the plant and the other in KEA's engineering office.

14. Between July and the end of September 2006, EPS and KEA personnel installed the fiber optic cable at the KEA wind plant which provides communication between the wind plant and the SCADA system in the diesel plant. Primarily, this cable was installed in existing high-density polyethylene tubing previously used for communications cables at the site.

KEA personnel, with the permission and assistance from the local Kotzebue telephone company, installed the high-speed radio link. This repeater was installed on the telephone cell tower located on a hill between the diesel power plant and the wind site and also supports the necessary communications between the wind plant and diesel plant. As pictured in Figure 17, the antenna for the high-speed radio link is mounted on the substation building outside the power plant.

15. KEA's crew installed the power cable tray and power cable. After the cable and cable tray were installed between the diesel engines in the old section of the plant, the KEA line crew completed the terminations and connections.

16. After main power lead terminations and connections were completed and while work continued on the conversion of the old section of the plant, the KEA line crew installed the new bus cables in the existing cable trays between the two sections of plants.

Figure 17. Antenna for High-Speed Radio Link Mounted on Substation Building

17. The next stage of the power plant conversions was the removal of the switchgear in the newer section of the plant (with the exception of Unit 10) and the installation of the new switchgear. To facilitate this work, an old switchgear panel from the old plant was stripped

of everything except for the bus section. This piece of switchgear was placed in the substation and was used as a junction point between the temporary 750 mcm aluminum bus leads from the old section of the plant, the power leads from Unit 10 switchgear, and the substation transformers.

Once the new switchgear in the old plant and SCADA were operational this allowed use of the generators in the old plant in conjunction with the temporary rerouted output from Unit 10 to feed the town electrical load and replace the switchgear line up in the newer section of the plant.

18. The old power plant conversion was completed the first week of September 2006. After completing the temporary bypass on Unit 10 and the old section of the plant to the substation (described above), the crews took a short break over Labor Day.

19. In early September the old switchgear was removed from the new power plant by the KEA crew and the new switchgear was brought in through a large overhead door by a front-end loader and was moved into position by a combination of overhead crane and floor rollers. The new switchgear for the newer section of the plant is shown in Figure 18. KEA and EPS personnel installed, leveled, aligned, and interconnected the new switchgear.

Figure 18. Installation of New Switchgear in Newer Section of Plant

20. After the new switchgear was installed, the KEA crew installed the power cable tray and cable between the engine generators and the switchgear. They also installed the cable tray and bus cables interconnecting the two sections of the plant and between the switchgear and the outside substation transformers.

21. In the newer section of the power plant, the EPS crew installed the SCADA PLC engine control panels, two of which were shown in Figure 9. EPS also installed the control and communication cable trays, the fiber optic cables, and other control cables.

    In addition, EPS installed the master PLC which controls the city water system, the after-cooler radiator system for the EMD generators, and the main radiator cooling system for the plant. All of these systems are manually controllable in the event of a PLC failure. The demand control system which controls engine dispatching also resides in the master PLC.

22. KEA installed a cable tray connecting the new switchgear in the newer section of the plant to the substation and the existing power cables to the substation were rerouted into the new cable tray.

23. In early October, the first phase of the upgrade for the newer section of the plant was complete. A short system outage was taken to disconnect the old section of the plant from the temporary junction point described in Item 17 above.

    At this point, Unit 10, in the old section of the plant, continued to carry the town electrical load while the new bus leads between the old and new sections of the plant were installed and terminated by the KEA line crew.

    Once the old section of the plant and units in the newer section of the plant were connected, the town load was transferred to these units and Unit 10 was shut down and converted to the new switchgear and to the new SCADA system.

24. In October 2006, EPS installed the substation PLC panel and, one by one, loop fed feeders on the distribution system. In this way they were able to disconnect individual feeder breakers in the substation and convert each to the new SCADA control, relaying, and monitoring. The radio link to the wind plant was also tied into the SCADA system through the substation PLC panel.

25. The last of the contracted items for the SCADA system was the large fuel tank monitoring. To do this, KEA's existing level gauges and newly added tank temperature sensors were connected to the SCADA system. Although this was started in late 2006, due to weather constraints, the work was not completed until May 2007.

The statement of work for Task 16 & 17 was developed in December 2001. The actual system was designed in 2004 and built in 2006. In the interim, labor and equipment costs increased, resulting in a SCADA system that varied from the system initially envisioned.

The primary difference in the system as envisioned in 2001 and the system built in 2006 is the exclusion of a synchronous condenser. The synchronous condenser was to be installed for VAR control. Currently, the added VAR load imposed by the wind turbines does not affect the system stability. Changes in the excitation system of the diesel units are partially responsible for the increased system stability. Although a VAR control system was not installed, the SCADA was designed with the ability to monitor and control any form of VAR control that may be added later.

As-built drawings for the KEA power system, including the diesel plant and wind plant, were developed during the system design for the power plant upgrade and are provided as Appendix G.

Task 18: Local Secondary Load

This task includes a local secondary energy load (dump load) and a system for controlling the frequency and other electric characteristics of the KEA system. This system will include an array of solid-state relays, a boiler system capable of providing replacement heat that is currently provided by the engine/generators, and the communications infrastructure and software to receive data and control the equipment while keeping the electric system stable. The system will be computer controlled for automated operation and fault detection.

For a high wind penetration system, the implementation of secondary energy loads is essential to providing not only energy efficiency, but in assuring system stability. As wind penetration increases, additional local and remote secondary loads can be added to the system. The majority of the control infrastructure for supporting future secondary loads will already be in place with the completion of this task.

Funds initially allocated to this task were used to offset the significant increase in costs associated with the completion of Task 16 & 17. No funds were allocated to this task. The wind penetration is not currently impacting the diesel power plant loading and heating at a level that requires a secondary load. However, the new KEA SCADA system was designed with the ability to monitor and control multiple secondary loads that may be added later.

Task 19: Wind Project Expansion

KEA will install and commission an additional 100 kW of wind capacity. Including the capacity installed and previously funded for installation, the additional 100 kW will bring the total installed wind capacity to 1.124 MW. This level capacity could result in instantaneous wind penetration in excess of 60% of load. The wind capacity is expected to provide approximately 10% of annual electricity requirements for the City of Kotzebue.

The 100 kW of capacity is expected to be another NW 100 turbine, two Bergey 50-kW turbines (currently under development in cooperation with NREL), two AOC 15/50s, or one Bergey and one AOC. KEA will also consider the use of a larger reconditioned turbine(s). The size and type of turbine(s) to be installed is dependent on the availability of the turbines.

The additional turbines and related work are expected to be performed on the existing 148-acre project site. This work and affected areas are covered in the original Environmental Assessment Report prepared by the DOE Golden Field Office in May 1998. In addition, KEA has provided an updated GO-EF1, Environmental Checklist, with this proposed grant allocation.

The costs associated with this task include the equipment and balance-of-system procurement as well as the installation costs. Cost estimates are based on historical cost information from the wind turbines already installed in Kotzebue. Cost estimates were adjusted where appropriate based on current information.

Due to limitations on turbine availability and other factors, KEA decided to purchase and install a refurbished Vestas V-15 turbine under this task. The V-15 is a three-bladed downwind turbine with a 15-m rotor diameter. The V-15 is rated at 65 kW and has a proven reliability in the wind energy industry. The V-15 was installed in June 2006 and is operating reliably. Photographs of the foundation and mounting of the nacelle are provided in Figure 19 and Figure 20.

Figure 19. The V-15's Four-Legged Lattice Tower Piling Foundation

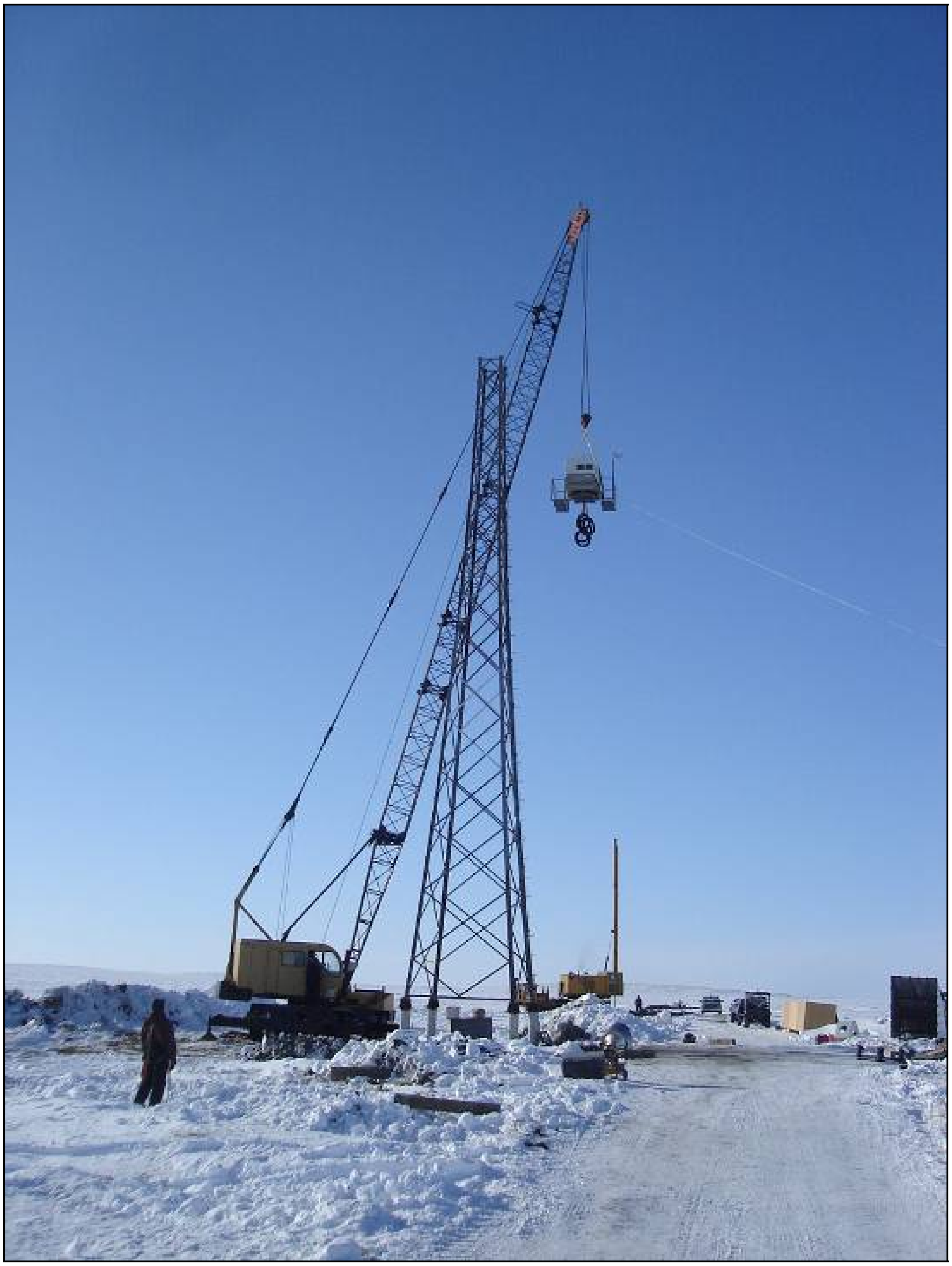


Figure 20. Mounting the V-15 Nacelle on the Tower

Task 20: Design and Implement Tilt-Up Towers

A tilt-up tower was designed but never implemented at the KEA Wind Project. However, the tilt-up tower for the AOC turbines was implemented in Wales, Alaska. Based on KEA's experience with the wind turbine installations in Wales, they will make several minor design modifications *and implement the new design in Kotzebue. This modified tilt-up tower design will also facilitate small turbine installations in other remote locations.*

The cranes that were required to stand up the towers and mount the turbine nacelles were available in both Kotzebue and Selewik. The need for a tilt-up tower has not yet been needed. Consequently, this task was not performed. KEA did not allocate any funds this task.

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These reports can be obtained from http://epri.com by searching for “Kotzebue Wind.”