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THE EPRI/DOE UTILITY WIND TURBINE PERFORMANCE VERIFICATION PROGRAM

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In 1992, the Electric Power Research Institute (EPRI) and the U.S. Department of Energy (DOE) initiated the Utility Wind Turbine Performance Verification Program (TVP). This paper provides an overview of the TVP, its purpose and goals, and the participating utility projects.

BACKGROUND

Improved technology has significantly reduced the cost of energy from wind turbines since the early 1980s. In 1992, turbines were producing electricity for about $0.07–$0.09/kilowatt-hour (kWh) (at 7 m/s [16 mph sites]), compared with more than $0.30/kWh in 1980. Further technology improvements were expected to lower the cost of energy from wind turbines to $0.05/kWh. More than 17,000 wind turbines, totaling more than 1,500 MW capacity, were installed in the United States, primarily in California and Hawaii. The better wind plants had availabilities above 95%, capacity factors exceeding 30%, and operation and maintenance costs of $0.01/kWh. However, despite improving technology, EPRI and DOE recognized that utility use of wind turbines was still largely limited to turbines installed in California and Hawaii during the 1980s. Wind resource assessments showed that other regions of the United States, particularly the Midwest, had abundant wind resources.

EPRI and DOE sought to provide a bridge from utility-grade turbine development programs under way to commercial purchases of the wind turbines. The TVP was developed to allow utilities to build and operate enough candidate turbines to gain statistically significant operating and maintenance data. The program is funded through contributions from EPRI, DOE, and host utilities. EPRI manages the program on behalf of the funding organizations. EPRI and the National Renewable Energy Laboratory (NREL), a DOE laboratory, provide technical and management guidance.

OVERVIEW OF PROGRAM STRUCTURE

The program has been implemented in three phases. The first phase was initiated in 1992. Construction was completed on the two projects selected in Phase I in 1996 and the wind plants are operational. The second phase was initiated in 1994. Phase III began in 1996 and awards will be made in early 1997.

Phase I and Phase II

In Phases I and II, the objective of EPRI and DOE was to support projects through host utilities or utility consortia. Each project was to include up to 20 turbines, each rated at 300 kW or more. Projects were to include wind power plant design, construction, startup, testing, evaluation, and documentation for the first three years of operation. EPRI and DOE offered up to $3 million in direct support. In return, EPRI and DOE would receive thorough documentation of the entire project.

The host utility or utility consortium would benefit from firsthand experience with, and ownership of, a demonstration wind power plant of at least 6 MW using the latest technology, recognition for leadership in renewables development, influence on technology development, and early access to information on other demonstration wind power plants.

Host utilities were selected based on site and wind resource documentation, geographic and climatic diversity among selected hosts, evidence of intent to include wind power as a generation resource and relevance of program to future use of wind power, and prospects for sufficient funding to achieve project implementation.

Two host utilities were selected in Phase I: Central and South West Services, Inc. (CSW) , Dallas, Texas, and Green Mountain Power (GMP), South Burlington, Vermont. One utility was selected in Phase II but negotiations were never finalized.

Central and South West Services

Central and South West's facility, located in west Texas near Fort Davis, was commissioned in September 1995. The wind plant consists of twelve 550-kW Z-40A (aileron) wind turbines manufactured by Zond Systems, Inc., Tehachapi, California with a rated capacity of 6.6 MW. CSW selected the turbine through a competitive solicitation. The turbines are expected to generate more than 12 GWh net output a year in normal wind conditions. The total estimated project cost is $10.8 million, of which EPRI and DOE will contribute $2 million through the TVP. EPRI also contributed $3.4 million in tailored-collaboration funds. Central and South West personnel operate the plant.

Central and South West was already making progress towards adding renewable energy to its generation mix when the TVP solicitation was announced. In 1993, CSW formally announced its commitment to the Renewable Energy Project, a five-year, $17 million effort to examine and collect data on renewable technologies at test sites near Fort Davis. In addition to wind energy, the project includes various applications of photovoltaics. The project also includes taking wind and solar measurements throughout the service territory to support future renewables additions. A 2-MW wind energy facility was planned as part of the project. The utility's long-term strategic interest in renewables fit well with the goals of TVP, and the TVP solicitation, along with EPRI-tailored collaboration funds, provided the utility an opportunity to increase the project to 6.6 MW.

The project site, Robison Ridge, elevation 1,829 m (6,000 ft), is approximately 32 km (20 miles) southwest of the town of Fort Davis in west Texas. The ridge is oriented north-south and is a high lightning area. CSW wanted to locate the wind plant near their Solar Park, north of Fort Davis, and they noted that the DOE Wind Energy Atlas[1] showed ridgetops near Fort Davis to have Class 5 (approximate mean wind speeds of 6.0 to 6.4 m/s at 10 m) wind to have an annual average wind speed of 6.7 m/s (15 mph) at 40 m (131 ft). The wind blows predominately from the east or west, depending on the time of year.

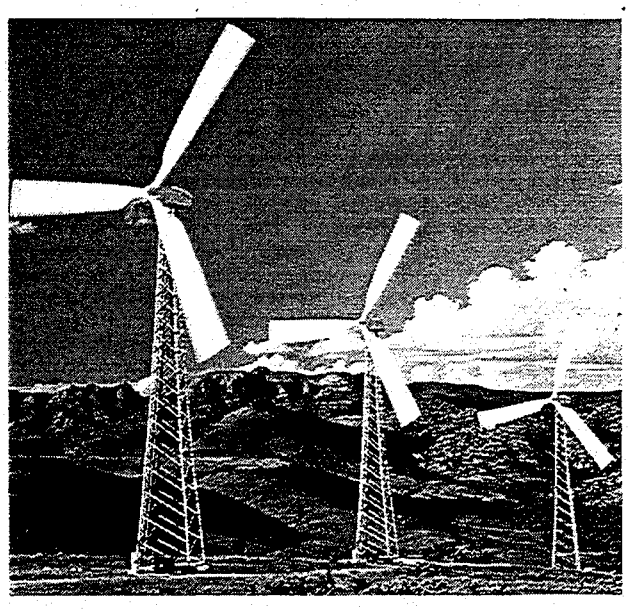

FIG. 1. ZOND Z-40A WIND TURBINES AT THE CENTRAL AND SOUTH WEST SERVICES WIND PLANT IN THE DAVIS MOUNTAINS NEAR FORT DAVIS, TEXAS.

CSW conducted a number of studies related to the project; some of the studies are still in progress. An environmental and cultural impact study found no significant environmental or land use impacts. A societal acceptance study is under way. Preliminary results show strong support for renewables and the specific renewables projects in the area. An acoustics (noise) study will compare measurements taken before and after construction. An avian study[2] is under way and early results show only one species of concern, golden eagles, in the study area. A power quality study will address electric characteristics of renewables, harmonics, voltage flicker, and reactive power compensation. Others studies will include power performance measurements and lightning investigations.

The Z-40A (aileron) is a three-bladed, upwind, rigid hub turbine with an active yaw drive. The turbine uses ailerons for power regulation and overspeed control and has a 40-m (131-ft) freestanding lattice tower. The wind plant uses a Zond SCADA (Supervisory Control and Data Acquisition) system to monitor turbine operational performance, status, and condition from a central site computer and remote locations. This state-of-the-art turbine was developed under the DOE/NREL Value-Engineered Turbine Project. Under that project, one prototype turbine was field-tested in Tehachapi, California, prior to construction of the CSW wind plant, which is the first commercial installation of the Z–40A model.

CSW chose to share the project construction and installation responsibilities with Zond. Zond was responsible for turbine manufacture and installation up to the padmount transformer (turbines, towers, foundations, SCADA system, and geotechnical work). CSW was responsible for wind resource assessments; site selection; wind power plant design; permitting, construction and installation of the roads, power collection system, new 27.4 km (17 mile), 25-kV distribution line, and site operations building.

Zond and CSW are also sharing operation and maintenance responsibilities. Zond trained CSW personnel, handling turbine start-up and acceptance testing, providing scheduled maintenance for two years of operation, and furnishing a five-year warranty on turbine hardware, performance, and availability. CSW is handling day-to-day operation and management and turbine performance verification, including data collection, analysis, and reporting. CSW plans to take over maintenance after the two-year maintenance contract ends.

The wind plant is in its second year of operation. During the first quarter of 1996, the turbines were subjected to extensive acceptance tests to ensure proper operation. Wind plant energy production exceeded 8.3 GWh for 1996. Utility personnel are regularly monitoring turbine performance, energy production, fault conditions and alarms, power quality, wind conditions, and noise. They are studying the impact of the turbines on birds and other wildlife and are also tracking how nearby residents respond to the new facility.

CSW has shared information about the project at TVP meetings, utility and industry conferences, and local professional organization meetings. CSW has also conducted a vigorous public relations and

education campaign. A town meeting was held in Fort Davis in January 1995 and local residents were involved in the site dedication ceremony held in September 1995. A newsletter is distributed to local businesses, CSW employees, and industry members. Site tours are available by request.

Green Mountain Power

Green Mountain Power completed construction of its new wind facility near Searsburg, Vermont, in December 1996. The facility is situated in a sparsely populated, forested area on privately owned land. The 6.0-MW plant consists of eleven 550-kW Z-40FS (full-span) turbines which are expected to generate about 14 GWh of electricity a year in normal wind conditions. Zond turbines were selected by competitive solicitation. The estimated project cost is $10.4 million, of which EPRI and DOE will contribute $3.5 million in TVP funds. EPRI also contributed $460,000 in tailored-collaboration funds. Green Mountain Power will conduct a three-year testing and evaluation program.

Like CSW, GMP was involved with renewables prior to TVP. The utility has been studying the wind resource and environmental issues in Vermont since the early 1980s. It also has experience operating two 100-kW test turbines in a cold, icy climate near Manchester, Vermont, from 1990 to 1994.

FIG. 2. A ZOND Z-40FS WIND TURBINE AT THE GREEN MOUNTAIN POWER WIND PLANT NEAR SEARSBURG, VERMONT. SPECIALLY COATED BLACK BLADES REDUCE ICING.

The site chosen for the TVP project is on privately owned land in a sparsely populated and heavily forested region. Clearing for the project was held to a minimum. The ridge is 884 m (2,900 ft) in elevation with a northeast to southwest orientation. Wind speed measurements show the site to have an annual average wind speed of 8 m/s (17 mph) at hub height.

GMP conducted years of on-site wind monitoring. Additional site studies included a sight impacts study which suggested measures to minimize sight impacts of the project, an on-going black bear study to assess any impacts to habitats near the site, and an avian study to examine potential impacts on birds. Although no threatened or endangered birds will be affected by the project, avian monitoring will continue. A preconstruction societal acceptance survey was mailed to residents of Searsburg and the surrounding towns, which will be followed by a survey when the wind plant is operational. A final report is in preparation.

To educate and inform interested parties, locally and nationally, GMP is distributing a newsletter on the project, making plans to host site tours, and will share information about lessons learned through reports, TVP presentations, and other forums. A TVP workshop and site visit was held in September 1996 for industry members and local officials.

The Z-40FS turbines used in Vermont feature full-span, variable-pitch blades and were designed to ensure reliable cold-weather operation. The full-span pitch rotor, like the ailerons, is designed for power regulation and overspeed control, but may be better suited to operate reliably in icing conditions. This turbine model includes specially coated black blades, which absorb solar energy to reduce icing; cold-temperature steel for the towers; heaters for the control systems, gearbox oil, and hydraulic fluids; a large nacelle to protect maintenance workers from inclement weather; and a 40-m (131-ft) freestanding tubular tower that provides access to the turbine top through an internal ladder. One prototype of the Z-40FS was field-tested in Tehachapi, California prior to construction of the GMP wind plant. This is the first commercial installation of the Z-40FS model.

Zond has a turnkey contract with GMP which includes turbine manufacture, wind plant design, construction, and installation. As with the CSW project, Zond will provide two years of scheduled maintenance and a five-year warranty.

Phase III: Distributed Wind Turbines as a Generation Resource

After starting the TVP in 1992, EPRI and DOE noted changes in utilities' interests in owning and operating large wind turbine facilities. A combination of factors, including an available supply of low-cost surplus power, uncertainty about impacts of electricity industry restructuring, and increasing competition in the electricity industry have caused utilities to delay significant generating capacity additions, including large wind projects. However, a new market for wind power may be emerging, which is characterized by smaller, dispersed wind turbine generation facilities, connected directly to a distribution line, and owned and operated by cooperative, municipal, or investor-owned utilities; independent power producers; or other nonutility generators.

To address this evolving new market, EPRI and DOE are adding a new dimension to TVP that will focus on distributed wind turbine

projects. Through TVP, EPRI and DOE support several new distributed wind projects with differing levels of technical risk. Funding provided by the program will be commensurate with the risks assumed. In early 1997, EPRI and DOE will announce the projects to receive funding. From three to five awards are expected.

The program will emphasize (1) evaluation of the distributed wind generation concept; (2) verification of the performance, reliability, and cost of new wind turbine designs and components in a commercial utility environment; and (3) documentation and communication of project results.

Each dispersed wind generation project will include at least two turbines with a minimum rating of 250 kW each and a total capacity up to 5 MW. The project scope will include wind power plant design, construction, start-up, acceptance testing, performance and availability monitoring, and documentation for the first two years of commercial operation. The host utility can either own and operate the wind turbine facility or contract with an independent power producer or nonutility generator to supply power to the utility. Projects can be owned by any entity, but proposals must be submitted by the host utility. EPRI and DOE/NREL will provide substantial technical and management guidance.

Each host utility or utility consortium will select the installation site, specify operating conditions, solicit bids, and establish agreements with selected vendors. With EPRI and DOE assistance, the host will establish a test program, evaluate turbine performance and the role of distributed wind turbine generation in operating the electrical system, and assist in transferring information to the utility and wind power industries.

Depending on the project's technical risk level, the TVP may contribute from 25% to 50% of project costs. In addition, if the host is eligible, EPRI tailored-collaboration funds can be applied. To be eligible for funding, a project must employ wind turbines substantially manufactured in the United States. EPRI and DOE will receive complete documentation of the project for the benefit of the utility and wind power industries. In addition, sponsors have the option to gather data and install load measurement and other instrumentation on the host's turbines. The projects are expected to start during the period 1997–1998.

Benefits to the host utility or consortium include involvement and firsthand experience with distributed wind turbine generation, influence on technology development, electrical system benefits of distributed generation, access to technical support, early information on other wind turbine verification projects, and recognition for leadership in renewables development and use of "green" programs.

Criteria for selecting host utilities include project and site characteristics, technological diversity among program projects, geographic and climatic diversity among selected hosts, evidence of intent to use wind as a generation resource and relevance of project to future use of wind, cost-effectiveness of TVP funds required relative to importance of expected project results, and strength of project management team and level of organizational commitment.

CONCLUSIONS

The TVP is making progress towards the goal of providing a bridge from turbine development programs to commercial purchases of wind turbines. Utilities and turbine manufacturers are obtaining valuable experience in wind power plant development, operations and maintenance, and technology transfer. The Central and South West project has been operational for more than a year. An EPRI report, *Central and South West Wind Power Project Development,*[3] which summarizes the TVP project through wind plant acceptance, was published in 1996 and is available from EPRI. The Green Mountain Power project is undergoing acceptance tests in early 1997 and will begin collecting operational performance data upon acceptance.

Through the restructuring of Phase III to meet the current utility environment, TVP will continue to support the evaluation of early commercial wind turbines at sites developed with significant participation by U.S. electric utility companies.

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