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AN OVERVIEW OF DOE'S WIND TURBINE DEVELOPMENT PROGRAMS

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Abstract

The development of technologically advanced, higher efficiency wind turbines continues to be a high priority of the U.S. wind industry. The United States Department of Energy (DOE) is conducting and sponsoring a range of programs aimed at assisting the wind industry with system design, development, and testing. The overall goal is to develop systems that can compete with conventional electric generation at $0.05/kWh at 5.8 m/s (13 mph sites) by the mid-1990s, and with fossil-fuel-based generators $0.04/kWh at 5.8 m/s sites by the year 2000. These goals will be achieved through several programs. The Value Engineered Turbine (VET) Program will promote the rapid development of U.S. capability to manufacture wind turbines to take advantage of near-term market opportunities. These value-engineered turbines will stem from units with known and well-documented records of performance. The Advanced Wind Turbine Program will assist U.S. industry to develop and integrate advanced technologies into utility-grade wind turbines for the near term (1993-1995), and to develop a new generation of innovative turbines for the year 2000. The Utility Wind Turbine Performance Verification Program, a collaborative agreement between the Electric Power Research Institute (EPRI) and DOE, will deploy and evaluate commercial-prototype wind turbines in typical utility operating environments to provide a bridge from development programs currently under way to commercial purchases of utility-grade wind turbines.

Background

Wind generation of electricity for delivery to the electric grid must compete with other utility sources of electricity in a complex world of financing, tax credits and penalties, competing cost formulas and set asides. Despite the actual complexity of the energy market, relatively new technologies such as wind turbines must still compete on a pure cost of energy (COE) basis with the well-developed fossil fuel infrastructures for the production of electricity. Wind systems can only grow by eliminating perceptions of poor reliability and availability through technological developments, innovation, and improvement. Wind turbine operators have made great strides to eliminate these perceptions using current technology, but that is not enough. Existing wind turbines produce electricity at $0.07-0.09/kWh. Decreases on the order of 50% are needed to help make wind energy competitive. New advances in aerodynamics, materials, generators, controls, and design tools must be incorporated into turbine designs to make wind-generated electricity competitive with conventional energy sources.

Four Steps to the Future

The next five years are critical for the U.S. wind industry. Market opportunities are multiplying as utilities, state and local governments, and the public are becoming more aware of the potential for wind power. The wind industry must place itself in a position to take advantage of these opportunities. The DOE programs are designed to assist industry activities to meet these challenges. First, existing wind plant operators and developers must remain healthy and competitive. Second, new products, which combine the best of existing designs with new research and technology, must be ready for deployment in the near term. Third, a next generation of utility-grade wind turbines must be developed for the year 2000 and beyond. Finally, prototype turbines must be thoroughly tested and introduced to the marketplace through utility participation.

The goal of the VET Program is to assist the U.S. wind industry in developing near-term (mid 1990s) conventional commercial wind turbines for both domestic and international markets, and in strengthening domestic production of commercial turbines.

The goal of the Advanced Wind Turbine (AWT) Program is to assist U.S. industry in incorporating advanced wind turbine technology into utility-grade wind turbines for the near term (1993-1995), and to provide the next generation of utility-grade wind turbines for the midterm (late 1990s).

The goal of the Utility Wind Turbine Performance Verification Program is to deploy and evaluate commercial-prototype wind turbines in typical utility operating environments to provide a bridge from development programs currently under way to commercial purchases of utility-grade wind turbines.

These programs will help introduce new products into the marketplace, support the development of new jobs domestically, help create greater stability and strength in the wind industry by attracting utility participation, broaden the national use of wind energy, and increase competitiveness in the international marketplace.

Value Engineered Conventional Technology

Over the past ten years, U.S. wind plant operators have gained considerable knowledge and operating experience with the current generation of wind turbines in the California wind farms, and have developed an understanding of the most dependable features in conventional wind turbine designs. Many wind turbines of this generation have achieved the high levels of reliability sought by wind plant operators, but the energy generated by these turbines is still more expensive than tolerable for long-term survival in an increasingly competitive global energy market. The VET program will support these U.S. wind plant operators in the value analysis, manufacturing, and commercialization of these turbines, and it will endeavor to assure that highly reliable, economically competitive U.S.-built wind turbines are available to meet near-term market demands. The value engineering of proven designs will provide a fast transition to more economic wind systems, with low technical and financial risk. The concept of value engineering focuses on removing unnecessary costs from a design while assuring that its quality, reliability and performance are maintained.

The primary objectives of the VET Program are to (1) support U.S. organizations that have demonstrated expertise in wind energy to improve the cost effectiveness, reliability and manufacturing quality of proven conventional wind turbine configurations for near-term market opportunities; (2) expand the domestic production of commercial wind turbines; and (3) accelerate the maturation of existing U.S. wind energy businesses by promoting the development of sustained engineering and manufacturing capabilities.

A Request for Proposal (RFP) scheduled for issue on November 25, 1992, will initiate the VET program. Subcontractors selected under this program must be capable of rapidly developing a manufacturing capability to produce a utility-grade wind turbine generator in one to two years. These value-engineered turbines will be of a conventional design and will not depart from the turbine configuration upon which they are modeled in any radical way. For example, the number of blades and the rotor control method will not be changed. Value-engineered turbines will be based on reliable, proven configurations with high demonstrated capacity

factors and a multi-year operating history with at least 20 MW of cumulative installed capacity worldwide. It is anticipated that wind turbine development projects similar to the VET Program are already under way at various stages of progress within the wind energy industry. To accommodate this diversity, the VET Program will consider a range of project types to assist wind plant operators in implementing their existing wind turbine development plans.

Project teams under the VET Program will characterize the performance of the proposed turbine or configuration, and perform value engineering analyses of wind turbine components and subsystems. Subcontractors will prepare detailed engineering designs of final wind turbine configurations, develop business plans, fabricate and install one value-engineered prototype turbine system, and conduct field tests.

Near-Term Innovative Products

The AWT Program is assisting U.S. industry to explore and develop new wind turbine products. The first projects conducted under the AWT Program were Conceptual Design Studies. The purpose of this early work, which began in 1990, was to (1) study improvements to existing wind turbine configurations, designs, and manufacturing methods that would make wind energy a significantly more competitive electricity source in the 1993-1995 timeframe; and (2) initiate conceptual studies of advanced wind turbine configurations that would be competitive for bulk electricity generation at moderate wind speeds over large geographic regions by 1998-2000. Results of the conceptual design studies show promising performance and reliability enhancements and COE reductions for improved next-generation wind turbine designs.

Concepts identified as key elements to improve existing designs included (1) increased rotor sizes to take advantage of advanced NREL airfoils, (2) flow-through rotor structures, (3) aileron controls, and 4) integrated gearboxes and mainframes. In many cases, the application of new engineering tools points to simple design changes that can greatly improve reliability and performance.

The final task of the conceptual design studies required the introduction of innovations and major architectural changes to overcome the problems associated with the existing machines. Concepts that were developed to significantly improve the performance of the next-generation of wind turbines include (1) aerodynamically shaped, wood/epoxy rotating towers; (2) totally integrated drivetrain configurations directly mounted to tower top castings; (3) improved thin and thick airfoils optimized for new aero-controls; and 4) taller towers.

Ideas developed by these subcontractors only scratch the surface of potential innovations. Numerous ideas arose in the 1970s and 1980s and were not fully developed because of a lack of funds, resources, or time. Many other promising ideas were prematurely implemented on wind turbine designs and, as a result, were discredited. History has shown that the understanding of many wind engineering concepts was at best intuitive, and that many assumptions about performance and reliability of materials and equipment were incorrect. A rigorous iterative process of design, build, and test before commercialization is a key component to future success.

The current activities under the Near-Term Product Development Phase of the AWT Program focus on products for introduction to an expanded marketplace in the 1995 timeframe. The introduction of the federal $0.015/kWh tax incentive opens a wide range of possibilities for the introduction of wind technology into yet untapped wind resource areas. New machines that can produce electricity at $0.05/kWh will be well suited to take advantage of the offered tax credit for new capacity, as well as to fill existing space or replace non-working units in wind farms still covered under active Standard Offer 4 contracts.

During fiscal year 1992, an RFP was issued under the AWT Program for the development of improved near-term products that were based on existing designs. Five subcontracts are anticipated under this project, with durations of two to three years. These subcontractors will develop prototype turbines that will implement incremental improvements to units currently running in a production environment. Subcontractors began their

work during the summer of 1992 to design, fabricate, and test prototypes based on these existing designs. Eight principal design tasks make up the scope of work for each of the subcontractors: (1) assessing a baseline turbine for design improvements; (2) determining the potential of candidate improvements; (3) analyzing the effects of proposed improvements on the preliminary advanced wind turbine system design; (4) fabricating critical components and subsystems and performing qualification tests; (5) developing a final prototype advanced wind turbine design; (6) developing manufacturing, maintenance, and commercialization plans; (7) fabricating two prototype advanced wind turbine systems; and (8) installing two prototype advanced wind turbine systems and performing field tests for a minimum of one wind season. Carefully applying improved design techniques and tools, integrated with thorough testing, is key in these projects. DOE will support the refinement of these turbines through research, testing, and other cooperative activities. Field tests of preprototype turbines, and qualification tests of improved components and subsystems under this project, are scheduled to begin as early as January 1993.

A Next Generation of Technology

The objective of the Next-Generation Phase of the AWT Program is to stimulate U.S. industry to explore new concepts and apply cutting-edge technology for the development of commercial utility-grade wind turbines for the 1998-2000 timeframe. These innovative wind turbines are expected to produce electricity for the grid at $0.04/kWh at 5.8 m/s (13 mph) wind sites. Primary factors must be addressed to reach this COE goal, including reduced turbine capital cost, increased performance and reliability, and decreased operations and maintenance costs.

The development of innovative utility-grade designs cannot be accomplished by step-wise or incremental improvements to old designs, even though such step-wise improvements may offer important insights into performance and reliability problems. The Next-Generation Phase will encourage participants to broaden their vision and emphasize innovation. By starting with a blank sheet of paper and taking an overall systems view of wind energy, the program will foster new ideas and concepts. Participants will explore high-risk, high-reward components and configurations. Uncoupling designers from current ideas is critical to making a quantum jump in performance.

The Next-Generation Phase will consist of two projects. The Preliminary Design Project will be first, and will ask participants to (1) document an innovative, utility-grade wind turbine concept; (2) design, fabricate, and test innovative components; and (3) develop a complete preliminary design of an advanced prototype wind turbine. Participants will be encouraged to complete as many cycles of design and testing as can realistically be accomplished in the planned duration of these projects; because only through iterative testing and design refinement can the best new ideas be perfected.

The second project in the Next-Generation Phase is the Prototype Turbine Development Project, which will support industry to develop final designs and fabricate, install, and test utility-grade prototype wind turbines incorporating innovative concepts. These activities will be executed over a period of 24-36 months depending on the size and complexity of turbines and long lead times for critical components.

This cycle of preliminary design followed by prototype turbine development will be repeated again in 18 months to two years after the start of the first preliminary design contract. A third cycle of preliminary design and prototype turbine development is planned to begin 18 months to two years after the start of the second cycle. This continuing cycle of design and development will allow many participants to conceive new designs and evolve them to working prototypes for testing. The first solicitation for next-generation projects is scheduled for January 1993. This RFP will include specifications and evaluation criteria developed with input from members of the wind industry and the utility industry. A notice of intent to issue the first next-generation RFP was published in the *Commerce Business Daily* and the American Wind Energy Association newsletter, and it was independently distributed to key members of the utility community during the summer of 1992 to obtain input to this process.

NREL will continue to support industry during these development activities with direct engineering support and parallel research activities. Other DOE cooperative research programs will also provide a means to continue the refinement of these prototype turbines beyond the AWT Program.

Entering the Marketplace

The primary market for the products developed under DOE's Wind Turbine Development Programs is the utility industry. Successful utility market penetration will depend on key factors such as low COE to compete with conventional energy sources, high reliability to reduce technical and financial risks, and minimal environmental impact. Utility acceptance of wind-generated electricity will continue to increase as the performance and reliability of new wind turbine products are thoroughly demonstrated. The Utility Wind Turbine Performance Verification Program is being developed with the goal of deploying and evaluating commercial-prototype wind turbines in typical utility operating environments to provide a bridge from DOE sponsored and private development programs currently under way to commercial purchases of utility-grade wind turbines. The underlying foundation for the EPRI and DOE collaborative venture in wind power development is to hasten wind power commercialization and the realization of its environmental and energy-security benefits.

From this foundation, the following program objectives have been set: (1) Establish deployment and testing projects with at least four host utilities that will provide statistically valid performance, operation, and maintenance experience with commercial-prototype, utility-grade turbines. Two of these projects are to be established by mid-1993. (2) Document and communicate the experience from these projects over the period 1993-1997 for the benefit of utilities, turbine suppliers, and others in the wind-power development and user communities.

Competitively selected host utilities will choose the installation site, specify the operating conditions, solicit bids from wind turbine vendors, and establish agreements with selected vendors. With EPRI and DOE assistance, the host utility will establish a test program, evaluate turbine performance and reliability, and assist in transferring information to the utility and wind power industries. Benefits to the host utility will include the following: first-hand experience with, and ownership of, a demonstration wind power plant of at least 6 MW using the latest technology; recognition of leadership in renewables development; influence on technology development; and early access to information on other demonstration wind power plants.

Conclusion

The combined activities under the AWT, VET, and Utility Wind Turbine Performance Verification programs form a broad approach to expanding U.S. competitiveness in wind turbine technology, engineering skills and manufacturing capability. Such a diversified approach is necessary to accelerate the development of wind technology as a cost competitive, environmentally benign, energy source to meet the projected needs of growing domestic and international markets. Development programs supported by DOE, EPRI, and utilities will assist U.S. industry to develop advanced wind technology necessary to meet energy demands in the 1990s and the 21st century.