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The Federal Advanced Wind Turbine Program

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THE FEDERAL ADVANCED WIND TURBINE PROGRAM

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ABSTRACT

The development of technologically advanced, higher efficiency wind turbines has been identified as a high priority activity by the U.S. wind industry. The Department of Energy's Wind Energy Program has begun a multi-year development program aimed at assisting the wind industry with the design, development, and testing of advanced wind turbine systems that can compete with conventional electric generation for $0.05/kWh at 13 mph sites by the mid-1990s and with fossil-fuel-based generators for $0.04/kWh at 13 mph sites by the year 2000. The development plan consists of four phases: 1) Conceptual Design Studies, 2) Near-Term Product Development, 3) Next Generation Technology Integration and Design, and 4) Next-Generation Technology Development and Testing. The Conceptual Design Studies were begun in late 1990, and are scheduled for completion in the Spring of 1992. Preliminary results from these analyses are very promising and indicate that the goals stated above are technically feasible. This paper includes a brief summary of the Conceptual Design Studies and presents initial plans for the follow-on activities.

BACKGROUND

Current designs of wind turbines deliver energy to the electric grid at a generation cost of about $0.07/kWh to $0.09/kWh, depending on the design and the wind resource. Although these costs may have been economically feasible during the early to mid-1980s, when most of the current wind farm developments were installed, they would not be considered profitable in today's utility market. A decade ago, electric utilities were forecasting steep escalation rates for the costs of most fossil fuels and thus were willing to sign contracts with wind farm developers that offered very lucrative buy-back rates.

This is not the case today, and wind-generated electricity must now compete with conventional generation sources at much lower rates, starting as low as $0.02/kWh, depending on the generation mix and load-demand growth of the participating utility. These avoided costs are primarily constituted by fuel displacement; however, some capacity credit may be warranted, depending on the match between the wind generation and the utility's peak loads. Utility-avoided costs are projected to increase at a modest rate over the next 10 to 20 years as the excess capacity for generation sources with very inexpensive operating costs, such as hydro and nuclear, is used up.[1]

To compete in this dramatically changing market, the wind industry must improve the technology so the cost of delivered energy is reduced to 50% of that of the current technology deployed in California. Figure 1 shows the cost of energy (COE) projections for wind energy as a function of annual average wind speed and time. The figure also includes the projected fuel costs for generating electricity from natural gas and coal as a function of time.

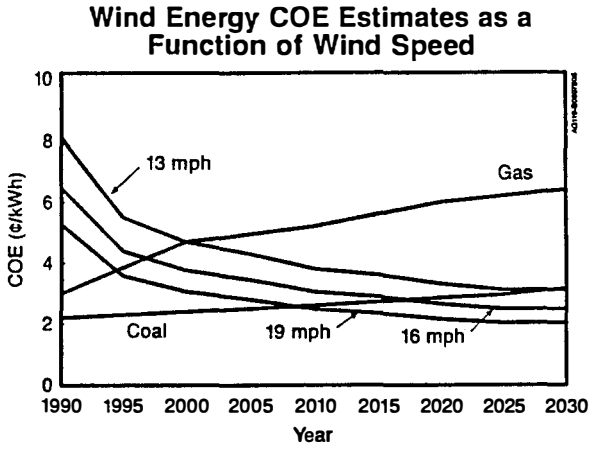


Figure 1. Wind Energy COE Estimates as a Function of Wind Speed

Present wind turbine designs are representative of the technology level of the early 1980s and reflect an inadequate knowledge of the operating environment. Wind turbines currently deployed in the California wind farms are being subjected to a real-world environment that imposes unanticipated loads on rotors, drive trains, and towers. Subsequently, many of the wind turbines are experiencing operational problems including substandard performance and reliability. The operational experience of the last decade, combined with recent research and technological advancements, provides the wind community with the opportunity to develop improved hardware at reduced costs.[2] The Federal Wind Program intends to build on this knowledge and assist industry with the development of advanced wind turbine systems to enhance industry's efforts to compete in the marketplace.

PROGRAM GOAL

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

The success of this program will help introduce new products into the marketplace; help create greater stability and strength in the wind industry by attracting utility participation and broadening the National use of wind energy; and increase competitiveness in the international marketplace.

The plan for the program consists of four phases: 1) Conceptual Design Studies, 2) Near-Term Product Development, 3) Next-Generation Technology Integration and Design, and 4) Next-Generation Technology Development and Testing. The two-path development approach is depicted in Figure 2, showing both the Near-Term Product Development (Phase II) and the Next-Generation Technology Development (Phases III and IV).

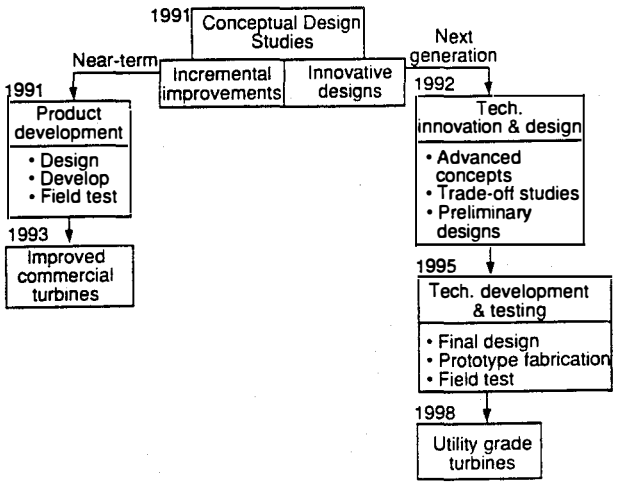


Figure 2. Advanced Wind Turbine Program

PHASE I: CONCEPTUAL DESIGN STUDIES

The first program phase, Conceptual Design Studies, began in late 1990 with the award of three subcontracts and will continue through the spring of 1992. The objectives of the first phase are to: 1) study improvements to existing baseline wind turbine configurations, designs, and manufacturing methods that will 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 will be competitive for bulk electricity generation at moderate wind

speeds over large geographic regions by 1998-2000. Initial study results have projected promising performance and reliability enhancements and cost of energy reductions for the improved wind turbine designs in comparison with the baselines.

The three subcontracts were awarded to Atlantic Orient Corporation, Northern Power Systems, and R. Lynette and Associates. Each of these subcontractors assembled teams of experts in order to address the diverse technical requirements of the conceptual design effort. The team members are presented in Figure 3. We believe that the participation of component manufacturers, wind farm operators, and maintenance suppliers, as well as electric utilities, provides a well-balanced team that can address all of the important aspects of wind turbine design and integration.

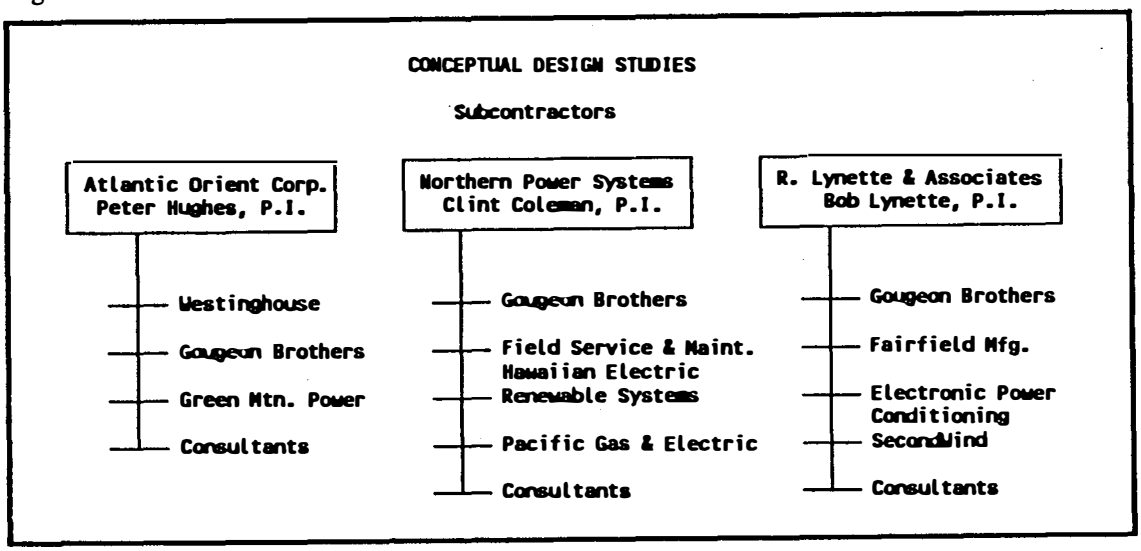
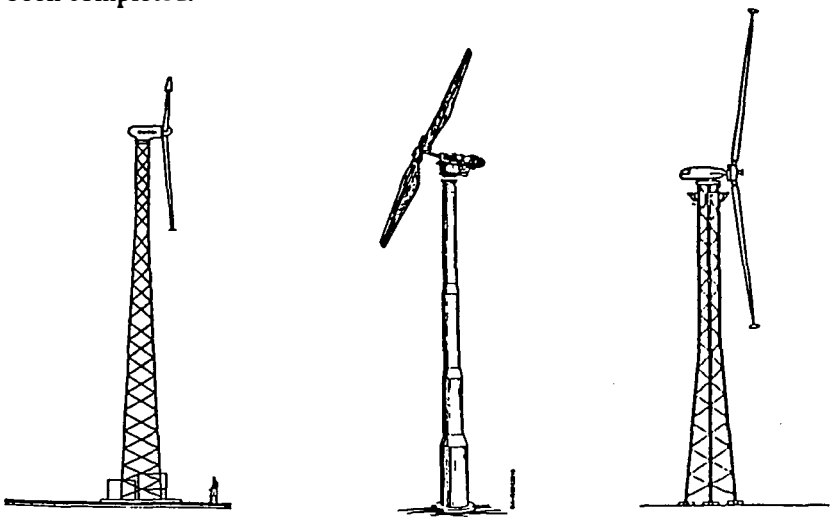


Figure 3. Conceptual Design Studies Participants

The approach used for this conceptual design study is comprised of three tasks. Under Task 1, the subcontractors assessed an existing wind turbine, examining component weights and costs, loading histories, energy capture, operation and maintenance costs, and durability or expected lifetime. From this in-depth analysis, they identified problems associated with the turbine. Potential solutions involving incremental improvements to the baseline design were then described in Task 2, to achieve a mature technology targeted for 1993-1995. Figure 4 shows the baseline turbines selected by each of the studies: the Enertech 44, the Northwind 100, and the ESI-80. Tasks 1 and 2 have been completed.



Atlantic Orient Corp.
Enertech 44

Northern Power Systems
North Wind 100

R. Lynette & Assoc.
ESI-80

Figure 4. Baseline Turbines

Task 3 of the studies, currently under way, allowed the introduction of new innovations and major architectural changes to overcome the problems associated with the baselines. The innovative designs targeted for 1998-2000 are expected to be comprised of currently unexplored subsystem concepts. The objective here is to further reduce costs, while increasing energy capture and reliability.

The relative merits of the baseline, improved design, and innovative design are computed under the assumption that the turbines will be installed in a 50-MW wind farm. This installation size also defined the production level for estimating initial costs and annual operation and maintenance costs. The primary figure of merit used in this study for comparison purposes is the life-cycle cost of energy as defined in detail in Reference 3. Since the annual energy output depends on the operating wind regime, the mean annual windspeed frequency duration curve, turbulence levels, and wind shear characteristics were defined for three representative sites.

Final reports from each subcontract will be published in the spring of 1992. Initial results indicate that the cost goals set by the Wind Energy Program for both the near-term and the next-generation designs are technically feasible.

PHASE II: NEAR-TERM PRODUCT DEVELOPMENT

The objective of the second program phase, Near-Term Product Development, is to rapidly develop advanced wind turbine systems that will be commercialized in 1994-1995 and meet near-term utility market needs for nonpolluting electrical energy supplied for $0.05/kWh at 13 mph wind sites. The project, consisting of competitively selected subcomponents, is structured to minimize the cost, risk, and time of developing a cost-competitive, reliable advanced wind turbine for the expected near-term utility market. The successful completion of this effort will increase the competitiveness of U.S. industry in the near term, and also encourage regional diversification of wind energy.

The approach for the Near-Term Product Development Project will begin with the evaluation of an existing baseline wind turbine that has a proven operational history and a thorough data base. The baseline turbine will be used to guide the redesign and improvement of key components and subsystems. The most promising component and subsystem improvements will be integrated into the baseline to develop an improved wind turbine that can meet the enhanced performance, reliability, and reduced cost of energy needs of the near-term utility markets. Special emphasis will be placed on applying efficient manufacturing methods, and on defining system production costs during the development. Two prototype turbines will be field tested at a wind farm site to validate the operational and structural characteristics of the system design.

The Wind Energy Program expects to award between two and four subcontracts under this phase of the AWT Program, with anticipated starting dates in the summer of 1992. Prototype testing for the Near-Term Product Development project is planned to be completed by the end of 1994.

PHASES III AND IV: NEXT GENERATION TECHNOLOGY DEVELOPMENT

The planned third and fourth phases of the AWT Program form the Next-Generation Technology Development Program. The objective of these two phases is to develop innovative, utility-grade wind turbines that will be commercialized in 1998-2000 and can supply electricity for $0.04/kWh at 13 mph wind sites. The Next-Generation Technology Development Program is structured to maximize wind turbine design innovation to obtain large increases in performance and reliability and a reduction in the cost of energy.

In order to foster a broad range of innovation, the development effort has been structured in two separate phases. Phase III, the Technology Integration and Preliminary Design activity, will focus primarily on the development of new innovations; at the same time, it will reduce the risk inherent in product development. Phase IV, the Technology Development and Testing Phase, will involve the final design, fabrication, and field testing of next-generation wind turbine prototypes. Phase III is planned to begin by the end of 1992 and to last about 2 years. Phase IV will follow and begin in 1994, and end with operational tests by 1997.

CONCLUSIONS

The AWT Program has been initiated to assist industry efforts in incorporating advanced technology into the marketplace. The Program is planned to span about 7 years and is designed to be performed in cooperation with

industry partners. The successful completion of the development efforts will signficantly increase the competitiveness of the U.S. industry for the near-term (1995) and the mid-term (2000). This, in turn, will stimulate increased utility participation and acceptance of the technology, leading toward regional diversification of wind energy and a significant penetration into domestic and international utility markets.

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