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STATUS OF WIND-ENERGY CONVERSION

by Ronald L. Thomas and Joseph M. Savino
Lewis Research Center
Cleveland, Ohio 44135

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by Ronald L. Thomas and Joseph M. Savino

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio

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INTRODUCTION

Can the energy in the winds be utilized to help meet our nation's energy needs? That is the primary question to be answered concerning a very old but presently little-used source of energy.

Wind energy has several advantages that make it worthy of a re-evaluation as a potential energy source. These advantages include:

1. Wind energy is a free, clean, nondepletable energy source. Wind is a form of solar energy that nature concentrates in certain areas and allows us to capture it without using a large amount of land area.

2. Preliminary estimates indicate that wind could supply a significant amount of our electrical requirements.(1)

3. Utilizing energy from the wind is technically feasible; this is discussed more in detail below.

The disadvantages of wind energy include its variability and the high systems costs of past efforts. On an hourly or daily basis, the winds are not dependable, but on a monthly and yearly average the winds are a rather firm energy source. Past experience has shown that wind energy systems have usually cost about two to five times as much as fossil fuel systems on a cost per kilowatt-hour basis.(2) However, now that fuels are becoming expensive, it is important to re-examine wind energy systems to determine if such systems can be made compatible with the variability of the wind and if the high costs of such systems can be reduced.

Obviously there is no doubt that wind generators are technically feasible. The question can then be asked: Why haven't they been more fully utilized? There appears to be several reasons:

1. The costs of wind-generator systems have been high compared to fossil-fuel systems.

(1) NSF/NASA Solar Energy Report: Solar Energy as a National Energy Resource, Dec. 1972.

(2) E. W. Golding, "Electrical Energy from the Wind," The Engineering Journal (England), June 1957.

2. The wind is variable and the wind generator by itself cannot always produce power on demand.

3. There have been no recent sustained development efforts, primarily because of reasons 1 and 2.

EXPERIENCE WITH WIND GENERATORS

Wind generators are technically feasible. Many moderate sized machines have been built and tested, for example:

1. The Dutch have used wind generators for years to provide power for pumping water and grinding grain. Figure 1 shows a typical Dutch windmill.

2. An experimental 100 kilowatt wind generator was built by the Russians at Balaclava in 1931. This wind generator, shown in figure 2, had a 100-foot-diameter rotor on a 100-foot tower and delivered 100 kilowatts at a wind speed of 24 miles per hour. In addition to this machine, many smaller machines have been installed in Russia to supply power to agricultural communities.

3. The Danes used wind as a major source of power for many years. They built the Gedser Mill System, shown in figure 3, in 1957 and operated it through 1968. This wind generator produced 200 kilowatts in a wind of 33 miles per hour with a rotor diameter of 79 feet and a tower height of 85 feet.

4. The English built several large wind generators. One machine was the Enfield-Andreau shown in figure 4. This machine was built in the early 1950's and had a maximum output of 100 kilowatts. The rotor was 79 feet in diameter mounted on a 100-foot tall tower.

5. The Smith-Putnam machine, shown in figure 5, was built in Vermont in 1941 and supplied power into the hydroelectric grid. This wind generator was the largest ever built with a rating of 1.25 megawatts in a 30 miles per hour wind from a 175 foot diameter rotor on a 110 foot tower.

6. The Germans did some fine work in the 1950's and 1960's under the direction of Dr. U. Hutter. Machines of 10 kilowatts and a 100 kilowatt were built and tested over this period. The machines used light Fiberglas blades with a simple hollow pipe tower with guy wires as shown in figure 6. An interesting point of this design is that it delivered its rated output of 100 kilowatts at 18 miles per hour. At 18 miles per hour most of the other machines were just beginning to produce power. The German effort represents the most modern work to date for machines of this size.

No large machines are presently in operation. However, several firms around the world are supplying wind generators in the range of

5 kilowatts or less.

DISCUSSION

As mentioned above, the wind is not dependable on a short-term basis but on a monthly and yearly basis, the winds are fairly reliable. Several options are available for reducing or accommodating the effects of wind variability; these are:

(1) Storage systems, such as those shown in figure 7, including batteries, flywheels, pumped hydro-storage, compressed air, and electrolysis of water to hydrogen

(2) Connecting wind generators to small diesel-electric systems as shown in figure 8. Such systems would save fuel and provide supplemental power.

(3) Large wind systems may be connected to hydroelectric systems (fig. 9) to provide base-load power. In such an arrangement the wind generators could supply power whenever the wind is blowing allowing water to be saved to be used as the wind drops off. Our hydroelectric systems are water limited and wind generators could increase the base load of the systems.

(4) Wind generators connected in a large grid (fig. 10) may prove practical for generating base-load power. Over a large area the wind may be always operating some percentage of the wind generators.

PLANNED PROGRAM

Studies sponsored by NASA and the NSF are planned to assess these applications and to determine the cost goals for the wind-generator systems. Several research areas will be included in the program for the development of wind as a practical energy source; these include:

(1) Cost reduction of subsystems, components and total systems

(2) Wind characteristics to determine practical potential in the U.S., the wind regions, and preferred sites

(3) The user requirements including verification of site characteristics

(4) The legal, environmental, institutional, and aesthetic issues

(5) The testing of larger and improved systems

Some of the first steps in this program are:

(1) Design, build, and test modern machines for actual applications. This will provide baseline information for assessing the potential of wind energy as an electric power source.

(2) Operation of wind generators in selected applications for determination of actual power costs

(3) Identification of subsystems and components that may be further reduced in cost.

The practical conversion of wind energy is a major part of the NSF $12 million FY 1974 Solar Energy Program. The NASA-Lewis Research Center **has also been working in the area of wind conversion for about two years. Lewis, at the request of the Puerto Rican government, has** agreed to perform a conceptual design of a wind generator for Puerto Rico. Puerto Rico has favorable winds and a rapidly increasing demand for electric power. Possibly, wind power may prove to be a valuable source of energy for Puerto Rico. The NASA will be contributing to the overall NSF Wind Program, particularly in the 100 kilowatt and megawatt size conversion systems. From the 100 kilowatt and megawatt systems tests, it will be possible to make a realistic assessment of wind energy conversion systems costs, operating characteristics, and the potential for significant power production.

As its part of the program, NASA will design the 100 kilowatt system for test in 1975. This machine will be similar to the German design shown in figure 6. The NASA design calls for a rotor of 125 feet in diameter mounted on a 125-foot tower. The machine is designed to provide a net output of 100 kilowatts in a wind velocity of 18 miles per hour. The controls will be located in a remote control room at the base of the tower. The pitch of the rotor blades will be varied to maintain synchronous speed for the generator.

The NASA-designed 100-kilowatt system will provide operation and performance data and an indication of the costs of wind energy. By 1976 additional 100 kilowatt field tests are planned in several locations of the country. In parallel with the 100 kilowatt projects, megawatt designs will also begin this year. The results of the 100 kilowatt tests and the Phase 0 applications and wind studies will help directly in the megawatt systems design. If these results are satisfactory, testing of a megawatt system is planned for 1976-77, with larger systems following.

CONCLUDING REMARKS

In conclusion, the following comments are relevant to the utilization of wind energy as a source to help meet our energy needs.

1. The utilization of wind energy is technically feasible as evidenced by the many past demonstrations of wind generators.

2. The cost of energy from the wind has been high compared to fossil-fuel systems; a sustained development effort is needed to obtain economical systems. Also, wind-energy systems will become more economically competitive if present fossil fuels continue to rise in price.

3. The variability of the wind makes it an unreliable source on a short-term basis. However, the effects of this variability can be reduced by storage systems or connecting wind generators to (1) fossil fuel systems, (2) hydroelectric systems, or (3) dispersing them throughout a large grid network.

4. Wind energy appears to have the potential to meet a significant amount of our energy needs. It will not meet all our needs, as will no other one source.

Wind energy is one of the clean, nondepleting energy sources that should be seriously investigated as a source to help meet our nation's energy needs.

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Figure 1. - Typical Dutch windmill.

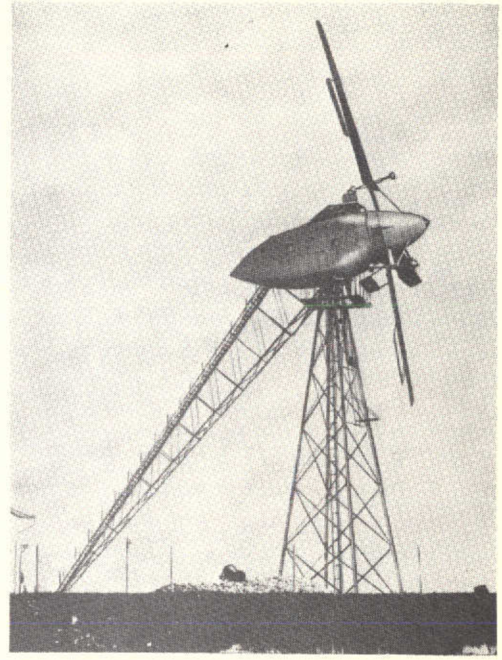

Figure 2. - 100 kW (24.6 mph wind) Russian wind generator.

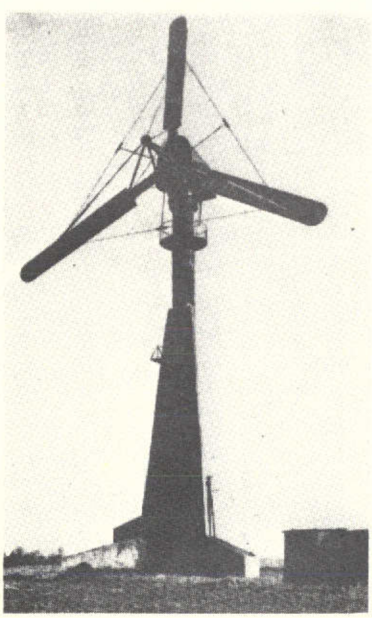

Figure 3. - Danish Gedser mill wind-turbine 200 kW (33.6 mph wind).

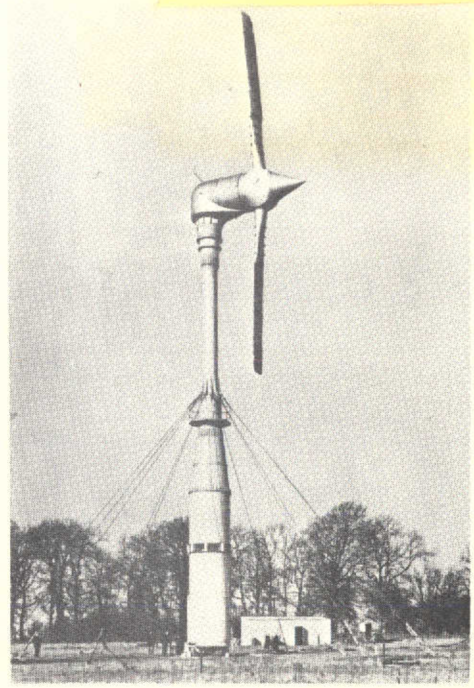

Figure 4. - English Enfield-Andreau wind-turbine 100 kW. (30 mph wind.)

Figure 5. - American Smith-Putnam wind generator 1.25 mW (30 mph wind).

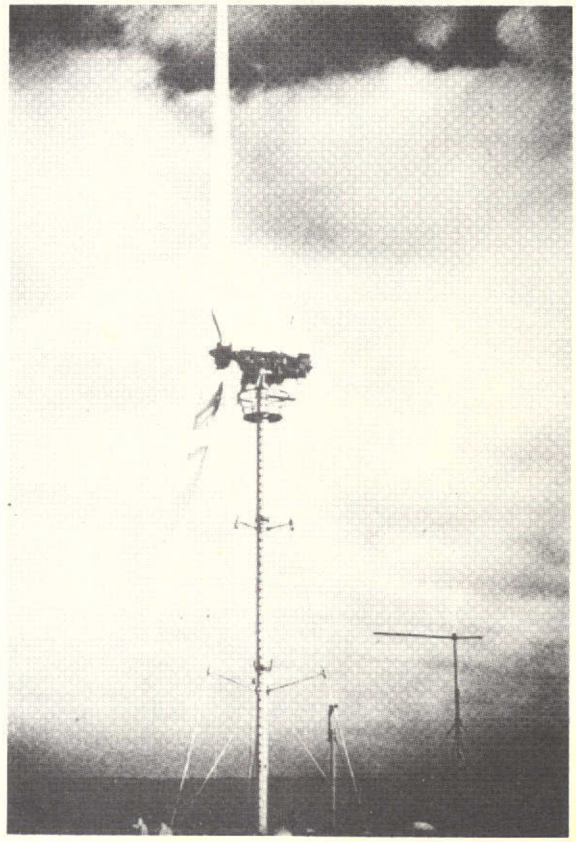

Figure 6. - German (Hutter designed) wind generator 100 kW (18 mph wind).

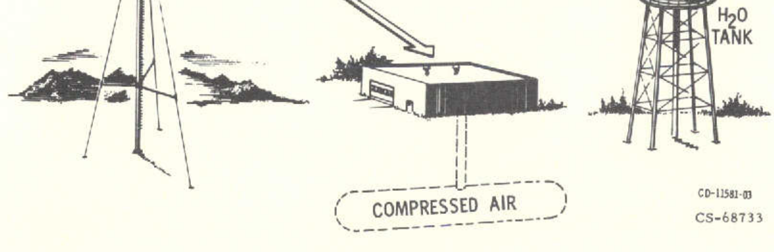

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Figure 7. - Storage systems for wind generators.

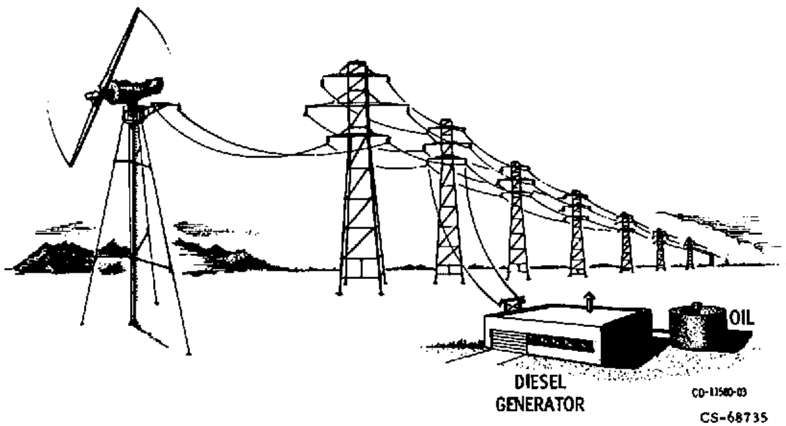

Figure 8. - Wind generators with existing Diesel-Electric Systems.

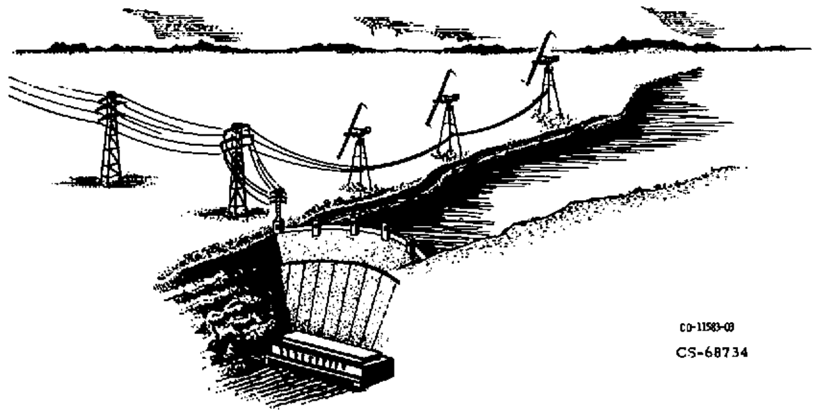

Figure 9. - Wind generators integrated with Hydro-Electric Systems.

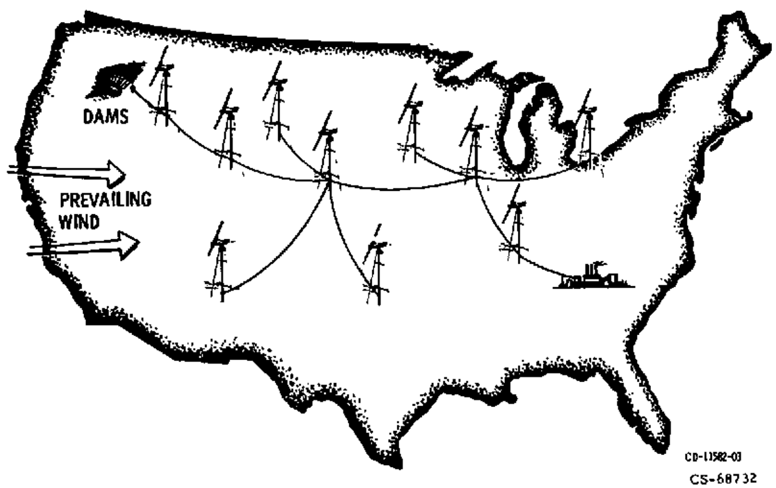

Figure 10. - Wind generators integrated on a large grid.