CHIMIA 43 (1989) Nr. 7–8 (Juli–August)

Wind Energy

Marc S. Chappell, Finn Ingebretsen, Hans Larsen, Joergen Loevseth, and Jorge A. Gil Saraiva*

Jorge A. Gil Saraiva: Born 1951 in Lisboa, Portugal. Received his Ph.D. in structures in 1983 from National Laboratory for Civil Engineering (LNEC) where he worked at the Applied Dynamics Division, in the field of natural actions effects on structures. He joined Renewables Energy Department of National Laboratory for Engineering and Industrial Technology (DER/LNETI) in 1987 to head the Wind Energy Program. He is Deputy Director of DER and Invited Professor of Fluid Mechanics at the College of Engineering (IST) of Lisbon University.

1. General Perspectives

In considering the question «Where should wind energy technology be in 25 years from now?» and the concomitant «What needs to be done to get there?», the group made two general observations. Firstly, in some countries wind energy could contribute 10% or more of national electricity supplies (in absolute terms a very large amount of energy indeed). Secondly, it was anticipated that although significant research and development is still needed to achieve these levels of energy contribution it will be predominantly evolutionary, rather than revolutionary in nature.

Considerable progress has already been made towards adequate understanding of the major aspects of wind energy conversion technology, viz:

- characterization and assessment of the resource;
- performance and energy conversion;
- structures and materials;
- integration and exploitation.

Indeed, two general configurations of *wind energy conversion systems* (WECS) have emerged from an almost infinite array of conceivable mechanisms: the *horizontal axis wind turbine* (HAWT) and the *vertical axis wind turbine* (VAWT). Both have similar technical potential, somewhat similar technical problems, and indeed much of the wind energy R&D done to date is equally applicable to both configurations.

In considering the overall-system aspects of wind energy conversion, the group noted that as the resource is already in the form of kinetic energy, it is inherently sensible that the conversion process(es) retain the high quality of the resource energy. Therefore, conversion of wind energy to mechanical and/or electrical energy is appropriate. Given the distributed nature of the resource, conversion to electricity has the added attraction of enabling wind energy to be integrated into existing electrical distribution networks. Moreover, techniques and equipment for further conversion of «aeroelectricity» into other energy sources are readily available, highly efficient, and cheap.

Notwithstanding the above, it is important that research and development of smaller non-electric wind energy systems be supported. Although such systems may not make significant contributions to national energy supplies, small wind energy systems (e.g. water pumps) are expected to be very important for technosociological growth in certain countries.

Wind energy conversion systems are chemically benign. They do not contribute to any form of chemical pollution, but they may have minor aesthetic, acoustic, and electromagnetic environmental impacts. A major environmental problem in the long run in some countries may be a limited number of acceptable on-shore sites for installing wind turbines.

2. Research Requirements

The basic tenets of wind energy technology and economics are understood, but substantial near- and longer-term research requirements have been identified as necessary for proper development and exploitation of this renewable energy resource.

2.1. Characterization and Assessment of the Resource

A better knowledge about the flow field is necessary for the development of better WECS, not only to improve the efficiency, but also to cope safely with extreme conditions and consequent design loads and fatigue problems. Hence, the characteristics of the Earth Boundary Layer (at the sites of installation) must be further assessed, namely the characteristics of turbulence (spectra, spatial correlations), extreme values of wind velocity, and the effects of topography. At the same time the phenomena of interference between wind and machine (machine elements) and between machines will have to be examined in much greater depth to establish adequate methodologies. In particular, research is needed to enable accurate and reliable

* For correspondence address, see List of Participants, p. 242.

hourly, day, and seasonal forcasting of wind intensity to enable production of wind power contribution as a function of time for utility system control and scheduling of generation equipment. Such forcasting capability would enable realistic capacity credits for WECS in integrated systems.

2.2. Performance and Energy Conversion

The power extraction of a wind turbine has a well-defined limit. Current (good) technology achieves about 80% of that limit, hence no real breakthrough is anticipated in this area. Energy production is equally dependent on reliability (i.e. power operating time) and availability over 95% is not unusual. However, more work is needed in order to achieve similar high values for the larger machines to be used in the future! Hence, it is observed that, though both performance and reliability will increase with time, no major gains are to be expected and no high-priority research topics were identified in this area. However, longer-term consideration should be given to co-optimal aerodynamic/structural-dynamic rotor designs and to specialized electrical conversion systems that better suit the wind turbine rotor characteristics. Such considerations might include high-torque/low-rpm generators, and power conditioning equipment to enhance compatibility whith electric utility networks.

2.3. Structures and Materials

Some of the most important subjects in relation to the future prospects for wind energy are the improvement of reliability and lifetime. At the same time, the amount of material used for the various structures is of paramount importance to the economoy of the wind turbine. This calls for long-term research and development with respect to improved materials developed for the special conditions encountered in wind turbines. The materials should be optimized with respect to weight, durability, costs, and lifetime. Among specific research areas can be mentioned:

- Better long-term fatigue data for currently used materials. Fundamental research is needed in order to understand the fatigue problems involved.
- Development of special materials for wind turbines, especially rotors.

On the basis of the research carried out concerning wind loads etc. improved design can be developed in order to optimize the entire (static and rotating) structure.

Hans Larsen: Born 1945 in Denmark. M.Sc. (Elec. Eng.), Ph.D. in reactor physics (1973). From 1973 to 1976 at Dragon project, AEE Winfrith, UK. Since 1976 at Risø National Laboratory, Roskilde, Denmark: Energy Technology Department 1976–1980, working with systems reliability; Head of Energy Systems Group 1980–1984, special interest: long-term prospects for new energy technologies; Head of Systems Analysis Department from 1985.

2.4. Integration and Exploitation

Wind generators are currently being coupled directly into the existing grids. Energy contributions of 5 to 10, and maybe 15% are thought to provoke relatively small problems or rather low extra cost.

International grids, effectively averaging the wind over a larger region will make integration into existing power supply systems easier. Integration into hydroelectric systems may be less problematic than other systems. If energy storage is needed, water can be pumped into existing reservoirs. The integration problem should be studied using existing programs from the utilities coupled with estimates for the available wind power at any time.

Wind/diesel systems are currently being studied for use in isolated communities. In the future, wind/biomass or wind/alcohol systems should be developed, e.g. the biomass driving a gas turbine system or steam turbine coupled to a generator.

In developing countries especially, there is a need for water pumping systems. Given a reservoir of some size, these systems will have storage capacity. Continued work on such systems should be encouraged.

Wind energy will fit nicely into a hydrogen system with some storage.

Wind energy can also be converted by using it (when available) to extract minerals using sea-water as a source, with fresh water as a valuable additional product. Special uses (on site) of the mechanical energy from the wind should be considered.

Wind energy combined with existing power sources, and future renewable energy resources, should be studied from a systems viewpoint. Larger diversity will in general increase the capacity factor.

3. Economics of Wind Energy

Wind energy conversion is economic today in certain applications, typically where wind velocities are high and conventional sources of electricity are expensive. Such circumstances are common in isolated communities, islands, etc. «Aeroelectricity» contributions into major grid networks are also now economic in premium wind areas. The value of «aeroelectricity»

Marc S. Chappell: Born 1936 in England. Emigrated to Canada. B.A.Sc. in mechanical engineering (1958) from University of British Columbia, and M. Eng. in aeronautical engineering (1964) from Carleton University. Worked at National Research Council Canada (NRCC) on gas turbine dynamic performance, cycle analyses, and compressor design; became Manager, Canadian Wind Energy R&D Program and Assistant Director of NRCC Energy Division; served for two years as Science and Technology Counsellor at the Canadian High Commission, London; currently Co-ordinator, Transportation Technology Program, NRCC.

will increase further when forcasting techniques are developed to enable accurate prediction of wind energy contribution, thus enhancing capacity credit.

More study and effort is required to establish fair and equitable criteria for judging the economic attractiveness of grid-integrated wind systems, including true value of energy, capacity credit, etc. An essential part of this process is to develop better mutual understanding and co-operation with elecrical utility companies.

4. A Future System?

The idea for placing wind turbines in the fast jet streams (well above 1000 m) has been put forward for some years. It has not yet been pursued towards any practical solution. The critical component in such a system is the combined electrical-mechanical connection to the surface.

The development of new light-weight, high-conductivity materials can change the feasibility from idea to reality within the next 25-year period.

5. Conclusions

Wind energy can make a substantial contribution to national and global energy supplies in the long term. Most of this energy will be contributed as electricity into existing systems, but important mechanical and other special applications of wind energy must be examined and assessed. Achievement of such goals will occur primarily by evolutionary progress in areas now being explored.

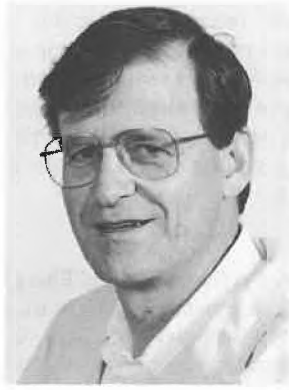
Wind energy has no significant chemical impact on its environment, during construction, operation or disposal of the WECS.

6. Recommendations

- Increase understanding of the resource characteristics by research on:
  - scale frequency of transients, ranging from turbulence (with significant effects on WECS) to longer-term variations (which affect energy capture and survival design criteria);
  - further develop methodologies for translation of large-area wind maps (wind atlases) into wind load data accounting for topographical influences;
  - develop windspeed forcasting methods (perhaps involving satellite data) to improve wind energy prediction and thus increase capacity credit;
  - investigate in detail the interaction mechanisms between the wind and the WECS, and between neighbouring WECS in arrays or clusters.
- Improve understanding of material and structural requirements of WECS, especially:
  - better fatigue data for currently used materials;
  - development of materials designed to WECS requirements;
  - co-optimize aerodynamic and structural-dynamic design of the entire WECS.
- Increase exploitability of WECS by devising and assessing special systems and applications well-suited to the variable, high-quality nature of wind energy.
  Applications might include:
  - material extraction (desalination) from seawater;
  - «freezing factory» with its inherent energy storage.

  Special systems might include:
  - ultralight (collapsible) constructions for very low wind requirements;
  - jet-stream WECS tethered by power-delivery cables.

  In certain circumstances, novel applications may require novel conversion mechanisms from the rotor-shaft power to end-use energy form.
- Together with proponents of other forms of renewable energy, create and develop economical forms of energy storage, with particular attention to storage of higher forms of energy such as electrical and mechanical energy.
  Furthermore, perform detailed and wide-ranging systems studies of wind energy systems combined with other renewable and conventional energy systems with the goal of establishing symbiotic combinations that are mutually beneficial, perhaps with little or no storage.
- Improve infrastructural aspects including:
  - methodologies for comparative cost/value analyses;
  - understanding/appreciation of integration difficulties;
  - knowledge of environmental impacts.



Finn Ingebretsen: Born 1937 in Oslo, Norway. Dr. philos. in nuclear physics from the University of Oslo (1973). Postdoctoral fellow at Chalk River Nuclear Laboratories, Canada. Associate professor at the University of Oslo from 1973. Main field of research: experimental nuclear physics and instrumentation, applied solar energy. Teaching physics and energy-related subjects. Member of various advisory committees on energy research policy. Head of physics department, University of Oslo.

This paper is supported by: B. Qvale (DK), A.J. Nozik (USA).