INTERNATIONAL ENERGY AGENCY

Programme of Research and Development on Wind Energy Conversion Systems (IEA R&D WECS)

ANNUAL REPORT 1984

A report by the IEA R&D WECS Executive Committee

January 1985

INTERNATIONAL ENERGY AGENCY

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Wind Energy Conversions Systems
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FOREWORD

This is the seventh Annual Report of the IEA Programme for Research and Development on Wind Energy Conversion Systems (IEA R&D WECS). The report summarizes the progress during 1984, and briefly reviews the achievements of the Programme since its start in 1977.

The report has been prepared by the Secretary of the Executive Committee with contributions from the Operating Agents. It is submitted to the IEA in accordance with the recommendations of the IEA Committee on Research and Development.

B Maribo Pedersen
Chairman of the
Executive Committee

/

B Pershagen
Secretary of the
Executive Committee

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EXECUTIVE SUMMARY

The IEA Programme for Research and Development on Wind Energy Conversion Systems (IEA R&D WECS) was initiated in 1977 by nine parties from Austria, Canada, Denmark, Germany, Ireland, the Netherlands, New Zealand, Sweden and the United States of America. Japan and Norway entered in 1978 and the United Kingdom (two parties) in 1980, bringing the total number of Contracting Parties to thirteen.

The IEA R&D WECS Programme started with four Tasks which have now been successfully completed. Three additional Tasks have been adopted, one of which has been completed. The Tasks are either cost-sharing or task-sharing or both. The level of effort is generally 10-20 person-years over 2-4 years. The status of the Tasks is as follows:

<u>Task I</u>	Environmental and Meteorological Aspects Wind Energy Conversion Systems
	Completed 1981
Operating Agent	National Board for Energy Source Development, Sweden
Participants	Austria, Canada, Denmark, Germany, Ireland, Japan, the Netherlands, New Zealand, Norway, Sweden, the UK and the USA
<u>Task II</u>	Evaluation of Models for Wind Energy Siting
	Completed 1983
Operating Agent	US Department of Energy
Participants	Canada, Denmark, Germany, Japan, Norway, Sweden, UK, USA

<u>Task III</u>	Integration of Wind Power into National Electricity Supply Systems
	Completed 1983
Operating Agent	Kernforschungsanlage Jülich GmbH, Germany
Participants	Germany, Japan, Netherlands, Sweden, USA
<u>Task IV</u>	Investigation of Rotor Stressing and Smoothness of Operation of Large-Scale Wind Energy Conversion Systems
	Completed 1980
Operating Agent	Kernforschungsanlage Jülich GmbH, Germany
Participants	Denmark, Germany, Japan, Netherlands, Sweden, USA
<u>Task V</u>	Study of Wake Effects behind Single Turbines and in Wind Turbine Parks
	Completed 1984
Operating Agent	Netherlands Energy Research Foundation
Participants	Canada, Denmark, Ireland, Japan, Netherlands, Sweden, UK, USA
<u>Task VI</u>	Study of Local Wind Flow at Potential WECS Hill Sites
	To be completed 1985
Operating Agent	National Research Council of Canada
Participants	Canada, Denmark, Germany, New Zealand, UK
<u>Task VII</u>	Study of Offshore WECS
	To be completed 1986
Operating Agent	Central Electricity Generating Board, UK
Participants	Denmark, Netherlands, Sweden, UK, USA

Results from the completed and on-going Tasks have been documented in a wealth of technical reports of restricted circulation and published as conference papers or in scientific journals. Selected documents are listed in the report.

The Standing Committee for Recommended Practices for Wind Turbine Testing and Evaluation, a subsidiary body to the IEA R&D WECS Executive Committee, has published three documents during the year, concerning fatigue evaluation, measurement of noise emission, and quality of power. Earlier documents in this series have received wide circulation in the wind energy community.

The IEA R&D WECS cooperation has produced useful results and clearly stimulated wind energy research and development in the participating countries. The Executive Committee is actively considering new opportunities for collaborative work. During 1984 two new Annexes were adopted on a Study of Decentralized Applications for Use of Wind Energy and on Extended Wake Effect Studies. Additional proposals were discussed some of which are likely to develop into new Annexes.

Italy, Spain, Switzerland and the Commission of European Communities were invited to join the Agreement. Representatives of these countries and the CEC participated as observers in Executive Committee meetings.

THE IEA R&D WECS PROGRAMME

This report reviews the progress during 1984 of the Programme of Research and Development on Wind Energy Conversion Systems (IEA R&D WECS) initiated in 1977 under the auspices of the International Energy Agency. For special reasons, an overview of the achievements during the previous years is also presented.

IEA R&D WECS is one of two IEA programmes in wind energy. The companion programme is directed to Co-operation in the Development of Large-Scale Wind Energy Conversion Systems (IEA LS WECS) and is reported separately.

The general objectives of IEA R&D WECS is to undertake collaborative research and development Tasks as defined in Annexes to the Implementing Agreement. To-date seven Tasks have been initiated, five of which have been completed. In 1984, two additional Tasks were approved by the Executive Committee, but the legal procedures for implementing the corresponding Annexes have not yet been concluded. The Tasks are listed below:

Task I — Environmental and Meteorological Aspects of Wind Energy Conversion Systems
Operating Agent: National Board for Energy Source Development, Sweden
Completed 1981

Task II — Evaluation of Models for Wind Energy Siting
Operating Agent: US Department of Energy
Completed 1983

Task III — Integration of Wind Power into National Electricity Supply Systems
Operating Agent: Kernforschungsanlage Jülich GmbH, Germany
Completed 1983

Task IV Investigation of Rotor Stressing and Smoothness of Opeartion of Large-Scale Wind Energy Conversion Systems
Operating Agent: Kernforschungsanlage Jülich GmbH, Germany
Completed 1980

Task V Study of Wake Effects behind Single Turbines and in Wind Turbine Parks
Operating Agent: Stichting Energieonderzoek Centrum Nederland
Completed 1984

Task VI Study of Local Wind Flow at Potential WECS Hill Sites
Operating Agent: National Research Council of Canada
Initiated in 1982, to be completed in 1985

Task VII Study of Offshore WECS
Operating Agent: Central Electricity Generating Board, United Kingdom
Initiated in 1983, to be completed in 1986

Task VIII Study of Decentralized Applications for Use of Wind Energy
Operating Agent: To be determined
Approved in 1984

Task IX Intensified Study of Wake Effects behind Single Turbines and in Wind Turbine Parks
Operating Agent: To be determined
Approved in 1984

The Implementing Agreement was originally signed by nine parties from Austria, Canada, Denmark, Germany, Ireland, the Netherlands, New Zealand, Sweden and the United States. Japan and Norway joined in 1978 and the United Kingdom (two parties) in 1980. The countrywise participation in the implemented Annexes is shown in Table 1.

Tasks I, III and IV are cost-sharing projects, which means that the participating countries contribute in-cash to a project carried out in one of the countries. Tasks II, VI and VII are task-sharing which means that the participating parties contribute in-kind to a joint project coordinated by the Operating Agent. Task V is a mixed cost-sharing and task-sharing project. Normally, the level of effort is 10-20 person-years per Task.

Table 1 Participation in IEA R&D WECS Annexes

Country	Annex						
	I	II	III	IV	V	VI	VII
Austria	x						
Canada	x	x			x	x	
Denmark	x	x		x	x	x	x
Germany	x	x	x	x		x	
Ireland	x				x		
Japan	x	x	x	x	x		
Netherlands	x		x	x	x		x
New Zealand	x					x	
Norway	x	x					
Sweden	x	x	x	x	x		x
United Kingdom		x			x	x	x
United States	x	x	x	x	x		x

In addition to the Tasks, special studies of Recommended Practices for Wind Turbine Testing and Evaluation are being conducted for the Executive Committee by a Standing Committee under the direction of Denmark.

The results of the completed Tasks and the status of the current Tasks are summarized in the following sections. References to selected technical reports are given in the last section.

TASK I ENVIRONMENTAL AND METEOROLOGICAL ASPECTS OF WIND ENERGY CONVERSION SYSTEMS

This Task comprised eight Sub-tasks carried out in Ireland, the Netherlands and Sweden as follows.

Sub-Task	Title	Responsible organization
A1	Study of WECS farm area and WECS safety limit requirements	Aeronautical Research Institute Stockholm
A2	Study of combined wind-biomass systems	National Board for Science and Technology, Dublin
A3	Wake effect studies	Organization for Technical Research TNO, Apeldoorn
A4	Study of the impacts of large-scale WECS on the performance of electro-magnetic wave systems	Dr Neher Laboratorium of the Dutch PTT, Leidschendam
A5	Study of aesthetic factors and visual effects of large-scale WECS	National Board for Energy Source Development, Stockholm
B1	Investigation of the uncertainty in wind forecasting for wind power networks	Swedish Meteorological and Hydrological Institute Norrköping
B2	Load case recommendation	Saab-Scania AB, Linköping

The main results are summarized below:

Sub-Task A1: A manual for safety analysis of WECS was prepared, including data on materials, identification of failure possibilities, critical loads and load combinations. The trajectory of a broken blade or blade fragment was calculated as a basis for assessing the probability that a person be hit by the separating object (ref 4).

Sub-Task A2: Co-location of a wind turbine and a short-rotation energy farm was shown to have marginal advantage at best, the reason being the reduced wind speed and air turbulence over a forested area (ref 5).

Sub-Task A3: The wake of a rotating model of a vertical-axis wind tubine was measured in a wind tunnel and simulated with a stationary object. By simulating arrays of wind turbines, it was shown that the optimum power output from a finite array could be 9 watts per square meter ground area at a mutual distance of about 6 rotor diameters (ref 6).

Sub-Task A4: An inventory was made on the restrictions for siting large-scale WECS with respect to the tele-communication systems applied in the Netherlands. It was found that a wind turbine cannot be installed within an area bounded by a distance of 100 m from the center-line of a fixed service link, and that the minimum distance between a wind turbine and the transmitting antenna of a broadcasting service has to be 6 kilometers. Calculations were made of the electromagnetic scattering from simulated horizontal-axis wind turbines. Means of reducing the scattering were investigated. Field measurements were made on a 25 m horizontal-axis machine (ref 7).

Sub-Task A5: The visual effects of a WECS unit and arrays of units were investigated by means of perception theory, field observations and case studies. Pictures and films of rotating models in natural environments were obtained. It was shown that for wind farms of the same generating capacity, a smaller number of larger units was visually to preferred to a larger number of smaller units (ref 8).

Sub-Task B1: The accuracy of wind forecasting methods was verified by comparison with observed data with respect to diurnal, seasonal, geographical, height and time variation. It was found that the studied forecast methods were generally not adequate to meet the requirements, as suggested by a utility, for daily scheduling and hourly dispatching of WECS operation (ref 9).

Sub-Task C1: A systematic review was carried out of generally applicable principles for the selection of load cases, safety factors, and allowable material strains. The results were expressed as a set of basic design recommendations for horizontal- and vertical-axis wind turbines. Recommended methods for load calculation were also presented (ref 10).

A full description of the work and results is given in the final report of the Task (ref 11).

The methods and results of Sub-Task A3 merited continued investigation in an independent cooperative project, see Task V below.

TASK II EVALUATION OF WIND MODELS FOR WIND ENERGY SITING

In this Task five different numerical models of wind flow over terrain were tested in a task-sharing effort (ref 12). The models ranged in complexity from a simple kinematic wind extrapolation routine to sophisticated models that solve the complete hydrodynamic equations of motion. The models were tested by comparing their predictions of surface wind flow with sets of wind observations. These data sets covered a range of meteorological and topographical conditions. The input data used to run the various models were fairly meagre. This sparcity of data is thought to be typical of the conditions under which these models would actually be run when used for wind turbine siting.

In this particular study, there was no correlation between model complexity and ability to simulate the surface flow. The simplest models, a wind extrapolation routine that produces a non-divergent wind field, did as well in simulating flow over topography as the most sophisticated hydrodynamic model. In fact, the simple model did considerably better than some of these models. The conclusion to be drawn from this observation is that including more physics in a model does not guarantee improved performance if many of the crucial data needed to run the more sophisticated model are not available.

From the viewpoint of wind turbine siting, this study shows that numerical wind field modeling can be useful in the initial stages of siting where a relatively large area is screened for those portions having the greatest wind energy potential. However, the study showed that the accuracy of modeling results is low. To be most effective, numerical modeling techniques should be applied only by persons with practical experience in problems of flow over topography. This experience will be needed in evaluating whether a model is producing believable results or not.

TASK III INTEGRATION OF WIND POWER INTO NATIONAL ELECTRICITY SUPPLY SYSTEMS

The variability of the wind has important implications for the integration of wind power into existing main networks. For power systems dominated by fossil-fuelled plants the effect of introducing wind power may be expressed by:

- the fuel savings, defined as the sum of the various fuels saved by wind power generation, minus the fuel consumption required for additional regulation of the conventional power plants
- the capacity credit, defined as the sum of all installed generating capacity that can be saved by the introduction of wind power, without sacrificing the prescribed security of power supply.

The fuel savings and the capacity credit depend on wind data and turbine performance, on the utility system plant mix and load characteristics, and on the penetration of wind power in the system. An economic value can be attributed to wind power under the given circumstances.

In this Task a methodology for estimating the value of wind power was developed and applied to the case of Germany. It was found that for wind power stations in the North German coast region feeding into the national grid at a penetration of 5, 10 and 15 %, the fuel savings were 4.3, 8.8 and 13.9 % of the fuel used without wind power. The corresponding capacity credit was 1.7, 2.6 and 3.2 % of the installed fossil-fuelled capacity.

The methodology and results are described in the final report of the Task. A revised and abbreviated version of the final report was published in book form (ref 13).

In a continuation of Task III, called Task IIIa, the cases of the Netherlands, Japan, Sweden and USA were studied with the same method as that used for Germany. The studies provided some insight in the potential role of wind power in these countries and allowed comparisons to be made of the effects of different conditions (ref 14).

TASK IV INVESTIGATION OF ROTOR STRESSING AND SMOOTHNESS OF OPERATION OF LARGE-SCALE WIND ENERGY CONVERSION SYSTEMS

The rotor blades of a wind turbine are subject to useful loads providing the input power, and unsteady, non-productive loads resulting from gravity, wind shear and gusts. The loads interact in a complex manner and can lead to excessive stresses or unacceptable vibrations. The unsteady loads can be reduced by flexible rotor design and blade regulation during operation.

The objective of Task IV was to investigate possibilities for low rotor stressing, high operational smoothness and system vibration control for a large wind turbine. This was achieved by developing advanced calculational methods and verifying them in wind tunnel experiments. The project was carried out at the Institut für Aerodynamik and Gasdynamik and the Institut für Statik and Dynamik der Luft- und Raumfahrtkonstruktionen at the University of Stuttgart.

In the first part of the project, two-bladed rotors with optimized aerodynamic properties were determined numerically using specially developed computer methods. Stressing of the blades was reduced and smoothness of operation increased by using a special rotor concept with individual flap, lead-lag and flap-pitch coupling. In the second part, various flexible steel tower designs were studied using finite element methods. The towers (cantilever, guyed kinematic) were investigated for stresses, displacements and eigenfrequencies in various load cases. In the third part of the project, several small wind tunnel models were designed, built and tested.

The work and results are described in some 15 scientific reports which are available in German and English (ref 15-26).

TASK V STUDY OF WAKE EFFECTS BEHIND SINGLE TURBINES AND IN WIND TURBINE PARKS

Experimental wake effect studies were carried out as part of Task I. In Task V these studies were extended to cover horizontal-axis turbines and to include field measurements on real wind turbines. Work was performed jointly in the Netherlands and the United Kingdom in three major areas:

- Measurements of individual wake structure and decay
- Measurements of turbine performance in velocity fields of the type that may be encountered in a wake
- Theoretical and experimental modeling of turbine cluster performance by combining information on individual wakes with knowledge of machine performance in wake-type flows.

The Task resulted in a wealth of experimental data available to the participants. The data were analyzed and empirical correlations derived. The validity of simulators for wind tunnel tests of clusters was established. The comparison between the experimental results and predictive models for cluster efficiency showed a reasonable agreement. The major uncertainties of the predictive models lie in the equations used to describe the decay of a single wake. Decisive evaluation requires reliable full-scale measurements which are as yet lacking. It was therefore proposed to extend the work in a new cooperative project, including full-scale measurement.

The results of Task V are documented in some 20 technical reports of restricted circulation and 17 conference reports and publications, examples of which are given in ref 27-33. The final report of Task V was issued in January 1984 (ref 34).

TASK VI STUDY OF LOCAL WIND FLOW AT POTENTIAL WECS SITES

The field experiments at Askervein, a 125 m high hill about 2 km in diameter on the island of South Uist, Outer Hebrides, Scotland, which form the core of this task were conducted in September 1982 and September/October 1983. During 1984, most of the data from the 1983 experiment have been analyzed and included in a draft report. A final version is in preparation and will be submitted early in 1985. This, together with an earlier report (ref 33) and an executive summary will essentially complete the Task, although several participants will continue to work with the data in model intercomparison and validation exercises.

The basic objective of the field experiments was to obtain an extensive, high-quality set of full-scale data describing the local effect of an isolated, small-scale 3-D hill on mean wind and turbulence characteristics. This was satisfactorily achieved and the experiments have provided an extensive set of vertical and "horizontal" (i.e. constant height above surface) profiles of mean wind speed and turbulence parameters in the flow over the hill. Mean flow speed-ups of up to 80-90 % were observed, depending on wind direction and position on hill.

Considerable progress has been made in 1984 with both wind tunnel and mathematical model simulations of the flow over Askervein. In wind tunnel studies (Canada, New Zealand, UK) there has been good agreement in the shape of speed-up profiles in comparison with the field data but some overestimation (∿ 5 %) of magnitude. Different scale models and differences in surface texture have an effect on flow separation in the lee of the hill and the models need to be roughened in order to adequately simulate the flow in this region. The numerical model simulations, MS3DJH/3 - see Taylor et al (ref 34) -, also differ from the field observations in the lee of the hill but show good agreement elsewhere. Figure 1, taken from a recent conference paper (ref 35), illustrates the agreement in a typical case. Data (o with standard deviations I) are based on ten minute average winds over a three-hour run. Measurements (and model predictions) are at a height of 10 m along a line through the centre point of the hill and are normalized by an upstream reference wind.

Task VI is now almost complete. Collaboration between different groups involved in this joint project has been extremely good and we are very satisfied with the results that have been obtained.

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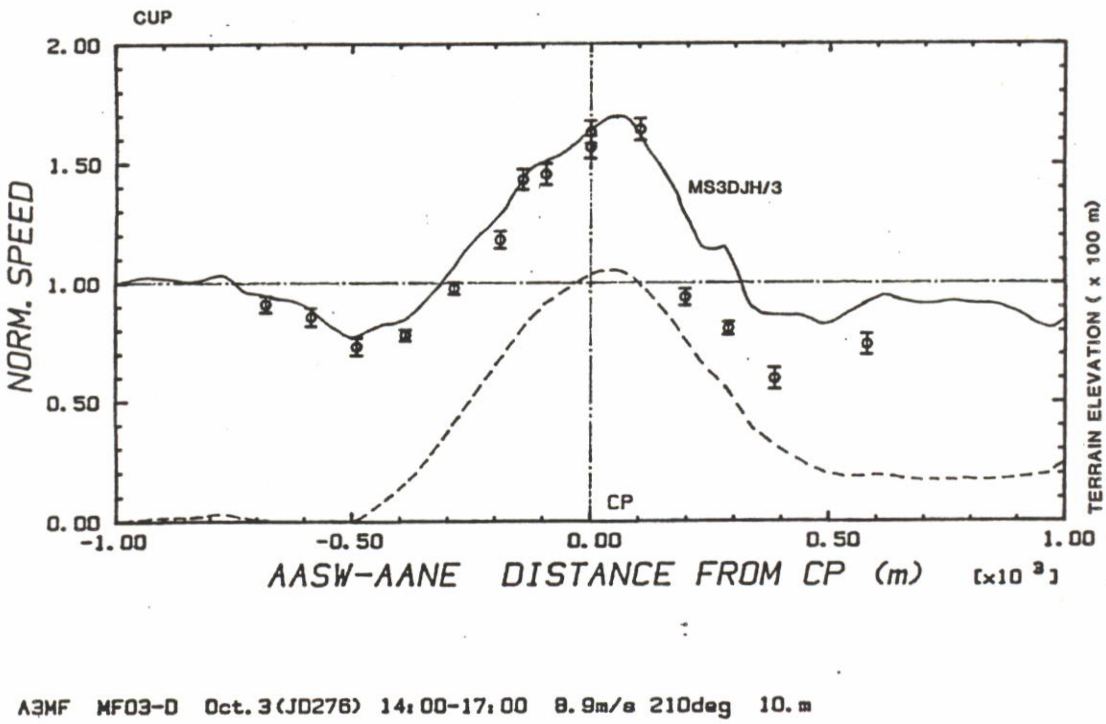

Fig 1 Comparison of field data and mathematical model predictions of wind speed above Askervein

TASK VII STUDY OF OFFSHORE WECS

This Task was initiated in 1983 to assess the viability of offshore wind power, to define design criteria for an offshore WECS prototype, and to outline a plan for the design, construction and operation of a possible joint prototype. This would be achieved in a two-year task-sharing effort involving about 25 person-years from Denmark, the Netherlands, Sweden and the United Kingdom.

During 1984, a substantial change in both the content and programme has occured. A new Sub-Task, led by the USA, on structural dynamics has been added and the time-scale for completion of the rest of the Task extended. The final report is now scheduled for the end of 1986.

Meeting of specialists were held to discuss the various Sub-Tasks as follows:

Sub-Tasks B and C:	9-10 April 1984 at ETSU, Harwell, UK
Sub-Task A :	16 July 1984 at CERL, Leatherhead, UK
Sub-Tasks B and E:	8-10 October 1984 at ECN, Petten, NL

Sub-Task A - Data collection and analysis

At the meeting of participants from Denmark, Sweden and the UK on 16 July, considerable progress was reported and substantial reports were tabled for circulation.

Sub-Task B - Conceptual design for an offshore WECS power station

At the meeting of participants from the Netherlands, Sweden and the UK on 9-10 April, the Netherlands agreed to produce a draft note defining common areas and the difference in approach of the different countries. Participants agreed that a further meeting was necessary which was held on 8-10 October. Although this meeting was primarily to discuss Sub-Tasks C and D, it was felt that the completion of Sub-Task B and of the Task as a whole should be delayed, mainly because neither the Netherlands contribution nor that of the UK (based on their phase IIB offshore study) would be available until March 1985.

Sub-Task C - Development of design specification

Sweden presented a draft specification for Sub-Task C and outlined probable further chapters. This work is continuing and a draft for circulation should be ready soon.

Sub-Task D - Generic studies

This was formally discussed on 3-4 October 1983 in Denmark. At the suggestion of that meeting, a bibliography was produced by CEGB and tabled at the meeting on the 16 July 1984 for circulation and comment. Further input to Sub-Task D will be a paper on generic studies which is being prepared by ETSU. It was indicated at the 8-10 October meeting that it would be appropriate to prepare the final Sub-Task report towards the end of the Task when generic requirements would be clearer.

Sub-Task E - Dynamic of structures

The USA propose to modify existing computer codes which were prepared by Sandia Labs and which have been validated using field data obtained from the Mod-2 wind turbines. The modifications will take account of the wave-structure interaction as well as wind effects. During the latter part of the Sub-Task, model tests will be carried out as part of the validation procedure.

Because of the late entry of the USA into the Task, their contribution will not be in phase with the rest of the programme. Nevertheless it is seen to be an extremely valuable contribution and the final report on the whole Task will be delayed to the end of 1986 in order to include this work.

TASK VIII STUDY OF DECENTRALIZED APPLICATIONS FOR USE OF WIND ENERGY

Decentralized uses of wind energy involve the use of small to medium size WECS for either autonomous (non-grid-connected) applications or to supply electricity in combination with diesel generators for local networks in isolated areas.

In March 1984 the Executive Committee approved an Annex VIII for a cooperative task-sharing research project with two Sub-Tasks:

- Site evaluation techniques for small decentralized systems
- Analysis of wind/diesel systems

Sub-Task A will identify numerical models or techniques for cost-effective assessments or measurements to obtain site-specific wind data for planning and specifying decentralized WECS installations.

In Sub-Task B certain basic wind/diesel systems operating in the participating countries will be selected for case studies of tests and measurements to be performed by the participants. Selected models will be used for analyzing the performance. Based on the results, general guidelines for planning and designing wind/diesel systems will be developed.

In order to initiate the Task by preparing the detailed work programme, the tentative Operating Agent distributed questionnaires to likely participants. Considerable interest has been shown from several countries, including countries not presently represented in the Executive Committee. By the time of the fall meeting of the Executive Committee on 19 October 1984, two countries had executed their notice of participation. The expected number of participating countries is 7-10, involving a total level of effort over three years of about 15-20 person-years.

TASK IX INTENSIFIED STUDY OF WAKE EFFECTS BEHIND SINGLE TURBINES AND IN WIND TURBINE PARKS

Wake effects have been studied in Task I Sub-Task A3, and in Task V. One conclusion of Task V was that full-scale measurements were needed for a decisive evaluation of the predictive models. A draft Annex for extended wake and cluster studies was endorsed by the IEA/CRD Renewable Energy Working Party in November 1983. At the spring 1984 Executive Committee meeting, definite interest in participation was expressed by Denmark, the Netherlands, Sweden, the UK and the USA.

The Task will include full-scale individual wake and wake interaction measurements as well as further improvement of the mathematical models for single wakes. A proposal for the detailed work plan was circulated to prospective participants by the tentative Operating Agent in October 1984. The work plan will be further explored at a workshop in January 1985, when possible minor revisions of the Annex will also be discussed.

RECOMMENDED PRACTICES FOR WIND TURBINE TESTING AND EVALUATION

As a response to a widely recognized need for a set of standard procedures for testing and evaluating the performance, economy etc of wind turbines, the Executive Committee formed an expert group in 1980 to recommend such procedures (ref 36). The group identified seven areas of interest:

- Power performance
- Costing of WECS
- Fatigue evaluation
- Quality of power
- Acoustic noise
- Electromagnetic interference
- Safety and reliability

For each area different persons are selected as active participants, each one being a specialist in the field. To-date five documents have been published (ref 37-41), three of which during 1984, and others are nearing completion. The Executive Committee has instituted a Standing Committee to continuously update the recommendations as needed, when experience from their application is obtained (ref 42). It should be noted that standards as such are not aimed at, but rather a common frame of reference and an agreed set of measurement procedures.

PROPOSALS FOR NEW COOPERATIVE ACTION

The Executive Committee is continuously examining new proposals for cooperation. The following proposals have been discussed during 1984:

- Comparison of Test Facilities.
  A round-robin test of a wind turbine for comparing performance testing methods
- Fast Time Response of Wind Turbines and Arrays.
  A study of the temporal and spatial wind variation in the second-to-minute scale and its implications for the stability of wind power generation
- Wind/diesel Hardware Project.
  Construction, testing and analysis of a modular system for autonomous power supply

- Study of Airflow in Irregular Terrain. A task-sharing effort, pooling on-going experimental and theoretical work, could result in improved methods for WECS siting.

At an IEA LS WECS expert meeting on Developments in Aerodynamic Calculational Methods in October 1984, a collaborative effort was proposed for theoretical and experimental studies of three-dimensional airfoil characteristics. This subject is of great importance for blade loads, energy yields, and design of stall-regulated WECS.

ACTIVITIES OF THE EXECUTIVE COMMITTEE

The Executive Committee regularly meets twice a year. The 13th meeting was held on 26 March 1984 at The Head Office of the North of Scotland Hydro-Electric Board, Edinburgh and the 14th meeting on 19 October 1984 at the Head Office of Germanischer Lloyd, Hamburg. At the 14th meeting Mr B Maribo Pedersen (Denmark) and Dr R Windheim (Germany) were elected Chairman and Vice-Chairman for 1985. A list of EC members and alternate members is attached.

In response to interest shown in the activities of the Executive Committee, representatives of the Commission for European Communities (CEC), Belgium, Spain and Switzerland were invited as observers to the 13th meeting and of the CEC, Australia, Italy, Spain and Switzerland to the 14th meeting. Representatives of the CEC and Spain attended the 13th meeting and of the CEC and Switzerland the 14th meeting. The Executive Committee continues its efforts to have new parties join the Agreement.

The status of on-going Tasks and other joint activities was reviewed at the meetings and appropriate decisions taken. Proposals for new cooperative action were discussed. Two draft Annexes for new Tasks (VIII and IX) were approved. Task V was formally concluded by approval of the final report.

An amendment of the Implementing Agreement to formally institute the sharing of costs for Executive Committee secretariat and other administrative expenses was adopted at the 14th meeting.

A presentation of the IEA wind energy programmes was given at the European Wind Energy Conference in Hamburg, 23-26 October 1984 (ref 3).

LIST OF SELECTED REPORTS

General

1 Annual Reports 1978-1983
Submitted to the IEA by the IEA R&D WECS Executive Committee

2 Evaluation of IEA Wind Energy Research 1977-1981.
NE 1982:8
National Swedish Board for Energy Source Development, 1982

3 B Pershagen, B Maribo Pedersen, E Kinsella
The International Energy Agency Wind Energy Cooperation
Paper U1, the European Wind Energy Conference Hamburg, October 23-26, 1984

Task I

4 S Eggwertz, I Carlsson, A Gustafsson, M Linde, C Lundemo, B Montgomerie, S-E Thor
Safety of wind energy conversion systems with horizontal axis
FFA Technical Note HU-2229
The Aeronautical Institute of Sweden, 1981

5 E Kinsella
IEA R&D WECS Task I, Sub-Task A2
Final report
National Board for Science and Technology, Dublin, 1980

6 P J H Builtjes
Wind turbine wake effects
TNO Report 79-08375
TNO, Apeldoorn, 1980

7 J M G A Ouderling, J T A Neesen
An inventory of conditions and requirements for the installation of large-scale windmill networks with respect to their impact on telecommunication
PTT Report 475 TM
Dutch PTT, Leidschendam, 1981

8 S Engström, B Pershagen
Aesthetic factors and visual effects of large-scale WECS
NE 1980:20
National Swedish Board for Energy Source Development, 1980

9 S Bodin, U Fredriksson
Uncertainty in wind forecasting for wind power networks
SMHI Report RMK 25
Swedish Meteorological and Hydrological Institute, 1981

10 G Törnkvist
Basic design recommendations for wind energy converters
Saab-Scania Report FKL-V-80.9

Design recommendations for wind energy converters with horizontal axis
Saab-Scania Report FKL-V-80.10

Design recommendations for wind energy converters with vertical axis
Saab-Scania Report FKL-V-18.11

11 B Pershagen (Ed.)
Environmental and meteorological aspects of wind energy conversion systems
Final Report of Task I
NE 1981:25
National Swedish Board for Energy Source Development, 1981

Task II

12 W T Pennell
An evaluation of the role of numerical wind field models in wind turbine siting
PNL-SA-11129
Battelle Pacific Northwest Laboratories, 1983

Task III

13 L Jarass, L Hoffmann, A Jarass, G Obermair
Wind energy: An assessment of the technical and economic potential. A case study of the Federal Republic of Germany
Springer Verlag, 1981

14 W Dub, H Pape
Integration of wind power into national electricity supply systems
Final Report of Task IIIa
University of Regensburg, 1982

Task IV

The following reports were published during 1979-1980 by the Institute für Aerodynamik und Gasdynamik and the Institut für Statik and Dynamik der Luft- und Raumfahrtkonstruktionen of the University of Stuttgart, Germany.

15 F X Wortmann
Tragflügelprofile für Windturbinen

16 J H Argyris, K A Braun
Lastwechselzahlen and Materialwerte für die Auslegung einer Windturbine speziellen Naben-Konstruktion

17 J H Argyris, K A Braun, B Kirchgässner
Statische Untersuchung von Rotorblättern unter Eigengewicht und im stationären Betrieb

18 G A Walter
The influence of airfoil properties on the flapping motion and rotor forces of two-bladed wind turbines with flapping hinges and flap-pitch coupling under gust loading

19 S Mickeler
An analytical investigation relating to two-bladed wind turbines with flapping hinges and flap-pitch coupling at mains-driven operation

20 M Mayer
One-bladed turbine with torsionally-compliant and partially-hinged balancing mass

21 F X Wortmann
A gust generator for wind turbines

22 J H Argyris, K A Braun, B Kirchgässner
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