

International Energy Agency

Programme of Research and Development on
Wind Energy Conversion Systems

IEA R&D Wind Energy

ANNUAL REPORT 1988

Published by

National Energy Administration

Sweden,

for the IEA R&D WECS Executive Committee

Statens energiverk

1989:R1

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FOREWORD

This is the eleventh Annual Report of the IEA Programme for Research and Development on Wind Energy Conversion Systems (IEA R&D WECS), reviewing the activities during 1988. The report is submitted to the IEA in accordance with the recommendations of the IEA Committee on Research and Development.

Staffan Engström
Chairman of the
Executive Committee

Bengt 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) started in 1977. There are 16 Contracting Parties to the Implementing Agreement from 15 countries : Austria, Belgium, Canada, Denmark, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom and United States. Two new Contracting Parties joined during 1988 : the Ente Nazionale per l'Energia Elettrica (ENEA) of Italy and the UK Atomic Energy Authority.

The IEA R&D WECS programme comprises eleven Tasks, seven of which have been successfully completed. Current Tasks include :

Task VIII	Study of Decentralised Applications for Wind Energy
Task IX	Intensified Study of Wake Effects behind Single Turbines and in Wind Turbine Parks
Task XI	Base Technology Information Exchange
Task XII	Universal Wind Turbine for Experiments (UNIWEX)

Tasks VIII, IX and XI are task-sharing projects, whilst Task XII is mixed task- and cost-sharing. In the task-sharing projects the participants are committed to in-kind contributions to a joint programme, managed by an Operating Agent. The UK National Engineering Laboratory acts as Operating Agent for Task VIII, the UK Central Electricity Generating Board for Task IX, the Department of Fluid Mechanics of the Technical University

of Denmark for Task XI, and the Institute for Computer Applications of the University of Stuttgart for Task XII.

Task VII Study of Offshore WECS was completed during the year and the final report was issued. The main conclusion is that offshore wind energy can be an economic alternative to other forms of electricity generation under favourable conditions in some countries. There are firm plans to construct an offshore demonstration WECS in the UK.

Substantial progress is reported from the ongoing Tasks. Ten countries are participating in Task VIII, which has two Subtasks on Site Assessment Techniques and on Wind-Diesel Systems. The background activity and data interchange continued towards the creation of two handbooks which will seek:

- to set out guidelines on how to appraise a potential site for a decentralised system
- to give advice on how to configure an optimised, combined wind-diesel system for a specific site

The Task is scheduled for completion in 1989.

Eight countries are participating in *Task IX* Intensified Study of Wind Turbine Wake Effects. A revised work plan, expanded to include contribution from Italy and Spain, was adopted during the year. A technical meeting was held in London in June, when progress with the Task was reviewed and recent technical reports were exchanged. Information from instrumented wind farms was presented and the benefit from comparisons between the datasets and between theoretical models and the operational data were discussed. A target date of mid-1990 is set for the draft final Task report.

From 1988, the preparation and publication of documents in the series of Recommended Practices for Wind Turbine Testing and Evaluation appear as Subtask A of *Task XI* Base Technology Information Exchange. A first edition of Vol 6 Structural Safety was issued during the year as was a second edition of Vol 4 Acoustics. Second editions of Vol 1 Power Performance and Vol 3 Fatigue Evaluation are in preparation. These documents have proven very useful and have received a wide circulation in the wind energy community .

In Subtask B of Task XI, an expert meeting on the Safety Requirements for Large-Scale Wind Turbines took place in October in Rome. The meeting was attended by about 30 specialists from the participating countries and was very successful. Proceedings are being published by the German Contracting Party, KFA Jülich.

In Subtask C of Task XI, progress is reported on the Joint Action on Aerodynamics of Wind Turbines and on the Joint Action on Fatigue. An expert meeting on Aerodynamics was held in November in Copenhagen. In the Joint Action on Fatigue, the ad hoc working group on the definition of a load spectrum for fatigue testing finished its work.

Task XII Universal Wind Turbine for Experiments (UNIWEX) was initiated during the year with participation from Germany, the Netherlands and Sweden. The Task comprises experimental studies of aerodynamics, operational behaviour, load spectra and control strategies as well as the validation of computer codes. Use is made of the experimental wind turbine at the Ulrich Hütter Wind Test Field near Schnittlingen, Germany.

The Executive Committee met twice during the year. The progress of ongoing Tasks was reviewed and proposals for new co-operative action were discussed. The possibilities of co-operation with the Commission of European Communities Directorates General XII and XVII were discussed. As a result, a representative of CEC DG XII will be invited to participate as an observer to the Spring 1989 meeting of the Executive Committee.

THE IEA R&D WECS PROGRAMME

The Programme of Research and Development on Wind Energy Conversion Systems (IEA R&D WECS) was initiated in 1977. IEA R&D WECS is one of two IEA programmes in wind energy. The companion programme is the Co-operation in the Development of Large-Scale Wind Energy Conversion Systems (IEA LS WECS), which is reported separately.

The general objective of IEA R&D WECS is to undertake collaborative research and development *Tasks*, as defined in *Annexes* to the Implementing Agreement. To-date eleven Tasks have been initiated, seven of which have been successfully completed :

- | | |
|----------|--|
| Task I | Environmental and Meteorological Aspects of Wind Energy Conversion Systems
Operating Agent : the National Swedish Board for Energy Source Development
Completed in 1981. |
| Task II | Evaluation of Models for Wind Energy Siting
Operating Agent : US Department of Energy - Battelle Pacific Northwest Laboratories
Completed in 1983. |
| Task III | Integration of Wind Power into National Electricity Supply Systems
Operating Agent : Kernforschungsanlage Jülich GmbH
Completed in 1983. |
| Task IV | Investigation of Rotor Stressing and Smoothness of Operation of Large-Scale Wind Energy Conversion Systems
Operating Agent : Kernforschungsanlage Jülich GmbH
Completed in 1980. |

- Task V Study of Wake Effects behind Single Turbines and in Wind Turbine Parks
Operating Agent : Netherlands Energy Research Foundation
Completed in 1984.
- Task VI Study of Local Wind Flow at Potential WECS Hill Sites
Operating Agent : National Research Council of Canada
Completed in 1985.
- Task VII Study of Offshore WECS
Operating Agent : UK Central Electricity Generating Board
Completed in 1988.
- Task VIII Study of Decentralised Applications for Wind Energy
Operating Agent : UK National Engineering Laboratory
To be completed in 1989.
- Task IX Intensified Study of Wind Turbine Wake Effects
Operating Agent : UK Central Electricity Generating Board.
To be completed in 1990.

Two new Tasks were initiated in 1988 as follows :

- Task XI Base Technology Information Exchange
Operating Agent : Department of Fluid Mechanics, Technical University of Denmark
To be completed in 1990.
- Task XII Universal Wind Turbine for Experiments (UNIWEX)
Operating Agent : Institute for Computer Applications, University of Stuttgart
To be completed in 1991.

There are 16 Contracting Parties to the Implementing Agreement, representing 15 countries. The UK Atomic Energy Authority and the Ente Nazionale per l'Energia Elettrica (Italy) joined during

the year. The countrywise participation in the current Tasks is shown in Table 1.

In Tasks VIII, IX and XI, the participants contribute manpower and work - usually in their home countries - to a joint programme coordinated by the Operating Agent. The total level of effort is typically about 10 manyears per Task.

Table 1
Participation per country in the current Tasks. OA indicates country of Operating Agent.

Country	Tasks			
	VIII	IX	XI	XII
Austria				
Belgium		x		
Canada	x		x	
Denmark	x	x	OA	
Germany			x	OA
Italy		x		
Japan				
Netherlands	x	x		x
New Zealand	x			
Norway	x		x	
Spain	x	x	x	
Sweden	x	x	x	x
Switzerland	x			
United Kingdom	OA	OA		
United States	x	x		

CURRENT TASKS

TASK VII - Study of Offshore Wind Energy Conversion Systems

This Task was largely complete in 1986 with the exception of one Subtask which was completed and report issued in January 1988. The Task Final Report was issued in draft form in March 1988 and final version in November 1988.

The main results and conclusions of the Task were presented in the previous Annual Report, including a list of selected reports. The following reports were issued during 1988 :

Oscar, D S and P L Paez; *Analysis of Wind Turbines on Offshore Structures Excited by Random Wind and Random Waves.*

IEA 7 - 0.37 (SAND 87 - 1689. UC - 60) Sandia National Laboratories, January 1988.

Walker J F ; *Study of Offshore Wind Energy Conversion Systems,* IEA R&D WECS Annex VII Final Report, November 1988.

Task VIII - Decentralised Applications for Wind Energy

The background activity and data interchange continued towards the creation of two handbooks which will seek :

- 1 To set out guidelines on how to appraise a potential site for a decentralised system, taking into account the wind micro-climate, load variations and system parameters.
- 2 To give advice on how to configure an optimised, economically viable, combined wind-diesel system for a specific site.

During 1988 one Task meeting was held in May on Prince Edward Island, Canada, which was arranged to coincide with a Wind-Diesel Workshop organised jointly by the Canadian and American Wind Energy Associations. The Task meeting was attended by 21 delegates representing seven participating countries.

The main topic of the meeting was discussion associated with the production of the two handbooks and the consideration of the draft text that had been produced to date. An action list was discussed in depth to resolve a number of outstanding technical difficulties and additional activity was agreed in order to achieve a final text for both handbooks.

The time scales that were agreed called for all outstanding material to be in the hands of the Chapter Coordinators by the end of July 1988. The subsequent penultimate text was to be circulated by end September 1988 for comment and the finalised version re-distributed by November 1988. Investigation by the

Operating Agent indicated that some countries have not adhered to the agreed deadlines and the above schedules are now running late. It is impossible to estimate by how much at the time of writing.

After considerable discussion the group concluded that the present state of knowledge did not permit a definite handbook covering all aspects of wind turbine design. It has been agreed therefore to concentrate on the current state-of-the-art and highlight, for future researchers, those areas requiring further study. A format was agreed by the meeting, defining chapter and paragraph headings.

The handbook will be made up of the following chapters :

- | | |
|---|--|
| 1 | Introduction |
| 2 | Wind-Diesel System Options and their Applicability |
| 3 | Design Considerations and Constraints |
| 4 | Modelling Techniques |
| 5 | System Economics |
| 6 | Installation and Operation |
| 7 | System Testing, Commissioning and Monitoring |
| 8 | Conclusions. |

It is expected to have a complete draft for agreement at a meeting now scheduled to take place on 27-28 March 1989 at the National Engineering Laboratory in Scotland, UK, followed by a final meeting three months later in Norway.

Participating Countries and Organisations :

Canada	National Research Council
Denmark	Risö National Laboratory
Netherlands	ECN Research Centre
New Zealand	NZ Meteorological Service
Norway	Research Institute of Electricity Supply
Spain	Instituto de Energias Renovables, CIEMAT
Sweden	State Power Board, Vattenfall
Switzerland	Office Federal de l'Energie Oekozentrum Langenbruck Alpha Real AG
United Kingdom	Rutherford Appleton Laboratory
United States	Department of Energy Solar Energy Research Institute University of Massachusetts Atlantic Orient Corporation

Operating Agent :

United Kingdom National Engineering Laboratory

Task IX - Intensified Study of Wind Turbine Wake Effects

At a meeting in London on 13-14 June, attended by all the participating countries, the progress with the Task was reviewed and recent technical reports were exchanged. The work plans proposed by Spain and Italy were accepted for inclusion in the Task programme.

Preliminary information from measurements at a number of instrumented wind farms was presented. The meeting discussed the benefit to be derived from comparisons between the data sets and from comparisons between theoretical modelling techniques and operational data. It appears that the theoretical techniques predict power losses to a reasonable accuracy although there are a number of anomalies, possibly due to the effect of atmospheric stability on wake dissipation rates.

The importance of turbulence-induced blade loads in an array was recognised and techniques for predicting these were presented. However, there are still uncertainties associated with the need for careful prediction of turbulence in an array. Further work is needed, for example in predicting where the wake expansion ends and the centerline velocity starts to decay, i.e. the length of the so-called near-wake.

Highlights of the national contributions were as follows :

Belgium

Some preliminary results from the Zeebrügge wind farm were presented, showing a clear drop in output when the wind direction lines up with the string of wind turbines. The measurements will be supplemented by velocity data from two masts.

Denmark

Data from the Taendpipe wind farm will provide further information on the characteristics of a medium-sized wind farm, to be set alongside data from the larger machines at Masnedö and Nibe.

Italy

The Alta Nurra wind park, which will form the focus of the Italian contribution, has eight wind turbines and is well instrumented with six measuring towers.

Spain

Modelling of complex terrain is in progress and good agreement with test data from the Ampurdan wind farm has been achieved. However the importance of radial and angular velocity variations and of surface roughness in an array was highlighted.

Netherlands

Further development of the theoretical modelling techniques is being undertaken, using results from wind tunnel tests, the 25 m turbine at Petten and other data which are being contributed to the programme.

Sweden

The principal contribution to the study will be wake measurements from the 75 m machine at Näsudden. These have been made using sodar and kites; comparisons are being made. When processing the data, a study of the effects of stability and of thrust coefficient will be made. Data from a small windfarm of four 180 kW machines will also be reported.

United States

In addition to measurements from the MOD-2 machines, some of which have now been reported, it was envisaged that further data arrays of smaller machines will become available. These illustrate the cumulative effects in arrays clearly, particularly the energy losses and increased turbulence.

United Kingdom

Further results from the CEC-funded work at Nibe were presented, showing the marked increase in fatigue damage rates when the machine operates in wake flows. This is partly due to the asymmetric velocity profiles, partly to turbulence. An analysis of turbulence effects in the wind farms was also discussed.

A discussion on methods of measuring performance of arrays concluded that perhaps the most reliable indicators of velocity come from the machines themselves, through the power output. If meteorological masts were available it was necessary to look at correlations between them, as it was possible that large scale vortices were affecting some results. It was noted that most experiments were using averaging periods of around 10 minutes - in line the IEA recommended practices - although it was accepted that averaging periods down to one minute gave better resolution of wake effects.

The reporting programme is likely to be substantially complete by the end of 1989. A target date of mid-1990 is set for the draft final Task report.

Task XI - Base Technology Information Exchange

This Task was initiated with the objective of formalising a number of co-operative activities which have been going on for some time on an informal basis under the direction of the Executive Committee. The Task has three Subtasks :

- A Development of Recommended Practices for Wind Turbine Testing and Evaluation
- B Topical Expert Meetings
- C Joint Actions

In *Subtask A* , a Standing Committee of five members and ad hoc working group of experts are established to define and update consensus procedures for wind turbine testing. The Standing Committee had its 9th meeting on 2-3 June in Copenhagen. In the series of documents on Recommended Practices, the first edition of Vol 6 Structural Safety was published during the report period as well as a second edition of Vol 4 Acoustics.

The Operating Agent participated as an observer in the first meeting of the IEC Technical Committee on the Safety of Wind Turbine Generator Systems (IEC TC 88) on 7-8 November in Dubrovnik, Yugoslavia.

In *Subtask B* , an expert meeting on the Safety Requirements for Large-Scale WECS took place on 17-18 October in Rome, Italy. The meeting was attended by about 30 delegates and was very successful. Proceedings will be published by KFA Jülich.

In *Subtask C* , a second meeting in the Joint Action on Aerodynamics of wind turbines was held on 21-22 November in

Copenhagen. In the Joint Action on Fatigue, a workshop was arranged on 21-22 March in Harwell, England. The work on the definition of a load sequence for fatigue testing was completed. The Joint Action continues in the expert group responsible for updating the fatigue document in the Recommended Practices series.

Selected Reports

Ljunggren S and A Gustafsson (Editors) ; Recommended Practices for Wind Turbine Testing and Evaluation, Vol 4 *Acoustics. Measurement of Noise Emission from Wind Turbines*. 2nd Edition, 1988

Beurskens J (Editor) ; Recommended Practices for Wind Turbine Testing and Evaluation, Vol 6 *Structural Safety*. 1st Edition, 1988

Maribo Pedersen B ; *The International Energy Agency Recommended Practices for Wind Turbine Testing and Evaluation*, Paper at the Asian and Pacific Area Wind Energy Conference, Shanghai, August 1-4, 1988.

Participating Countries/Contracting Parties

Canada	Energy, Mines and Resources
Denmark	Ministry of Trade and Industry
Germany	Kernforschungsanlage Jülich GmbH
Norway	Norwegian Water Resources and Energy Administration
Spain	Instituto de Energias Renovables
Sweden	National Energy Administration
<u>Operating Agent</u>	Department of Fluid Mechanics of the Technical University of Denmark

TASK XII - Universal Windturbine for Experiments (UNIWEX)

The objective of this Task is to investigate advanced design strategies to reduce investment costs and to improve machine reliability. Jointly funded experiments will be performed at an experimental wind turbine (UNIWEX) at the Ulrich Hütter Wind Test Field near Schnittlingen, Germany, during a period of three years from 1 May 1988. So far three countries are involved : Germany, the Netherlands and Sweden. Participation of further countries is possible and foreseen.

All three participants met several times to lay down the work programme and the procedure for acquisition of funding from the respective national agencies. The main activities in the Task are listed below :

At ICA / University of Stuttgart

- 1 Numerical simulation of the aeroelastic behaviour of the test wind turbine : Using the computer code ARLIS the turbine in its 1987 hardware configuration was simulated for a variety of hub configurations.
- 2 Improvements in the simulation software : Upgrades concerning the description of the wind field and the post-processing facilities as well as an installation on the Cray 2 computer were performed.
- 3 Hardware changes in the UNIWEX turbine :
Exchange of the whole drive train.
Changes for both upwind and downwind operation.
Redesign of the electric equipment and wiring.

Improvement and partial replacement of measuring equipment in both the rotor blades and the hub kinematics.

- 4 Acceptance tests in the laboratory :
Comparison of the two blades with regard to geometry and eigenfrequencies.
Check out of measurement system in the blades.
Extensive tests with the new load cells (functions, temperature sensitivity, fatigue).
Functional tests with the hydraulic slip ring.

At FFA/Sweden

- 1 Steps in preparation of an investigation with the computer code GAROS.
- 2 Preparation and discussion of measurement campaigns and their influence on the programme of work, both at FFA and with the other parties.

At ECN/the Netherlands

- 1 Preparation of contracts between the Dutch participants and acquisition of funding from the Management Agency for Energy Research (NOVEM)
- 2 Preparation and discussion of measurement campaigns and their influence on the programme of work, both between the Dutch participants and the international partners.

Survey reports on the predecessor project OPTIWA

Argyris J und K A Braun ; *OPTIWA Optimierung grosser Windenergieanlagen*, Abschlussbericht Phase II, Teil I, Berechnungen und Software-Entwicklung, ICA-Bericht Nr 17/1, Stuttgart 1987.

Argyris J und M Müller ; *OPTIWA Optimierung grosser Windenergieanlagen*, Abschlussbericht Phase II, Teil II, Entwicklung einer rechnergesteuerten Versuchs-Windturbine ICA-Bericht Nr 17/2, Stuttgart 1987.

Participating Countries/Contracting Parties

Germany	Kernforschungsanlage Jülich GmbH
Netherlands	Energieonderzoek Centrum Nederland
Sweden	The National Energy Administration

Operating Agent

Institute for Computer Applications, University of Stuttgart

PROPOSED NEW WORK

Draft ANNEX X - Systems Interaction

Revision of the Draft Annex X was discussed and adopted by the Executive Committee at its Spring meeting. The proposed Annex was submitted to the IEA for review and endorsement by the Renewable Energy Working Party. Interest in participation was expressed by EC Members from Denmark, Germany, Spain, Sweden and the UK. An expert meeting is planned for early 1989, on the basis of which a detailed work plan will be prepared.

Continued Study of Offshore WECS

At the Fall meeting, the Executive Committee discussed two proposals for future studies of Offshore WECS, based on the results and recommendations of the completed Task VII. The EC agreed to undertake a Joint Action to investigate the possibilities of co-operation between the countries planning to install offshore WECS prototypes.

ACTIVITIES OF THE EXECUTIVE COMMITTEE

The 21st meeting of the Executive Committee took place on 16 March, 1988 at the Main Office of Force Motrices Bernoises/ Bernische Kraftwerke in Berne, Switzerland. The 22nd meeting was held at the Waikiki Beachcomber Hotel in Honolulu, Hawaii on 16 September 1988 in conjunction with the Windpower '88 Conference and Exhibition. At the meetings, the EC reviewed the progress with the ongoing Tasks and discussed proposals for future work.

At the Honolulu meeting, Mr S Engström (Sweden) and Mr J Beurskens (the Netherlands) were re-elected Chairman and Vice Chairman for 1989. Some changes in membership were announced. An updated list of EC Members and Alternate Members is attached.

The Executive Committee discussed possibilities of co-operation in the field of wind energy between the IEA R&D WECS and the Commission of European Communities (CEC). Letters were exchanged between the EC Chairman and the CEC Directorate General XII. As a result, the EC decided to invite a representative of CEC DG XII to participate as an observer at the next EC meeting in the Spring of 1989.

IEA R&D WECS EXECUTIVE COMMITTEE

December 1988

(M = Member, A = Alternate Member)

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Tidigare har följande publikationer utgivits i statens energiverks rapportserie

- 1984:1 IEA Forestry Energy, Annual Report 1983
- 1985:R1 IEA Forestry Energy Project, A Study of Biomass Liquefaction test Facility
- 1985:R2 IEA Forestry Energy, Annual Report 1984
- 1985:R3 IEA Peat Production and Utilization Project, Annual Report 1984
- 1985:R4 Demand for Commercial Energy in Developing Countries, Phil O'Keefe, Beijer Institute
- 1985:R5 Kommunal energiplanering
Fem uppsatser
- 1986:R1 IEA Forestry Energy
Annual Report 1985
- 1986:R2 LÅGA OLJEPRISER?
Effekter på svensk energiförsörjning
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- 1986:R4 Förutsättningar för minskning av svavelhalten i oljeprodukter i Sverige
Underlagsmaterial till statens energiverks utredning om svavelhalten i oljeprodukter
Nils Elam, Atrax Energi AB
- 1986:R5 Reduction of sulfur content in gasoil and heavy fuel oil
Background material for the National Energy Administration's study of the sulphur content in oil products
Prepared for the National Energy Administration by Purvin & Gertz, Inc.

- 1986:R6 Avsvavling av petroleumprodukter
Tekn. lic. Arne Bergholm
Framställning av lågsvavliga eldningsolja
Sveriges tekniska attachéer, Washington
Underlagsmaterial till statens energiverks
utredning om svavelhalten i oljeprodukter
- 1986:R7 IEA Peat Production and Utilization Project
Annual Report 1985
- 1986:R8 Nedsättning av energiskatterna inom industrin
- 1986:R9 IEA District Heating. Small-Scale Combined Heat
and Power Plants
- 1986:R10 IEA District Heating. Cost Analysis of District
Heating Networks
- 1986:R11 Efter Tjernobyli
Elförbrukning för uppvärmning i övrigsektorn
Eje Sandberg, Rolf Westerlund, K-konsult
- 1986:R12 Efter Tjernobyli
Ny elproduktion vid forcerad kärnkraftavveck-
ling, PFBC
ÅF-Energikonsult, Stockholm
- 1986:R13 Efter Tjernobyli
Förgasning av inhemska bränslen för elproduk-
tion i kraftvärmeverk
Jan Fors, Leif Magnusson, Teknikgruppen AB
- 1986:R14 Efter Tjernobyli
Försörjningsmöjligheter för extremt lågsvavlig
olja till kraftverken i Stenungsund och Karls-
hamn
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