International Energy Agency

Programme of Research and Development on
Wind Energy Conversion Systems

IEA R&D Wind Energy

ANNUAL REPORT 1989

Published by
National Energy Administration
Sweden, for the
IEA R&D WECS Executive Committee

Statens energiverk
1990:R1

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FOREWORD

This is the twelfth Annual Report of the IEA Programme for Research and Development on Wind Energy Conversion Systems (IEA R&D WECS), reviewing the activities during 1989. 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 Sysytems (IEA R&D WECS) is one of two IEA programmes on wind energy, the companion one being the Co-operation in the Development of Large-Scale Wind Eneergy Conversion Systems (IEA LS WECS). IEA R&D WECS has sixteen Contracting Parties from fifteen countries: Austria, Belgium, Canada, Denmark, F R Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom and United States.

The IEA R&D WECS programme has ~~eleven~~ twelve Tasks, ~~seven~~ nine of which have been successfully completed. The ongoing Tasks include:

Task VIII	Study of Decentralised Applications for Wind Energy Operating Agent: National Engineering Laboratory, UK
Task IX	Intensified Study of Wake Effects behind Single Turbines and in Wind Turbine Parks Operating Agent: UK Central Electricity Generating Board
Task XI	Base Technology Information Exchange Operating Agent: Department of Fluid Mechanics, Technical University of Denmark
Task XII	Universal Wind Turbine for Experiments (UNIWEX) Operating Agent: Institute for Computer Applications, University of Stuttgart, F R Germany

Tasks VIII, IX and XI and XIII are task-sharing projects, whilst Task XII ~~is~~ are mixed task- and cost-sharing. In the task-sharing projects the participants are committed to in-kind contributions to a joint programme, managed by the Operating Agent.

Ten countries are participating in Task VIII, which has two Subtasks: Site Assessment Techniques and Wind-Diesel Systems. Considerable progress was made over the year towards the preparation of a Guidebook on Wind-Diesel Systems, including their siting considerations. Two meetings were held during the year at which the format and strategy of preparation

as well as the preliminary draft text of the book was agreed. The final draft will be available for circulation early 1990.

Eight countries are participating in Task IX Intensified Study of Wind Turbine Wake Effects. A substantial amount of experimental data has been collected from operating wind farms and progress is reported on the development of theoretical models. Initial comparison between data and models indicates that power deficits behind two or more rows of wind turbines may be less than predicted by existing theories, although detailed comparisons have still to be reported. The Task will be concluded during 1990 with a benchmark exercise which will bring together the experimental data and theoretical techniques.

Task XI Base Technology Information Exchange has nine participants. A main activity is the preparation and publication of Recommended Practices for Wind Turbine Testing and Evaluation. To date eight documents have been published, which have received a wide circulation in the wind energy community. The documents are updated as experience and feedback from the users is accumulated. A second edition of Vol 3 Fatigue Characteristics was issued during the year, and a second edition of Vol 1 Power Performance Testing is in the final stages of preparation.

Joint Actions represent the second Subtask in Task XI. In the Joint Action on Aerodynamics a symposium was arranged during the year, including presentations on the status and prospects of new airfoil sections, calculation methods and experimental results for rotors in yaw, and three-dimensional flow through rotors, in particular at or near stall conditions. In the Joint Action on Fatigue, an international group of experts agreed on a reference load spectrum for wind turbine blade fatigue testing. The group met during the year for exchanging information on the use of the spectrum.

As a third activity within Task XI, topical expert meetings are arranged and documented. Two meetings took place during 1989: Integrating Wind Turbines into Utility Power Systems, on 11-12 April in Herndon, Virginia, USA and Noise Generating Mechanisms of Wind Turbines, on 27-28 November in Petten, the Netherlands.

Task XII Universal Wind Turbine for Experiments (UNIWEX) has seven participants from three countries. The project aims at experimental studies of aerodynamics, operational behaviour, load spectra and control strategies for various hub concepts as well as at the validation of computer codes. The main activities during 1989 were directed to the development of software and numerical simulation, and to the development, testing and installation of hardware for the modified experimental wind turbine, which was re-erected in early September. The Dutch and Swedish contributions mainly concerned preparations for the analysis of experiments in progress.

The Executive Committee met twice during the year to review the progress of the ongoing Tasks and discuss proposals for new cooperative action. Cooperation with the Commission of the European Communities Directorate General XII (CEC DG XII) was established and a representative of CEC DG XII participated in the Executive Committee meetings. Brief presentations of the national and CEC wind energy research programmes were given at the meetings and progress and planning reports were exchanged.

At the request of the IEA/CRD Working Party on Renewable Energy Technologies an evaluation of the IEA R&D WECS Agreement was undertaken by the Executive Committee and the Operating Agents. The IEA wind energy Agreements have operated successfully for nearly twelve years. During this time wind energy technology has developed considerably and an impressive expansion of the wind industry has taken place. In spite of growing commercial interests and increasing activities within other international bodies, the Executive Committee strongly recommended a continuation of the IEA programme. A number of topics suitable for joint projects were suggested.

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 R&D 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 1990.

Task IX Intensified Study of Wind Turbine Wake Effects
Operating Agent : UK Central Electricity Generating Board.
To be completed in 1990.

Task XI Base Technology Information Exchange
Operating Agent : Department of Fluid Mechanics,
Technical University of Denmark
To be completed in 1991

Task XII Universal Wind Turbine for Experiments (UNIWEX)
Operating Agent : Institute for Computer Applications,
University of Stuttgart, F R Germany
To be completed in 1991.

There are 16 Contracting Parties to the Implementing Agreement, representing 15 countries. 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	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	x	
United States	x	x		

CURRENT TASKS

TASK VIII Decentralised Applications for Wind Energy

Over the year the Task made considerable progress towards the preparation of a Guidebook on Wind-Diesel Systems. The activities of the specialist sub-groups who had been preparing material for the two Subtasks were reported on at a meeting hosted by the National Engineering Laboratory UK in April 1989. The meeting which was attended by 14 representatives of nine of the participating countries was able to agree a common format and strategy for the preparation of a single multidisciplinary book covering all aspects of Wind-Diesel systems and their siting considerations. A work programme was agreed and tasks assigned to individuals and groups to prepare specific chapters.

Difficulties caused by country representatives not being able to continue with the work due to changing priorities within their own countries continue to plague the Task as does the introduction of substitute representatives.

A meeting where the text of the handbook, drawn together by the Operating Agent and previously circulated to the Annex members, was discussed, was hosted by the Norwegian Institute for Electricity Supply A/S (EFI) in Trondheim, Norway in late August. The meeting was attended by 16 delegates representing nine of the participating countries. As a result of the meeting further refinement of the draft text was agreed as well as provision for missing content due to representative substitution by some countries. It was agreed that all material should be available to the Operating Agent in time for circulation of the final draft early in 1990 with submission to the Executive Committee in time for their Spring meeting.

Participating Organisations

Canada	National Research Council
Denmark	Risø 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
Switzerland	Federal Office of Energy
	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

A technical progress meeting was held in London in June 1989 at which all the participating countries reported progress and discussed future plans.

Previous progress meetings had been concerned mainly with theoretical modelling techniques, and plans for field masurements. In contrast, the 1989 meeting was dominated by presentations of experimental data from wind farms, and discussion on the interpretation of the measurements. Substantial amounts of data have now been collected at Zeebrügge, Tændpipe and at a US wind farm on the Castello Ranch in Altamont Pass. Data collection is also in progress at Masnedø and Alta Nurra. The experimental data include measurements of turbine power, wind flow and rotor loads.

Detailed comparison with theoretical models have still to be reported, but initial assessment indicates that power deficits behind two or more rows of turbines may be les than predicted by existing theories.

Progress was also reported at the meeting in June on the development of theoretical methods. Further work has been undertaken using the UPM finite-difference model. and a number of theoretical techniques have been tested against data from the Nibe experiment. Modellers are now moving towards predictions of turbulence quantities in wind farms. Predictions are now possible of wake turbulence for single wakes using a number of theoretical models (the UK eddy-viscosity model, the TNO model and UPM finite-difference model) and predictions are also available from an empirical parameterisation due to Garrad-Hassan. Whilst it is unlikely that a proven technique for predicting turbulence in multiple wakes will become available on the time scale of this Task, data on this will be available from the experimental programme,

It is planned to bring the experimental data and theoretical techniques together during 1990 in a benchmark exercise based around Näsudden (for the evaluation of single wakes models) and Tændpipe (for the evaluation of wind farm models). A technical review meeting will be held in June 1990 in

London at which data analysis from the wind farm measurements will be reported, together with results of the benchmark exercise. It is expected that the final report will be available around mid-1989.

Highlights of national contributions:

Belgium
Results are now available from Zeebrügge, indicating little reduction in power output beyond the second machine in a row. This is contrary to standard theory, and requires further investigation. More detailed comparisons with theoretical models are envisaged.

Denmark
Data collection is in progress at Masnedø, and the data include dynamic loads. A large amount of data has been collected at Tændpipe, including turbulence spectra and power fluctuations. Analysis of these data is in progress.

Italy
Mesurements have been made from the array at Alta Nurra. These data include measurements from seven operating machines spaced seven rotor diameters apart. Further measurements are planned using a row of four machines.

The Netherlands
Data collection at Sexbierum is awaiting recommissioning of the wind turbines. Comparisons of existing models with data from Tændpipe and Zeebrügge are in progress.

Spain
Work is continuing on the development of finite-difference modelling codes. Agreement with wind tunnel data is fair, but agreement with field data from Nibe is less good. Prediction of turbulence quantities looks very promising. Work is also being undertaken on the theoretical modelling of the interaction of a wake flow with topography, in two dimensions. Wake results from the UPM code will be parameterised for use in a wind farm program, based on the Lissaman approach, and the results compared with measurements

from Zeebrügge and Ampurdan. Comparisons will also be made with data from Tændpipe as part of the benchmark exercise.

Sweden

Wake measurements have been made on the turbine at Maglarp, and the measured deficits agree well with those measured earlier at Näsudden. Measurements are planned to investigate in greater detail the turbulence structure of the wake behind a single wind turbine. These measurements will complement the theoretical developments on the prediction of wake turbulence.

United Kingdom

Work on data analysis from the Nibe experiment has been completed, and the final report is now near to completion. The eddy-viscosity wake program has been used to make some estimates of wake turbulence, and although the results are not quantitatively precise, the technique shows promise. The empirical parameterisation of wake turbulence undertaken by Garrad-Hassan has now been reported.

United States

An assessment has been made of the wake effects in an array of 35 Fayette 120 kW wind turbines in Altamont Pass. This work has been reported. The initial indications are that energy losses in a large wind farm may be less than would be predicted by traditional Lissaman-type programs.

All countries will be invited to participate in the benchmark exercises which are designed to provide an assessment of the reliability of currently available wake and wind farm models, as well as to provide a common means of comparing experimental data. It is expexted that results of the exercises will form a significant part of the final Task report.

Participating Organisations

Belgium	RUCA Antwerp
Denmark	Risø National Laboratory
Italy	ENEL
The Netherlands	TNO
Spain	Universidad Politecnica de Madrid (UPM)
Sweden	University of Uppsala
United Kingdom	Central Electricity Generating Board
	ETSU for the UK Department of Energy
	Garrad-Hassan Consultants
United States	US Department of Energy

Operating Agent

United Kingdom Central Electricity Generating Board

Technical Reports and Papers

Country	Ref	Date	Title	Authors
Belgium	BM-1	7/87	The Windfarm at Zeebrügge: Instrumentation for Measument of Wake Effects	J Van Leuven D Cosaert
	BM-2	7/88	The Windfarm at Zeebrügge: Experimental Set-Up	J Van Leuven D Stevens J Van Den Poel P Vanderborght
	BM-3	7/89	Wind and Power Measurements in the Wind Farm at Zeebrügge	J Van Leuven
Denmark	D-01	5/89	Wake Interaction Measurements at the Masnedø wind farm	I Katic
	D-02	7/89	Supervising and Measuring at Tændpipe Wind Farm - Progress Report	J Højstrup I Katic P Norgard
Italy	IT-01	7/88	Wind Turbulence Analysis in the Alta Nurra Wind Power Station Area	G Botta R Castagna
	IT-02	7/89	Preliminary Results of Wake Measurements at the Alta Nurra Wind Power Station	ENEL
Netherlands	NL-01	9/85	Wind Tunnel Measurements of the Wake of a Tipvane Rotor Model (Summary)	E Luken
	NL-02	8/85	Wake of a Horizontal Axis Wind Turbine Model	A M Talmon
	NL-03	1/86	Evaluation of Three Mathematical Wind Turbine Wake Models in Various Types of Flow	E Luken A M Talmon P E J Vermeulen
	NL-04	11/86	Literature Data Base on Wind Turbine Wakes and Wake Effects	E Luken

	NL-05	12/87	Comparison of Wind Tunnel and Full Scale Measurements of the Wake at the 25 m HAWT Site at ECN Petten	E Luken J W M Dekker
	NL-06	7/89	The Wind Load of Wind Turbines in Clusters - Literature Survey	E Luken
Spain	SP-01	7/88	Validation of Turbulence Models of Wind Turbine Wakes	A Crespo J Hernandez E Luken
	SP-02	7/89	Analysis of Wind Turbine Wakes	A Crespo J Hernandez
	SP-03	7/89	Wind Farms in Complex Terrain - Second Order Effects	A Crespo J Hernandez C Andreu
Sweden	SW-01	7/87	A Field Study of the Wake Behind a 2 MW Wind Turbine	U Högström D N Asimakopoulos A Smedman
United Kingdom	UK-01	7/87	Siting Guidelines for Wind Turbine Arrays	D J Milborrow J S Holt
	UK-02	7/87	Wake Modelling and the Prediction of Turbulence Properties	J F Ainslee
	UK-03	7/87	Fluctuating Loads on a Wind Turbine Operating in a Wake	G J Taylor
	UK-04	7/88	Near Wake Wind Tunnel Studies	D R Green
	UK-05	7/88	Wake Interaction Studies on the HWP-300 and WEG MS-1 Wind Turbine Generators on Burgar Hill	A Scott
	UK-06	7/88	The Impact of Wind Turbine Wakes on Machine Loads and Fatigue	U Hassan G J Taylor A D Garrad
	UK-07	7/89	Comparison of NWAKE Model with Data from Nibe Wake Measurements Project	J F Ainslee

	UK-08	10/89	Characterisation of Wind Turbine Wake Turbulence and Its Implication on Wind Farm Spacing	D Quarton
United States	US-01	4/88	An Examination of Wake Effects and Power Production for a Group of Large Wind Turbines (PNL-6528)	D Elliott J Buck J Barnard
	US-02	4/89	Wake Effects in a Fayette 95-115 Wind Turbine Array (SERI/STR-217-3186A)	R Simon D Matson J Fuchs

TASK XI Base Technology Information Exchange

The objective of this Task is to promote wind turbine technology by co-operative activities and information exchange on R&D topics of common interest. There are two Subtasks:

A Development of Recommended Practices for Wind Turbine Testing and Evaluation

B Joint Actions

In addition, topical expert meetings are arranged as agreed by the Participants, acting in the Executive Committee.

The final Annex text was approved by the Executive Committee at the Spring 1989 meeting. The duration of the Task was extended until 31 December 1991.

In *Subtask A* , the second edition of Vol 3 Fatigue Characteristics was issued during the report period. A second edition of Vol 1 Power Performance Testing is in the final stages of preparation. A list of the documents published so far is shown in Table 2. The reports are available on request from the national representatives in the Executive Committee.

The preparation and updating of the documents are carried out by ad hoc groups of experts. The activities are controlled by a Standing Committee, which met twice during the year: on 6 April in Petten, the Netherlands, and on 18-19 December in Stockholm, Sweden.

Table 2 Documents in the series of Recommended Practices for Wind Turbine Testing and Evaluation

Vol	Title	1st Ed	2nd Ed
1	Power Performance Testing	1982	In print
2	Estimation of Cost of Energy from Wind Energy Conversion Systems	1983	
3	Fatigue Characteristics	1984	1989
4	Acoustics. Measurement of Noise Emission from Wind Turbines	1984	1988
5	Electromagnetic Interference (Preparatory Information)	1986	
6	Structural Safety (Preparatory Information)	1988	
7	Quality of Power. Single Grid-Connected WECS	1984	
8	Glossary of Terms	1987	

Subtask B presently includes two activities:

- Joint Action on Aerodynamics
- Joint Action on Fatigue

In the Joint Action on Aerodynamics, a symposium was held on 16-17 November 1989 at Harwell, UK. Presentations were given on the status and prospects of new airfoil sections, calculation methods and experimental result for rotors in yaw, and three-dimensional flow through rotors, in particular at or near stall conditions.

The Harwell symposium was the third of its kind. Proceedings of the second symposium in November 1988 at Lyngby, Denmark, were published during the report period by the Department of Fluid Mechanics of the Technical University of Denmark.

In the Joint Action on Fatigue, a group of experts agreed on a reference load spectrum for wind turbine blade fatigue testing. The spectrum is known as WISPER (WInd turbine load SPEctrum Reference). The group met on 31 August - 1 September at Risø, Denmark, to discuss the experience from applying the spectrum.

Two topical expert meetings were organised during the year: on Integrating Wind Turbines into Utility Power Systems, and on Noise Generating Mechanisms of Wind Turbines. Proceedings from the Rome meeting in October 1988 were published by the German Contracting Party, Kernforschungsanlage Jülich GmbH. The cumulated list of topical expert meetings arranged under the IEA Wind Energy Agreements is shown in Table 3.

Table 3
IEA Wind Energy Expert Meetings

No	Title	Date	Venue
1	Seminar on Structural Dynamics	12 Oct 78	Munich, Germany
2	Control of LS WECS and Adaption of Wind Electricity to the Network	4 Apr 79	Copenhagen, Denmark
3	Data Acquisition and Analysis for LS WECS	26-27 Sep 79	Blowing Rock, N Carolina, USA
4	Rotor Blade Technology with Special Respect to Fatigue Design	21-22 Apr 80	Stockholm, Sweden
5	Environmental and Safety Aspects of the Present LS WECS	25-26 Sep 80	Munich, Germany
6	Reliability and Maintenance Problems of LS WECS	29-30 Apr 81	Aalborg, Denmark
7	Costing of Wind Turbines	18-19 Nov 81	Copenhagen, Denmark
8	Safety Assurance and Quality Control of LS WECS during Assembly, Erection and Acceptance Testing	26-27 May 82	Stockholm, Sweden

9	Structural Design Criteria for LS WECS	7-8 March 83	Greenford, UK
10	Utility and Operational Experience from Major Wind Installations	12-14 Oct 83	Palo Alto, California
11	General Environmental Aspects	7-9 May 84	Munich, Germany
12	Aerodynamic Calculation Methods for WECS	29-30 Oct 84	Copenhagen, Denmark
13	Economic Aspects of Wind Turbines	30-31 May 85	Petten, the Netherlands
14	Modelling of Atmospheric Turbulence for Use in WECS Rotor Loading Calculations	4-5 Dec 85	Stockholm, Sweden
15	General Planning and Environmnetal Issues of LS WECS Installations	2 Dec 87	Hamburg, Germany
16	Requirements for Safety Systems for LS WECS	17-18 Oct 88	Rome, Italy
17	Integrating Wind Turbines into Utility Power Systems	11-12 Apr 89	Herndon, Virginia USA
18	Noise Generating Mechanisms for Wind Turbines	27-28 Nov 89	Petten, the Netherlands

Participating Organisations

Canada	Energy, Mines and Resources
Denmark	Department of Fluid Mechanics, Technical University of Denmark
Germany	KFA Jülich
Italy	ENEA
Norway	Directorate of Energy
Netherlands	ECN
Spain	IER/CIEMAT
Sweden	FFA
United Kingdom	ETSU for the Department of Energy
	National Engineering Laboratory
United States	Department of Energy

Operating Agent

Department of Fluid Mechanics of the Technical University of Denmark

Technical Reports and Papers

Recommended Practices for Wind Turbine Testing and Evaluation
Vol 3 Fatigue Characteristics
Published by the IEA R&D WECS Executive Committee

Joint Action on Aerodynamics
Proceedings of the Second Symposium on the Aerodynamics of Wind Turbines, 21-22 November1988 at Lyngby, Denmark
Published by the Department of Fluid Mechanics of the Technical University of Denmark

Requirements for Safety Systems for Large Scale Wind Turbines
Proceedings of the Expert Meeting 17-18 October 1988, Rome , Italy
Published by the Kernforschungsanlage Jülich GmbH

W J Stam, N J C M van der Borg
Noise Generating Mechanisms of Wind Turbines
An Introductory Note for the IEA Expert Meeting 27-28 November 1989, Petten, the Netherlands

TASK XII Universal Wind Turbine for Experiments (UNIWEX)

UNIWEX is a computer-controlled, two-bladed experimental wind turbine of 16 m rotor diameter installed at the Ulrich Hütter Wind Test Field near Schnittlingen, West Germany. The main goals of the project are the experimental study of aerodynamics, operational behaviour, load spectra and control strategies for different hub concepts, as well as the validation of computer codes.

So far, seven organisations from three countries are participating; participation of further countries is intended. In the case of Italy, the prospects are good and preparations with respect to the technical programme have been undertaken.

The Annex XII text was modified during the year in coordination with the Legal Office of IEA Paris.

Representatives of all participants met on the following occasions:
- three technical meetings (14 March, 7 April and 14-15 December)
- two Executive Committee meetings (19 April and 18 October)
- EWEC '89 (10-14 July)

The activities are described in some detail in the corresponding publications, listed in the references. As a consequence of the technical meetings, the work plan was updated with respect to priorities in the technical topics and the time schedule. The project was presented at the two EC meetings , at the IEA Headquarters in Paris (24 May) and at the EWEC '89 Conference.

The main technical activities in 1989 are listed below:

At ICA/University of Stuttgart

1. Software Development and Numerical Simulation
- Discussions of an improved modelling of the induced wind velocity
- Software development
  * Description of the wind field for upwind rotors
- Software applications
  * Calculation for instationary gusts
  * Investigation of the influence of generator stiffness

* Re-analysis of the rotor blade

- Modelling of the modified UNIWEX wind turbine
  * Adaption of the numerical models for tower, drive train and rotor blade
- Graphic post-processing
  * Development of new tools
  * Computer animation for eigenmodes of the UNIWEX turbine and the rotor blade
- Compilation of the wind turbine data for the oyher participants

2 Hardware Development, Tests and Measurement System

- Hydraulic system
  * Completely new system for the hub hydraulics due to new drive train
  * Overhaul with respect to increased safety and user comfort
  * Passive safety device to avoid loss of the hydaulic generator moment replacing an active device
- Electronic system and real-time software
  * Adaption of the hub electronics to the new computer system on the ground
  * New control and data retrieval system, also due to active yaw option
  * Adaption of the software to the new ground computer software
  * New menu-oriented operations control/graphic display system
- Tower system
  * Implemetation of the option for controlled active yawing
  * Overhaul of the tower on the occasion of re-installing the nacelle
  * Improvement of erection/fold down procedyre
- Rotor system
  * New spinner due to changed pitch kinematic (upwind operation) and in order to simplify maintenance and weather protection
  * Both friction and play in the pitch bearings were reduced
- Wind measurements
  * A new cup anemometer was manufactured and installed
  * A new beam for wind measurement devices was constructed
- Re-erection of the wind turbine on 7 September 1989
  * Trial runs and re-commissioning

At FFA, Sweden

1 Theoretical Part - GAROS Analysis Program

- Introduction of induced velocity in the rotor plane for calculation of aerodyamic forces in the time response analysis

2 Measurement Programme

- Because of the delay in the instrumentation and erection of the UNIWEX machine, no data analysis has been done in this area.

At ECN,the Netherlands

1 Finalization and signing 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 work programme, both between ECN, DUT, SPE and with the international partners

3 Discussion of the technical data of UNIWEX in order to establish the input data for the Dutch simulation codes PHATAS II (ECN), FLEXLAST (SPE) and DUWECS (DUT)

4 Preliminary calculations with PHATAS II, using the input data from ICA Stuttgart.

Participating Organisations

Germany	Kernforschungsanlage Jülich GmbH (KFA) Institute for Computer Applications (ICA), University of Stuttgart
Netherlands	Netherlands Energy Research Foundation (ECN) Delft University of Technology (DUT) Stork Product Engineering (SPE)
Sweden	National Energy Administration Sweden (STEV) The Aeronautical Research Institute of Sweden (FFA)

Operating Agent

Institute for Computer Applications, Stuttgart

Technical Reports and Papers

1 Handouts for the technical meetings, dated 89-03-14

2 A Hopf: Auslegung eines Rotorblattes für eine Windturbine mit Hilfe der Methode der finiten Elemente, Studienarbeit, ICA, Stuttgart, 1989

3 K A Braun, M Müller: Status Report on UNIWEX presented at the 23rd IEA R&D WECS EC meeting, 19 April 1989, Antwerpen

4 M Müller: Eine rechnergesteuerte Windturbine zur Simulation und Überprüfung von Konstrutionskonzepten, 12. GESA-Symposium, Veitshöchheim, 11-12 May 1989

5 K A Braun, A Finkel: Numerical Aeroelastic Simulation of the Two-Bladed Test Wind Turbine UNIWEX, EWEC '89, Glasgow,UK, 10-13 July 1989

6 M Müller: Experimental Investigation with the Universal Test Wind Turbine UNIWEX, EWEC '89, Glasgow, UK, 10-13 July 1989

7 Progress Report on Task XII given at the 24th IEA R&D WECS EC meeting, 18 October 1989, Wilhelmshaven, Germany

8 H Snel: Purpose of the Dutch Participation in the UNIWEX Project, Presentation at the 24th IEAR&D WECS EC meeting, 18 October 1989, Wilhelmshaven, Germany

9 K A Braun, A Finkel: Compilation of Data for the UNIWEX Wind Turbine, Stuttgart, November 1989

PROPOSED NEW ACTION

Systems Interaction

After the Herndon expert meeting on Integrating Wind Turbines into Utility Power Systems, the proposed draft Annex was restructured by the US Contracting Party, taking a new, case study approach. A detailed work plan will be prepared after the Spring 1990 EC meeting. The study will be complementary to the planned second phase of the CEC penetration study.

Offshore Studies

Offshore WECS wind turbines are now being installed in Denmark and Sweden, and projects have been proposed in the Netherlands and the United Kingdom. A meeting will be arranged by the UK EC Member to explore the possibility of intensified information exchange between countries who are actively planning offshore Wecs installations. Interest in participation has been expressed by EC Members from Denmark, Germany, Italy, the Netherlands and Sweden.

ACTIVITIES OF THE EXECUTIVE COMMITTEE

The 23rd meeting of the Executive Committee took place on 19 April 1989 at the Rijksuniversitair Centrum Antwerpen, Belgium. The 24th meeting was held on 18 October 1989 at the Jade Windpark, Wilhelmshaven, F R Germany. At the meetings the EC reviewed the progress of the ongoing Tasks and discussed proposals for future work.

Mr S Engström (Sweden) and Mr J Beurskens (the Netherlands) served as Chairman and Vice Chairman during the year. At the fall meeting Mr J Beurskens and Mr P Surman (UK) were elected Chairman and Vice Chairman for 1990.

Some changes in membership were announced during the year. An up-dated list of EC Members and Alternate Members is attached as Appendix 1.

A Conformed Copy of the Implementing Agreement including Annexes, taking into account changes and amendments since the original version of 1977, is being prepared by the IEA Secretariat.

Cooperation between the IEA R&D WECS and the Commission of European Communities Directorate General XII (CEC DG XII) was established during the year. A representative of CEC DC XII participated in the EC meetings and technical reports were exchanged.

As agreed by the EC at its fall meeting 1988, brief reviews of the national and CEC wind energy R&D programmes were presented at the EC meetings. Each member country will report once a year in the future.

At the request of the IEA/CRD Working Party on Renewable Energy Technologies, a self-evaluation of the IEA R&D WECS activities was undertaken by the Executive Committee and the Operating Agents of the various Tasks. The findings and recommendations are summarised as follows:

- Wind energy technology has developed considerably over the past decade and an impressive expansion of the wind industry has taken place in the lead countries

- By the end of 1988 about 1800 MW of wind system capacity was installed in about 20 000 units, mainly in California

- Current-day wind turbines can compete with other electricity generating systems under favourable conditions

- Prospects of further cost reductions and the large wind resource potential make wind energy the most promising of the renewable technologies in the near term

- Many countries have substantial national programmes for basic research and advanced components development for intermediate to large (megawatt-sized) wind turbines

- The IEA wind energy Agreements have operated successfully for nearly twelve years. Seven Tasks have been completed and four Tasks are currently ongoing

- In spite of growing commercial interests and increasing activities within other international bodies, there is a strong need for continued IEA cooperation.

The evaluation was presented by the EC Chairman at the Spring meeting 1989 of the IEA/CRD Working Party on Renewable Energy Technologies.

Report by the Executive Committee
The IEA Wind Energy Programme 1977-1988 - A Strategic Review
April 1989

A list of selected reports and publications produced within the IEA R&D WECS Agreement from the above report is found in Appendix 2.

IEA R&D WECS EXECUTIVE COMMITTEE ADDRESS LIST

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	(A)	Mr D F ANCONA - same address -		

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