INTERNATIONAL ENERGY AGENCY

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

ANNUAL REPORT 1986

A report by the IEA R&D WECS Executive Committee

January 1987

INTERNATIONAL ENERGY AGENCY

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FOREWORD

This is the ninth Annual Report of the IEA Programme for Research and Development on Wind Energy Conversion Systems (IEA R&D WECS) reviewing the progress during 1986. It is submitted to the IEA in accordance with the recommendations of the IEA Committee on Research and Development. The report is edited by the Secretary of the Executive Committee with contributions from the Operating Agents.

D F Ancona
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) started in 1977. Fourteen countries (Austria, Canada, Denmark, Germany, Ireland, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, United Kingdom and United States) are participating.

During 1986 the Instituto de Energias Renovables (IER) of Spain and the Swiss Federal Office of Energy became Contracting Parties to the Implementing Agreement. The Italian Commission for Nuclear and Alternative Energy Sources (ENEA) is in the process of joining. Formal notice of withdrawal, effective 1 October 1987, was given by the Irish Contracting Party.

The IEA R&D WECS programme comprises nine Tasks, six of which have been completed. Current Tasks include Task VII Study of Offshore Wind Energy Conversion Systems, Task VIII Study of Decentralized Applications for the Use of Wind Energy, and Task IX Intensified Study of Wake Effects behind Single Turbines and in Wind Turbine Parks. All current projects are task-sharing, i.e. the participating parties are committed to in-kind contributions to an agreed programme co-ordinated by an Operating Agent. The Central Electricity Generating Board (UK) is acting as Operating Agent for Task VII and Task IX, and the UK National Engineering Laboratory for Task VIII.

Substantial progress is reported from the ongoing Tasks. The study of Offshore WECS (Task VII) is substantially complete, although one of the subtasks, the structural dynamics study, which

was begun later than the other subtasks is scheduled to be completed by the first quarter of 1987. The study has tentatively established a range of generating costs from a low value, which could well be competitive with many alternative forms of generation, to a high value which would be competitive only in very specific circumstances.

Tasks VIII on Decentralized Applications for Wind Energy has attracted considerable interest and eleven countries are now participating. A revised programme has been adopted which aims at finishing the Task by the end of 1988. Working parties have been formed for both of the two subtasks: A. Site Assessment and B. Wind-Diesel Systems. Subtask A involves not only wind resource prediction methods but also demand assessment techniques. The outline structure of a handbook has been decided, and drafting of various sections is underway. Subtask B is concerned with the validation of models for prototype wind-diesel systems in order to derive appropriate strategies whereby various systems can be appraised and subsequently optimized.

Administrative problems have delayed the formal start of Task IX on Intensified Study of Wind Turbine Wake Effects. A number of informal exchanges of data have taken place, however. Measurements of blade loads in arrays are becoming available together with theoretical techniques for predicting the associated reductions in the fatigue life of critical components. The UK is contributing information from wind tunnel tests and measurements from the machines on Burgar Hill, Orkney. Full-scale wake data from the MOD-2 cluster in the USA and the two large Swedish machines are used to

validate theoretical wake models developed by CEGB in the UK and TNO in the Netherlands.

An expert group study of Electromagnetic Interference was published during the report period. This is the sixth volume in the series of documents on Recommended Practices for Wind Turbine Testing and Evaluation. Another document on Safety and Reliability is nearing completion. Revised editions of other volumes in the series are in progress. A Glossary of Terms in Wind Energy is also being prepared.

Workshops were held during the year in the two Joint Actions on Aerodynamical Calculational Methods and Fatigue Testing. Progress was made in the effort to define a reference load spectrum for fatigue testing.

THE IEA R&D WECS PROGRAMME

This report reviews the progress during 1986 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. IEA R&D WECS is one of two IEA projects in wind energy. The companion programme is the Co-operation in the Development of Large-Scale Wind Energy Conversion Systems (IEA LS WECS) and 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 nine Tasks have been initiated, six of which have been completed:

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

Task II Evaluation of Models for Wind Energy Siting
Operating Agent: U.S. Department of Energy
Completed in 1983

Task III Integration of Wind Power into National Electricity Supply Systems
Operating Agent: Kernforschungsanlage Jülich GmbH, Germany
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, Germany
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: Central Electricity Generating Board (U.K.)
To be completed in 1987

Task VIII Study of Decentralized Applications for Use of Wind Energy
Operating Agent: National Engineering Laboratory (U.K.)
To be completed in 1988

Task IX Extended Wake Effect Studies
Operating Agent: Central Electricity Generating Board
To be completed in 1989

There are fourteen Contracting Parties to the Implementing Agreement. The countrywise participation in current Tasks is shown in Table 1.

In the current Tasks the participants contribute manpower and work usually in their home countries to a joint programme coordinated by the Operating Agent (OA). The total level of effort is typically about 10 manyears per Task.

In addition to the Tasks the Executive Committee has established a Standing Committee for the preparation, publication and review of a series of documents on Recommended Practices for Wind Turbine Testing and Evaluation.

Table 1
Participation in current Tasks

Country	Task VII	VIII	IX
Austria			
Canada			
Denmark	x	x	x
Germany			
Ireland			
Japan			
The Netherlands	x	x	x
New Zealand		x	
Norway			
Spain		x	
Sweden	x	x	x
Switzerland		x	
United Kingdom	OA	OA	OA
United States	x		x

The Executive Committee is also operating Joint Actions on Aerodynamical Calculational Methods and on Fatigue Testing and Load Spectrum Definition.

The progress of the current Tasks, the activities of the Standing Committee, and the Joint Actions are briefly reviewed in the following sections.

TASK VII STUDY OF OFFSHORE WIND ENERGY CONVERSION SYSTEMS

During 1983, the study of offshore wind energy conversion systems (OWECS) was commenced 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.

In pursuit of these objectives, five subtasks were initiated:

A. Data collection and compilation
B. Conceptual design of an OWECS power station
C. Development of design specifications
D. Generic studies
E. Structural dynamics study

A considerable number of major reports and papers have been contributed to the study, some of which are referred to below. The work will be substantially complete by the end of 1986, although Subtask E, the structural dynamics study, which was begun later than the other subtasks is scheduled to be completed by the first quarter of 1987.

The aims and objectives as formally adopted are outlined in Annex VII of the Implementing Agreement.

SUBTASK A DATA COLLECTION AND COMPILATION

Meteorological and other data are required so that the following characteristics can be determined for a given site with the required accuracy:

- Wind turbine performance
- Wind turbine structural response
- Optimum construction, operation and maintenance schedules

In the original objectives of Annex VII the following elements were identified:

1 Review and analysis of existing data

2 Structure of wind over the sea

3 Sensitivity of WECS structures and systems to meteorological parameters

4 Measurements of offshore wind data

5 Investigations of land to sea wind speed recovery

6 Studies of the prediction of hourly mean wind speed at site

To which we must add:

7 Provision of wave and marine data

Wind speed data comes from a variety of sources which need to be reconciled using a suitable wind speed model, so that the wind distribution can be determined for a particular site. Two distinct aims can be distinguished. The first is the determination of the wind distribution at each chosen national site so that the economic viability of offshore wind power can be determined as seen by each participating country. The second aim is to access the wind speed distribution for the chosen site of the prototype machine.

Of necessity, the first aim has already been achieved for each of the national studies of OWECS economics, with the best possible accuracy in present circumstances. The average annual wind speeds for each of the specifically referenced

studies show that the range of values is 7.6 to 8.9 m/s. However, the reconciliation of each of the national sets of data has not yet been done.

Data have been obtained for each study from a variety of sources, including measurement techniques. A factor which is of importance in addition to the variation of mean annual wind speed from site to site, the spatial variation, is the variation from year to year, or the temporal variation. A UK study has shown that the annual variation on land, and by extension, over the sea, can be substantial. For example, in the period 1898-1954 at a specific site a notional 60 m dia wind turbine would have had an output of annual mean power falling monotonically from about 480 kW to about 325 kW from 1917 to 1933. The annual power available would than have remained in the region of 300 kW for about another 20 years. Clearly, estimates of wind speed for the period 1917-1933 would have given substantially higher available power than for the next twenty years, and estimates of the economic viability of offshore wind power must take such variability resulting from medium term climatic changes into account.

SUBTASK B CONCEPTUAL DESIGN OF AN OWECS STATION

The agreed objectives were as follows:

- To assess whether an offshore wind energy power plant is economically viable over time
- To develop a conceptual design for a turnkey cost-effective power station for a single owner. The design will incorporate results of studies of support systems and marine operational procedure

The work will include the following elements:

1 Definition of the scale and general layout of an OWECS

2 Analysis of structural concepts for a range of site characteristics, with preliminary design of support structures, fabrication and marine installation resulting in a yearly production module

3 Estimation of capital and operational costs, taking into account expected project technical lifetime

4 Evaluation of wind regime, turbine size and type, system efficiency, and yearly energy production

5 Assessment of economic viability of the full-scale OWECS power station as a function of time, including a prediction of the break-even time and drafting of a long-term development plan

6 Collaboration with participants in Subtask C to define structural and design criteria for an OWECS prototype.

There has been substantial progress on Subtask B despite the fact that national priorities in this area have not been as well aligned with the objectives of the subtask as would have been desirable.

Each of the participants has produced studies based on defined OWECS power stations, (objective 1) which of necessity have required realisation of objectives 2-5, namely, analysis of structural concepts, estimation of capital and operational costs, and evaluation of wind regime, turbine size and type, system efficiency and yearly energy production.

We should again note that the reported studies are nationally orientated and that as for Subtask A there is the need for correlation on an inter-

national basis. The question of international comparison is discussed again below with regard to the final task report.

Two reports produced by the Netherlands have included definition of the scale and operational layout of an OWECS power station, and a study of the conceptual design of supporting structures in which it is concluded that steel structures are preferable on economic grounds to concrete. This is in contrast to the conclusions of the other three studies by Sweden, Denmark and the UK which all favour concrete. All three studies consider the economic prospects for OWECS power stations, the results being summarised below.

SUBTASK C DEVELOPMENT OF DESIGN SPECIFICATION

The objectives of the subtask were:

- To define the function of an OWECS prototype, considering the following factors:

  1 Site description, including specification of wind data and relevant environmental conditions

  2 Operational requirements

  3 Strength requirements

  4 Structural design, construction and erection, maintenance procedures and safety considerations

  5 Instrumentation and data collection

  6 Inspection and testing

  7 Collaboration with participants in Subtask B to define structural and design criteria for an OWECS prototype.

- To generate basic technical specifications for an OWECS prototype, and propose a plan to design, construct and operate a joint OWECS prototype.

Two of the objectives have been fulfilled, in that the functions of an OWECS prototype have been defined and the basic technical specification is now in final draft form and will shortly be available. However, a plan has not yet been prepared for design, construction and operation of a joint OWECS prototype, since participants are currently of the opinion that this is now somewhat less urgent. Nevertheless, it is still felt to be an important objective which will be addressed before the study is completed.

In the introduction to the specification, the requirement for the prototype has been broadly defined, which is for an offshore based wind turbine complete with support structure and all necessary ancillary equipment. It must be capable of operating unattended with the required degree of safety, reliability and availability for a specified life and it must be based as far as possible on proven technology. The prototype may be of horizontal or vertical axis design. Reference is made in the specification to the need to conform to appropriate national and international codes and standards and to the requirements for a quality assurance programme.

SUBTASK D GENERIC STUDIES

The agreed objectives are:

- To identify theoretical and experimental studies necessary for offshore siting of wind conversion energy projects, initiating and co-ordinating studies in their own countries.

1 Corrosion of mechanical and electrical installations in an OWECS

2 Corrosion fatigue in cyclically-stressed structures due to a salty marine environment.

Due to the nature of the subtask, little has yet been done formally. However, participants have made considerable progress in realising the first objective in pursuit of each national study. However, further effort is required before the study ends to ensure that the existing information is reviewed and assessed so that the extent and nature of generic requirements can be clearly established.

SUBTASK E STRUCTURAL DYNAMICS STUDY

The agreed objective of the study is to develop the tools necessary to perform a structural dynamics analysis of an OWECS. Included elements will be:

1 Examination and assessment of existing structural dynamics models used for the design of shallow water offshore structures in order to determine their suitability to analyse an OWECS design

2 Analyse the complex physical forces acting on an OWECS using adaptations of suitable existing models

3 Evaluation of the resulting models with subscale systems tests.

Sandia National Labs (SNL) have been addressing the problem of analysing structures excited by random wind and wave loads with the goal of performing structural dynamic analysis of wind turbines supported by offshore platforms subjected to ocean environments. The basic tool is an SNL-developed code for horizontal axis wind turbine (HAWT) structural analysis known as

HAWTDYN. HAWTDYN is finite element code which analyses an HAWT as a rotating structure (the rotor) attached to a non-rotating structure (the tower) subjected to stochastic winds. HAWTDYN accurately predicts the natural frequencies, teeter response to wind shear, and mean and cyclic flapwise bending moment for the rotor blade of the US MOD 2 HAWT (300 ft.dia., 2.5 MW rated power). Given the wind and wave loading of the elements of the turbine and support structure modes, HAWTDYN can determine the structural time response of the model elements in terms of element displacements, velocities, accelerations, loads and stresses.

As of September 1985, a code (based upon linear wave theory) to generate random wave velocities and accelerations has been written, and HAWTDYN has been modified as necessary to accept loads resulting from these wave velocities, apply them to a turbine/platform model, and determine the model response. Tasks to be completed include a linearisation of Morison's equation to calculate the structural wave loadings, incorporation of a turbine support structure finite element model into the structural response under various wind and sea conditions. The placement of offshore platforms will probably be in 10 to 15 metres (33 to 50 feet) of water, so the use of linear wave theory may not be appropriate. This will be reviewed, the limitations in fetch length and wind velocity determined and noted, and the use of shallow water theories investigated. In addition, the validity of Morison's equation will be assessed as concrete gravity support structures several metres in diameter may be used. In this case, the structure would be expected to have a significant effect on the wave motion in the vicinity of

the structure. The use of diffraction wave theory to determine forces on the structure will be investigated.

TASK REPORT

The final task report will include the following findings, which address the basic objectives of the study outlined in the introductory paragraphs:

1 Economic viability of offshore wind energy conversion systems

2 Technical specifications for an OWECS prototype

3 Implementation plan for an OWECS prototype

As already noted there has been progress towards the overall objectives of the study, with the reservation that individual contributions have, quite naturally, tended to be written from a national view point, although this is not the case with the completed work on Subtask C. As part of the work required to align the work internationally, the UK is carrying out a comparison of UK, Swedish and Danish studies. This points the way towards the final goal of the study in its consideration of the different design concepts and presentation of a range of generation costs.

There is considerable similarity between each national study but there are also a number of differences, the main ones being in rotating plant costs, plant availability, cluster arrangements and efficiency, and in operation and maintenance procedures and costs.

The generating costs derived in each study are not quoted in detail because they have not yet been put on a fully comparable basis to take into account factors such as the national discount rate, currency rates of exchange, assumed plant lifetimes and the need to refer all costs to a common price date. However, as a preliminary indication only, the estimated generation costs range from a maximum of 6.9 p/kWh for the UK study at a mean wind speed of 8.5 m/s to 3.1 p/kWh for the Swedish Öland installation, or, for the Swedish advanced design which has not been studied in detail, 2.1 p/kWh. The Danish costs are somewhat higher than those of the Swedish study. These figures should be taken as a broad indication only of the range of values which will come out of the completed study.

Further detailed examination is needed of the reasons for the principal differences between the studies.

CONCLUSION AND COMMENT

The study of offshore wind energy conversion systems has tentatively established a range of generating costs from a low and perhaps very optimistic value of about 2.1 p/kWh, which could well be competitive with many alternative forms of generation, to about 6.9 p/kWh which would be competitive only in very specific circumstances.

In the final part of the study, which will assess the economic viability of offshore wind power, it will be necessary to determine a most probable value of generating costs as well as a credible range, and to compare these values with those for alternative forms of generation. This must take

into account future cost trends over the projected lifetimes of the alternatives, an important element of which will be fossil fuel price movements in the long term. In addition, more work is needed to ensure that the results are fully representative of the extensive work completed by participants, and that they can be fully utilised by contributing countries.

The study promises a very valuable outcome. At the same time we should recognise that natural priorities have not always coincided with those of the IEA and some delays have resulted.

PARTICIPATING COUNTRIES

Denmark	Ministry of Energy
The Netherlands	Energy Research Foundation ECN
Sweden	National Energy Administration
United Kingdom	Central Electricity Generating Board
United States	Department of Energy
OPERATING AGENT	Central Electricity Generating Board

TASK VIII DECENTRALISED APPLICATIONS FOR WIND ENERGY

The agreed aims of this Task are twofold:

1 To define cost-effective models and techniques suitable for obtaining wind and load data necessary for planning and specifying decentralised Wind Energy Conversion System installations

2 To apply and further develop models suitable for analysing the performance of wind/diesel systems, and to obtain a sound analytical basis for planning and designing such systems

The Task effectively restarted in mid-1985 when the UK National Engineering Laboratory took over the responsibilities of Operating Agent. Prior to this, the role had been filled by a number of countries and establishments, and this lack of consistency had not allowed the Task to progress.

The structure of the Task is now more settled and to date eleven countries have formally joined the programme or are in the process of so doing and renewed requiries have been made by Japan. Three meetings of participants have been held, and the fourth has been rescheduled for 28/29 January 1987 in Martigny, Switzerland. Working parties have been formed for both of the Subtasks, which correspond to the two stated objectives, in order to allow detailed technical discussion to take place. The working parties are also providing technical guidance for the Task.

In addition to the project reports which the Task will produce, it has been agreed that the participants will aim to publish advisory booklets, which will be of use to the wider wind energy community. These booklets will be of use to those who wish

to assess a site for a wind-diesel installation, and will also be of assistance in configuring the optimum system for given load and wind conditions.

In September 1986, the Operating Agent submitted a detailed work programme and schedule to the IEA Executive Committee. The programme had previously been approved by the participants. In overview, the programmes for the two Subtasks are as follows

SUBTASK A SITE ASSESSMENT

To date, participants have identified to the Operating Agent those models and techniques which could be particularly relevant to wind resource and load assessment for potential wind-diesel sites. These have been categorised by the Working Group in terms of terrain and methodology, and attempts are currently underway to carry out initial cross validations of the models. This exercise, together with future comparisons, will allow typical accuracies for each model to be estimated, and hence those techniques/models with the best accuracy to cost ratio will be identified. Since wind variation in the short term is of great importance to the operation and performance of wind-diesel systems, particular regard will be given to those models capable of predicting turbulence accurately.

The outline structure of the site assessment handbook has been decided, and drafting of various sections is already underway.

Subtask A not only involves wind resource prediction methods, but also load demand assessment techniques. Thought has been given to deciding upon the important factors in small grid networks, and suitable assessment guidelines have been discussed. Participants have made typical loading patterns available for inspection. To ensure that the load studies are particularly appropriate to wind-diesel systems, the Site Assessment Working Group is liaising closely with Subtask B.

Future work will consist of further validation of wind resource assessment methods, and particular emphasis will be placed on topographical effects.

Additionally, load evaluation techniques will be further examined, the guidance booklets will be finalised, and full reports will be issued regarding the wind assessment trials.

SUBTASK B WIND-DIESEL SYSTEMS

The Task has a large number of prototype wind-diesel systems, and a variety of modelling packages available for examination and testing. Details of these have been collected via a series of questionnaires. The participants are proposing to validate the models in order to derive appropriate strategies whereby various wind-diesel systems can be appraised and subsequently optimised. If successful, this programme will provide knowledge which will be invaluable at the planning stage for future hybrid systems.

The models themselves fall into two categories, namely those which are "short-term" in nature and can be used for modelling system behaviour in the

time domain, typically for periods up to a day, and secondly those which are "long-term" and deal more with the overall statistical behaviour and performance of a system. To appraise a wind-diesel system using the former type of model, "typical days" of wind and load data are used, whereas using the latter approach involves using complete, long-term wind and load records. Both approaches are being pursued. Data to be used in the validation exercise will come from the large number of prototype systems available from the various participants.

To date, details of the available models and systems have been collected. It appears as if only a limited number of these will be immediately available for study, since many of the wind-diesel programmes in participating countries are at an early stage.

A Working Party has been formed which has looked at various "long-term" modelling packages, and plans are at present being laid to conduct an initial proving trial validation, which will determine how logistically feasible it is to validate a model using data from various systems. The success of this exercise will determine how comprehensive the subsequent validation programme will be. Appraisal of the model validation results will be carried out independently by the Operating Agent.

Once all possible validations have been completed, those models which are found to be particularly cost effective and accurate will be identified. Consideration will then be given to the techniques employed by such models, and from this study,

guidance notes will be drawn up on how to model and hence evaluate and optimise a wind-diesel combination.

At present, it is foreseen that the Task VIII programme will be completed by the end of 1988. This will depend to some extent upon how quickly the various participating countries develop their wind-diesel systems and models.

However, a number of models and test-systems are already well established in a few countries, and at present, those countries are the most active in the programme.

PARTICIPATING COUNTRIES

Canada	National Research Council
Denmark	RISO National Laboratory
Italy	ENEA
Netherlands	Energy Research Foundation, ECN
New Zealand	Meteorological Service
Norway	Institute of Electricity Supply (EFI)
Spain	Instituto de Energias Renovables, IEN
Sweden	State Power Board
Switzerland	Office Federal de L'Energie
United Kingdom	Rutherford Appleton Laboratory/ International Research and Development Co Ltd
United States	Department of Energy
OPERATING AGENT	UK - National Engineering Laboratory

TASK IX INTENSIFIED STUDY OF WIND TURBINE WAKE EFFECTS

The administrative problems which have delayed this Annex have now been resolved and a formal start is expected shortly, a decision is awaited on Belgian participation. A number of informal exchanges of data have taken place, however, and measurements of blade loads in arrays are now becoming available, together with theoretical techniques for predicting the associated reductions in the fatigue life of critical components.

The UK Department of Energy has now formally indicated its willingness to contribute information from funded studies now in progress which include wind tunnel tests and measurements from the 22 m machines on Burgar Hill, Orkney. The latter study, which is also supported by the CEGB, has indicated that substantial increases in dynamic blade loads may be expected in certain circumstances but confirmation of these preliminary results is awaited.

Further development of the theoretical wake models has taken place within the UK by the CEGB and in the Netherlands by TNO. Further development of these is restricted only by the scarcity of full scale wake data but recent measurements in the MOD-2 cluster in the USA and on the two large Swedish machines are now being assimilated. Some of the latter measurements were made using a sodar device and one of the subsidiary aims of the study is to evaluate the potential of such devices. A portable, lightweight system is under development by the CEGB.

Further data on interactive effects have been derived from measurements in the MOD-2 wind farm and some of the large wind farms in California. The early conclusions that changes in blade loads are more significant than losses of energy will be examined carefully as the study proceeds.

PARTICIPATING COUNTRIES

Denmark	Ministry of Energy
The Netherlands	Energy Research Foundation, ECN
Sweden	National Energy Administration
United Kingdom	Central Electricity Generating Board
United States	Department of Energy

OPERATING AGENT	Central Electricity Generating Board

RECOMMENDED PRACTICES FOR WIND TURBINE TESTING AND EVALUATION

The sixth document in the series of "Recommended Practices" Vol 5 Electromagnetic Interference, was published during the year. The report indicates the mechanisms that have so far been identified as contributing to the interference, reports some of the undesirable effects that have been noted, and recommends appropriate remedial action. It is intended that this will indicate the type of studies that should be undertaken on each wind turbine. At present this must be done on a case by case basis. With more experience it will be possible to establish a code of practice.

A preliminary report on Safety and Reliability is being finalized for publication in early 1987. This will be 7th volume in the series. Revised editions of Vol 1 Power Performance, Vol 3 Fatigue Evaluation, and Vol 4 Acoustics are in progress. A Glossary of Terms in Wind Energy is also being prepared.

The Standing Committee held its 5th meeting in Copenhagen on 18-19 February, and its 6th meeting in Petten on 2 September 1986. The working group on Acoustics met on 28-29 October in Stockholm.

JOINT ACTIONS

A meeting on Aerodynamical Calculational Methods was held on 15 October 1986 at the CEGB Headquarters in London. The topics included:

- Rotor loads during pitch change and unsteady inflow conditions
- Horizontal-axis rotors in yaw
- Rotors during stall conditions

A workshop on Fatigue Testing was held on 22-23 May 1986 at the FFA (Aeronautical Institute of Sweden) in Stockholm. At this meeting three activities were reviewed and discussed:

- Revision of the Recommended Practices document on Fatigue
- Ongoing measurement activities in the member countries
- Definition of a reference load spectrum for fatigue testing.

The last activity, which is co-sponsored by the CEC (Commission for European Communities), is known as WISPER (Wind Turbine Spectrum Reference).

PROPOSALS FOR NEW CO-OPERATIVE ACTION

A draft Annex on Systems Interaction has been prepared by the US Contracting Party and circulated to the member countries for comment. The Annex addresses issues and barriers to the successful delivery of wind turbine power to operating utilities.

Several other technical topics have been proposed for possible co-operation, including:

- Basic wind description
- Wind resource assessment
- Environmental issues
- Public acceptability
- Assessment of advanced control
- Wind assisted ship propulsion

ACTIVITIES OF THE EXECUTIVE COMMITTEE

The 17th Executive Committee meeting was held on 17 March 1986 at the National Energy Administration in Stockholm. The 18th meeting took place on 6 October 1986 at the ENEA Headquarters in Rome in connection with the EWEC '86 Conference.

At the 18th meeting Mr D F Ancona (USA) and Mr S Engström (Sweden) were unanimously reelected Chairman and Vice-Chairman for 1987. Some changes of members and alternate members were announced. A revised address list is attached.

During the report period the Instituto de Energias Renovables (IER) of Spain and the Swiss Federal Office of Energy became Contracting Parties to the Implementing Agreement for participation in Annex VIII. The National Board for Science and Technology (Ireland) gave formal notice of withdrawal. Information was received to the effect that ENEA of Italy was in the process of joining the Agreement.

The 18th meeting was a joint meeting between the IEA R&D and LS WECS Executive Committees mainly for discussing future activities. It was noted that the Implementing Agreements had been in force for nearly ten years, and that wind energy technology has developed considerably during this time. It was therefore appropriate to review part and present activities and to formulate a strategy for the future. The findings and recommendations were summarized as follows:

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

- By the end of 1985 about 1200 MW wind system capacity was installed, mainly in wind farms in California

- While current-day wind turbines are not yet directly competitive with other electricity generating systems, the large potential of wind energy as one of the most promising of the renewable technologies has been clearly demonstrated

- Many countries have substantial national programmes for basic research and advanced components development for intermediate - to megawatt-size wind turbines

- The IEA Agreements in wind energy have operated for nearly ten years. Eighteen Executive Committee and fifteen expert meetings have been held, six technical Tasks have been completed and three Tasks are underway. Six Recommended Practices documents and numerous other progress reports have been published

- In spite of growing commercial interest and increasing activities within other international bodies there is a need for continued co-operation within the IEA Agreements. This is also indicated by the interest shown by new countries to join

- There has been a trend from cost-shared to task-shared Annexes and to undertake joint activities not covered by Annexes. In order to adapt to this development and to facilitate for new participants to join, a broadly defined Annex should be established

- A number of technical topics suitable for co-operative efforts are suggested, including basic wind description, wind resource assessment, materials fatigue data bank, procedures for testing and evaluation, environmental issues, public acceptability, assessment of advanced control, quality of power, offshore systems, and wind assisted ship propulsion.

APPENDIX 1

December 1986

IEA R&D WECS EXECUTIVE COMMITTEE - ADDRESSES

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