EUROPEAN COMMISSION

Community Research

European Wind Energy Projects 1998-2002

DG Research

Introduction:

The European Commission's 5th Framework Programme for R&D does fund demonstration projects (short to medium term impact) and research projects with medium to long term impact on the market.

The 23 funded research projects can be divided into the following categories:

A. Wind turbines

B. Blades and rotors

C. Wind resources forecasting and mapping

D. Wind farm development and management

E. Integration of wind power

windmills, courtesy of ESN

The new 6th Framework Programme has launched its first call for proposals and will select first projects to be funded in the course of 2003.
Here is the list of presently funded projects including a general justification for the funding of the specific project(s):

A – Turbines

A1. Research and development of a 5 MW Wind Turbine
Reference: ENK5-CT-2000-00300 **Project Acronym:** 5 MW WIND TURBINE
Larger wind turbines offer economies of scale and make better use of good sites.

A2. Development of a MW scale wind turbine for high wind complex terrain sites
Reference: ENK5-CT-2000-00328 **Project Acronym:** MEGAWIND
On complex terrain with high wind speeds, turbines must be easy to transport and to install and they must be able to endure higher mechanical loads. Use of such sites increases the potential for use of the wind resource.

A3. Recommendations for design of offshore wind turbines
Reference: ENK5-CT-2000-00322 **Project Acronym:** RECOFF
Experience from first offshore installations is used to define norms and standards for this type of wind turbines. This will decrease the technical and financial risk of future installations.

A4. Exploring new concepts for small and medium-sized wind mills with improved performance.
Reference: ENK5-CT-2002-30034 **Project Acronym:** EXPLOREWIND
A CRAFT initiative to investigate the efficiency, cost reduction, and environmental issues found in new wind turbine concepts for non-grid-connected power systems, by developing and testing small and medium-sized windmills.

#	Contract Reference	Project Acronym	Total Budget	EC Contrib.	Duration (months)
A1	ENK5-CT-2000-00300	5 MW Wind Turbine	3 521 311	1 760 656	36
A2	ENK5-CT-2000-00328	MEGAWIND	3 536 065	1 999 704	36
A3	ENK5-CT-2000-00322	RECOFF	1 596 446	798 223	36
A4	ENK5-CT-2002-30034	EXPLOREWIND	689.150	344.550	24

B – Blades and rotors

The blades are the most critical components of wind turbines:

- the aerodynamic properties of the blades can still be improved using experimental data from operating wind turbines and from wind tunnel measurements or e.g. by knowledge transferred from aeronautics; this does lead to more efficiency and to less noise;
- the dynamic behaviour of blades can be improved with new materials and their skilful combination, especially in view of reducing overall weight;
- the hub, too, can become less heavy and more resistant to dynamic loads with the use of new materials.

B1. Wind turbine rotor blades for enhanced aeroelastic stability and fatigue life using passively damped composites
Reference: ENK6-CT-2000-00320 **Project Acronym:** DAMPBLADE

B2. Wind Turbine Blade Aerodynamics And Aeroelastics: Closing Knowledge Gaps
Reference: ENK6-CT-2001-00503 **Project Acronym:** KNOW-BLADE

B3. Model rotor experiments under controlled conditions
Reference: ENK5-CT-2000-00309 **Project Acronym:** MEXICO

B4. Reliable Optimal Use of Materials for Wind Turbine Rotor Blades
Reference: ENK6-CT-2001-00552 **Project Acronym:** OPTIMAT BLADES

B5. Silent rotors by acoustic optimisation
Reference: ENK5-CT-2002-00702 **Project Acronym:** SIROCCO

B6. Aerolastic stability and control of large wind turbines
Reference: ENK5-CT-2002-00627 **Project Acronym:** STABCON

B7. Innovative Composite Hub For Wind Turbines
Reference: ERK6-CT-1999-00008 **Project Acronym:** COMHUB

#	Contract Reference	Project Acronym	Total Budget	EC Contrib.	Duration (months)
B1	ENK6-CT-2000-00320	DAMPBLADE	1 990 056	1 138 822	36
B2	ENK6-CT-2001-00503	KNOW-BLADE	1 534 453	999 923	36
B3	ENK5-CT-2000-00309	MEXICO	2 340 774	1 500 000	36
B4	ENK6-CT-2001-00552	OPTIMAT BLADES	4 403 140	2 399 088	52
B5	ENK5-CT-2002-00702	SIROCCO	3 749 101	1 700 000	36
B6	ENK5-CT-2002-00627	STABCON	3 613 783	1 900 000	48
B7	ERK6-CT-1999-00008	COMHUB	1 389 096	785 489	36

C – Wind resources forecasting and mapping

Better knowledge of wind resources significantly reduces the cost of wind energy production by:

- selection of the most appropriate sites with high wind and more steady conditions,
- better forecasting of power production (increasing reliability of supply)
- preventive action to protect wind turbines from excessive wind loads

C1. Development of a next generation wind resource forecasting system for the large-scale integration of onshore and offshore wind farms
Reference: ENK5-CT-2002-00665 **Project Acronym:** ANEMOS

C2. A high resolution numerical wind energy model for on- and offshore forecasting using ensemble predictions
Reference: ENK5-CT-2002-00606 **Project Acronym:** HONEYMOON

C3. Wind energy mapping using synthetic aperture radar
Reference: ERK6-CT-1999-00017 **Project Acronym:** WEMSAR

#	Contract Reference	Project Acronym	Total Budget	EC Contrib.	Duration (months)
C1	ENK5-CT-2002-00665	ANEMOS	5.396.542	2.500.000	42
C2	ENK5-CT-2002-00606	HONEYMOON	1.176.361	891.690	24
C3	ERK6-CT-1999-00017	WEMSAR	1.192.244	596.122	36

D – Wind farms

windmills courtesy of ESN

Wind farms, i.e. groups of wind turbines installed at given sites, offer economies of scale and make better use of the sites. The funded projects aim to improve the management, monitoring and surveillance of such wind farms and to provide recommendations how best to set up such wind farms.

D1. Advanced management and surveillance of wind farms
Reference: ERK6-CT-1999-00006 Project Acronym: CLEVERFARM

D2. Efficient development of offshore windfarms
Reference: ERK6-CT-1999-00001 **Project Acronym:** ENDOW

D3. Condition Monitoring For Offshore Wind Farms
Reference: ENK5-CT-2002-00659 **Project Acronym:** CONMOW

#	Contract Reference	Project Acronym	Total Budget	EC Contrib.	Duration (months)
D1	ERK6-CT-1999-00006	CLEVERFARM	833 503	498 000	36
D2	ERK6-CT-1999-00001	ENDOW	1 204 000	697 902	36
D3	ENK5-CT-2002-00659	CONMOW	1 977 915	1 070 189	48

E – Integration of wind power

Wind is a source of electric power, which varies in time and is produced in a decentralised way (even if modern offshore wind parks will soon have generation capacities comparable to conventional power plants). This creates special problems, especially if wind is to provide a high share of overall electric power supply. These problems can be solved or at least alleviated by dedicated research efforts on the integration of wind power into the local and/or (inter-) national grid.

E1. Wind Energy Network
Reference: ENK6-CT-2001-20401 **Project Acronym:** WIND ENERGY NETWORK

E2. Towards high penetration and firm power from wind energy
Reference: ERK5-CT-1999-00016 **Project Acronym:** FIRMWIND

E3. More advanced control advice for secure operation of isolated power systems with increased renewable energy penetration and storage
Reference: ERK5-CT-1999-00019 **Project Acronym:** MORE CARE

E4. Wind power integration in a liberalised electricity market
Reference: ENK5-CT-2002-00663 **Project Acronym:** WILMAR

E5. Cluster Pilot Project For The Integration Of Res Into European Energy Sectors Using Hydrogen
Reference: ENK5-CT-2001-00536 **Project Acronym:** RES2H2

E6. Solar And Wind Technology Excellence, Knowledge Exchange And Twinning Actions Romanian Centre
Reference: ENK5-CT-2002-80667 **Project Acronym:** RO-SWEET

#	Contract Reference	Project Acronym	Total Budget	EC Contrib.	Duration (months)
E1	ENK6-CT-2001-20401	WIND ENERGY NETWORK	653 421	400 000	42
E2	ERK5-CT-1999-00016	FIRMWIND	876 208	463 040	36
E3	ERK5-CT-1999-00019	MORE CARE	1 515 841	900 000	36
E4	ENK5-CT-2002-00663	WILMAR	3 214 682	1 400 000	36
E5	ENK5-CT-2001-00536	RES2H2	5.266.610	2.500.000	60
E6	ENK5-CT-2002-80667	RO-SWEET	391.300	350.000	36

	Total Budget	**EC Contrib.**
23 projects in total:	**52 062 002 €**	**27 593 398 €**

In the following pages, you will find the project summaries ordered as above.

European Commission Contact:

Thierry LANGLOIS d'ESTAINTOT
European Commission
Office MO 75 7/23
B-1049 Brussels Belgium
Tel. direct: +32-2-295.07.65 secretariat: +32-2-295.60.70
Fax: +32-2-2993694
Email: thierry.d'estaintot@cec.eu.int

#	Contract Reference	Project Acronym	Total Budget	EC Contrib.	Duration (months)
A1	ENK5-CT-2000-00300	5 MW Wind Turbine	3521311	1760656	36
A2	ENK5-CT-2000-00328	MEGAWIND	3536065	199704	36
A3	ENK5-CT-2000-00322	RECOFF	1596446	798223	36
A4	ENK5-CT-2002-30034	EXPLOREWIND	689150	344550	24
B1	ENK6-CT-2000-00320	DAMPBLADE	1990056	1138822	36
B2	ENK6-CT-2001-00503	KNOW-BLADE	1534453	999923	36
B3	ENK5-CT-2000-00309	MEXICO	2340774	1500000	36
B4	ENK6-CT-2001-00552	OPTIMAT BLADES	4403140	2399088	52
B5	ENK5-CT-2002-00702	SIROCCO	3749101	1700000	36
B6	ENK5-CT-2002-00627	STABCON	3613783	1900000	48
B7	ERK6-CT-1999-00008	COMHUB	1389096	785489	36
C1	ENK5-CT-2002-00665	ANEMOS	5396542	2500000	42
C2	ENK5-CT-2002-00606	HONEYMOON	1176361	891690	24
C3	ERK6-CT-1999-00017	WEMSAR	1192244	596122	36
D1	ERK6-CT-1999-00006	CLEVERFARM	833503	498000	36
D2	ERK6-CT-1999-00001	ENDOW	1204000	697902	36
D3	ENK5-CT-2002-00659	CONMOW	1977915	1070189	48
E1	ENK6-CT-2001-20401	WIND ENERGY NETWORK	653421	400000	42
E2	ERK5-CT-1999-00016	FIRMWIND	876208	463040	36
E3	ERK5-CT-1999-00019	MORE CARE	1515841	900000	36
E4	ENK5-CT-2002-00663	WILMAR	3214682	1400000	36
E5	ENK5-CT-2001-00536	RES2H2	5266610	2500000	60
E6	ENK5-CT-2002-80667	RO-SWEET	391300	350000	36
	23 contracts	**TOTALS:**	**52062002**	**25793398**	

A-TURBINES

CONTRACT No : ENK5-CT-2000-00300

PROJECT ACRONYM : 5 MW WIND TURBINE

TITLE : Research and Development of a 5 MW Wind Turbine

PROJECT CO-ORDINATOR :

Mr. Lars BUDTZ
VESTAS WIND SYSTEMS A/S
Smed Soerensens Vej 5
DK- 6950 Ringkoebing
Tel: + 4596752575
Fax: + 4596752608
Email: sdp@vestas.dk

PARTNERS :

- **HANSEN TRANSMISSIONS INTERNATIONAL N.V . (BE)**
- **MOTEURS LEROY SOMER (FR)**

PROJECT START DATE : 1/1/2001 DURATION: 42 MONTHS

PROJECT SUMMARY

Objectives and problems to be solved:
Several factors have stimulated the trend towards bigger and bigger wind turbines: economics of scale, scarcity of sites & off-shore locations and the learning curve of the technology. Using new technical concepts and new this project will establish the complete technical and economical platform for a later production of a 5 MW WT. All the research, development and engineering - including manufacturing, operation, testing and evaluation of prototype components - needed for the manufacturing of a complete prototype 5 MW WT. The project is as such a design project and does not encompass the actual production of a complete WT. Expected data for a 5 MW WT are hub height: 120m, rotor diameter: 120m, nominal output: 5 MW, mode of operation: variable speed, each blade with intelligent pitch control.

Description of work:
The work will focus on the following R&D issues:
· integrated drive train concept with a potential nacelle weight reduction of 25% relative compared to present 2 MW machines.
· light weight blades/rotor using composite materials and new (non-NACA) pro files; expected relative weight reduction 15%.
· concept of direct conversion of output from a synchronous generator to HVDC.
· Integration in a 5 MW WT with variable speed and intelligent pitch control.

The work will be organised as outlined below:
WP1 Project management and coordination; integration of part-results to a common 5 MW machine platform.
WP2 New nacelle drawing the full benefits of planned weight and load reductions.
WP3 120 m rotor, lightweight blades of composite materials with a new profile.
WP4 Power concept for direct conversion to HVDC of output of a synchronous generator operating at variable speed.
WP5 5 MW synchronous generator optimised for this power concept.
WP6 Integrated drive train concept (no main axle) with a potential weight reduction of 25% relative compared to state-of-art 2 MW machines.
Prototypes of components and sub- assemblies will be manufactured as needed, but no complete operational WT will be produced.

Expected results and exploitation plans:
The main result of the project will be the reduction of the cost of kWh produced. This will be achieved by reduced extreme loads, by the reduction of nacelle w eight to ±30 kg/kW, of rotor weight by 15% and edgewise loads by 20% and by an efficiency increase of 1-2 % due to the new profile. The new HVDC concept reduces power losses, removes the need for a low voltage converter and perhaps also for slip rings in the power circuit.

CONTRACT N°: ENK5-CT-2000-00328

PROJECT ACRONYM: MEGAWIND

TITLE: DEVELOPMENT OF A MW SCALE WIND TURBINE FOR HIGH WIND COMPLEX TERRAIN SITES

PROJECT CO-ORDINATOR :

Mr. P. S. VIONIS
CRES, Centre for Renewable Energy Sources, Greece
19th km Marathonos Ave,
GR-19009 Pikermi, Greece
Phone: +302106603300
Fax: +302106603301
E-mail: pvioni@cres.gr

PARTNERS :

- **MADE (ES)**
- **NECSO (ES)**
- **GEOBIOLOGIKI (GEO) (GR)**
- **CIEMAT (ES)**
- **JRC-EC-ISIS (IT)**
- **ICE-HT/FORTH (GR)**
- **University of Patras (UP) (GR)**
- **National Technical University of Athens (NTUA) (GR)**
- **Newcastle Univ. (DU-NU) (UK)**

PROJECT START DATE: 1/1/2001 DURATION: 48 MONTHS

CONTRACT No :**ENK5-CT2000-00328** PROJECT ACRONYM: **MEGAWIND**

TITLE: **Development of a MW scale Wind Turbine for High Wind Complex Terrain Sites**

PROJECT SUMMARY

Objectives and problems to be solved

The high penetration of wind energy mainly in the Southern part of Europe but also in some regions in Central and Northern Europe is directly related to installing large capacity turbines in mountainous-complex terrain sites. It is anticipated that nearly 25% of the 40GW target for wind turbine installations in Europe by 2010 will be developed in such areas. In this connection the challenge for the European industry is twofold: to develop procedures which circumvent the barriers set to the transport and erection of MW -size machines in areas of limited infrastructure and to reduce costs by means of design optimisation and tailoring. MEGA WIND sets out to formulate such procedures and apply them to the design and construction of a 1.3 MW prototype for high wind sites.

Description of work

The conventional wind turbine design procedure is revised and adapted in the following four aspects: i) The geometry of the blade is optimised for maximum energy capture under high wind speed conditions. The structural design follows a split-blade concept. ii) On-site manufactured towers, featuring composite material shells and concrete or other core material kernels are introduced. iii) The gearbox is specifically designed for high wind high turbulent conditions aiming at developing a highly reliable, low cost, low weight, low noise emission geared drive system. iv) The introduced compact design concept (split-blades, on-site tower construction, lightweight components) will facilitate machine transportation and erection under reduced infrastructure requirements. The wind turbine design is conducted according to the IEC 61400-1 standard using state-of-the-art tools, extensively validated in complex terrain applications. The performance of the prototype components will be evaluated through systematic testing.

Expected results and exploitation plans

The introduction of new materials and design options in wind energy industry will impose favourable socio-economic impacts in Europe by enhancing industry competitiveness, supporting employment and promoting social cohesion by the regional industrial development. MEGA WIND has been designed to overcome the bottlenecks that hinder the full exploitation of large capacity machines in complex terrain. In particular the MW -size technology will be applied to complex terrain, a MW size machine will be designed for high wind speed, the compact design concept is introduced for easier -cheaper- transportation and erection of large wind turbines and the construction of the prototype components will verify the design approach.

Achievements to date

The design of the rotor blade, the composite material tower and the transmission system have been finalised, as well as extensive sub-component testing undertaken to verify the design at early stages. Moreover, the prototype 30m split-blade has been manufactured and its laboratory testing is under preparation. The full-scale composite material tower is under construction and its installation for full-scale testing is in preparation.

CONTRACT No : ENK5-CT-2000-00322

PROJECT ACRONYM : RECOFF

TITLE : RECommendations for design of OFFshore wind turbines

PROJECT CO-ORDINATOR :
Dr. Sten T. FRANDSEN
RISOE NATIONAL LABORATORY
Frederiksborgvej 399
DK- 4000 Roskilde
Tel: + 4546775072
Fax: + 4546775083
Email: sten.frandsen@risoe.dk

PARTNERS :

- **CENTRE FOR RENEWABLE ENERGY SOURCES (GR)**
- **GERMANISCHER LLOYD WINDENERGIE GMBH (DE)**
- **GARRAD HASSAN AND PARTNERS, LTD (UK)**
- **NETHERLANDS ENERGY RESEARCH FOUNDATION (NL)**

PROJECT START DATE : 1/1/2001 DURATION: 44 MONTHS

CONTRACT No **: ENK5-CT-2000-00322** PROJECT ACRONYM **: RECOFF**
TITLE **: Recommendations for Design of Offshore Wind Turbines**

PROJECT SUMMARY

Objectives and problems to be solved

The objective has been to prepare guidelines and recommendations for design of offshore wind turbines. The main intended use of the project results has been the provision of recommendations for European and national standards for offshore wind turbines and the development of certification rules for offshore wind turbines. The success of the project will be marked by the delivery of reliable and robust design methods and certification rules needed for the safe development of offshore wind farms. This will have direct impact on the readiness to invest in offshore wind energy projects and cut objections connected with project safety.

Description of work

Readily available information has been reviewed and utilisation to the extent possible has been made. In several areas a need for research was identified and generic results were obtained. Specifically, we emphasize the following subjects where recommendations have been obtained:

- *External conditions*: review of existing standards, regulations and literature resulting in recommendations for good practice.
- *Analysis methods*: methods for lumping, mainly with respect to wave loading, of fatigue load cases
- *Analysis methods*: principle of synthesizing load cases for different wind directions, wind speeds, and sea states in order to obtain extreme response during normal operation
- *Design load cases*: drafting, partially based on project results, proposals for a suitable, i.e. limited and representative, DLC table for offshore turbines
- *Probabilistic methods*: review of general methods and application of probabilistic calibration methods to the combined action of wind and wave loads in the storm event.
- *Structural integrity*: based on discussions about reliability levels onshore and offshore and based on comparisons with current practise proposals for safety factors in fatigue and extreme load events are given.
- *Operation and maintenance*: documents with recommendations regarding labour safety, and monitoring of turbine performance have been prepared.

Results and exploitation

The RECOFF project has run in parallel with a working group (TC88-WG03) set up by the IEC (International Electro-technical Commission) and assigned the task of preparing a separate international standard for design of offshore wind turbines. Several of the RECOFF partners are members of the IEC-TC88-WG03, which has caused a strong interaction with current international standardisation work, and a rapid implementation of the findings of the RECOFF project in terms of obtaining the status of being standards' material. Once the IEC standard has been accepted it will soon become a European CENELEC standard as well. Thus the intended aim of the project has been achieved.

Achievements to date

The project has been finalised. See above.

CONTRACT N°: ENK5-CT-2002-30034

PROJECT ACRONYM: EXPLOREWIND

PROJECT TITLE: Exploring new concepts for small and medium-sized wind mills with improved performance.

PROJECT CO-ORDINATOR:

Dr. Torger Tveter
IDEUTVIKLING AS
NO-2110 Slaastad Norway
Tel. +47 6296 7292
Fax. +47 6296 7172
Email: ideutvikling@netcom.no

PARTNERS:

SME proposers

- **Ideutvikling (NO)**
- **Mjosplast (NO)**
- **Desmi (DK)**
- **GEA (IT)**
- **Solaris(PL)**

RTD Performers

- **Sintef (NO)**
- **Labor (IT)**
- **Canary Islands Institute of Technology(ITC**

PROJECT START : 1/1/2003 DURATION : 24 MONTHS

CONTRACT No **: ENK5-2002-30034** PROJECT ACRONYM **: EXPLOREWIND**

TITLE **: Exploring new concepts for small and medium-sized wind mills to improve performance**

PROJECT SUMMARY

Objectives and problems to be solved

EXPLOREWIND is expected to investigate the efficiency, cost reduction, and environmental issues found in new wind turbine concepts for small sized non-grid-connected power systems.

Description of work

The workplan has been built around the following objectives:

A. Development of a downwind turbine with basic new aerodynamic design in the purpose of achieving increased efficiency

B. Improving performance by:

- New design of top mast section to eliminate mast turbulence to the downwind turbine.
- Test set up with direct drive of ground based pumps, generators etc. connected to the turbine by bevel gear and mechanical mast transmission, exploring how gyro forces may affect the turbine through the bevel gear
- Attention to develop a tidy package for transport and to simple mounting and rising solutions

C. Achieving manufacturing and installation costs of less than 8.000 Euro for a 5 kW wind mill, or 1 kW at a total cost of 4.500 Euro, by means of:

- Components modularity
- Design and manufacturing for ease of transportation and installation

Expected results and exploitation plans

EXPLOREWIND is expected to provide future life to downwind technology, creating a family of low costs, easy scaleable, stand-alone small sized wind generators.This family is expected to address directly the market segment of stand-alone applications, existing in Europe and mostly in the third world countries, where there are many areas in which the connection to a power grid is expensive or unreliable.The research proposed in this project will be ideal for use in small communities located in remote areas, in third world countries and wherever it is necessary to produce energy close to where it is consumed, making it possible to implement easily new applications powered by the available ground based mechanical drive (e.g. centrifugal pumps in the purpose of running desalination systems, etc).

Achievements to date

The design phase has been completed, and full computational fluidodynamic investigation has been performed.A prototype is available and testing is expected to start in early October 2004. The prototype is prepared with 3 different sets and lengths of turbine blades. Tests will be made with different mixes of 3 and 6 blades.

The turbine diameter with long blades is 4 meters. With small blades the diameter is respectively 2,4m and 2,2m. The test set up with registration of flow and pressure from the pump, will give a wide documentation of the turbine efficiency from low to high wind speeds.

B-BLADES & ROTORS

CONTRACT No : ENK6-CT2000-00320

PROJECT ACRONYM : DAMPBLADE

TITLE : Wind Turbine Rotor Blades for Enhanced Aeroelastic Stability and Fatigue Life Using Passively Damped Composites

PROJECT CO-ORDINATOR :

Dr Panagiotis Chaviaropoulos
CRES, Centre for Renewable Energy Sources, Greece
19th km Marathonos Ave,
GR-19009 Pikermi, Greece
Phone: +302106603300
Fax: +302106603301
E-mail: tchaviar@cres.gr

PARTNERS :

- **RISOE (DK)**
- **ECN (NL)**
- **ICE/HT-FORTH (GR)**
- **GEOVIOLOGIKI S.A. (GR)**
- **UNIVERSITY OF PATRAS (GR)**
- **DTU (DK)**

PROJECT START DATE : 1/1/2000 DURATION 48 MONTHS

Date of issue : 23/8/2004

CONTRACT No :ENK6-CT2000-00320 PROJECT ACRONYM : DAMPBLADE
TITLE : Wind Turbine Rotor Blades for Enhanced Aeroelastic Stability and Fatigue Life Using Passively Damped Composites

PROJECT SUMMARY

Objectives and problems to be solved

The development of damped composite wind-turbine blades and direct prediction of composite damping into future blade design practices are the main objectives of the project. Additional objectives are the development of missing critical analytical technologies enabling explicit modelling of composite structural damping and a novel "composite blade design capacity" enabling direct prediction of aeroelastic stability and fatigue-life; development and characterization of damped composite materials; and evaluation of new technology via design and fabrication of damped prototype blades and full-scale laboratory and field-testing.

Description of work

These objectives will be attained through many research and validation tasks. Unique composite damping mechanisms are exploited: tailoring of laminate damping anisotropy, damping layers and damped polymer matrices. Novel composite damping models and damping finite elements, aeroelastic tools, and fatigue-life models are developed. New higher-damping polymers have been engineered and extensive characterization of new damped composite materials and laminates has been conducted to establish a complete database with elastic, damping, strength and fatigue-life data. A unified blade design capability is established enabling direct improvements in aeroelastic performance. Two prototype -damped- blades are designed, fabricated and tested. A rotor is manufactured and will be field-tested to demonstrate aeroelastic improvements. The project will provide unique aeroelastic and life prediction capabilities by providing missing composite damping models. Damped blades will contribute towards development of large W/Ts, by helping to overcome current "bottleneck" problems related to aeroelastic stability.

Expected results and exploitation plans

Significant results are: verified damping elements, the material data bank, a verified stability tool, the "blade design capacity", damped blades, and measured lab- and field-data. The project will have significant impact towards increasing the durability and operational life of current blades.

Achievements to date

All tasks with the exception of the rotor field-testing have been successfully completed. Lab-testing of a redesigned damped glass-polyester blade yielded more than 80% damping capacity improvement, in both (first) flap and lead-lag modes, compared to the original blade.

CONTRACT N° : ENK6-CT-2001-00503

PROJECT ACRONYM : KNOW-BLADE

TITLE :
WIND TURBINE BLADE AERODYNAMICS AND AEROELASTICITY: CLOSING KNOWLEDGE GAPS

PROJECT CO-ORDINATOR :

Dr. Niels N. Sørensen
RISOE, Risø National Laboratory, Denmark
DK-4000 Roskilde Denmark
Phone: +45 46775053
Fax: +45 46775083
Email: niels.soerensen@risoe.dk

PARTNERS :

- **RISOE (DK)**
- **CRES (GR)**
- **DLR (DE)**
- **FOI (SE)**
- **DTU (DK)**
- **NTUA (GR)**
- **VUB (BE)**
- **FORTH (GR)**
- **LMG (DK)**

PROJECT START DATE : 1/12/2001 DURATION : 36 month

Date of issue : 19-12-2003

CONTRACT No: **ENK6-CT-2001-00503** ACRONYM: **KNOW-BLADE**

TITLE: **WIND TURBINE BLADE AERODYNAMICS AND AEROELASTICITY: CLOSING KNOWLEDGE GAPS**

PROJECT SUMMARY

Objectives and problems to be solved

The objective of the project is to fill in important knowledge gaps in the wind turbine community by applying Navier-Stokes (NS) solvers to a series of unsolved aerodynamic and aeroelastic problems. Focus is especially given to the following four topics:

- Improving the power prediction capability of existing 3D Navier-Stokes solvers.
- Introducing models for aerodynamic accessories, vortex generators, stall strips etc, in existing Navier-Stokes solvers.
- Aeroelastic modelling in two and three-dimensions with Navier-Stokes aerodynamics.
- Investigation of industrial flow details: Tip-shapes and loads during stand still.

Description of work

The task of improving the prediction capability of NS-solvers has been concentrated on implementing laminar/turbulent transition in the codes, investigating the potential of advanced Reynolds Averaged Navier-Stokes turbulence models and Detached Eddy Simulation (DES) techniques. The activities around aerodynamic accessories have been following two paths, one group has used 2D simulations to investigate phenomenological models, changed surface geometries and special boundary conditions. Another group has investigated vortex generators in 3D either by directly resolving the vortex generators, using kinematic boundary conditions or introducing vorticity directly in the domain. The aeroelastic work has concentrated on developing a full 3D aeroelastic NS-tool, and using 2D aeroelastic NS tools to investigate the damping properties of airfoils equipped with aerodynamic devices. Finally, work has been done on industrial details, investigating several different tip shapes and load cases for rotors during stand still for two different blade geometries.

Expected results and exploitation plans

As the project is nearly finished several of the results has already been achieved of which some are listed below, the main way of exploitations is through direct interaction with industry using the developed methodologies and through publication in journals.

Achievements to date

During the project several laminar/turbulent transition models have been implemented indicating a potential for improving the power prediction capability. Additionally, the first DES of a full wind turbine rotor has been performed in the project.

The work on aerodynamic devices has shown that the simple 2D models can give some insight to the qualitative behaviour of the devices both aerodynamically and with respect to their aeroelastic behaviour but that they are not accurately enough to give quantitative values. A full 3D NS-aeroelastic model has been implemented, and can be used for predicting aeroelastic stability of rotors. Finally, a series of different tip shapes has been studied aerodynamically during rotational conditions and loads for rotor blades during standstill have been computed providing high quality data.

CONTRACT N° : ENK6-CT-2000-00309

PROJECT ACRONYM : MEXICO

TITLE : Model Experiments in Controlled Conditions

PROJECT CO-ORDINATOR :

Dr. Herman Snel
The Energy Research Center of the Netherlands ECN
Wind Energy
Westerduinweg
P.O. Box 1
1755 ZG Petten
The Netherlands
E-Mail : snel@ecn.nl
Phone: +31(0)224 564170
Fax : +31(0)224 568214
Internet: http://www.ecn.nl/

PARTNERS :

- National Aerospace Laboratory NLR (NL)
- Delft University of Technology DUT (NL)
- Israel Institute of Technology TECHNION (IL)
- Risoe National Laboratory (DK)
- Danish Technical University DTU (DK)
- Aeronautical Research Institute of Sweden FFA (SE)
- Centre for Renewable Energy Sources CRES (GR)
- National Technical University of Athens NTUA (Associate) (GR)

PROJECT START DATE : 1/1/2001 DURATION : 60 months

Date of issue: January 2004

PROJECT SUMMARY

Objectives

With the growing size and investment cost of wind turbines, there is an equally growing demand for more reliable design methods. This is especially the case for offshore turbines, where the reliability of the machine and its design are among the most important challenges. At present the uncertainty in design calculations is 10%-20% for performance prediction (the higher number relating to stall conditions) and 30% for dynamic load prediction.

The principal objective of this project is to significantly reduce these uncertainties by providing an experimental database obtained under controlled and hence known conditions and by using the increased physical insight resulting from the experiments in engineering design methods. At the same time, the database is necessary to provide a validation tool for the upcoming area of Navier Stokes based calculation techniques. The improvement of engineering design codes is a short term objective; it will be available at the end of the project. The effect of Navier Stokes validation on the design practice can be expected to take place within a period of five to seven years.

In order to meet the objectives a work plan was devised [1], consisting of four phases. The first phase culminates in the detailed design of a sophisticated wind tunnel model to be tested in the Large Scale Low Speed facility of the DNW. The second phase consists in the construction and instrumentation of the model, the design and manufacturing of the data transfer and data acquisition system and the design of the experiment, i.e. the detailed programme of measurements and conditions to be covered. The actual performance of the measurement campaigns, the data processing and the data interpretation is done in the third phase. Finally the fourth phase consists in the possible adaptation of BEM modelling based on improved insight and knowledge, and in some initial Navier Stokes comparisons with the measured data. Also the available data will be organized in a data base for easy access.

Work performed/Achievements to date

Although significant progress has been made, some uncertainties surfaced, mainly within the second year, but to a smaller extent in the third year as well. The lengthy discussions on these uncertainties led to delays in the overall progress and made it inevitable to postpone the actual DNW wind tunnel experiment. Thereto a new workplan has been prepared and a 2 years extension in project duration was requested at the EU. The necessary contract amendment was approved in December 2003.
The main delays and modifications are:

- Immediately after the signature of the contract, one of the partners, Aerpac B.V. went bankrupt. After a long period of negotiations, Aerpac B.V. was replaced by another blade manufacturer: Polymarin B.V. Unfortunately Polymarin went bankrupt in November 2002. Another period of negotiations followed in which it was attempted to find a substitute for Polymarin. Finally, it was decided to continue the project without a blade manufacturer.

- Within the project some CFD calculations were carried out, which showed considerable blockage effects for the DNW wind tunnel configuration. Although the understanding of the physics behind the blockage effects has been enhanced considerably, the PCC (Project Co-ordination Committee) decided to pay more attention to the blockage disturbance than originally planned. Thereto an experimental verification of expected tunnel effects in a so-called pilot tunnel test was considered to be essential for the interpretation and understanding of the final results. The decision to perform the pilot tunnel test effected the work plan and the budget distribution considerably.
- Conflicting requirements between structural requirements on the model blade on one hand, and the required space for the electronics in the model blade on the other hand, led to a considerable delay in the design of the blade. The original decision to mount all pressure sensors in one blade even had to be changed.
- Decisions on the test matrix led to considerable changes in work plan and budget. This holds in particular for a new measurement technique in the DNW which has developed very rapidly: PIV (Particle Image Velocimetry). This technique was not scheduled within the original work plan, but the possibilities of this technique are so promising that the PCC decided to apply PIV.
- It was decided to use the DNW tunnel balance for the measurement of the integral rotor loads. Unfortunately, mounting this balance is very time consuming and will be charged from the available tunnel time. Hence the available tunnel time for the actual tests is reduced.
- The tunnel slot which was anticipated for November 2002 was no longer realistic. The first possible tunnel slot is now January 2005

At present (January 2004), the status of the project is as follows:

- In July/August 2003, the pilot tunnel test has been performed. The results of this test, together with new insights from additional CFD calculations, gave indications that tunnel effects were less severe than originally feared;
- A new test matrix has been defined in draft;
- The design of the system (blades, nacelle, nacelle, dynamometer, instrumentation) is completed. It turned out to be necessary to distribute the pressure sensors over different blades. Some details still need to be finalised regarding the design of the tower;
- At present, the electrical components for the pitching mechanism are delivered. The mechanical components of the pitching mechanism are manufactured. Many nacelle components are manufactured and delivered where some other components are currently manufactured. The components for the dynamometer have been delivered.
- Much effort was needed in the negotiations with potential subcontractors which could manufacture the blades. Anticipated candidates were found to be not eligible for administrative reasons and new candidates needed to be found. In February 2004 the subcontract was closed.
- PIV will be applied. As a result, the project group decided to skip the near wake measurements with the so-called near-wake rig, since PIV offers a good alternative for this. Furthermore PIV made the flow-visualisation activities with liquid crystals and smoke superfluous; in fact the PIV technique combines quantitative information with flow visualisation.
- Data acquisition and storage will be extended with a Data Grabber. The Data Grabber is a PC based system, with a special National Instruments extension card for reading the high speed data streams that grabs data out of the continuous data streams coming from the rotor. On the PC an application specific software package is running. This package

provides data grabbing and storage of the 5 data streams from the rotor over a certain adjustable period of time. The start of data storage is triggered by a hardware signal after the operator has enabled the system to start grabbing data.
- The construction of the DU 91-W2-250 airfoil for the (2D) wind tunnel measurements is completed and first measurements are performed. A new tunnel entry is still needed. The construction of the NACA 64-418 airfoil is currently underway.

Time schedule

- The manufacturing of the blades will start in February 2004 to be finished by May 2004. This includes the manufacturing, the measurement of blade contours, and some preliminary tests.
- The manufacturing of all other model components, including the PCB's will be done in parallel: The pitching mechanism will be finished in February 2004, the nacelle will be finished in March 2004 and the dynamometer will be finished in the beginning of April 2004. The tower will also be finished in the beginning of April 2004. The PCB's will be finished in the beginning of April 2004.
- The Kulite pressure transducers are expected to be shipped in April 2004. Thereafter a delivery test will be performed;
- At the end of May 2004, the model components will be shipped to the DNW preparation hall, where the Kulites, the PCB's etc., and the additional sensors will be integrated into the model. This will be ready by the end of June 2004.
- Thereafter the model is integrated and placed on the model support frame. This will be finished b the end of August 2004.
- The mechanical tests, including the static balancing and including a rotating stability test, need another 2 months (until the end of October 2004). An experiment set-up test hall is available.
- The first possible tunnel slot in the LLF tunnel will then be the beginning January 2005.

Apart from model construction and assembly, the following preparatory activities are performed in parallel:
- The Processing software will be developed.
- The second entry for the 2D wind tunnel measurements on the DU 91-W2-250 airfoil will be performed in March 2004. The 2D wind tunnel measurements on the NACA 64-418 airfoil will be carried out in June 2004.

After the measurement program is completed in the LLF tunnel of DNW, the measurements will be processed, stored into a database and analysed. The analysis aims to improve engineering type of models, based on blade element momentum theory. In addition more advanced CFD methods will be improved on basis of the measurements.

Expected end results

It is expected that the resulting database, additional to its short and medium term objectives, will serve the wind community for many years to come as a basis for further model improvement and validation. To underline this expectation, it should be noted that the much more reduced and limited database that resulted from FFA measurements (more than ten years ago) in the Chinese CARDC wind tunnel is being used even in the present (e.g. Project Viscel, Contract JOR CT98-0208).

Dissemination of the results is an essential element to reach the pursued objective. To this effect a CD-ROM based database with all results is to be made. More importantly a package with material to conduct workshops for the wind energy industry is to be prepared and presented at least once during the project. The package will be available to all participants to conduct future workshops. This task is to be co-ordinated with EWEA and its future R&D platform.

CONTRACT N°: ENK6-CT-2001-00552

PROJECT ACRONYM: OPTIMAT BLADES

TITLE: Reliable Optimal Use Of Materials For Wind Turbine Rotor Blades

PROJECT CO-ORDINATOR:

Dr. Arno M. van Wingerde
Wind turbine Materials and Constructions
Knowledge Centre WMC
P.O. Box 43
NL-1770 AA Wieringerwerf The Netherlands
Tel: +31-227-504922 / -504949 (secr.)
Fax: +31-227-504948
E-mail: A.M.vanWingerde@wmc.tudelft.nl
Web: www.wmc.tudelft.nl

PARTNERS:

- Energy research Centre of the Netherlands, ECN.WE, (NL, financial co-ordinator)
- Knowledge Centre Wind turbine Materials and Constructions, WMC (NL, Technical Co-ordinator
- Deutsches Zentrum für Luft- und Raumfahrt e.V. DLR.IBK (DE)
- Deutsches Windenergie-Institut GmbH, DEWI (DE)
- Council for the Central Laboratory of Research Councils, CLRC.RAL (UK)
- Risø National Laboratory, RISØ.DM (DK)
- Centre for Renewable Energy Sources, CRES.WED (GR)
- Vrije Universiteit Brussel, VUB.FTW.MEMC (BE)
- University of Patras, UPAT.DME (GR)
- Technical Research Centre of Finland, VTT.ET (FI)
- Germanischer Lloyd WindEnergie GmbH, GL WIND (DE)
- Det Norske Veritas Danmark A/S, DNVD.WTC (DK)
- LM Glasfiber A/S, LMG.RD (DK)
- Polymarin Beheer BV, POLYMARIN (NL)
- Nordex Energy GmbH, NORDEX (DE)
- Gamesa Eólica SA, GAMESA.ED (ES)
- GE Wind Energy GmbH (DE)
- Vestas Wind Systems A/S, VESTAS.RD (DK)

PROJECT START DATE: 1/1/2002 DURATION: 52 MONTHS

CONTRACT No **: ENK6-CT-2001-00552** PROJECT ACRONYM **: OPTIMAT BLADES**
TITLE **: Reliable Optimal Use Of Materials For Wind Turbine Rotor Blades**

PROJECT SUMMARY

Objectives and problems to be solved

The project aims to provide accurate design recommendations for the optimised use of materials within the next generation of wind turbine rotor blades and to achieve improved reliability. This considers the design of new blades, but also the prediction of the residual strength and life. To achieve this overall objective, the project will investigate the structural behaviour of the composite material under the unique combination of conditions experienced by rotor blades such as variable amplitude loading, complex 3-D stress states, extreme environmental conditions, thick laminates and their possible interactions. For life extension, condition assessment and repair techniques will be developed.

Description of work

The fundamental research is carried out in 5 Task Groups investigating the effects of Variable Amplitude loading, Complex Stress states, Extreme Environmental Conditions, Thick laminates & Repair and Residual Strength & Condition Assessment. The Task Group leaders, together with the Certification Bodies, will form Task Group 6, which has the objective to implement the results into design recommendations. The work is divided in 2 main phases. During the first phase the work will be concentrated on one reference material. During the second phase new materials expected to be used for future blades and the interactions of the phenomena investigated during the first phase will be addressed.

Expected results and exploitation plans

The main result of the project will be accurate and reliable design recommendations, allowing for the design of reliable blades with optimised use of materials. Together with the application of condition assessment and repair, this will result in:

- Reliable blades
- Reduced use of material
- Life extension of blades
- Less waste of material
- Larger availability of wind turbines
- Larger turbines possible

All these aspects can contribute to the reduction of costs for wind energy. The increased reliability and weight reduction of the blades will stimulate further the offshore exploitation with large capacity wind turbines.

Achievements to date

- Establishment of a general geometry usable for both uni-direction and multi-direction fibre reinforced materials, for tests on static tension, static compression, fatigue (all stress ratios), and residual strength.
- Establishment of fatigue testing procedures including load levels and frequencies for the reference material and some procedures for establishing testing for other materials.
- Development of tubular and cruciform geometries for bi-axial tests.
- A material database with about 1500 tests from the project has been generated.
- A number of publications have been written.

CONTRACT No. ENK5-CT-2002-00702

PROJECT ACRONYM: SIROCCO

TITLE: Silent Rotors by Acoustic Optimisation

PROJECT CO-ORDINATOR:

Dr. Gerard SCHEPERS
The Energy Research Center of the Netherlands ECN
Wind Energy
P.O. Box 1
1755 ZG Petten, The Netherlands
Tel. +31 (0) 224564115
Fax +31 (0) 224568214
e-mail: schepers@ecn.nl

PARTNERS:

- **University of Stuttgart –UST (Germany)**
- **NLR (The Netherlands)**
- **Gamesa Eólica S.A. – GAM (Spain)**
- **CTC (The Netherlands)**
- **NOI (Germany)**

PROJECT START DATE: 1/1/2003 DURATION :36 MONTHS

Date of issue: February 2004

PROJECT SUMMARY

Objectives

Wind turbine noise is still one of the major hindrances for the widespread use of wind energy in Europe. For modern large turbines, aerodynamic (in particular trailing edge) noise is considered to be the dominant noise source. In a number of European and national projects in the last decade, the understanding of aerodynamic noise from wind turbines has increased significantly, and new noise reduction concepts have been developed.
The principal objective of the SIROCCO project is to obtain a noise reduction of 3-6 dB on fullscale wind turbines, without a reduction in power performance, by improving the aerodynamic flow at the trailing edge of wind turbine blades. Such a noise reduction has a large potential, not only with respect to noise regulations, but also in terms of e.g. a smaller distance to the nearest building, an increased tip speed, or increased public acceptance. In this way, the implementation of wind energy in Europe can be increased greatly. In order to achieve this goal, acoustic field measurements are being performed to characterise the noise sources on two existing (baseline) wind turbines. A new measurement technique, developed in a past EU project with acronym DATA ('Design and Testing of Acoustically Optimised Airfoils for Wind Turbines') will be extended and utilised to localise and quantify noise sources on the rotating blades. In DATA the developed noise reduction concepts resulted in a noise reduction of 3-6 dB on a model scale wind turbine in a large wind tunnel. Parallel to the field measurements, a combined acoustic/aerodynamic design methodology that was developed in DATA is being extended to design low-noise airfoils. Airfoils are being developed, which in contrast to the DATA project exhibit the noise reduction in the polluted (rough) state, the normal state for a wind turbine under real-world conditions. Subsequently the new airfoils will be tested in small scale, two-dimensional acoustic and aerodynamic wind tunnel tests. If the results are satisfactory, low-noise blades will be designed. The designs are being assessed analytically and if the outlook is promising, the blades will be manufactured to validate the acoustic and aerodynamic performance on full-scale wind turbines.

Work performed / Achievements to date

In the first phase (year 1), acoustic field measurements were planned to characterise the noise sources on both baseline turbines. The objective of doing so was to use the acoustic array measurement technique, to verify whether indeed trailing edge noise is the dominant noise source. If other noise sources were present (e.g. gear box, tip noise, holes/slits), it would be attempted to reduce or eliminate these noise sources.
Originally noise tests would be carried on one wind turbine in the Netherlands (selected by NOI and manufactured by Lagerwey) and one wind turbine in Spain (selected and manufactured by the project partner Gamesa). Due to contractual problems with the owner of the Dutch wind turbine and due to the later bankruptcy of Lagerwey during the course of 2003, the wind turbine that the project partner NOI had in mind was neglected and a wind turbine located in Spain was selected instead.
This change to the original project plans influenced both the original planning and budget of the project. NOI succeeded to keep its project costs within budget, but the project accumulated a large delay in the first phase.
In order to minimise the delay; some minor changes were performed to the planning. If no further speed-ups of the project can be achieved, the total project delay will be approximately 11 months.
On the other hand, the first results achieved from the acoustic measurements taken to the wind turbine of Gamesa are very promising. These results show that, as expected, the main wind turbine noise source seems to be aerodynamic noise. This means that apparently no measures need to be taken to solve non-aerodynamic noise. If that's also the case for the wind turbine NOI

has selected, this could speed up the project by approximately 4 months, leading to a general project delay of about six to seven months.
In the field of developing the code for analysis of aerodynamic noise, the University of Stuttgart made large improvements. Moreover, UST designed a variable trailing edge system to be used during the noise tests on the wind-tunnel laboratory in 2004. Extensive boundary layer measurements have been performed on an airfoil with variable trailing edge. In addition UST performed two-dimensional aerodynamic wind tunnel tests on the referenced airfoils already.
In summary, the following achievements can be reported (end 2003):
1. The trailing-edge noise prediction model is being completely re-coded and extended;
2. The extended airfoil analysis code has been validated by comparisons to experiments in a wind tunnel;
3. Two-dimensional scaled models of the reference airfoils of the wind turbine blades have been manufactured by UST and completely tested in clean and rough conditions;
4. Acoustic measurements on one of the chosen turbines (Gamesa) were successfully performed at the end of 2003. The first conclusions with respect to location of aerodynamic noise and the effect of surface roughness are already available.

Future work
In the second phase (years 2003 & 2004, according to original planning), a combined acoustic/aerodynamic design methodology will be utilised to design acoustically optimised airfoils. The new airfoils will be compatible to the inner blades of the baseline turbines, while maintaining the aerodynamic requirements. In the third and last phase (years 2004 & 2005, according to original planning) the design of fullscale rotor blades with the new airfoils will be performed. Using analytical tools, it will be assessed how promising the new designs will be. In this phase (year 2005, according to original planning) the full-scale optimised blades will be also manufactured, after which their acoustic and aerodynamic performance with respect to the baseline blades will be verified in detailed field measurements for varying conditions. On the basis of the experimental results a final evaluation and assessment of the business potential of the new blades will be performed for both turbines.

Expected end results and intentions for their use
Due to the technical risks and the large investments involved in the current project, major milestones are defined in between each of the three phases the project includes. At these points in time it will be assessed whether the results are promising and whether they justify the continuation of the project. On the basis of this assessment a go/ no go decision will be taken for the rest of the project, in consultation with all partners.
The final result of SIROCCO will be the delivery of two sets of validated full-scale, low-noise rotor blades for the baseline turbines, with the same power performance as the existing blades. Furthermore, a validated integrated design methodology will be available, which will enable manufacturers to design silent but efficient rotor blades. These results will be accomplished through a number of intermediate results, such as a validated design methodology for low-noise airfoils, and a proven acoustic measurement technique for location and quantification of rotating noise sources.
Silent rotors have the potential to accelerate the implementation rate of wind energy in Europe significantly. Furthermore, these rotors will improve the competitive position of the European Wind Turbine Industry with respect to e.g. the United States and Japan. The research institutes within SIROCCO will exploit the low-noise airfoil design methodology and acoustic measurement techniques in their consulting activities to wind turbine and other industries, such as aeronautics. Finally, the understanding of fundamental noise mechanisms will be further improved.

CONTRACT N° : ENK5-CT-2002-00627

PROJECT ACRONYM : STABCON

TITLE : AEROELASTIC STABILITY AND CONTROL OF LARGE WIND TURBINES

PROJECT CO-ORDINATOR :

Dr. Flemming RASMUSSEN
RISOE, Risø National Laboratory, Denmark
DK-4000 Roskilde Denmark
Phone: +45 46775053
Fax: +45 46775083
Email: flemming.rasmussen@risoe.dk

PARTNERS :

- **The Energy Research Centre of The Netherlands ECN (NL)**
- **Center for Renewable Energy Sources CRES (GR)**
- **National Technical University of Athens NTUA (GR)**
- **Technical University Denmark DTU (DK)**
- **Universität Stuttgart USTUTT (DE)**
- **Delft University DELFT (NL)**
- **NEG Micon A/S NEGM (DK)**

PROJECT START DATE : 01/11/2002 DURATION : 48 MONTHS

Date of issue: 31/12/2003

CONTRACT No **: ENK5-CT-2002-00627** PROJECT ACRONYM **: STABCON**
TITLE : **AEROELASTIC STABILITY AND CONTROL OF LARGE WIND TURBINES**

PROJECT SUMMARY

Objectives and problems to be solved

The main objective of the STABCON project is to form a European Research Network on the aeroelastic stability of wind turbines with active control. This is a fundamental issue in the development of large megawatt size wind turbines. The project consortium develops reliable design tools for analysis and optimization of large wind turbines with respect to aeroelastic stability and active control.

Description of work

Part 1 concerns the aeroelastic stability of wind turbines that have active power regulation but no active aeroelastic control. All types of aeroelastic wind turbine instabilities are considered including stall-induced vibrations and classical flutter. New stability tools are developed and used to predict the stability limits for an existing 2.75 MW turbine. The project utilizes 3D CFD to assist the modelling and understanding of instability mechanisms. The predicted damping characteristics of the test turbine are measured in the field using newly developed experimental methods.
Part 2 concerns the active aeroelastic control of wind turbines. A morphological study of possible wind turbine control systems is performed. Collective and individual blade pitch and other concepts to control power and loads are considered; including controller for active damping of vibrations. Aeroelastic codes and stability tools are refined to include these new control systems, and optimizations are performed for each of the three objectives (independently and by conditional weighting): Instability suppression, turbulence- and gust alleviation, and power enhancement.

Expected results and exploitation plans

Derived guidelines describe how to:
· Identify important parameters for aeroelastic stability, and optimize them for increased damping to passively suppress instabilities and reduce loads.
· Identify the potentials of active aeroelastic control to reduce loads by suppressing instabilities and alleviating gusts, and enhance power production.
· Perform integrated design studies of active-stall and pitch-regulated turbines to allow control of lifetime consumption and adaptation to specific conditions.

Achievements to date

The development is in progress of several tools for prediction of aeroelastic stability limits for wind turbines. The tools are based on different aeroelastic modelling approaches and different linearization techniques. Three tools have been completed and another three tools are well in progress. An experimental investigation on a 2.75 MW turbine has been performed. The pitch control system of the turbine was used to excite turbine vibration modes and the aeroelastic damping was estimated. The experimental results are at present being used to validate the stability tools.

CONTRACT No : ERK6-CT-1999-00008

PROJECT ACRONYM : COMHUB

TITLE : Innovative composite hub for wind turbines

PROJECT CO-ORDINATOR :
Dr. Josep COSTA
UNIVERSITAT DE GIRONA
DEPARTMENT OF PHYSICS
Avenida Montilivi
ES-17071 GERONA SPAIN
Tel: +34-97-2418383
Fax: +34-97-2419098
Email: josep.costa@udg.es

PARTNERS :

- **MADE TECNOLOGIAS RENOVABLES SA** (ES)
- **GERMANISCHER LLOYD WINDENERGIE GMBH (DE)**
- **NOI-ROTORTECHNIK GMBH (DE)**
- **TECHNISCHER UEBERWACHUNGSVEREIN NORD E. V. (DE)**

PROJECT START DATE : 1/3/2000 **FINISHED**

CONTRACT No : **ERK6-CT-1999-00008** PROJECT ACRONYM : **COMHUB**
TITLE : **INNOVATIVE COMPOSITE HUB FOR WIND TURBINES**

PROJECT SUMMARY

The objective of the COMHUB project was the development of a glass fibre-epoxy composite hub. Traditional cast-iron hubs are expected to be a bottleneck in the development of the emerging industry of large wind turbine generators because they are heavy and because of limitations in volume of production and size. Due to is low specific weight and easy manufacture a composite hub is expected to overcome this problem and enhance the production of large wind turbines (larger than 2 MW). In particular, the light weight, enhanced swept area and corrosion resistance of a composite hub will facilitate the wind energy exploitation in offshore sites.

In this project, a pitch-controlled 800 kW wind turbine was chosen for the design (according to wind class IEC II a) and subsequent installation of the composite hub prototype.

The structural design of such a composite part has involved different steps. The constraints for the composite hub design from both the wind turbine and rotor blades side have been thoroughly identified. A iterative process to define an optimitum conceptual design has been followed. Attention has been paid to the standardisation of hub flanges in order to ensure the adaptability to standard blades. Specific geometries for hub-blade and hub-rotor joints have been developed. The structural design has been developed by means of the Finite Element methods in which several user subroutines have been implemented for fatigue calculation, delamination analysis, etc. A major issue has been the modelling and data analysis of thick shell composite materials and the fatigue and fracture analysis. An original methodology for the lifetime estimation of thick composites under complex load states has been developed and implemented in FEM codes. The design has obeyed the compromise between low weight, high structural stiffness and the maximization of material property usage. In parallel to the numerical modelling tasks, an experimental investigation of the static and fatigue properties of the lay-outs to be used has been performed.

The Composite hub was designed with a 4 m diameter. Pitch flanges to the blades where 1.400 mm in diameter. The interface to the main shaft was designed following the criteria of exchangeability of the composite hub to a traditional cast iron hub.

The production of the first composite hub has been successfully finished within the present project. The Resin Injection Mould technology that had been chosen for the prototype production can be considered to be adequate also for large series productions. Thus, the production of the first composite hub for wind turbine is an innovative step for the further development of lightweight rotor systems.

The potential user is widespread. On one hand side, turbine manufacturers are seeking for a technical and economical solution for the weight reduction of the rotor for new turbine designs. On the other hand, wind farm operators are looking for an option in order to increase energy capture with a larger swept area using a composite hub by substituting a cast iron hub. But mainly, composites hub may represent a diversification of business activities for blade manufacturers with high acquired know-how in composite parts production.

C-WIND RESOURCES FORECASTING & MAPPING

CONTRACT No.:ENK5-CT-2002-00665

PROJECT ACRONYM: ANEMOS

PROJECT TITLE: "Development of a Next Generation Wind Resource Forecasting System for the Large-Scale Integration of Onshore and Offshore Wind Farms"

PROJECT CO-ORDINATOR:

Dr. George Kariniotakis
Ecole des Mines de Paris, Centre d'Energétique
B.P. No 207, F-06904 Sophia-Antipolis Cedex, France.
Tel.: +33-4.93.95.75.01
Email: georges.kariniotakis@ensmp.fr

PARTNERS:

- **Association pour la Recherche et le Développement des Méthodes et Processus Industriels – ARMINES (FR).**
- **ARIA Technologies - S.A ARIA (FR)**
- **Universidad Carlos III de Madrid - UC3M (ES)**
- **Centro de Investigaciones Energeticas, Medioambientales y Technologias - CIEMAT (ES)**
- **Technical University of Denmark - DTU (DK)**
- **Meteo France - METEO-FRANCE (FR)**
- **OVERSPEED GmbH & Co. KG - OVERSPEED (DE)**
- **Council of the Central Laboratory of the Research Councils - CCLRC/RAL (UK)**
- **Risø National Laboratory - RISOE (DK)**
- **Institute of Accelerating Systems and Applications - IASA (EL)**
- **University of Oldenburg - Univ-Oldenburg (DE)**
- **Electricité de France - EDF (FR)**
- **Corporación Energía Hidroeléctrica de Navarra - S.A. EHN (ES)**
- **ELSAM A/S - ELSAM (DK)**
- **National Grid, Electricity Supply Board - ESB (IRL)**
- **EWE Aktiengesellschaft/Abteilung HV-BE - EWE (DE)**
- **Public Power Corporation S.A. - PPC (EL)**
- **Red Eléctrica de España - REE (ES)**
- **Instituto para la Diversificación y Ahorro de la Energía - IDAE (ES)**
- **Institute of Communication & Computer Systems - National Technical**
- **University of Athens - ICCS/NTUA (EL)**
- **Ecole Nationale Supérieure des Mines de Paris-Centre d'Energétique - ENSMP-CENERG (FR)**
- **Centro Nacional de Energías Renovables - CENER (ES)**

PROJECT START DATE: 1/10/2002 DURATION : 42 MONTHS

CONTRACT No : **ENK5-CT-2002-00665** PROJECT ACRONYM : **ANEMOS**
TITLE : **Development of a Next Generation Wind Resource Forecasting System for the Large-Scale Integration of Onshore and Offshore Wind Farms**

PROJECT SUMMARY

Objectives and problems to be solved

Accurate forecasting of wind power production up to two days in advance is recognised as a major contribution for reliable large-scale wind power integration. Especially in a liberalised electricity market, prediction tools enhance the position of wind energy compared to other forms of dispatchable generation. The ANEMOS project aims to develop advanced forecasting models that will significantly outperform current methods. Emphasis is given to challenging situations such as complex terrain, extreme weather conditions, as well as to offshore prediction for which no specific tools currently exist.

Description of work

In the initial stage, the prediction requirements are defined in collaboration with end-users (utilities, transmission system operators, a.o). The project aims to develop advanced prediction models based on both a physical and statistical approaches. Research on physical models gives emphasis to techniques for use in complex terrain and the development of prediction tools based on CFD techniques, model output statistics or high-resolution meteorological information. Statistical models (for example based on artificial intelligence) are developed for downscaling, power curve representation, and upscaling for prediction at regional or national level. Methods to estimate on-line the uncertainty of wind forecasts are developed. The performance of purely meteorological forecasts, but also long-term wind predictability up to 7 days ahead, are evaluated in detail. Appropriate physical and statistical prediction models are also developed for offshore wind farms taking into account advances in marine meteorology such as interaction between wind and waves and coastal effects. Finally, a next generation forecasting software, ANEMOS, is developed to integrate the various models.

Expected results and exploitation plans

The project develops a prediction platform that will integrate the advanced models developed by the partners. The ANEMOS software is enhanced by advanced Information & Communication Technology functionality and can operate both in stand alone or remote mode, or be interfaced with standard Energy Management Systems. The software will be installed for on-line operation at onshore and offshore wind farms by the end-users participating in the project and the benefits from wind prediction will be evaluated at national, regional or at single wind farm level. The ANEMOS Consortium is committed for the exploitation of the developed software and models.

Achievements to date

Advanced prediction models have been developed as well as models for on-line uncertainty assessment. A benchmarking process was set up, which permitted to evaluate in detail the performance of the developed models and to compare them with existing ones using a number of representative case studies. The main modules of the ANEMOS prediction software were developed and their integration to the common platform is on going. *– More information in http://anemos.cma.fr*

CONTRACT N° : ENK5 – CT – 2002 - 00606

PROJECT ACRONYM : HONEYMOON

TITLE : High Resolution Numerical Wind Energy Model For On and Offshore Forecasting Using Ensemble Predictions

PROJECT CO-ORDINATOR :

Dr. Jess Joergensen
University College Cork
College Road
Cork IRL
Tel. +353 21 4903817
EMAIL: jess.joergensen@wanadoo.dk

PARTNERS :

- **EHF (Institute of Energy- and Semiconductor Research, University of Oldenburg - DE)**
- **DMI (Danish Meteorological Institute - DK)**
- **INM (Meteorological National Institute - ES)**
- **EPT (E.ON UK - Power Technology - UK)**
- **EED (Espace Eolien Développement - FR)**
- **RTE (Réseau de Transport d'Electricité - FR)**
- **EDL (E.ON UK Renewables - UK)**
- **EWE (EWE AG - DE)**

PROJECT START DATE : 1/1/2003 **DURATION : 24 months**

Date of issue: 25 August 2004

CONTRACT No **:ENK5 - CT - 2002 - 00606** PROJECT ACRONYM **: HONEYMOON**
TITLE : **A High resOlutioN wind EnergY Model for On and Offshore forecastiNg using ensemble predictions**

PROJECT SUMMARY

Objectives and problems to be solved

The experience with most real time wind power prediction systems is that the ultra short term predictions (< 6h) for larger groups of wind farms are often of good quality. Serious forecast errors mostly and frequently occur for prediction horizons greater than the ultra short range. These experiences suggest that the major source of the wind power prediction errors can be found in the prediction of basic weather parameters that are used to calculate the wind power, rather than the calculation of the wind power itself. The project is designed to identify these errors and, if possible, reduce them.

Description of work

The work is split into four work packages:
WP1 contains the central Honeymoon prediction system, which is linked to meteorological centres, where the required input data are retrieved. WP2 contains the NWP ensemble prediction system and utilities that are required to use the ensemble forecasts. For wind power predictions the utilities convert the ensemble predictions into a probability distribution function for a particular location or area. WP3 contains the power curve analysis tool and an improved wind power parameterisation. In WP4 the Honeymoon model system is validated with end-user data.

Expected results and exploitation plans

The combination of realtime data and an online historical forecast archive for efficient generation of power curves will allow new end-users fast and easy access to high quality forecasts. The end-user will not need to deal with many subtasks such as the wind to power conversion utility, the maintenance of it, the required input data from a meteorological center, etc. The Hooneymoon system is a self-contained system, which additionally provides an uncertainty estimate of the forecasts to the end-user.

Achievements to date

The first 18 months of the project have been used to develop and setup the Honeymoon system and test it in offline mode. The offline simulations have been running since the 2nd half of year 2003. They have been used for monitoring the Honeymoon system and to create a forecast archive for the generation of power curves.
The work on the model system has been spread over three areas. The surface stress parameterisation and the air sea interaction in the model system have been improved and an uncertainty estimate of the wind power predictions developed.
The consortium has agreed upon and designed the model system such that the central Honeymoon system will deliver forecasts of wind power in real time and wind power relevant atmospheric variables such as wind speed and direction in different heights in offline mode. The demonstration phase will start in the autumn 2004.

CONTRACT No : ERK6-CT-1999-00017

PROJECT ACRONYM : WEMSAR

TITLE : Wind Energy Mapping Using Synthetic Aperture Radar

PROJECT CO-ORDINATOR :

Dr. OLA M. JOHANNESSEN
Nansen Environmental and Remote Sensing Center
Thormøhlensgate 47
N-5006 Bergen, NORWAY
Tel: +47 55205800
Fax: +47 55205801
Email: Ola.Johannessen@nersc.no

PARTNERS :

- **ENTE PER LE NUOVE TECNOLOGIE, L'ENERGIA E L'AMBIENTE (IT)**
- **RISOE NATIONAL LABORATORY (DK)**
- **NEG Micon Project Development A/S (DK)**
- **TERRA ORBIT AS (UK)**

PROJECT START DATE : 1/3/2000 FINISHED

CONTRACT No : **ERK6-CT-1999-00017** PROJECT ACRONYM : **WEMSAR**
TITLE : **Wind Energy Mapping Using Synthetic Aperture Radar**

PROJECT SUMMARY

Objective:
The overall objective was to develop, validate, and demonstrate the potential of satellite-based Synthetic Aperture Radar (SAR), scatterometer and altimeter to map wind energy in offshore and near-coastal regions for potential wind turbine siting.

Background:
An important aspect of wind turbine siting is including the potential for offshore wind turbine parks. Several parks are already constructed, and many are in the planning phase. Many countries lack suitable land-based wind turbine sites, and moving the wind-turbines off shore is therefore more appropriate. Just as important is the fact that wind speeds are often higher offshore than onshore, differences of 20% within a small area on/offshore are not uncommon. An important aspect in mapping coastal wind-energy areas from satellite is the advantage of combining the continuous spatial coverage with equally spatial continuous data sets of ocean bathymetry, i.e. ocean depth. Obviously offshore wind installations will need to be located in relatively shallow areas to keep the construction costs as low as possible.

Description of work:
The project consisted of the following work packages;
- Implementation of existing algorithms for wind data retrieval from satellite radars, based on a literature search.
- Satellite data from SAR, altimeter and scatterometer will be obtained, processed and analysed, and wind information obtained. Validation of SAR wind energy retrieval.
- The micro-siting model will be tuned for optimal integration in the WEMSAR tool.
- Development of an integrated WEMSAR tool for optimum data synergy for maximum site selection efficiency.
- WEMSAR validation.
- Production of a marketing plan including a cost/benefit assessment for identifying potential customers, where the customers operate and the time frame of their projects. This task includes planning and initiation of product exploitation.

Achievements:
The main result from the project is a prototype satellite SAR wind retrieval and statistical analysis tool, called WEMSAR tool. The tool is an add-on tool to the widely used Wind Analysis and Application Programme (WAsP) for wind turbine siting. After a literature review it was decided to use the commonly accepted and validated C-band algorithms. SAR images from the test sites in Norway, Denmark and Italy was analysed to derive wind speed using, whenever possible, SAR retrieved wind direction and new model simulations of the wind fields in the test sites was carried out. Based on the work with comparison of the model, satellite and in situ observations, the WEMSAR tool was defined and developed.
The methods developed in the WEMSAR project can prove valuable for mapping coastal wind energy potential on a global scale. A cost-efficient method for mapping this valuable renewable energy source has the potential to be adopted by international organizations, foreign governments as well as private companies.

D-WIND FARMS

CONTRACT No : ERK6-CT-1999-00006

PROJECT ACRONYM : CLEVERFARM

TITLE : Advanced Management And Surveillance of Wind Farms

PROJECT CO-ORDINATOR :

Dr. LARS LANDBERG
RISOE NATIONAL LABORATORY
Frederiksborgvej 399
DK- 4000 Roskilde
Tel: + (45) 46775024
Fax: + (45) 46775970
Email: Lars.landberg@risoe.dk

PARTNERS :

- **DANISH METEOROLOGICAL INSTITUTE (DK)**
- **Institut für Solare Energieversorgungstechnik e.V. (DE)**
- **Renewable Energy Systems Ltd. (UK)**
- **SEAS Distribution AmbA (DK)**
- **NEG Micon Project Development A/S (DK)**
- **Carl-von-Ossietzky University Oldenburg, Faculty of Physics (DE)**
- **Projekt Projektierungsgesellschaft fuer regenerative Energiesysteme mbH (DE)**

PROJECT START DATE : 1/3/2000 FINISHED

PROJECT SUMMARY

Objectives and problems to be solved:
The idea behind this project is to take the by now many very advanced techniques developed for optimising and enhancing the performance of wind farms, integrate them into one system and implement the system at a number of wind farms. The techniques include remote measuring of the status and production of the wind farm, short-term prediction of the expected power output from the wind farm, models for wake calculations, remote control of wind farm production and so on. By combining these techniques we will make the wind farm seem intelligent to an outside viewer. For example, the wind farm will send immediate warnings to the maintenance crew if something goes wrong. It will also send e-mail to the electrical utility (and power brokers) containing its expected production over the next two days, it will suggest optimal periods for preventive maintenance, it will reduce its production if it experiences an extreme weather condition or if the power quality drops, it will give the wind farm operator real time images from the wind farm and so on.

Description of work:
The main work to be carried out in the project will be to identify and streamline the existing techniques (hardware and software), to develop the "intelligence" of the system and to implement and test the developed system at one to three wind farms, one of which will be off-shore. The group participating in this proposal is a unique combination of industry (wind turbine manufacturers and electric utilities), wind farm operators, consultancy and research making it possible for the first time to carry out such a project successfully. The group consists of expertise in implementation of power prediction systems, remotely controlled sensor systems, wind turbine control, maintenance, and wind farm operation.

Expected Results and Exploitation Plans:
The output of the project will be a system, which will be sold by a consortium formed by the project partners. The system consists of hardware (servers, sensors, cameras, cabling infrastructure) and software. We do not expect to develop a 100% bullet-proof system, which is why the user interface to the wind farm operator will be given much thought and emphasis, to make sure that the operator can intervene based on the best available information about the status of the wind farm. To make the system work it will be necessary to have a subscription to on-line weather predictions from the local meteorological service. The system will be platform independent because it is based on open standards as HTML (and XML) and Java, making it extremely easy to implement in almost any environment. It is not foreseen, however, that the system can be sold as a software package, it will be sold as a licence to a software system and it will be installed by members of the consortium at the wind farm. The system is anticipated to be used in potentially any wind farm, with a special emphasis on off-shore and remote on-shore wind farms.

CONTRACT No : ERK6-CT-1999-00001

PROJECT ACRONYM : ENDOW

TITLE : Efficient Development Of Offshore Windfarms

PROJECT CO-ORDINATOR :
Dr. REBECCA BARTHELMIE
RISOE NATIONAL LABORATORY
Frederiksborgvej 399
DK- 4000 Roskilde
Tel: + (45)46775020
Fax: + (45)46775970
Email: R.Barthelmie@risoe.dk

PARTNERS :

- **UPPSALA UNIVERSITY (SE)**
- **GARRAD HASSAN AND PARTNERS LTD (UK)**
- **THE ROBERT GORDON UNIVERSITY (UK)**
- **Carl-von-Ossietzky University Oldenburg,Faculty of Physics (DE)**
- **Energi E2 (DK)**
- **ELSAMPROJEKT A/S (DK)**
- **NEG Micon Project Development A/S (DK)**
- **Netherlands Energy Research Foundation (NL)**

PROJECT START DATE : 1/3/2000 **DURATION: 36 MONTHS**

CONTRACT No **: ERK6-CT-1999-00001** PROJECT ACRONYM : **ENDOW**
TITLE : **Efficient Development Of Offshore Windfarms**

PROJECT SUMMARY

Objectives and problems to be solved:
Europe has large offshore wind energy potential that is poised for exploitation to make a significant contribution to the objective of providing a clean, renewable and secure energy supply. Using experience gained through the demonstration projects currently operating offshore, this project aims to reduce uncertainties in estimating power production introduced due to wake effects in large offshore wind farms particularly those operating in areas affected by the coastal discontinuity where the atmosphere is not at equilibrium with the surface. The major objectives are to evaluate wake models in offshore environments and to develop and enhance existing wake and boundary-layer models accounting for complex stability variations to produce a design tool to assist planners and developers in optimising offshore wind farms.

Description of work:
The proposed work was divided into five areas:
1. Evaluation of current wake models and production of standardised databases of observations from offshore wind farms to be used in their initialisation. These case studies were used as the basis for evaluation of six different wake models varying in complexity from engineering solutions to complex computational fluid dynamics codes;
2. Development and enhancement of wake and boundary layer models for use in offshore areas and construction of a model interface to link these models. The performance of the models under different atmospheric conditions was utilised to develop consistent model evaluation specifications and define criteria for model improvement;
3. The performance of the coupled models was evaluated based on simulations for existing databases and also results from an offshore wind farm experiment designed to offer direct measurements of the wake influence on downstream profiles of meteorological parameters and power output. During this experiment, SODAR measurements provided additional vertical resolution;
4. Based on the experience gained, a design tool was developed for use in offshore wind farm planning. This is based on enhancements to existing commercial software currently used by the wind energy industry and is modular;
5.Demonstration of the design tool in different environments offshore. The demonstration projects represent offshore areas of Europe including different wind speed and stability regimes and different water depths.

Expected Results and Exploitation Plans:
The project focuses on maximizing industry input to enhance existing wind farm design tools. The design tool allows wake impacts on power output from large offshore wind farms to be minimised. A module for minimising grid connections was also incorporated to provide selection criteria for optimal wind farm design. These tools were rigorously evaluated for both scientific/technological and computing performance prior to their demonstration in the design of three planned offshore wind farms. Significant improvements in the state of art of wake and marine boundary-layer models and a thorough evaluation of wake models were achieved. The design tool will ensure that both turbine and wind farm developers have the capability to more accurately design and predict power output from large offshore wind farms.

CONTRACT N° : ENK5-CT-2002-00659

PROJECT ACRONYM : CONMOW

TITLE : CONDITION MONITORING FOR OFFSHORE WIND FARMS

PROJECT CO-ORDINATOR :
Ir. L.W.M.M. (Luc) Rademakers
Energy Research Center of the Netherlands ECN
Wind Energy
P.O. Box 1
1755 ZG Petten, The Netherlands
Tel. +31 (0)224 564943
Fax +31 (0)224 568214
e-mail: rademakers@ecn.nl

PARTNERS :

- **ECN Wind Energy - NL**
- **Siemens Nederland N.V. - NL**
- **Loughborough University - UK**
- **Risø National Laboratory - DK**
- **Garrad Hassan and Partners Ltd. - UK**
- **Pall Corporation - E**
- **Gram&Juhl APS - DK**
- **Prueftechnik CM GmbH – D**

PROJECT START DATE : 01/11/2002 DURATION : 48 months

CONTRACT No : **ENK5-CT-2002-00659** PROJECT ACRONYM : **CONMOW**
TITLE : **Condition monitoring for offshore wind farms**

PROJECT SUMMARY

Objectives and problems to be solved

This project aims at developing techniques for diagnostics and condition monitoring of wind turbines (and farms) at remote areas and selecting and demonstrating a suitable set of techniques. The objectives in fact are fourfold.

1. Development of new algorithms for data processing by a case study of a turbine with variable speed and pitch control.
2. Improvement of currently available condition monitoring techniques and SCADA systems to the specific wind turbine needs and to make sure that they will meet the newly developed wind turbine communication standards as being developed for instance in IEC TC88 WG 25.
3. Investigating and demonstrating the benefits of condition monitoring techniques and generic SCADA systems in a wind farm and assessing the added value in the operation of large wind farms at remote (offshore) locations.
4. Implementing the selected procedures and techniques for condition monitoring into the O&M plan for the offshore wind farm with the aim to change from preventive and corrective maintenance to condition based maintenance.

Description of work

The project is separated into two main phases.
In the first phase, one single turbine will be instrumented extensively, not only with condition monitoring systems but also with the “traditional” measurement systems like load measurements in the blade root, torque of main shaft, , pitch system parameters, rotor speed, etc. An extensive measurement campaign on this turbine under normal and faulted conditions will be carried out. Inter-relationships will be determined between various turbine parameters and condition monitoring results. The condition monitoring techniques will be assessed on their added value for wind farm operation. If desired, the most suitable techniques will be improved.
In the second phase, the selected and improved methods will be applied on a larger scale (4 to 6 turbines) in a wind farm. The systems will be tested over a longer period of time. A generic SCADA system will be used to collect and store the data and to make the data accessible for the various users. In this testing phase, the condition monitoring techniques as well as the SCADA system will be improved continuously. Experiments will be done with automated surveillance.

Expected results and exploitation plans

The main result of this project is a set of condition monitoring techniques with recommended practices for use in offshore wind farms of which the added value is demonstrated for a group of wind turbines with variable speed and pitch control. Furthermore new algorithms and adjusted hardware and software for early failure detection and an improved generic SCADA system, implemented at a wind farm will become available.

Achievements to date

The single turbine has been instrumented and the “traditional” measurements are ongoing since mid 2002. The configuration of the vibrations monitoring systems and the installation of oil monitoring systems are nearly completed. Furthermore the processing of the data has been started.

E-INTEGRATION OF WIND POWER

CONTRACT N°: ENK6-CT-2001-20401

PROJECT ACRONYM: WIND ENERGY NETWORK

PROJECT TITLE: Wind Energy Network

PROJECT CO-ORDINATOR:

Hugo Chandler
European Wind Energy Association
26, Rue du Trône
B-1000 Brussels Belgium
Tel. +32 2 546 1940
Fax. +32 2 546 1944
Email : hugo.chandler@ewea.org
www.wind-energy-network.org

PARTNERS :

- **NEG-Micon (DK)** (representing turbine manufacturers)
- **Pauwels (BE)** (representing component manufacturers)
- **Investitionsbank Schleswig Holstein (DE)** (representing financiers and insurers)
- **ECN (NL)** (representing R&D, Testing and certification Centres)
- **Risø (DK)** (representing R&D, Testing and certification Centres)
- **BWE (DE)** (representing end-users: turbine Owners)
- **RES (UK)** (representing end-users: developers)
- **Elsam (DK)** (representing utilities and end users other than developers and owners)

PROJECT START DATE: 1/12/2001 DURATION: 48 MONTHS

CONTRACT N°: **ENK6-CT-2001-20401** PROJECT ACRONYM: **WIND ENERGY NETWORK**
PROJECT TITLE: **Wind Energy Thematic Network**

PROJECT SUMMARY:

Description of Work and Objectives
The Wind Energy Thematic Network's overall aim is to ensure that EU funded wind energy R&D meets the needs of the European wind industry - to maintain and increase its competitiveness in EU and external markets; and to develop to meet European Commission and national targets for renewable energy use and greenhouse gas reductions from energy generation, amongst other policy objectives of the union.

Previously, the wind industry has not had a coherent R&D strategy. With a view to further R&D under the FP7 technology platforms, such a strategy is increasingly important. The network provides the opportunity for the wind energy sector to contribute fully to the European Research Area: through better coordination of EC-funded and Member State R&D; the promotion of a common industry view on R&D needs; coordination of industry inputs to R&D and policy discussions; and providing the European Commission with rapid access to this information.

Activities are organised around key themes for the industry. Examples include socio-economic, policy and market issues, environmental impact, design issues, standardisation and certification, integration into Energy Systems, O&M issues, unconventional sites, offshore developments and Multi-MW turbines.

Network objectives include the following:
- Establish industry discussion groups to promote information exchange and networking within the industry, including networking between different sectors in the industry.
- Promote discussion of indicators to track wind technology development to feed into policy.
- Evaluate R&D requirements to maintain EU leadership of the wind energy sector.
- Undertake a structured, regularly reviewed programme of strategy development, responding to new external influences, resulting in a final strategy for future EU R&D, divided between public and private sectors.
- Establish and review existing support to wind energy R&D in EU member states.

Achievements to Date
An active network of over three hundred participants has been established, 200 of which are registered users of the project website.

To date, five strategy workshops have been held, yielding detailed R&D requirements, which have been woven into the Strategy. The sixth (and final) workshop will be held in Brussels in the spring of 2005 before finalisation of the Strategy.

Alongside these strategy workshops, five updates of the strategy have been developed, and five updates of national support for wind energy R&D. January of 2004 saw the successful public launch of the strategy.

CONTRACT No : ENK5-CT-1999-00016

PROJECT ACRONYM : FIRMWIND

TITLE : Towards High Penetration And Firm Power From Wind Energy

PROJECT CO-ORDINATOR :
Dr. RAYMOND HUNTER
RENEWABLE ENERGY SYSTEMS LTD
11 ELMBANK STREET
UK- G2 4PB GLASGOW UNITED KINGDOM
Tel: + (44-141)2212467
Fax: + (44-141)2212470
Email: ray.hunter@glasgow.res-ltd.com

PARTNERS :

- **DEUTSCHES WINDENERGIE - INSTITUT GMBH (DE)**
- **SINTEF Energy Research (NO)**
- **Proven Engineering Products Ltd (UK)**
- **Bremen Institute of Production Technology and Applied Work Science (DE)**
- **Econnect Ltd (UK)**

PROJECT START DATE : 1/5/2000 **FINISHED**

PROJECT SUMMARY

Objectif :

Due to variability, Wind Energy within an Electrical Distribution System has a limited Capacity Credit. This limits exploitation, particularly in remote, weak grids, in island grids and in rural electrification schemes. 'FIRMWIND' will investigate innovative measures to increase Wind Energy's realisable capacity Credit. The project proposes holistic, energy management control of the distribution system including generation plant, consumer loads, storage devices and the import/export link. The project will select and analyse real situations in Europe and in export markets. The analysis will combine analysis methods used by utilities with design techniques used for autonomous 'wind-diesel' systems. The optimum solutions will be found by techno-economic assessment. The feasibility of the solutions will be investigated in the context of deregulated market mechanisms.

CONTRACT N° : ERK5-CT-1999-00019

PROJECT ACRONYM: MORE CARE

TITLE : More advanced control advice for secure operation of isolated power systems with increased renewable energy penetration and storage

PROJECT CO-ORDINATOR :

Prof. Nicholas HATZIARGYRIOU
INSTITUTE OF COMMUNICATION AND COMPUTER SYSTEMS
42, Patission Street
GR-10682 ATHENS
GREECE
Phone: +(30-210) 7723661
Fax: +(30-210) 7723659
Email: nh@power.ece.ntua.gr

PARTNERS :

- **ELECTRICITY SUPPLY BOARD (IRL)**
- **ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS (FR)**
- **PUBLIC POWER CORPORATION(GR)**
- **EMPRESA DE ELECTRICIDADE DA MADEIRA(PO)**
- **INESC PORTO - INSTITUTO DE ENGENHARIA DE SISTEMAS E COMPUTADORES DO PORTO(PO)**
- **ARISTOTLE UNIVERSITY OF THESSALONIKI(GR)**
- **COUNCIL FOR THE CENTRAL LABORATORY OF THE RESEARCH COUNCILS (UK)**
-

PROJECT START DATE : 2000-03-01 **FINISHED: 2003-02-28**

CONTRACT N° : **ERK5-CT-1999-00019** PROJECT ACRONYM: **MORE CARE**
TITLE : **More advanced control advice for secure operation of isolated power systems with increased renewable energy penetration and storage**

PROJECT SUMMARY

Objectives and problems to be solved:
Isolated and weakly interconnected power systems are presently affecting and limiting the economic development of more than 12 millions of European citizens, not taking into account Great Britain and Ireland. Penetration of renewable energy sources in such situations can substantially increase their quality of life, if advanced control tools are available to the operators of these systems. The main objective is the development of an advanced control software system aimed at optimising the overall performance of isolated and weakly interconnected systems in liberalised market environments. This will allow increasing the share of wind energy and other renewable forms. The main features of the control system comprise advanced software modules for load and wind power forecasting, unit commitment and economic dispatch of the conventional and renewable units and on-line security assessment capabilities integrated in a friendly man-machine environment.

Description of the work:
The proposed work comprises collection and analysis of renewable, electrical and operating data and identification of the needs for the following developments of on-line control functions:

- Improved wind power forecasting modules for a short-term (0-8 hour) and medium time horizon (4-48 hours).
- Hydropower forecasting functions.
- Unit Commitment and Economic Dispatch modules that take into account the availability of hydro-storage, liberalised market conditions and increased security conditions.
- On-line security modules to provide both preventive and corrective advice in case of predetermined disturbances.
- Installation of the enhanced and new forecasting, operational planning and security modules on three selected EU sites. The aim of these pilot installations is to test the system functions under the new operating conditions with very high wind power penetration.

A number of alternative technologies have been applied for the update and development of new software modules providing flexibility for their adaptation in island systems with increased renewable penetration.

Expected Results and Exploitation Plans:
MORE CARE advanced control functions developed and installed on the islands of Crete, Ireland and Madeira with the active co-operation of the local Utilities. Socio-economic impacts will be then assessed. Results should demonstrate the effectiveness of the proposed approach and provide valuable feedback for the dissemination of MORE CARE in other EU and developing countries.

Achievements to date:
The MORE CARE software system with advanced forecasting, operational planning and security modules has been installed in Crete and Madeira, in order to face effectively new operating conditions characterised by high wind penetration. Advanced wind power forecasting modules have been installed in Ireland. Evaluation during the first months of operation on Crete has shown clear economic gains from improved operational planning and timely warnings about potentially insecure operating conditions. Further installations are under negotiation.

CONTRACT N° : ENK5-CT-2002-00663

PROJECT ACRONYM: WILMAR

TITLE : Wind Power Integration in a Liberalised Electricity Market

PROJECT CO-ORDINATOR :

Dr. Peter Meibom
RISOE, Risø National Laboratory, Denmark
DK-4000 Roskilde Denmark
Phone: +45 46775119
Fax: +45 46775199
Email: peter.meibom@risoe.dk
Web: www.risoe.dk

PARTNERS :

- **Elsam A/S**
- **SINTEF Energiforskning A/S (NO)**
- **Kungliga Tekniska Hoegskolan (SE)**
- **Danmarks Tekniske Universitet (DK)**
- **Elkraft System a.m.b.a. (DK)**
- **Universitaet Stuttgart (DE)**
- **Nord Pool Consulting AS (NO)**
- **Technical Research Centre of Finland (FI)**

PROJECT START DATE : 2002-11-01 **DURATION : 36 months**

Date of issue: 2004-09-03

CONTRACT No : **ENK5-CT-2002-00663** PROJECT ACRONYM : **WILMAR**
TITLE : **Wind Power Integration in a Liberalised Electricity Market**

PROJECT SUMMARY

Objectives and Problems to be Solved

A fast introduction of large amounts of intermitting renewable power production as wind power can cause technical and economic problems for the power systems. These problems might arise due to the unpredictability of wind power or due to unbalance between local power demand and intermittent power produced causing grid instabilities. The main objective of this project is to investigate these problems and to develop a modelling tool, which can be used to simulate alternative solutions providing a firm basis for decision-making by system operators, power producers and energy authorities. Both the possibilities for integrating fluctuating power production by optimising the interaction of the existing units in a given electricity system, the possibilities lying in power exchange between regions, and the performance of dedicated integration technologies such as electricity storages are evaluated.

Description of Work

The modelling and simulation efforts can be divided into two parts. One part consists of an investigation of the issue of system stability, i.e., the wind integration aspects connected to the fast (below 10 minutes) fluctuations in the wind power production. Secondly, the wind integration ability of large electricity systems with substantial amounts of power trade in power pools is investigated. With the starting point in existing models, a planning tool is developed, and this modelling tool is used to investigate the technical and cost issues of integrating large amounts of wind power into the electricity system. The model will cover the two power pools: Nord Pool and European Power Exchange, i.e., Germany, Denmark, Norway, Sweden and Finland.

Expected Results and Exploitation Plans

The final Planning tool will be made publicly available such that organisations outside the project consortium can benefit from the work. Analysis based on the tools developed in the project will be used to provide an estimate of the costs connected to the integration of wind power, and to provide recommendations about the usefulness and performance of different types of integration measures.

Achievements to Date

The development of the Planning tool has shown good progress. A linear, stochastic, optimisation model with hourly time-resolution and covering several regions interconnected with transmission lines has been developed. One crucial input to this modelling tool is wind power production forecasts for each region in the model. A wind speed forecast model has been developed, which incorporates the correlations between wind speed forecast from one time step to the next and the correlations between wind speed forecasts in different regions. A stepwise power flow model used to study frequency changes from minute to minute in a Nordic power system as a function of changes in load and available production capacity as well as the availability of regulating power in the system has been developed. This model provides a suitable level of modelling in order to study basic problems related to primary and secondary control and provision of reserves.

CONTRACT N° : ENK5-CT-2001-00536

PROJECT ACRONYM: RES2H2

TITLE : Cluster Pilot Project For The Integration Of Res Into European Energy Sectors Using Hydrogen

PROJECT CO-ORDINATOR :
Mrs Africa CASTRO ROSENDE
Instalaciones Inabensa S,A,
Manuel Veslasco Pando 7
ES- 41007 Sevilla SPAIN
Phone: +34 95 493 7180
Fax: +34 95 493 7008
Email: africa.castro@inabensa.abengoa.com

PARTNERS :

- **CASALE CHEMICALS (CH)**
- **INSTITUTO NACIONAL DE TECNICA AEROSPACIAL(ES)**
- **PLANET - PLANUNGSGRUPPE ENERGIE UND TECHNIK GBR (DE)**
- **SOLANTIS ENERGY AG (DE)**
- **LABTECH LTD (BG)**
- **Etaing (DE)**
- **FREDERICK INSTLTUTE OF TECHNOLOGY (CY)**
- **OWK UMWELTTECHNIK UND ANLAGENBAU GMBH (DE)**
- **ELECTRICITY AUTHORITY OF CYPRUS (CY)**
- **CIA TRANSPORTISTA DE GAS CANARIAS S.A. (ES)**
- **INTEGRAL DRIVE SYSTEMS AG (CH)**
- **UNIÓN ELECTRICA DE CANARIA-II SAU (ES)**
- **CENTRE FOR RENEWABLE ENERGY SOURCES (GR)**
- **INSTITUTO TECNOLÓGICO DE CANARIAS , S .A (ES)**
- **C. ROKAS S.A. (GR)**
- **UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA (ES)**

PROJECT START DATE : 1-1-2002 **DURATION : 60 months**

PROJECT SUMMARY

Objective :

The main objective of the proposed project is the integration of RES, hydrogen production and utilisation into energy sectors. This will be done by designing, constructing and evaluating self-sufficient energy systems driven by wind energy, capable of generating hydrogen, electricity and water making use of the features of hydrogen as an energy vector.
Systems of this kind could be implemented in the near future in any area with high renewable (wind) energy potential for both pure hydrogen production and commercialisation as well as electricity and water demand coverage (renewable energy and water independent grids).

CONTRACT No : ENK5-CT-2002-80667

PROJECT ACRONYM: RO-SWEET

TITLE :
SOLAR AND WIND TECHNOLOGY EXCELLENCE, KNOWLEDGE EXCHANGE AND TWINNING ACTIONS ROMANIAN CENTRE

PROJECT CO-ORDINATOR :
Dr. Dan Ilie TEODOREANU
ICPE - New Energy Sources Laboratory
Splaiul Unirii 313, Sector 3
RO - 030138 Bucharest ROMANIA
Tel: + 40213467236, gsm : +40 745 122863
Fax: + 40213467236
Email: danteo@icpe.ro

PROJECT START DATE : 1/11/2002 DURATION: 36 MONTHS

CONTRACT No: **ENK5-CT-2002-80667** PROJECT ACRONYM : **RO-SWEET**
TITLE : **Solar and wind technology excellence, knowledge exchange and twinning actions Romanian centre**

PROJECT SUMMARY:

The overall aim of the Project "Solar and Wind Technology Excellence, Knowledge Exchange and Twinning Actions Romanian Center – ***"RO-SWEET"*** is to increase the liaisons between the Romanian Center and similar organizations from European Union, to stimulate the knowledge exchange, the twinning common research activities and to correlate the Romanian methods and research strategies with other research organizations from EU. The target is to enhance the level of Romanian research in the field of solar and wind technology and to integrate Romanian efforts into a common European Research Area.

Objectives and problems to be solved:

- Increase the linkage with EU research area in the field of photovoltaic, solar-thermal and wind systems
- Develop common actions together with partnership organizations to improve the existing design methods for isolated solar systems
- To enhance the level of knowledge of the Centre staff in the field of grid-connected photovoltaic applications
- To provide technical solutions for photovoltaic grid-connected applications for Romanian conditions
- To promote the applications developed by the Centre

Description of the work:

The work was organized in a set of five work packages aimed to different yet correlated tasks:

1. Reinforcing the research capabilities of the Center in the field of *photovoltaic*, *solar-thermal and wind*;
2. Enhancement of knowledge level of the Center in the field of building integration of solar (PV and thermal) systems;
3. Increase of the technological and knowledge level of the Center in the field of stand-alone hybrid (PV and wind) systems and micro-grids for rural electrification and tourism;
4. Organization of an annual Technical Conference (at European level) in the field of photovoltaic and wind energy;
5. Dissemination of the results and identification of new research opportunities.

Achievements to date:

- R&D and Innovative research for new components and systems:
  - 1,5 kW wind generator;
  - 1 kW charge controller for stand-alone PV systems;
  - 2,5 kW charge controller for combined PV and wind systems
  - PV system for marine and fluvial beacons
  - Wind rotor and blades
  - Mobile 500 W_P PV generator
  - Standard stand-alone PV systems for remote households
- Study visits/training activities:
  - Fellow visits of partnership researchers (two persons) from EU to the Centre;

  - Common research in building integration of photovoltaic and solar-thermal systems.
- Two types of PV/hybrid systems have been identified as suitable for **stand-alone and rural electrification:**
  - first, in the power range of 300-500 Wp, for small households and social centres in remote areas, only for lighting, radio-TV and other small consumers;
  - second, in the installed power range of 1–2 kW, for large households, mountain huts, monasteries and big social centres.
- Organisation of a technical **Workshop** on the topic: "New technologies for cost reduction of stand-alone PV and wind systems for rural remote households and social objectives"

- The **annual Conference** "SWIC – 2003", "Solar & Wind International Conference and Workhop", was organized at ICPE - Agigea Test Site Facility, on the Black Sea coast, between 15-24 September 2003. The Conference was structured on four sessions:
  - Session 1: "Stand-alone PV systems for rural electrification"
  - Session 2: "Mini-grid PV, hybrid and combined systems"
  - Session 3: "Building integration of solar systems"
  - Session 4: "EU and Romanian legislation for RES"

- RO-SWEET members are taking part in several research projects in the frame of the National Research, Development and Innovation Program (PNCDI):
  - "New Innovative Technologies and Systems for Electricity Supply from Renewable Energies"
  - "Hybrid Systems for Electricity Supply for Isolated Consumers in Remote Places"
  - "R&D of Architectonic Structures with Building Integrated Active and Passive Solar Elements"
  - "Solar Systems for Residential Applications in Remote Places"
  - "R&D Activities to Identify the Most Adequate Places and Technologies for Wind Turbine Applications in Romania"
  - "Development of an Ecological Building with Incorporated Elements of Artificial Intelligence"
  - "PV Stand-Alone System for Supply an Air Pollution Monitoring Remote Station".