Concerted Action

on

Offshore Wind Energy in Europe

Contract Nr.: **NEE5/1999/562**

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Contents

1 General

1.1 Introduction to the CA-OWEE project

The objective of the project Concerted Action on Offshore Wind Energy in Europe [CA-OWEE] has been to define the current state of the art of offshore wind energy in Europe. This has been achieved by the gathering and evaluation of information from across Europe, and the subsequent dissemination of the resulting knowledge to all interested parties.

The project has involved the cooperation of 17 organisations from 13 countries, thus covering the majority of the European Union coastline. The organizations involved cover a wide range of expertise and include developers, utilities, consultants, research institutes and universities:

- Delft University of Technology, The Netherlands
- Garrad Hassan & Partners, United Kingdom
- Kvaerner Oil & Gas, United Kingdom
- Energi & Miljoe Undersoegelser (EMU), Denmark
- Risø National Laboratory, Denmark
- Tractebel Energy Engineering, Belgium
- CIEMAT, Spain
- CRES, Greece
- Deutsches Windenergie-Institut (DEWI), Germany
- Germanischer Lloyd, Germany
- ECN, The Netherlands
- Espace Eolien Developpement (EED), France
- ENEA, Italy
- University College Cork, Ireland
- Vindkompaniet i Hemse AB, Sweden
- VTT, Finland
- Baltic Energy Conservation Agency (BAPE), Poland

Based on the information collated as part of the Concerted Action, the project team has attempted to identify the key problem areas which affect the future development of offshore wind energy. These problem areas include technology development, integration in the energy supply system, economics, public acceptance, environmental impact and the relation between onshore and offshore wind energy. Building on this work, recommendations have been formulated for a Research and Technological Development (RTD) strategy which is aimed at providing solutions to these problems.

1.2 Introduction to the RTD strategy

The RTD strategy, which is presented below follows the same thematic format as the information-gathering exercise which preceded it. The offshore wind energy industry has been considered under the following categories and sub-categories:

1. Offshore technology
    - Design
    - Installation and decommissioning

- Operation and maintenance / reliability

2. Grid integration and electrical transmission
3. Social, political and environmental issues
4. Recent and current activities
5. Resources and economics

Annexed to this summary report is a table with the key RTD actions identified by the project members. Also given in the table is a ranking in terms of the timescale on which progress must be made and the importance of that RTD action for the progression of the industry.

A summary of the table is presented in the following sections.

2 Offshore Technology

2.1 Design

The highest RTD priority relating to offshore technology is to gain further improved understanding of the behaviour of dynamically active wind turbine support structures subject to combined wind and shallow water wave loading (including breaking waves). Through the development of appropriate predictive methodology, the effects on fatigue and extreme design loads of wind, waves and seabed geotechnical characteristics should be advanced. Research is therefore required in order to characterise offshore environmental conditions, define appropriate design criteria, and develop reliable computer models of offshore wind turbines. A review of safety factors employed for optimal structural design should also be made a RTD priority. There is an immediate requirement for dissemination of experience gained from a decade of European offshore wind farm operation, the execution of detailed measurement programmes, and best practice guidelines drawn up to assist future developments.

In the short term with highest priority, inherent design for improved reliability and installation expediency must be addressed. The logistical difficulties presented by locating turbines offshore imply a much improved reliability requirement be placed on offshore specific wind turbine variants, reliability levels which must exceed those currently displayed on onshore wind farms. Manufacturers involved in offshore wind are currently addressing a fuller understanding of the effects of a maritime climate on wind turbines, and results are awaited for recently introduced technological improvements.

The cost of installation is an inherent economic problem to the viability of an offshore wind farm mainly due to the weather constraints and type of equipment required. Traditionally, floating cranes and jack-up barges have and continue to be utilised by offshore wind farm developers, equipment which in general has been developed and costed for oil and gas exploitation. There must be concerted action to eliminate the need for expensive vessels to be employed at installation and major component change-out. Consideration must also be given to the loads experienced by large wind turbine components during transportation and erection at sea.

The best-practice approach to support structure design continues to be a medium term goal, with consideration of installation for increasingly arduous site conditions.

In the medium term with highest priority, component development particularly with the mandate to improved reliability and maintainability becomes a feature. Aerolastic and structural design of rotor blades must evolve with the continued preference for larger and higher performance wind turbine units.

Within this timescale with less urgency, the goals for optimal structural design and design for reliability and maintainability come to the fore. As the wind power industry evolves, the development of standards relating to wind turbine design is bound to mature in proportion. The standards currently being developed by bodies such as the IEC should be extended to include all aspects of offshore wind turbine design. The development and validation of such standards is important because the lack of reliable and commonly accepted design guidelines has the effect of reducing the level of confidence with which offshore wind projects can be financed and implemented.

Optimal structural design will focus on recurrent wind turbine aspects such as reduction of fatigue loading by introduction of inherent flexibility, and more sophisticated control as examples. More particularly, the features of offshore environment will drive closer attention to issues such as wave induced tower vibrations, ice loading, and positive aspects such as allowance of higher blade tip velocities.

Design for reliability and reduction of scheduled and unplanned maintenance will include obvious topics for improvement such as enhanced corrosion and lightening strike protection and reduction in overall number of components. More ambitious plans include the modular design of turbines to facilitate change-out and installation, and justification for the introduction of redundancy at component and turbine level.

Finally within this priority category, the conceptual design of large wind turbines and wind farms should be explored for technological and commercial viability.

Efforts over the next five year period with low urgency shall focus on innovative and evolutionary design of structures and alternative rotor blade numbers and hub configuration, namely the reduction in blade number to two coupled with the elimination of a teetering mechanism.

Long term goals for offshore technology will address siting structures in remoter/deeper water and may include support structure rationalisation methods such as multi-rotor. With the advancement in tidal stream turbine and wave technology, there may be scope for combined wind/wave structural innovation mounted on support structures which have life-ratings well above the energy capturing devices that mount them to facilitate re-use.

Research into the engineering and economic feasibility of floating wind turbine systems for deep water sites should also be considered as a long term objective.

2.2 Installation and Decommissioning

The highest priority in the short-term for installation and decommissioning is firstly to improve dissemination of knowledge from offshore and marine related construction procedures and techniques. The oil and gas industry has over thirty years of offshore experience in European waters, and inshore construction specialists have been in operation for many hundreds of years. Secondly, due to the cost of offshore operations, number and time of offshore operations must be reduced by improvements in installation techniques and more efficient planning. Finally, the rationalisation of offshore lifting operations must be addressed to reduce cost of hiring expensive lifting barges.

Also in the immediate term, occupational health and safety standards and procedures should be developed in line with the rapid development of offshore wind farms. While there is no need to constrain the wind power industry to the same levels of safety required for offshore oil and gas exploitation, the working practices applicable to offshore are far more life threatening than the equivalent onshore practices.

In the medium term, to allow offshore working a wider weather window, installation methodologies should be made less sensitive to wind/wave conditions. The development of erection techniques may be subject to review where more assembly operations are conducted onshore prior to transportation to site.

Within the next five years but with lesser priority is to consider decommissioning requirements at conceptual design and build-in features which will assist at the inevitable later stages.

2.3 Operation and Maintenance

The highest priority in the short-term for operation and maintenance is the safety of personnel who are required to visit offshore turbines throughout the year. The responsible party must provide safe access through procedure and adequate equipment. Another top priority task issue is to facilitate the remote control access of turbine control systems in order to investigate, rectify and re-set trips where possible.

A related priority is the development of mooring systems which provide safe access to personnel alighting from a vessel and disembarking from a turbine access platform. The development of operation and maintenance models should continue, particularly taking cognisance of operational data and experience, providing input data when choosing a suitable site specific maintenance strategy.

In the medium term, the development of inexpensive purpose-built vessels should be considered. Future offshore wind farms may be large enough to justify the purchase of a dedicated vessel for installation, O & M, and decommissioning activities. With recent advancements in SCADA technology, condition monitoring of components which are susceptible to wear and failure must be explored to reduce the cost and requirement for site visits. Innovative maintenance strategies should be explored in conjunction with the development of O&M models.

3 Grid Integration & Electrical Transmission

The highest priority attached to grid integration and electrical transmission is to develop wind turbine generator models for dynamic grid simulation. In particular the characteristics of variable speed machines coupled to mechanical dynamics should be modelled.

Of lesser urgency is the requirement to explore HVDC multiple (up to 35kV) and single grid (up to 200kV) link designs, the effect of LSOWE projects on grid operation.

In the medium term, there should be the development of HVDC converter stations, cabling and associated infrastructure. A fundamental stumbling block to further advances in offshore wind exploitation is the scarcity of suitable existing points of grid connection and grid fragility. A study of the relationship between technical-economical offshore wind energy potential and the cost of providing adequate grid reinforcement is required.

Of lesser priority in this timescale, is the requirement to eliminate offshore transformers by either generation at high voltage or offshore substation development. Wind turbines can be used to assist grid control in terms of power factor and voltage control, and the cost associated with the development of this ability should be explored. The availability statistics of a wind farm are affected by grid faults, and there is merit in developing turbines which can withstand transient external faults without consequential disconnection from the network.

Efforts over the next five years with lower priority should focus on socially acceptable methods for apportioning the grid integration cost of offshore wind farms from energy provider to energy user. A study is required to address whether the existing safety distances between subsea cables can be reduced.

Long term goals for grid integration and electrical transmission issues include wind farm control using centralised converters, and finding suitable methods for power storage.

4 Social, Political and Environmental Issues

Stated objections to wind farms widely vary depending on country, population, spheres of influence, demographic structure, etc, etc. A current priority is to look at air safety particularly with regards to alleged disturbance of radar caused by wind turbines.

The environmental impact particularly at the construction stage of an offshore wind farm requires careful assessment, and mitigating measures implemented to reduce the effects on natural surroundings, e.g. piling effects on marine life. There is a need for ongoing studies identifying sensitive and protected areas which are not suitable for development.

In the short term with less priority, validation of predicted visual assessment must be carried out to ascertain the accuracy of models in varying weather conditions.

In the medium term, environmental impact data from existing offshore wind farms should be disseminated and appraised for future developments. Clearer definition and standardisation of marking requirements may negate conflict from the shipping industry.

Within the next five years but of less priority is the need for improved public relations to counter the often ill-informed views of national populations. This task may be assisted by a willingness to share information through visitor centres for example, and involve local populations throughout the development process.

The biological impact of developments as affecting bird, mammal and marine life must be assessed, and every measure taken to protect and enhance where possible natural habitats. The effect of acoustic and electromagnetic noise emissions must be studied and mitigation measures incorporated in wind turbine and wind farm design.

5 Recent and Current Activities

There is an immediate need for a database of information on existing operational offshore projects and research work.

In the medium term the owners of early offshore wind farm projects should be actively encouraged to freely disseminate and evaluate them with a view to steering future projects.

The potential benefits to employment and benefits to European industrial development should continue to be assessed.

6 Resources and Economics

Immediate priority is to be given to enhancing weather forecasting methods in order to gain imminent wind energy production several days in advance. Evaluation and prediction of wave effects and turbulence on power output of large wind farms needs addressing. There is also an immediate requirement for development of risk assessment techniques and quantifying uncertainty in energy yield estimates.

In the medium term, development and validation of models assessing inshore joint wind/wave and wave induced current simulations is required. Wind data collection methodology should be improved to provide valuable reliable data at a reasonable cost. There is a need for concerted European and national wind monitoring programmes.

On a lesser priority rating, there may be a requirement for finding test sites which exhibit benign to extreme offshore wind conditions while providing easy access, e.g. small islands with a causeway.

	CA-OWEE RTD Strategy Framework		
		Consensus	
		Timescale (2/5/10 yrs)	Importance (Low/Med/High)
1	Offshore Technology		
1.1	Design		
	Wind turbine design		
	Size and configuration:		
	Conceptual design of large wind turbines and wind farms (e.g. unit power rating greater than 5MW with rotors greater than 100m diameter, wind farm rating several hundred MW)	5	Medium
	Alternative rotor blade numbers and hub configuration	5	Low
	Research into multi-rotor systems	10	Low
	Combined wind/wave/tidal energy devices	10	Low
	Power performance improvement:		
	Higher blade tip velocities.	5	Medium
	Work to establish whether the different conditions offshore (particularly turbulence) affect the pros and cons of variable speed.	2	Medium
	Optimal structural design:		
	Better definition of design criteria and extreme wind/wave recurrence periods for inshore waters	2	High
	Development and validation of models for reliable prediction of fatigue and extreme loads	2	High
	Assess reliability of existing spectral wave models	2	High
	Assess importance of wave-driven fatigue on offshore wind structures	5	Low
	Development of standards	5	Medium
	Aeroelastic and structural design of large rotor blades	5	High
	Measurement campaigns on early projects	2	High
	Review of safety factors	2	High
	Reduction of fatigue loading by introduction of inherent flexibility, e.g. flexible towers, compliant couplings, etc.	5	Medium
	Reduction of fatigue loading through more sophisticated control. (Benefits of greater sophistication to be balanced against potential reliability problems.)	5	Medium
	Design for reliability and maintainability:		
	Improve corrosion protection systems	5	Medium
	Reduction of need for floating cranes by development of internal cranage capability for lifting all, including largest, components	2	Medium
	Controlled nacelle environments	2	Medium
	Enhanced lightning protection systems	5	Medium
	Reduction in overall number of components (e.g. new drivetrain concepts - Windformer, Aerodyn Multiwind, permanent magnet generators)	5	Medium
	Develop low maintenance/high reliability components	5	High
	Building in redundancy	5	Medium
	Modular design approach to facilitate changeouts	5	Medium
	Design for installation:		
	Consideration of transport and installation loads	2	Medium
	Sectional components to facilitate ease of transportation and lifting	5	Medium
	Support structure and tower		
	Investigation of breaking waves, shallow water effects and resulting loads.	2	High
	Development & validation of metocean prediction models	5	Medium
	Further research on geotechnics of inshore waters - improve understanding of the interaction of seabed/soil characteristics with system dynamics - sensitivity of resonant frequencies, fatigue loading etc.	2	High
	'Smart tower' which can alter natural frequencies	5	Medium

	CA-OWEE RTD Strategy Framework		
		Consensus	
		Timescale (2/5/10 yrs)	Importance (Low/Med/High)
	Better prediction of loading of various foundation configurations - validation through measurement programmes	2	Medium
	Decision as to whether components (namely turbine and support structure) are treated in an integrated way during design, reducing conservatism.	2	Medium
	Design for future re-use	10	Low
	Research into ice loading, support structure design to deal with ice	5	Medium
	Optimal design of interface between tower and support	5	Low
	Innovative and evolutionary design of structures	5	Low
	Design for deeper waters including floating systems.	10	Medium
1.2	Installation and decommissioning		
	Improved dissemination of knowledge of offshore marine related construction procedures and techniques amongst designers/developers	2	High
	Reduce sensitivity to wave / wind conditions	5	High
	Reduce time for offshore working	2	High
	Minimisation of offshore lifting operations	2	High
	Control costs of overall installation process	2	Medium
	Design for decommissioning	5	Low
	Occupational health & safety standards to be reviewed for offshore work	2	Medium
	Optimise the cost-effectiveness of offshore wind structure installation operations by making use of novel construction sequences and scenarios	5	Medium
1.3	O&M/reliability		
	Development of mooring systems	2	Medium
	Safety of personnel	2	High
	Remote control facilities to allow manual over-ride of turbine control system from an onshore base	2	High
	Development of O&M models	2	Medium
	Development of purpose built jack-up barges, floating barges and landing craft	5	High
	Develop condition monitoring via SCADA systems (enhanced capability, 2 from 3 decision-making, improved reliability)	5	High
	Develop and analyse innovative maintenance strategies	5	Medium
2	Grid integration and electrical transmission		
	Electrical transmission & grid connection		
	High voltage grid link designs, e.g.; multiple medium voltage links (up to 35 kV), single high-voltage link (100 to 200 kV), and HVDC	2	Medium
	Offshore substation design development	5	Medium
	Development of methods to allow LSOWE plants to withstand transient external faults without disconnecting from the network	5	Medium
	Develop offshore converter designs (optimisation of power factor and voltage control)	5	Low
	Wind farm control (e.g. centralised converter)	10	Medium
	Development of HVDC converter stations, cabling and insulation	5	High
	Development of methods to decrease currently required safety distances between sea cables	5	Low
	Elimination of offshore transformers, generation at high voltage (AC or DC)	5	Medium
	Power storage systems development and cost reduction	10	Medium

	CA-OWEE RTD Strategy Framework		
		Consensus	
		Timescale (2/5/10 yrs)	Importance (Low/Med/High)
	Grid Integration & Energy Supply		
	Evaluation of effect of early LSOWE projects on grid operation	2	Medium
	System analysis based on future LSOWE plans, taking account of spatial correlation of supply, existing system characteristics, future plans for cross-border links, etc.	5	Medium
	Analysis of the economical effect (cost) of requiring LSOWE plants to contribute to primary and secondary control	5	Medium
	Evaluate feasibility of demand-side measures to accept high penetrations of LSOWE	5	Medium
	Harmonization of electrical protection and reactive power requirements	5	Low
	Study of the impact of grid limitations on offshore wind energy potential ; study of the relationship between technical-economical off-shore wind energy potential and cost of required grid reinforcements	5	High
	Development of suitable wind turbine (generator) models for dynamic grid simulation codes (in particular for variable speed wind turbines, and including mechanical dynamics)	2	High
	Analysis of the effect on the transmission grid (at local, national, and international scale), including additional network costs and benefits, to accept offshore wind farms at high wind penetrations.	5	Medium
	Research in support of finding a socially acceptable way of allocating the system cost created by LSOWE (grid reinforcement, priority access, increase control requirements for conventional plants, …) to the different stake-holders (LSOWE project owners, all generators, all customers, all tax-payers)	5	Low
3	Resources & Economics		
	Development of forecasting methods for wind energy production up to several days ahead	2	High
	Improvements in methods for estimating wind resource in coastal areas:		
	Mean wind speeds	2	High
	Vertical wind speed and turbulence profile	2	High
	Development & validation of inshore joint wind/wave simulations	5	High
	Provide tests sites with suitable offshore conditions, e.g. small islands	5	Low
	Evaluation and prediction of wake effects and turbulence on power output of large wind farms	2	High
	European and national wind monitoring programmes	5	Medium
	Quantify uncertainty in energy yield estimates	2	Medium
	Cost reduction and reliability improvement for methods for offshore wind data collection	5	High
	Generic evaluation of LSOWE investment costs taking into account cost influencing factors (distance from shore, water depth, wind and wave climate, soil conditions, …)	5	High
	Risk assessment (construction cost, delay risk, energy production, operating costs, availability)	2	High
	Joint wind/wave loading on short time scales for weather forecasting, power output and improved maintenance scheduling	2	High
4	Recent & Current Activities & Prospects		
	Database of information on existing operational offshore projects and research work	2	High
	Develop standards for offshore wind industry	5	High
	Benefits to employment	5	Medium
	Benefits to European industrial development	5	Medium
	Systematic evaluation of the results of test and demonstration projects	5	High
5	Social, Political & Environmental Aspects		

	CA-OWEE RTD Strategy Framework		
		Consensus	
		Timescale (2/5/10 yrs)	Importance (Low/Med/High)
	Environmental impacts:		
	Biological impacts:		
	Baseline and impact studies from individual projects to be disseminated and jointly appraised	5	High
	Birds:		
	Layout design to accommodate flight paths, where these are defined.	5	Medium
	Sea mammals:		
	Avoidance of sensitive habitats	5	Medium
	Minimisation of atmospheric and subsea noise levels during construction and operation	5	Medium
	Study effect of electromagnetic fields	5	Medium
	Fish:		
	Manage public awareness of "stunned" fish during construction (pile driving)	2	High
	Minimise effect of structures and cabling on stocks	5	Medium
	Seabed fauna:		
	Study effect of electromagnetic fields	5	Medium
	Investigate value of local measures to enhance habitat	5	Medium
	Hydrography, currents and water quality:		
	Investigation of appropriate foundation design	5	Medium
	Guidelines for site works	5	Medium
	Visual:		
	Early assessment taking account of distance from shore and nature of viewpoints	2	Medium
	Validation of visual assessment	2	Medium
	Promotion of openness and local involvement	5	Medium
	Noise:		
	Ongoing PR work to counter poor publicity	5	Medium
	Maintain good standards of noise emission despite increases in turbine size and tip speed	5	Medium
	Conflicts of interest:		
	Traffic:		
	Ships:		
	Clearer definition of marking requirements	5	High
	Collation of collision risk analyses	5	Medium
	Air traffic:		
	Safety of civil air traffic	2	High
	Safety of air traffic related to project	2	High
	Defence:		
	Studies of disturbance to radar	2	High
	Safety of air crew training	2	Medium
	Fish, bird and other groups:		
	Identification and avoidance of sensitive areas	2	High
	Avoidance of site works during sensitive time periods	2	Medium