European wind turbine standards

Fact Sheet

Project Information

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Objective

The main objective of the proposed project is to remove vital constraints and bottlenecks in the technical harmonization of the European wind turbine market. Guidelines and recommendation will be developed on selected technical issues which are not (properly) covered by existing (draft) standards criteria (e.g. the IEC draft standard) or R&D projects (e.g. JOULE projects). With this information the official European standardisation bodies (CEN/CENELEC) can efficiently develop standards in a relatively short time. The project results will also be largely applicable for wind turbine designers and certification bodies.

Starting points in the project are:
- to address key issues which are vital for large wind turbines,
- to avoid unnecessary redundancy in project activities,
- to avoid expensive and time consuming calculations and measurement campaigns,
- to apply, where appropriate, the Probabilistic Reliability Analysis tools which recently became available for wind turbines.
recently become available for wind turbines.

A derived objective is to bring together participants who cover the required expertise and have the quality and the contacts to provide adequate background guidance for the technical harmonization of the EC wind turbine market, during the course of the proposed project and - if required - also after that period. This guidance will involve:
- continuous tracking of relevant developments in national and international standardization activities and in R&D work,
- screening of appropriate European Council Directives on their technical suitability in bringing about adequate harmonization,
- identification of constraints and estimation of their importance for European harmonization,
- reporting interim results to interested parties like CEN/CENELEC, national standardization committees, manufacturers organizations and the IEC-88 committee.

An additional objective is to investigate the possibility of ensuring that the standardised measurement procedures will be properly implemented in the measurement campaigns of the national wind turbine test stations in the CEC. This will eventually lead to a EUREC Agency network of centres which guarantee high quality measurement results, applying state of the art methodologies.

**Deliverables**
- A uniform methodology to derive wind turbine design load spectra. This methodology will allow for the implementation of load measurement results in the design loads and also include the determination of increased loads in wind farms.
- Procedures to calibrate safety factors (partial coefficients) to be taken into account in mechanical stress calculations, which are to be used in European wind turbine standards.
- A uniform methodology to evaluate wind turbine safety. This methodology will allow for a clear and unambiguous interpretation of the rules for wind turbine safety system design. It will also include operational guidelines to quantify failure probabilities.

The above mentioned results will ensure that the European standards on wind turbines:
- guarantee an adequate safety level for the environment, especially with large wind turbines,
- result in sufficient quality, efficiency and reliability of installed wind turbines,
- permit economic and effective measurement campaigns,
- result in well-balanced designs without avoidable conservatism.

Also a state of the art overview will be drafted of important constraints and bottlenecks which still are not addressed properly and should be removed in the near future in order to achieve proper technical harmonization.
Furthermore an action plan will be developed for the implementation of standardised measurement procedures in the test station members of EUREC Agency.

1.1. European implementation programmes In several European countries (e.g. Denmark, Germany, Great Britain, Spain, Italy, Greece and The Netherlands) large scale implementation of wind turbines is part of governmental energy policy. The implementation is actively supported by the Commission of the European Community (CEC DG-XII and DG-XVII). The existing implementation programmes plan a progressive increase which in the year 2000 will result in a total installed capacity of 4250 MW rising by the year 2010 to over 12000 MW. This will result in approximately 15000 wind turbines in the year 2000 and 3000 in the year 2010. The main part of the installed wind capacity will be achieved by means of MW-turbines.

1.2. Need for technical criteria and standards Wind turbines have a large potential impact on the surroundings in terms of safety risk, acoustic noise emission and visual impact.

Therefore, in some of the member states, specific standards and criteria for wind turbines have been drafted (e.g. in Denmark, The Netherlands and Germany) or are under development (Great Britain and Greece). These standards include, or are in line with, existing criteria of the local Building Authorities. These criteria mainly deal with safety aspects and measurement methods for the uniform evaluation of noise emission and power performance. Based on these criteria and standards, in order to support the above mentioned programmes, certification systems have been developed to guarantee safety and quality of installed wind turbines.

1.3. Need for harmonisation Properly designed and manufactured wind turbines are no dangerous installations, but they represent a certain risk for the environment in terms of damage to goods and persons. This risk should be as small as possible. Wind turbines are to be adequately safe in order to be installed at as many locations as possible.

The public acceptance of wind turbines has shown to be of vital importance for the success of implementation programmes. To maintain or increase this acceptance the social costs related to incidents and accidents with wind turbines are to be kept to a minimum. For the EC this means that wind turbines have to be designed according to uniform criteria and standards.

An other important item is that the free border trade of wind turbines should be facilitated.
guaranteed in the EC. Besides uniform standards and criteria, this also requires uniform assessment, testing and evaluation procedures by the European certification bodies and Test Stations.

The appropriate road towards formal European Harmonization has recently been investigated by the Danish Energy Agency under contract of the CEC DG-XVII. The final recommendations from this study can be summarized as follows.

- Development by CEN/CENELEC of harmonized European standards for wind turbines, where possible based on the IEC standards for wind turbines, which are presently under development in the IEC TC-88 committee.
- Define conformity assessment procedures according to the Global Approach, in order to guarantee uniform third party certification by certification bodies.

At this point it is not clear if these recommendations will be followed. Anyway, wind turbines will fall under the scope of one or more Directives. This can be a new one or modified versions of existing ones. These Directives can only ensure effective harmonization of the wind turbine market if they refer to appropriate European standards. These standards have to match the Essential Requirements of the applicable Directives. The most appropriate Directive at this moment is the Machinery Directive. However, its technical adequacy for wind turbines is doubtful. This proposed project will deliver information which could be used by CEN/CENELEC in the development of European Standards. This proposed project will not define the required procedures for conformity assessment necessary to obtain the CE-mark. These items could be developed within other European frameworks.

1.4. Requirements for criteria and standards

Harmonized European criteria and standards for wind turbines have to meet the following requirements.

- They should guarantee an adequate safety level, also of large wind turbines.
- They have to result in sufficient quality, efficiency and reliability. Measurement specifications should allow for economic and effective measurement campaigns.
- They should ensure a correct interpretation of the essential requirements of the applicable European Council Directives.
- They have to result in well-balanced designs without unnecessary conservatism.
- They should not hamper new technological developments (flexible elements, direct drive concepts, etc.).

Especially the last requirement is of great importance for large wind turbines. They have to be designed by means of analyses more than by means of general rules. Over-dimensioning of the construction and related (control and safety) systems will
drastically decrease cost-effectiveness. Recently, probabilistic reliability analyses methods for wind turbines became available as a result of the JOULE I project 'Probabilistic Safety Analysis of Wind Turbines'. These methods are very helpful to underpin certain safety aspects in order to arrive at well balanced safety standards.

2. CONSTRAINTS IN STANDARDIZATION
2.1. General The participants in this project have already investigated the above mentioned (draft) standards and recommendations in order to identify areas where vital information is missing. The results are summarized below.

The required standards and criteria can be split up into two parts. 1. Requirements to wind turbine designs with respect to both safety and quality (e.g. design conditions, mechanical load calculations, safety philosophy, safety factors and material properties). 2. Requirements to measurement techniques and procedures which are necessary to determine actual machine characteristics. In several EC Member States (e.g. Denmark, Germany and The Netherlands) specific measurements are required for the permit to erect a wind turbine or to obtain national fundings.

A general problem with the (draft) international standards is that they are heavily compromised and should be considered as a set of minimum requirements. Some items are not sufficiently based on knowledge and studies. Another problem is that the applicability of the design requirements to large wind turbines in the MW-class has not been demonstrated yet. They are mainly based on deterministic design rules. These rules concern the design of main components and safety systems. They neither facilitate the quantification of the degree of conservatism in the applied safety margins nor explicitly address the reliability and availability of the wind turbine.

There is a clear tendency in the European wind industry to incorporate measurement results in design calculations. For large wind turbines this is considered to be of vital importance, in order to avoid unnecessary conservatism. Measurement campaigns will undoubtedly be incorporated in European certification procedures. Harmonization of the specific measurement techniques and procedures is therefore essential.

2.2. Design analysis Load spectra In the various national and international requirements different approaches are used for the construction of design load spectra. For a specific wind turbine design, these different approaches result in different load spectra and therefore in different turbine weights. The IEC draft safety standard on itself allow for different approaches with this respect. None of the existing documents specify criteria for the implementation of load measurement results in design calculations. Nor do they properly address the issue of increased loads in wind farms.

It is necessary to establish a commonly accepted European methodology to create
wind turbine design load spectra, which takes into account the effects of wind farm wake effects and which also includes a methodology to use measurement results. Sub-project 1 'Load Spectra for Wind Turbine Design' is defined in order to deliver such a methodology. The objective of this sub-project is not to compare wind turbine design codes. Therefore, and in order to avoid expensive calculations as much as possible, the results of the JOULE-I project 'REFSTRESS' will be taken into account. The results of the JOULE-II project 'Dynamic Loads in Wind Farms' will be also be applied.

Safety factors In safety standards, partial safety factors (e.g. for loads and materials) are specified. They are used in load calculations to compensate for uncertainties in design parameters, in calculation models and in experimental results. Safety factors have a large impact on the economy of wind turbines. At the one hand they have to be sufficiently high to ensure adequate safety for people and the environment, at the other hand they should not be higher than necessary to avoid expensive overdimensioning. This aspect is even more important for large turbines. The presently applied or proposed wind turbine safety factors are not sufficiently underpinned. In analogy with e.g. building codes these factors have to be calibrated in line with the European Eurocode. Sub-project 2 "Safety Factor Calibration" is defined to work out procedures for this calibration. Probabilistic structural reliability methods will be applied as they have been specified or mentioned in the JOULE-I project 'Probabilistic Safety Analysis of Wind Turbines'.

Safety systems The requirements with respect to the safety concept of wind turbines vary in the European member states. The IEC draft standard is insufficiently precise with respect to safety system requirements. At present safety systems are designed in accordance with deterministic rules. Especially for large wind turbines these rules may not result in a safe and well-balanced design. An important constraint is that over-dimensioned mechanical brakes in large wind turbines introduce heavy mechanical fatigue loads in the rotor blades, resulting in a decreased safety level. It is felt necessary to reward measures to decrease the failure probability of a subsystem (e.g. by means of constant monitoring, reliability driven maintenance or adequate testing procedures) in terms of less required redundancy. The local and national authorities, especially in highly densed population regions ask more and more for an evaluation of safety and risk of industrial activities. For wind turbines this tendency is amplified because the rapidly increasing number of installed wind turbines results also in an increasing number of wind turbine failures. The present standards do not include analysis tools to carry out this type of safety evaluation.

Sub-project 3 'Evaluation of Wind Turbine Safety' is defined which will deliver recommendations for safety system requirements, which are based on a probabilistic methodology to quantify the probability of failure. In this sub-project, system reliability methods will be applied which have been developed in the JOULE-I project "Probabilistic Safety Assessment of Wind Turbines".
Site classes

An important condition for European harmonization is to classify the external conditions for wind turbine design in Europe, in order to evaluate the appropriate or required wind turbine class for a specific site. The procedure for this classification has still to be developed. However, this would require measurements to be carried out, extensive analyses of (new and already existing) measurements results and the evaluation of complex terrain effects. Also the partial overlap with wind classes in other technologies (e.g. the civil engineering branch) should be considered. Therefore this item is not included in this project.

2.3. Measurement techniques and procedures

Wind speed measurements

In almost all measurement campaigns on wind turbines the accurate measurement of the wind speed is of vital importance. The economics of a wind turbine project is strongly dependant on a guaranteed power performance curve, which in general is based on measurements. Inaccurate wind speed measurements will result in an unrealistic power curve, and consequently in a unrealistic cost break-down of the project. Also for load measurement the wind speed should be accurately measured, in order to avoid that erroneous data will be used in the wind turbine design parameters.

In the IEC-88 committee a standard for power performance determination is under development. In the draft document requirements are set to the accuracy of the wind speed measurements. European studies carried out under contract of CEC DG-XVII have demonstrated that in practice this accuracy is not obtained. This is mainly caused by the lacking of proper calibration procedures for anemometers (cup-anemometers, propeller vane anemometers, laser-doppler anemometers). Especially an absolute reference instrument is difficult to define. This issue will be taken care of in Sub-project 4 'Measurement methods and procedures'.

Power curve determination

As stated above, an accurately measured power curve is an important economic item. It is expected that the new IEC standard will cover most items adequately. A clear and important exception is the above specified issue of anemometer calibration. Site calibration is another important issue which is not yet covered properly in existing documents. The objective of most wind turbine measurement campaigns is to investigate the correlation between turbine parameters (power, rotational speed, mechanical loads, noise production) and the wind speed. The basic problem is that the wind speed at the anemometer location (e.g. on a meteo tower) can differ considerably from the wind speed seen by the wind turbine itself. The resulting inaccuracy can have a high impact on e.g. the measured power curves, and consequently also to the economics of wind turbine projects. Up till now this inaccuracy, which is strongly site dependant, has not been investigated properly. In Sub-project 4 existing measurement results (on power performance), obtained on various locations, will be re-analyzed on wind direction influences. From this the site effects can be quantified. Load measurements

Load measurement results become more and more an important basis for wind turbine design development. They are used to verify calculated design load spectra as well as to
optimize existing designs. Up till now measurement campaigns differ with respect to applied equipment, calibration procedures, selection of transducer locations (e.g. strain gauges) and data reduction methods. Up till now the only attempt to standardise these measurements has been done within the scope of the JOULE-I WEGA project. In this project templates were defined for comparison of measurements to be carried out on the turbines concerned in that project. There is an urgent need to harmonize load measurement methods in general: smaller and larger turbines, industrial types and prototypes. Drafting of these methods, starting from the 'WEGA Measurement Templates' is also a task of Sub-project 4.

Noise measurements At this moment a considerable effort is perpetrated in this field. Four well coordinated JOULE-II projects cover different issues related to wind turbine noise production, including measurements. Also IEC and IEA working groups are drafting standards and recommendations on measurement methods. Therefore, at this moment no additional actions are needed to arrive at adequate European harmonization of noise determination.

Power quality determination With the increasing number of installed wind energy capacity in Europe, the issue of required power quality becomes important. In Germany already manufacturers are obliged to specify the power quality in terms of peak powers, harmonic distortion, etc. Up till now, uniform measurement procedures and specification formats are not available. The drafting of these items is incorporated in Sub-project 4. When these recommendations are followed the electrical utilities will be able to assess the grid connectivity of wind turbines from any European manufacturer in the same way.

Blade test procedures Blade tests are indispensable to demonstrate adequate strength (static and fatigue) of blade designs of large wind turbines. They are or will be incorporated in existing national certification systems. Uniform procedures are required. The JOULE-II project "Strength and Fatigue Analyses" is expected to deliver recommended uniform procedures for blade tests. Therefore, at this moment, no actions will be taken on this issue. Implementation of standardized procedures Prior to formal standardization, the test station members of EUREC Agency have to some extend implemented available recommended methods and procedures in their wind turbine measurement campaigns. The actual implementation of standardized and uniform methods and procedures, however, is voluntary and there is no precise picture of the status of implementation of the newest scientific recommendations concerning measurement techniques in the different centres. Consequently, no guarantees can be given on the quality and reliability of measurement results. The national test centres have recognized the need for a common approach of the quality assurance of their measurement campaigns on wind turbines. For the realization of this common approach a clear organisational structure is
required. The EUREC Agency is expected to be able to serve as the basis for this structure. In Sub-project 5 'Structurized implementation of standardized wind turbine measurements' a detailed action plan is developed for the implementation of a common quality assurance programme, based on mutual accreditation. Especially the measurement campaigns in CEC’s large wind turbine programme will benefit from the availability of a EUREC network to perform high quality measurements on wind turbines.

3. PROJECT ORGANISATION
3.1 Structure
The project is split up into five sub-projects and one general task.
Sub-project 1.: Load Spectra for Wind Turbine Design
Sub-project 2.: Calibration of Wind Turbine Partial Coefficients
Sub-project 3.: Evaluation of Wind Turbine Safety
Sub-project 4.: Measurement Methods and Procedures
Sub-project 5.: Structurized Implementation of standardized Wind Turbine Measurements
General Task: Identification and Information
The work in the sub-projects is described in section 2.

The administrative coordination is carried out by the EUREC Agency. The Netherlands Energy Research Foundation performs the technical project coordination.

The general task contains:
- Identification of remaining constraints and bottle-necks in (draft) standards, criteria, guidelines and recommendation which are considered to hamper harmonization of the European wind turbine market, and which are not investigated in this proposed project. This also includes the screening of European Community Directives on their technical suitability to harmonize the wind turbine market.
- Drafting of custom made documents to inform interested parties of the interim results:
  * CEN/CENELEC
  * National Standardization Committees
  * Manufactures organizations
  * Project leaders of other related JOULE Projects
  * IEC-88 committee.
- Drafting of a final executive summary.

This general task will be carried out by all participants under coordination of the Project Steering Committee.

3.2 Participants
In order to improve efficiency and to reduce costs, the work in the sub-projects is distributed among the participants on the basis of their specific
competence and expertise. Where necessary, participants outside EUREC Agency are selected to fill up specific gaps in know-how and experience. Unnecessary redundancy in activities is avoided. The result is a combination of participants which cover expertise in wind turbine technology on the following issues:
- All relevant measurement techniques
- Wind turbine measurement campaigns
- Theoretical design evaluation
- Mechanical load calculations
- Probabilistic safety analysis techniques
- Wind turbine standardization
- Wind turbine assessment and certification.
This means that the proposed Project Steering Committee has the competence, the quality and the contacts to perform background guidance to the technical harmonisation of the EC wind turbine market. Furthermore this combination gives the guarantee that the project results are practical and applicable to designers and certification bodies.

Programme(s)

Topic(s)

Funding Scheme

CSC - Cost-sharing contracts

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