AUGUST 2001 ECN-C--01-059

EUROPEAN WIND TURBINE CERTIFICATION
EWTC

Guidelines for design evaluation of wind turbines

F.J.L. Van Hulle (ECN)
C. Nath (GL-Wind)
P.H. Jensen (Risø)
C. Eriksson (DNV)
P. Vionis (CRES)

Research funded in part by
THE EUROPEAN COMMISSION
in the framework of the
Non Nuclear Energy Programme
JOULE III

Acknowledgement
The work was financially supported by the European Commission, in the framework of the Joule 3 Programme under contract nr: JOR3-CT98-0265
ECN Project 7.4050

The following organisations, agencies etc. financially supported the work:
- Novem BV Utrecht Nl, contract 224.760-9822
- General Secretariat for Research and Technology, Athens, Greece
- Danish Energy Agency

The authors wish to thank the following persons who contributed to the results of the project:
ECN: Ben Hendriks, Paul Soullie, Servaas Ramakers
CIWI: Wim Stam
GL Wind: Axel Andreae, Kimon Argyriadis, Reinhard Schleesselmann
Risø: Poul Højholdt, Carsten Skamris, Torben Larssen
DNV: Bente Vestergaard
CRES: Kyriakos Rossis, Fragiskos Mouzakis
Enercon: Arno Hildebrand, Thorsten Jepsen,
Nordic Wind Power: Thomas Lyrner
Jeumont Industrie: Patrick Brutsaert

The authors thank the wind turbine manufacturers Enercon GmbH, Jeumont Industrie and Nordic Wind Power for their co-operation to the project.

Preface
The present report is the publishable version of the final report of the EWTC project. The structure of its contents is as prescribed by EU. Besides a concise description of objectives, work method, results and conclusions, it contains the full text of the Guidelines for Design Evaluation of Wind Turbines, the major project result.

CONTENTS

ABSTRACT - EXECUTIVE SUMMARY

The European institutes involved in wind turbine certification have carried a joint research project funded by the European Commission in the Joule 3 programme to arrive at a harmonised wind turbine certification in the European Union. This project - European Wind Turbine Certification (EWTC), contract JOR3-CT98-0265 started in May 1998 and was completed in April 2001.

The problem addressed in the project is the fact that the present situation in wind turbine certification world - characterised by co-existence of different wind turbine certification systems - hampers the trade of wind turbines in Europe. This situation has a lot of negative implications on the implementation of wind energy in political, commercial, environmental and legal sense.

The main objective of EWTC was to develop a common practice in order to overcome the different interpretation possibilities of the present standards used in certification i.e. the IEC 61400-1 which addresses technical and safety requirements for wind turbines and the IEC WT 01 which addresses the certification systems. The use of these documents - which contain a lot of sub-optimal compromises - in practice lead to different interpretations and hence to different conclusions in the evaluation of wind turbine design. As a result, wind turbines are not universally accepted. The ultimate objective is to work towards a uniform wind turbine certification all over Europe.

The basic method followed in the EWTC project was to identify the variation in interpretation by in parallel carrying out three “certification cases”. Based upon the differences encountered the project partners have worked out solutions for agreement. The result of this process is a set of guidelines to be used together with the above-mentioned IEC standards and other Certification Regulations used by the Certifying Bodies.

The project was carried out by a Consortium consisting of Germanischer Lloyd WindEnergie (D), Risø National Laboratories together with Det Norske Veritas (DK), Centre of Renewable Energy Sources CRES (GR) and Energy research Centre of the Netherlands ECN together with CIWI Holland. The coordination was done by ECN. The manufacturers Enercon GmbH (D), Nordic Wind Power (S) and Jeumont Industrie (F) provided the material for the case studies in terms of design documents and access to a wind turbine for testing.

Although it was not possible in practice to carry out a full scope type certification for the selected wind turbines, the case studies delivered a lot of discussion material and hence aspects to be clarified in Guidelines. As expected, the differences in evaluation methods between the project partners are considerable. Striking examples are the different evaluation methods of the loads and the different methods for evaluation of the wind turbine protection systems. In practice it appears that the level of detail of information required from the manufacturer is quite variable, and a similar variation of detail is visible in the evaluation reports of the Certifying Bodies.

After thorough discussion the partners have streamlined their conclusions towards common Guidelines for Design Evaluation. These Guidelines will be used on a voluntary basis by the partners who participated to the project together with the documents which are part of the formal set of certification regulations. The implementation of these Guidelines in a formal European system should take place after some experience has been collected. However it should not be assumed that this will happen automatically without a proper external mechanism that will maintain continuity in the harmonisation process.

PARTNERSHIP IN THE EWTC PROJECT

1 Co-ordinator, contractor
ECN Wind Energy,
PO Box 1,
1755 ZG Petten, The Netherlands,
Frans Van Hulle

2 Associated contractor of 1
CIWI Holland[1]
Arnhem, The Netherlands
Wim Stam

3 Contractor
Germanischer Lloyd WindEnergie,
Johannisbollwerk 6-8,
D-20459 Hamburg, Germany,
Christian Nath

4 Contractor
Risø National Laboratory,
4000 Roskilde, Denmark,
Peter Hjuler Jensen

5 Subcontractor of 4
Det Norske Veritas,
Tuborg Parkvej 8, 2900 Hellerup, Denmark,
Christer Eriksson

6 Contractor
CRES
19th km Marathonos Avenue,
190 09 Pikermi, Attki, Greece,
Pantelis Vionis

The Consortium carried out the project in co-operation with three European wind turbine manufacturers who contributed to the case studies:

- Enercon GmbH, Aurich, Germany
- Jeumont Industrie, Jeumont, France
- Nordic Wind Power, Taby, Sweden

[1] The activities of CIWI Holland in wind turbine certification have been suspended in 2000.

OBJECTIVES OF THE EWTC PROJECT

Main objective

The main objective of the EWTC project is to come to a uniform harmonised wind turbine certification in the European Union, in order to remove trade barriers, to speed up implementation and to further reduce wind energy costs. The harmonised certification should be adjusted to the needs of the wind energy industry and the requirements of the European legislation.

An explicit objective of the project is to contribute to a European standard on wind turbine certification. The realisation of this objective is guaranteed by the composition of the project team, of which the members are participating actively presently in the development of wind turbine standards in the framework of Cenelec and IEC.

Detailed objectives

The detailed project objective was to carry out case certifications and based upon the results:

1. To formulate common procedures for wind turbine certification to be used all over the EU;
2. To develop country specific guidelines for interpretation of a common certification standard where necessary;
3. To recommend formal procedures for implementation of the procedures on country and European level by communications to the relevant European standardisation bodies (Cenelec, EOTC) and to IEC TC88.

Background, problems and perspectives

The success of the implementation of wind energy largely depends on the quality of the wind power equipment. The fast expansion of the wind power capacity in the European Union is demanding for a consistent and well thought-out process of quality assurance. The fact that certification is mandatory in most wind energy implementation programmes proves that it is playing a vital role in the objective of quality assurance of the European wind turbine fleet.

Ideally, certification should be organised in such a way that it is not slowing down the pace of wind energy implementation. At the time of the project proposal (1997), this "ideal" situation was far from being reached. Wind turbine certificates issued in one country of the EU are not automatically accepted throughout the other member states. As a consequence, wind turbine manufacturers have to approach different institutes or to go through multiple assessments to get a particular wind turbine type certified all over the European Union. This involves high costs and time consuming procedures.

The problem is caused not only by the difference in local technical criteria (standards) and legislation, but also due to differences in certification procedures, in interpretations and in methods of work of the certifying bodies. The problem of uniform standards is being tackled by ongoing developments (Cenelec, IEC, European Wind Turbine Standards project). The harmonisation of certification procedures however still has a long way to go. Some initial steps are being taken within IEC TC88 (WG9) and Cenelec (BTTF-83/2), but the activities of these working groups are limited to formulating general directions to follow. A substantial effort remains to be delivered in order to develop consistent guidelines for a harmonised wind turbine certification all over the European Union.

The reduction of certification costs and the simplification of procedures is of vital importance for the implementation of wind energy in Europe. A harmonised system will also lead to an increased competition on the market of certification, which will ultimately lead to higher certification efficiency and further reduction of certification fees and hence of the cost of wind energy. The position of the European wind energy industry on the world market will be further strengthened if their products are provided with an harmonised European wind turbine certificate.

The wind turbine industry has been invited within the project to express its view on the efficiency of certification procedures. It is the aim of the project partners to adjust the uniform procedure optimally to the interests of the industry.

Wind turbine certification nowadays is concentrated in the Northern part of Europe. The development of uniform procedures will allow also other countries in the Southern part of Europe to undertake wind turbine certification activities. Wind energy implementation programmes in those countries will be facilitated as a consequence. The market for wind turbine certification will become more open.

BRIEF TECHNICAL DESCRIPTION OF THE EWTC PROJECT

The basic approach of the EWTC project consisted of identifying the specific mutual differences in certification method of the partners by carrying out certification of identical wind turbines and based upon the resolution of the differences encountered drafting of specific interpretation guidelines and unified requirements to be followed by the European certification bodies.

Within the round robin certifications every project partner (ECN/CIWI, CRES, GL, Risø/DNV) has certified the same set of design documents for the same wind turbine. This procedure has been carried out for three different turbines using IEC 61400-1, ed. 2 [1] for loads, safety and design and IEC WT 01 [2][2] for the overall procedure to obtain a Conformity Statement for Design Evaluation or a Type Certificate.

In order to obtain realistic results from the case certifications a careful approach has been worked out. First, in the selection of the wind turbines selection criteria have been applied in order to ensure that state-of-the-art design methods have been applied by the manufacturer and furthermore that sufficient discussion material would emerge from the case studies.

The type certification has been carried out in several steps following the different modules and elements in IEC WT 01. The modules are design evaluation, manufacturing evaluation and type testing. The first step in design evaluation is the evaluation of loads and safety concept being the basis for the design of the turbine. The second step is the evaluation of the strength and adequacy of the components and systems. Each step is concluded by each partner with a certification report, sufficiently detailed to allow a comparison of the evaluation work of the different partners.

The certification evaluations have been carried out according to the specific practices of every certification body involved. However in order to minimise the “disturbance” for the manufacturer having to deal with four parallel investigators, every certification case was co-ordinated by a case co-ordinator who streamlines the contact with the manufacturer.

From the comparison of the certification reports conclusions have been drawn on the necessity of additional guidelines. A Guidelines document has been drafted for aspects, which appeared to be not clear enough. The overall project sequence is schematically depicted in figure 1.

For management purposes, the project has been subdivided into the following main tasks:

A. Preparatory task : establishment of work method and assessment of state-of-the art in certification in Europe
B. Certification Case Studies
C. Comparison of case study findings
D. Drafting of requirements and interpretation guidelines.

Besides these four tasks, a separate task was continuously running, i.e. the co-ordination and management of the project.

[2] previously IEC 61400-22

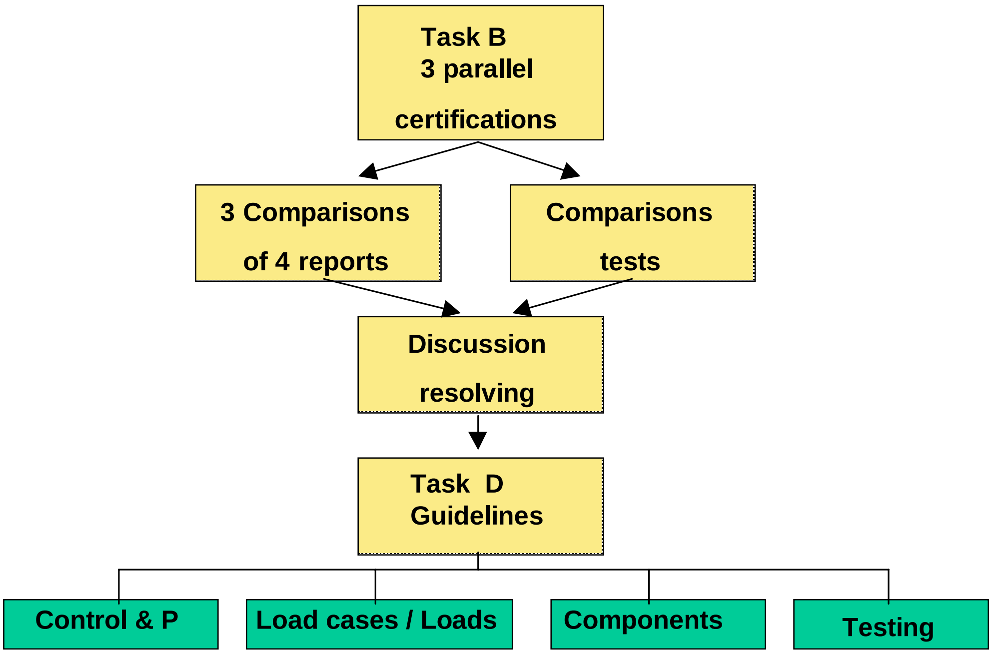

Figure 1: Main tasks in EWTC

Some basic data about the wind turbines used for the three case studies are given in the table below.

	Case 1	Case 2	Case 3
Manufacturer	Enercon GmbH (D)	Jeumont Industrie (F)	Nordic Wind Power (Sweden)
Type	E-40/6.44/E2	J48	Nordic 1000
Diameter (m)	43.7	48	53
Rated power (kW)	600	750	1000
Design features	Direct drive, Ring generator 3 bladed rotor Pitch regulated Variable speed	Direct drive, Disc generator 3 bladed rotor Pitch regulated Variable speed	Stall regulated, 2-bladed rotor, teetering hub Variable speed
Design code	IEC / GL	IEC	IEC
Case co-ordinator	GL/GL-Wind	ECN	DNV

RESULTS

General

The main project result is a set of guidelines for uniform certification. Besides the project team has been keeping track of the certification scenery in Europe and has made two overview reports. These results will be briefly described in this section.

Guidelines: scope

The purpose of the Guidelines document is to provide guidance in design evaluation where the existing standards used in wind turbine certification are insufficiently clear. The guidance is given in such a way that design evaluation by different Certifying Bodies in Europe does not lead to different results and that their design evaluation reports are mutually acceptable.

The recommendations are based upon the findings from the three case studies. The document reflects the common opinion of the EWTC partners on specific issues encountered during this exercise. It of course also reflects the present level of understanding within and between CB's in Europe.

These guidelines are complementary to the requirements in IEC 61400-1 [1] and IEC WT 01 [2], and in principle only include explicitly those points not sufficiently covered in the above mentioned standards. The Guidelines shall be used in combination with the latter documents. The objective is that the use of this set of documents will ensure uniform practice in wind turbine certification.

The scope of the Guidelines includes all items investigated in the process of wind turbine type certification as defined in IEC WT 01.

The EWTC project team specifically focused on the following items of wind turbine type certification, and hence formulated specific additional harmonising guidelines on these items:

- Control and Protection Systems;
- Load Cases and Loads;
- Components and Electrical System;
- Other Items of Design Evaluation;
- Reporting Format for Evaluation Reports;
- Inspection and Function Testing.

The team considered the remaining items of IEC WT 01 formulated as sufficiently clear and did not formulate additional guidelines for these items. The full text of the Guidelines is given in Annex (included in this document).

The document contains specific statements on many aspects of IEC WT 01. To illustrate this, some of the highlights of the document are summarised briefly here:

- The document gives more detailed specification on the documentation and descriptions needed to demonstrate the adequacy of the control and protection system, for example on the hydraulic and electrical auxiliary systems, braking systems etc. It is expected that this guidance will ensure better documentation by the manufacturer and more clarity on what has been evaluated by the CB.
- The document gives guidance on what has to be reported about independent load calculations.
- The document contains specific requirements and clarifications about some of the IEC 61400-1 load cases, which have been recently been debated, e.g. the load cases DLC 6.1 and 6.2. The Guidelines showed in this case to be a document in which more recent agreements between CB's can be incorporated, without having to wait for the approval of formal standards.
- The Guidelines contain detailed specification of items to investigate and report in the wind turbines inspection and function test.

Expected significance of the Guidelines
The participating certifying bodies can include the Guidelines in their internal schemes. Thus, harmonisation is achieved. However, it is not realistic to assume that the CB's will formulate, update and apply these Guidelines on a voluntary basis without external "enforcing" or supporting mechanisms. Therefore external formal circuits have to play a role in the implementation of the Guidelines. The CB's should maintain the proper amount of control on the contents which will not always be easy because e.g. the Guidelines will necessitate additional effort (mainly information supply) from the manufacturers. The project team decided to inform the following bodies about the Guidelines:
- The national standards committees in Europe (at least DK, NL, D);
- The certification board of IEC;
- The technical committee IEC TC88.

Overview of certification situation in Europe
An overview has been made about certification systems and practice in Europe. This inventory prepared in 1999 includes the following aspects:
- country specific rules and required approval procedures;
- applicable wind turbine standards for certification;
- wind turbine certification institutes and systems.

The information has been collected from various sources, including previous ECN publications and from contacts with relevant companies, institutes and key-persons. The following countries are described in the overview

Denmark	France
Germany	Sweden
Netherlands	Austria
Greece	Switzerland
United Kingdom	Belgium and Luxembourg
Ireland	Norway
Portugal	Finland
Spain	Italy

It is apparent that the European countries at present apply considerably different wind turbine certification systems, the scope of which is ranging from „no specific requirements„ to „full type certification„ plus assessment of site conditions and foundation design. In the overview the specific certification schemes and certification agencies have been described. The term certification is used as a synonym for examination, evaluations, approvals and certifications. The findings are reported in ref. [3].

The experience of wind turbine manufacturers with the different certification systems has been asked in the early stage of the project. The viewpoints have been asked on:
- validity and acceptance of present certificates;
- delay in time to market due to multiple certification;
- specific differences in requirements on different markets;
- specific wishes for harmonised system.

Most of the manufacturers have experience with certification, and many of them have strong opinions on the advantages and disadvantages of certification. In the present market, manufacturers are forced to go through the process of certification, very often on request of their customers. Although most of the manufacturers definitely see the advantage of type certification, the time needed for the process is felt as long, and the costs are high. There is a tendency in the opinions that small companies see the time and costs as a burden, whereas larger companies emphasise the advantage of an independent evaluation. There is a well-defined need for improvement on the certification procedures and some advantages are expected from a harmonisation not only on the European, but also rather on world wide level.

An improved system should be better adapted to the rapidly changing technology. For this purpose it should be more flexible and transparent and should incorporate the possibility for prototype certification as in Denmark. The findings of this task have been reported in ref. [4], and in a paper presented at the DEWEK conference in June 2000 [5].

CONCLUSIONS, EXPLOITATION PLANS AND ANTICIPATED BENEFITS

This chapter contains the evaluation on how much the project succeeded in reaching the objectives set out in the original work plan. These conclusions are given with respect to both the detailed and the general objectives. The chapter also indicates how the results are going to be used and give an indication of the anticipated benefits.

Common procedures

Based upon the conclusions and results of the project, the EWTC team recommends for uniform certification in Europe to basically follow the method of work that has been defined in the project. Wind turbine type certification is based on the two IEC documents (IEC 61400-1 and IEC WT 01), complemented by a Guidelines document. The team recommends keeping this document updated on a regular basis. The team realises that the updating now is on a voluntary basis and that there need to be a structured way to make updating of the Guidelines happen on a regular basis. The team recognises the need to seek the viewpoints of IEC TC88 on the contents of the Guidelines.

Country specific guidelines

The EWTC team has formulated Guidelines to be followed to ensure uniform interpretation of a common certification standard.

The Guidelines can be applied in every country of the EU. It is therefore not necessary to prepare specific Guidelines per country. From the comparison of the practices there was no evidence of a need for such specific guidelines. The project team concluded that the use of the IEC documents together with the Guidelines allows for design evaluation of wind turbines in the European countries in a mutually acceptable way.

Formal procedures for implementation

The EWTC team recommends a two step approach to establish formal procedures for implementation of the Guidelines:

- the Guidelines should be implemented in the accreditation systems of the certifying bodies in Europe;
- Consent about the Guidelines should be reached from the national committees and IEC TC88.

For both of the steps a mechanism should be in place to enforce the certifying bodies to keep working jointly on the common objective. Such mechanism could be a follow up of this European project.

Conclusions in view of the main objective of EWTC

The main objective is to come to uniform harmonised wind turbine certification, adjusted to the needs of the wind energy industry and the requirements of the European legislation. Although some progress has been made by working together on common certification projects, more efforts are needed before this objective can be fully reached. In the original stage of the EWTC project it was thought that the main problem preventing uniform certification was situated in the interpretation differences of the IEC documents. The EWTC project also was primarily geared to tackle this problem. One striking example of agreement is the clarification in the Guidelines of the DLC 6.1 in IEC 61400-1. Besides drafting Guidelines for common interpretation, the EWTC team has been able to pinpoint where difficulties are when preparing a joint certification report and found practical ways out in terms of: which additional input is needed in order to obtain a complete design documentation from the manufacturers, how to write certification reports that are mutually acceptable. In this respect, substantial progress has been made. The team has taken good notice from the manufacturers' signal that the uniform certification should be practical for the "real life", meaning that the harmonised certification should not be the sum of all national requirements.

By working together at different case studies, an improved common look at the broad scope of the harmonisation needed has been developed in the project team.
The present issues, which make a certification harmonisation necessary, are mainly situated in the following areas:

- environmental: practical implementation of the European Directives in the area of wind energy in order to deal with safety and noise issues related to wind energy projects;
- political: a uniform basis of assessment of wind turbine projects fitness for funding all over Europe;
- commercial: in the interest of investors, financiers, insurance companies, developers etc. in a uniform way wind turbines should exceed their expected lifetime. Certification is the basis for due diligence of wind energy projects. Manufacturers should be able to sell turbines all over Europe. More workforce in the certification bodies should be available to cover the demand for certification without delays.
- legal: certification is the basis for building permits / Type Approval
- technical: wind turbine type testing should be uniform all over Europe.

It is expected that in the near future continued harmonisation efforts by the certifying bodies will lead to:

- less problems in due diligence assessments for operators and financiers;
- input for relevant IEC projects (IEC WT 01 ed.2, IEC WG3 Offshore) and EU projects (RECOFF).

With respect to this last point it can be concluded that the EWTC project has already been contributing to a European wind turbine certification standard. The partners are actively involved in the above mentioned activities. There has been a direct link with the EWTC project in this respect. Moreover, these activities offer a scope for the continuity in harmonisation of certification.

Besides it should be remarked that in order to realise a change of the present scenery of diversity in certification, national legislation changes are needed.

REFERENCES

1. IEC 61400-1, ed. 2: Wind turbine generator systems. Part 1 Safety Requirements, 1999
2. IEC WT 01. IEC system for conformity testing and certification of wind turbines – Rules and procedures, 2001
3. F. Van Hulle. Overview of wind turbine certification systems in Europe, ECN C--01-061.
4. F. Van Hulle e.a.. Experience of wind turbine manufacturers with wind turbine certification, ECN-C--00-024, March 2000
5. C. Nath. e.a. Harmonisation of wind turbine certification in Europe, EWEC Conference 1999, Nice.

ANNEX 1. GUIDELINES ON DESIGN EVALUATION OF WIND TURBINES

EUROPEAN WIND TURBINE CERTIFICATION

DRAFT 1.1

Guidelines on design evaluation of wind turbines

Control & protection systems
Load cases and loads
Structural components
Type testing

Prepared jointly by ECN, GL-Wind, DNV, Risø and CRES
Version June 2001

1. INTRODUCTION

These guidelines have been prepared within the European Joule 3 Research project EWTC (European Wind Turbine Certification). The objective of the document is to provide guidance in design evaluation where the existing standards used in wind turbine certification are insufficiently clear, in such a way that design evaluation by different CB's in Europe does not lead to different results and that their design evaluation reports are mutually acceptable.
The recommendations are based upon the findings from three case studies carried out by four CB's within the RTD project EWTC. Each case study consisted of a full-fledged design evaluation and function test of a state-of-the-art wind turbine. The approach followed is described in the final project report [1].
The present document outlines the common position of the Certifying Bodies involved in EWTC on specific issues encountered during this exercise. It of course also reflects the present level of understanding within and between Certifying Bodies in Europe.
These guidelines are complementary to the requirements in IEC 61400-1 [2] and IEC WT 01 [3][3]. They shall be used in combination with the latter documents. The objective is that the use of this set of documents will ensure uniform practice in wind turbine certification.

2. STARTING POINTS

The basis for the uniform certification in Europe consists of:

- Technical criteria as described in IEC 61400-1 and underlying technical standards;
- Certification system and procedures as described in IEC WT 01

The present document elaborates on the two above-mentioned documents.
In principle the present document only lists explicitly those points not sufficiently covered in the above mentioned standards.

3. SCOPE

The scope of the present guidelines includes all items investigated in the process of wind turbine type certification as defined in IEC WT 01.

The EWTC project specifically focused to the following items of wind turbine type certification, and hence formulated specific additional harmonising guidelines on these items:

- control and protection systems
- load cases and load
- components
- function testing

The EWTC project team considered the remaining items of IEC WT 01 formulated as sufficiently clear and did not formulate additional guidelines for these items.

[3] The earlier drafts of the document IEC WT 01 have been denoted by the reference number IEC 61400-22

4. SYMBOLS AND ABBREVIATIONS

The symbols and abbreviations used in the present documents correspond to the ones used in the IEC documents.

5. CONTROL AND PROTECTION SYSTEM

5.1 Formulation in IEC WT 01

The scope of the examination as described in IEC WT 01: Paragraph 8.2.2 is as follows:

The Certification Body shall evaluate the documentation of a control and protection system, comprising:
- Description of wind turbine modes of operation;
- design and functionality of all elements;
- fail-safe design of the protection system;
- software, including logic and implementation;
- authentication of reliability of all safety critical sensors; and
- braking system(s) analysis.

The design documentation to be submitted in order to check the above points consists of the following items mentioned in Annex A of IEC WT 01.

3.0 Control and Protection System
3.1 Description and component specifications including transducers and sensors
3.2 Detailed control logic flow chart
3.3 Set point list
3.4 Control system software
3.5 Software release and version control
3.6 Remote control/ monitoring
3.7 Protection system logic
3.8 Fault analysis
3.9 Overspeed sensing
3.10 Overpower/current sensing
3.11 Vibration sensing
3.12 Emergency stop button

5.2 Specific guidelines for control & protection systems

The extent of the evaluation and the documentation shall always reflect the actual wind turbine concept and the experience with the particular concept or a concept very close to it.
For the various items corresponding to the numbering in Annex A of IEC WT 01, specific remarks are given below, where applicable.

5.2.1 Item 3.1 Description and component specifications

The descriptions and specifications shall give the details to such an extent that it is possible fully to assess proper function under the assumed conditions during the entire design life of the wind turbine.

In the evaluation of the control and protection system some design documentation from 1.0 General Turbine description and 5.0 Components are involved:

Turbine description and general specification (item 1.1):

- The documentation shall include an assembly drawing of the entire WTGS and a detailed assembly drawing of the nacelle and its components.
- Safety class and WTGS class shall be stated
- Other environmental conditions according to 61400-1 sect. 6.4 shall be stated and evaluated.
- At least the following operational limits shall be stated:

  Electrical power network conditions such as voltage and frequency tolerances, voltage imbalance and assumed network outages.
  Shut down wind speed (averaging time shall be stated)
  Max. rotor speed
  Max. 10 min. average power output.
  Max. 1 sec. average power output.
  Max. and min. ambient temperature for normal operation.
  Max. and min. extreme ambient temperature.
  Max. and min. operational temperature for components in the protection
  system including hydraulics.
  Max. yaw error, average and standard deviation.
  Max. hill slope of terrain

Hydraulics, auxiliary electrical systems and pneumatics for the control & protection system:

The documentation shall include flow diagrams, specification of the hydraulic and electrical components and the demand for periodic service and testing of system functionality (energy capacity of emergency power system).

- Normally hydraulics and electric systems are used for control & protection in wind turbines, consequently pneumatics are not dealt with here.
- Pitch and braking systems are often activated by hydraulics. When the pitch system is used as a part of the braking system it shall be considered as part of the protecting system and evaluated as such.
- Analysis of the pitch and braking system functionality and efficiency including the situation without external power supply shall be provided. The most unfavourable tolerances of the component specifications and extreme external conditions shall be considered.
- The situation with long time stand still without external power supply shall be considered.
- Increased friction in blade bearings, links, gearboxes etc. (e.g. caused by long time operation in the same position) has to be evaluated.
- Pitch systems can also be activated electro-mechanically e.g. with a DC motor driving the pitch mechanism through a gearbox. A battery package delivers power to the motor and a charging unit feeds the battery package. A close monitoring of the system is necessary. At least the documentation should include evidence on how to monitor the following parameters:
  - Battery energy condition
  - Pitch motor current
  - Time for full emergency pitch movement.
  - Battery temperature (if necessary artificial heating)

It shall be documented that the battery capacity and motor torque at the extreme external conditions are sufficient to activate the system in situations with maximum friction in pitch bearing and gearing and with the blade position where maximum pitch torque occurs.
The situation with long time stand still without external power supply shall be considered.
Increased friction in blade bearings, links, gearboxes etc. (i.e. caused by long time operation in the same position) has to be evaluated.

Aerodynamic brake system, pitch system and mechanical brake: (items 5.2, 5.3 and 5.10)
Concerning structural integrity these subjects are dealt with in the section 7. Components, however some additional aspects should be put forward.

Wind turbines equipped with aerodynamic tip brakes often use them together with the mechanical brake for the normal braking procedure. In that case the mechanical system has to be analysed concerning wear, to ensure a proper function throughout the entire design life. Procedures for regular maintenance and functionality tests shall be stated.

Most large wind turbines are pitch controlled and the pitch system constitutes one of the braking systems. In the activating system two principles are in use: systems with a *common activator*, which moves all blades and systems where each blade has its own *separate activator*. In the latter system it is obvious that a failure in one system will not immediately compromise the other(s). In such a system it is important to investigate for common cause failures e.g. failure of the slip ring, which transmits power to the activating systems in the hub.

For the mechanical brake an additional aspect is monitoring. For both negative and positive callipers the wear on brake linings should be monitored (on negative callipers the brake is activated by a sort of spring and deactivated with hydraulic pressure in contrary to positive calliper where it is opposite). For negative types the braking force will diminish as the linings wears, and at a certain amount of wear the minimum allowable brake torque will be reached. For both types excessive wear on linings may cause brake failure and even fire. For positive brake systems tolerances on system pressure have to be taken into account. The design documentation should include evidence on how these aspects are taken into consideration.

The average braking torque as well as the maximum and minimum braking torque have to be evaluated, i.e. tolerances on mechanical properties and components e.g. friction coefficient and hydraulic pressure have to be considered. For all systems the rise time to nominal braking torque has to be demonstrated.

5.2.2 Item 3.2 Detailed control logic flow chart

The control logic documentation (including flow charts) shall show all modes and transitions from one mode to another, which are assumed in the wind turbine specification.

5.2.3 Item 3.3. Set point list

The list of settings shall contain all parameters, which the protection system calls for to act in the assumed way, e.g. temperature, power output, rotational speed etc.

5.2.4 Item 3.4 Control system software

The control system concept shall be described to such an extent that it enables to understand the assumed functioning of the wind turbine.

5.2.5 Item 3.5 Software release and version control

The software release and version assumed in certification shall be assessed in relation to the software version used in:

- The wind turbine used for type testing
- The mass-produced wind turbines covered by the actual certificate.

5.2.6 Item 3.6 Remote control

No specific additional recommendations.

5.2.7 Item 3.7 Protection system logic

The control logic flow charts shall show all modes and transitions from one mode to another, which are assumed in the wind turbine specification.
From the protection logic flow charts it shall be possible to fully evaluate the consequences of any fault in the sensors or other equipment in the protecting system. It shall be detailed enough to enable the certification body to evaluate the fault analysis.

5.2.8 Item 3.8 Fault analysis

A rational systematic method shall be used and reported to demonstrate the conformity with the requirements for the control & protection systems. The methods could be e.g. FTA for common mode/cause failures and/or FMEA for dormant failures.

For the overall system it is necessary to identify the critical systems and components. The FTA and FMEA methods may be used for this purpose. For identified critical and complex systems it is necessary to perform a detailed FMEA.

It shall be demonstrated that any single fault in the control system will not compromise the function of the protection system.

5.2.9 Item 3.9 Overspeed sensing

Overspeed is normally detected at both the rotor shaft and the high speed shaft. It shall be demonstrated that the defined maximum rotational speed is not exceeded. Furthermore it shall be demonstrated that a fault in one sensor will cause transition to a safe mode without exceeding the maximum speed.
Some wind turbines are equipped with an independent overspeed sensing unit. If so, it shall be demonstrated that this system fulfils the same requirements as the normal speed sensor in the protection system.

5.2.10 Item 3.10 Overpower/current sensing:

Overpower is normally monitored by the computer, and if set points are as presupposed no further measures have to be taken. The averaging times for the power monitoring should be specified.

5.2.11 Item 3.11 Vibration sensing:

The vibration sensing shall ensure that no harmful vibrations will occur in the entire wind turbine or in specific components (e.g. chord-wise blade vibrations). It shall be demonstrated that the vibrating level at which the sensor(s) will react is not harmful for the wind turbine.

5.2.12 Item 3.12 Emergency stop button:

It shall be verified that emergency stop buttons are located at locations close to any dangerous working place e.g. near by rotating components and that the function of the emergency button is properly described in the manual. (The button close to a dangerous working place may have another intended effect on the turbine than the button on the control panel)

6. LOAD CASES AND LOADS

6.1 Formulation in IEC WT 01

The scope of the examination as described in IEC WT 01: Paragraph 8.2.2 is as follows:

The Certification Body shall evaluate the loads and load cases for compliance with IEC 61400-1 or IEC 61400-2. Description of loads shall be provided in a format that enables the Certification Body to carry out independent analysis.

The load values to be submitted shall be accompanied by the load case description, description of calculation models and input data such as:

– parameter values relating to aerodynamics;
– structural characteristics; and
– parameter values relating to the control system.

The design documentation to be submitted in order to check the above points consists of the items mentioned in Annex A of IEC WT 01:

4.0 Loads and Load Cases

4.1 General analysis approach

4.2 System dynamics model description :
- Degrees of freedom
- Mass and stiffness distributions
- Aerodynamic inputs (airfoil tables, blade geometry, etc.)

4.3 Partial safety factors

4.4 Validation of calculation models:
- Analytical
- Comparisons with test data

4.5 Dynamic behaviour of the system and of individual major components:
- Campbell diagrams,
- Spectral / frequency plots
- Mode shapes & frequencies
- Comparisons between predictions and measurements

4.6 Load cases (from IEC 61400-1 plus other identified cases):
- Fatigue load cases
- Ultimate load cases
- Failure modes

4.7 Loads for structural components:
- Blade
- Hub
- Locking device(s)
- Low speed shaft and bearings
- Main frame and gearbox structure
- Gearing and drive train (including gen., brake & couplings)
- Tower top/yaw bearing
- Tower
- Tower connection to foundation
- Foundation
- Other

4.8 Critical deflection (blade/tower)

6.2 Specific remarks and guidelines for load cases and loads

6.2.1 Item 4.1 General analysis approach

The description shall be detailed enough to allow for an independent calculation.

The verification report resulting from the independent analysis should contain the following information:

- Table with natural frequencies and structural damping for the deflection modes.
- Quasi static calculated power curve. If the turbine is pitch regulated or active stall regulated the corresponding pitch angles should be included as well.
- Stiffness distribution
- Mass distribution
- Rotor geometry
- Aerodynamic coefficients used along blade span

As the calculation results shall be compared to the design loads developed by the manufacturer, the verification reports should include:

- Power curve
- Maximum, minimum, mean and standard deviations of main sensors at different wind speeds. Normally 10, 15, 20 and 25 m/s are sufficient. The main sensors are normally flat-wise blade-root bending-moment, edge-wise blade-root bending-moment, main-shaft torque, main-shaft bending-moment and tower-top bending-moment and torsional-moment.
- Equivalent loads for the main sensors for each of the selected load cases.
- Power spectra for the main sensors.
- Time series of the calculated response for the main sensors.

It is not necessary for the verification report to contain information regarding the comparison between design loads calculated by the manufacturer and the loads from the independent analysis. The comparison will normally be included in the Design Verification Report for the load calculations. More guidance is given in ref. 4 for a specific design calculation programme (HawC).

Furthermore, the analysis should be verified by load measurements.

6.2.2 Item 4.2 System dynamics model description

No specific remarks made on this item.

6.2.3 Item 4.3 Partial safety factors

The partial safety factors for loads should be clearly stated in the loads report.

6.2.4 Item 4.4 Validation of models

No specific remarks on this item.

6.2.5 Item 4.5 Dynamic behaviour

The calculated natural frequencies shall be verified by (prototype) testing.
The calculated values of resonance shall be verified by testing as well.

6.2.6 Item 4.6 Load cases

6.2.6.1 General remarks

It shall be documented that the load cases are defined in compliance with the requirements in the IEC 61400-1 standard. The influence of the control & protection, the site conditions and the wind turbine concept may lead to additional load cases.
Near-resonance in case of low turbulence conditions shall be investigated.

6.2.6.2 Load Case: Power production (DLC 1.1 - 1.2)

In the design load cases with the normal turbulence model, a statistical evaluation has to be applied to determine the number /length of the realisations. The kind of statistical evaluation applied shall be stated, as well as the number of realisations with the NTM.

6.2.6.3 Parked (stand-still or idling) (DLC 6.1 – 6.4) paragraphs 7.4.6 and 7.4.7 of IEC 61400-1

In this design situation, the rotor of a parked wind turbine is either in a stand-still or idling condition. In DLC 6.1, 6.2 and 6.3 this situation shall be considered with the extreme wind speed model (EWM).

In the case of a rigid or well-damped wind turbine with little dynamic action, the steady extreme wind model may be used for the analysis. For more flexible wind turbine structures liable to resonant amplification the turbulent extreme wind model (to be further defined) shall be used for turbulence simulation analysis or quasi-steady analysis with correction (to be further defined) for gusts and dynamic response.

In DLC 6.1, a yaw error of up to ± 15 degrees using the steady extreme wind model or ± 8 degrees using the turbulent wind model shall be assumed, provided that no slippage in the yaw system can be assured. If not, a yaw error of up to ± 180 degrees shall be assumed.

In DLC 6.2 a loss of the electrical power network at an early stage in the storm containing the extreme wind situation, shall be assumed. Unless power back-up for the control and yaw system with a capacity of 6 hours of continuous operation is provided, the effect of a yaw error of up to ± 180 degrees shall be analysed.

In DLC 6.3, the extreme wind with a 1-year recurrence interval shall be combined with the maximum yaw error (yaw tolerance). If not justified otherwise, a yaw error of up to ± 30 degrees using the steady extreme wind model or ± 20 degrees using the turbulent wind model (to be defined) shall be assumed,

If significant fatigue damage can occur to some components (e.g. from weight of idling blades), the expected number of hours of non-power production time at each appropriate wind speed shall be considered in DLC 6.4. Idling below V_I should be included (if relevant for the wind turbine type).

Table - Design load cases in parked condition

Design situation	DLC	Wind condition		Other conditions	Type of analysis	Partial safety factors
6) Parked (standing still or idling)	6.1	EWM	*50 year recurrence interval*		U	N
	6.2	EWM	*50 year recurrence interval*	Loss of electrical power network	U	A
	6.3	EWM	1 *year recurrence interval*	Extreme yaw error	U	N
	6.4	NTM	V_{hub} < 0.7 V_{ref}		F	*
7) Parked and fault conditions	7.1	EWM	1 *year recurrence interval*		U	A

6.2.7 Item 4.7 Loads for structural components

No specific recommendations

6.2.8 Item 4.8 Critical deflections

No specific recommendations.

7. COMPONENTS AND ELECTRICAL SYSTEM

7.1 Formulation in IEC WT 01

The Certification Body shall evaluate the designs of structural, mechanical and electrical components for compliance with the requirements of this part of IEC 61400, IEC 61400-1 or IEC 61400-2 and the agreed additional codes and standards.
The design documentation relating to components will normally consist of specifications, descriptions, schematics and design calculations, which may be combined with measurement/test reports, drawings and part lists. The Certification Body shall require that the documentation clearly identifies the basis for the design, i.e. codes and standards, as well as loads and relevant external conditions.

The design documentation to be submitted in order to check the above points consists of the following items of Annex A of IEC WT 01.

5.0 Components
5.1 System Level Descriptions:
Assembly drawings
Material properties Sp

Rotor
5.2 Blade:
- Structure
- Root
- Blade/hub joint
- Aerodynamic brake mechanism

5.3 Hub:
- Structure
- Teeter system
- Pitch system (including power supply)
- Pitch bearing
- Hub/low speed shaft joint

5.4 Low speed shaft:
- Structure
- Bearings
- Bearing mountings

Nacelle
5.5 Structure:
- Main frame
- Enclosure

5.6 Gearbox:
- Housing structure
- Gearbox/mainframe connection
- Gearbox/generator coupling
- Gearing, bearings, cooling, lubrication, shafting & couplings

5.6 Generator:
- Structure of direct drive unit
- Generator/nacelle connection

5.7 Yaw system:
- Drive
- Bearing & connections

Tower and Foundation
5.8 Tower:
- Structure
- Connections
- Openings
- Cable twist
- Cable suspension
- Ladders, platforms, elevators

5.9 Foundation:
- Structure
- Connection to tower

Other
5.10 Brake (maximum & minimum torque rating plus energy capacity)
5.11 Locking Devices (including power supply requirements)
5.12 Auxiliary systems (hydraulic/pneumatic)
5.13 Auxiliary equipment (cranes, lifts, etc.)

6.0 Electrical
6.1 One line diagram (basic power circuit with safety devices)
6.2 Power circuit schematic
6.3 Electrical systems schematics
6.4 Power Converter
6.5 Generator electrical
6.6 Disconnection devices
6.7 Earthing
6.8 Lightning Protection

7.0 Component Test Reports
7.1 Component tests

7.2 Specific Guidelines for components

7.2.1 General

Generally strength and fatigue analysis shall be carried out for all components. If other types of analysis are relevant, these are specified in the following.

For the various items corresponding to the numbering in Annex A of IEC WT 01 specific remarks are given below, where applicable.

7.2.2 Item 5.1 System Level Descriptions:

Assembly drawings and material properties are needed for the assessment of the components.

7.2.3 Rotor

7.2.3.1 Item 5.2 Blade:

Blades are generally made from Glass fibre Reinforced Plastics (GRP). The reinforcement could also be by carbon fibres or laminated wood (veneers), however only glass fibres are considered in the following. As the blades become larger, the tendency to use epoxy resin instead of polyester increases.

Structure & Root

The analysis of the blade structure shall include strength, fatigue, stability and critical deflection aspects.

The testing shall be carried out in connection with the design validation, both for strength and fatigue. Testing shall be done based on IEC TS 61400-23, for fatigue testing a number of load cycles shall be applied to reveal the same damage as the design loads under consideration of the test factors specified in IEC TS 61400-23.

Description of determination of material properties and material partial safety factors can be found in NVN 11400-0 sections 8.2.2.2 and 8.3.2.2 for GRP and in sections 8.2.2.3 and 8.3.2.3 for laminated wood.

Blade/hub joint

The solutions considered are embedded studs, IKEA bolts or a mounted metal flange which is glued and/or screwed to the blade structure.

For all of the above solutions, the analysis shall cover both the extreme and fatigue strength as well as the GRP/metal interface(s). The analysis has to be validated by strength and fatigue tests in case of new design parameters.

Special consideration has to be taken for the GRP/metal interface, as this is not covered by the currently available codes.

Aerodynamic brake mechanism

The analysis shall cover both the extreme and fatigue strength as well as the moving and rotating parts. The analysis has to be validated by strength and fatigue tests in case of new design parameters.

Item 5.3 Hub:

Hubs are generally made from cast iron, some from cast steel and even fewer are welded structures.

Structure

The analysis of the hub structure shall consider extreme and fatigue strength, and in the application of the loads consideration must be taken to account for the phase relations of the blade loads. The quality of the material shall be specified together with test requirements. Cast iron shall satisfy the requirements of EN 1563, test results shall be produced from cast-on samples.

The fatigue analysis can be based on synthetic SN curves, which can be derived based on ref. 5 (Gudehus) and ref.6 (VDEh report ABF11). For the assessment of 3D fatigue guidance can be found in ref.7 (ASME Boiler & Pressure Vessel Code).

Pitch system (including power supply)
The pitch system can be electric or hydraulic, individual or global pitch. Pitch requirements are dealt with in the section for control and protection system.
For electric systems, relevant guidance can be found in the gearbox and electrical sections.
Hydraulic systems are to be assessed in accordance with the requirement for auxiliary systems.

Pitch bearing
Pitch bearings are generally four-point bearings.
The assessment of the pitch bearing can be found in the section for the low speed shaft/bearings.

Hub/low speed shaft joint
The hub/low speed shaft connection is generally a pretensioned bolt connection. The analysis of the bolt connection shall be done according VDI 2230 or similar. When analysing the fatigue strength of bolt connections, whose stress level is established in accordance with VDI 2230, deviating from Eurocode 3, section 9, the detail category 71 may be applied if it is intended to use bolts with rolled threads.

7.2.3.2 Item 5.4 Low speed shaft:

The low speed shaft is generally made from high-grade steel or from cast iron.

Structure
The structural analysis shall include the quality of the surface, notches and heat treatment.

Large low speed bearings
This section also covers the assessment of the pitch and yaw bearings. The bearings can be either roller or plain bearings.
Static load bearing capacity and service life is to be investigated. Extended service life analysis can be performed in line with ISO 281.
The deformations introduced into the bearing by the neighbouring components are to be observed in the evaluation to account for excessive values.
Applicable lubrication and the conditions of the lubricate has to be observed.

Bearing mountings
The bearing mounting / housing for the low speed shaft bearing is generally made from cast iron or structural steel. The housing or part of it may be an integral part of the main frame.
Analysis shall be assessed as described for the main frame.

7.2.4 Nacelle

In case elastic coupling elements are employed the dynamic behaviour in addition to their strength/life time shall be assessed.

7.2.4.1 Item 5.5 Structure:

Most wind turbine designs have a main frame as the structural component carrying the different items of the nacelle.

Main frame
The main frame is generally made from cast iron or structural steel.

The quality of the material shall be specified together with test requirements. Cast iron shall satisfy the requirements of EN 1563, test results shall be produced from cast-on samples. For welded structures Eurocode 3 shall be applied.
In the analysis due considerations of the individual load introductions and their phase relations have to be taken.
Normally a 3D FE analysis is being carried out, and where 3D stress states occur volume elementation is preferable. For the assessment of 3D fatigue guidance can be found in ASME Boiler & Pressure Vessel Code (ref. 7).
The fatigue analysis of cast iron designs can be based on synthetic SN curves, which can be derived based on refs. 5 and 6.

Enclosure
Generally enclosures are made from GRP mounted to structural items.
It is not common practice to assess analysis and drawings of the enclosure.

7.2.4.2 Item 5.3 Gearbox:

Analysis of the gearbox shall be provided for the housing and other structural parts, bearings, shafts and gears/teeth.

Housing and other structure
The housing is generally made from cast iron or structural steel, whereas the other structural parts (such as planet carrier) are generally made from cast iron or high grade steel.
Analysis shall be assessed as described for the main frame.

Gearbox / main frame connection
The gearbox / main frame connection is generally a pretensioned bolt connection.
The analysis of the bolt connection shall be done according VDI 2230.
When analysing the fatigue strength of screwed connections, whose stress levels are established in accordance with VDI 2230, deviating from Eurocode 3, Section 9, the detail category 71 is to be applied if it is intended to use tempered screws. For finish-rolled screws a more favourable category may be selected from ESDU.
Vendor specifications and test results shall be applied in case elastic couplings are being used.

Gearbox/generator coupling
The gearbox / generator coupling is generally a flexible coupling to account for deflections and misalignments.
Assessment is based on loads and vendor specifications.

Gearing, bearings, cooling, lubrication, shafting & couplings
The gearbox may have planetary and/or helical stages.
The bearings applied in gearboxes are generally roller bearings.
If cooling and filtering systems are present, they are integral parts of the lubrication system. Recent investigation has revealed that special attention shall be given to the lubrication system.
The assessment shall be carried out according to ISO 6336. Additional information can be found in DIN 3990 and the AGMA Recommended Practices.

7.2.4.3 Item 5.6 Generator:

The generator has to comply with the requirements of IEC 60034. The degree of protection against environmental impacts shall generally be IP54.
If the short circuit moment of the generator is design driving it shall be checked for correctness.

Structure of direct drive unit
The structure of the direct drive unit is generally made from structural steel. Some are from cast iron.
Analysis shall be assessed as described for the main frame.

Generator/nacelle connection
The generator / nacelle connection is generally a pre-tensioned bolt connection.
Analysis shall be assessed as described for the gearbox / main frame connection.

7.2.4.4 Item 5.7 Yaw system:

The yaw system is generally electrically driven.
If brakes are applied these have to be assessed as described in the brake sections.

Drive
Guidance for assessment can be found in the gearbox and electrical sections.

Bearing & connections
Guidance for assessment can be found in the large low speed bearings and gearbox / main frame connection sections.

7.2.5 Tower and Foundation

The stiffness of the foundation shall be taken into account in the analysis.

7.2.5.1 Item 5.8 Tower:

The towers are generally tubular or lattice steel structures, however also concrete towers are used.

Structure
The assessment shall be carried out based on Eurocode 3 for steel towers and Eurocode 2 for concrete towers.
The assessment shall include a comparison of the dynamic behaviour assumed in the load analysis with that of the actual tower and foundation designs as well as buckling of the tower including effects of openings.

Connections
The connections between tower sections are generally pre-tensioned bolt connections, which shall be assessed based on Eurocode 3.

Cable twist
Requirements for cable twist are dealt with in the section for control and protection system.

Cable suspension
The cable suspension shall be designed to withstand the relevant loads.

Ladders, platforms, elevators
Requirements for ladders and platforms are given in prEN 50308.
Requirements for elevators shall be fulfilled based on national codes.

7.2.5.2 Item 5.9 Foundation:

Requirements for foundations shall be fulfilled based on the relevant local or national codes.

Connection to tower
The connection to the tower is generally by foundations bolts or an embedded tower section. In both cases a pre-tensioned connection is applied.

7.2.6 Other components

7.2.6.1 Item 5.10 Brake (maximum & minimum torque rating plus energy capacity)

This section refers to mechanical brakes only.
Both maximum and minimum torque shall be assessed to account for the maximum load on the structure and the longest braking time and consequent heat-up. The brakes shall be designed such that when they are activated, the turbine is brought to standstill. Dynamic amplification of brake torque shall be considered for emergency stops. Requirements for the hydraulic system for the brake are dealt with in the section for control and protection system.

7.2.6.2 Item 5.11 Blocking Devices (including power supply requirements)

No specific additional requirements.

7.2.6.3 Item 5.12 Auxiliary systems (hydraulic/pneumatic)

Generally the auxiliary systems are hydraulic, therefore pneumatic systems are not dealt with here.
The assessment of the hydraulic systems shall be based on ISO 4413.

7.2.6.4 Item 5.13 Auxiliary equipment (cranes, lifts, etc)

Requirements for cranes, lift etc. shall be fulfilled based on the relevant local or national codes.

7.2.7 Electrical components

The general requirements for electrical components are given in IEC 61400-1.

6.1 One line diagram (basic power circuit with safety devices)
6.2 Power circuit schematic
6.3 Electrical systems schematics
6.4 Power Converter
6.5 Generator electrical

In the assessment of the electrical part of the generator among others IEC 60034 shall be considered.

6.6 Disconnection devices
6.7 Earthing
6.8 Lightning Protection

Lightning protections shall be assessed based on IEC 61400-24.

8. OTHER ITEMS OF DESIGN EVALUATION

8.1 Component Test Reports (item 7.1)

The general requirements for component tests are given in IEC WT 01.

7.1 Component tests

8.2 Plans (items 8.1 - 8.3)

The general requirements for plans are given in IEC WT 01.

8.1 Manufacturing plan
8.2 Installation plan
8.3 Maintenance plan

8.3 Personnel safety (items 9.1 - 9.4)

The general requirements for personnel safety are given in EN 50308.

9.1 Workplace requirements
9.2 Emergency stop
9.3 Blocking devices
9.4 Safety instructions

9. EVALUATION REPORT FORMAT

Evaluation reports in the various modules of the certification should as a minimum contain the following elements.

- introduction
  - manufacturer’s name etc.
- scope
  - wind turbine type
  - classification: wind turbine class - safety class
  - certification scheme
  - optional: reference to internal certification procedures and accreditation
- list of documents examined/considered
- reference standards
- remarks / comments
- interfaces with other certification modules
  - within design evaluation
  - outside design evaluation
- conclusions

The above contents apply for all evaluation reports. There is not a consensus between the Certifying Bodies on the necessity of a summary report along with the Design Evaluation Conformity Statement.

10. INSPECTION AND FUNCTION TESTING

10.1 General

The purpose of inspection and functional testing is to verify that the wind turbine under test displays the behavior predicted in the design and that provisions relating to personnel safety are properly implemented.
The present document describes guidelines for performing an inspection and functional test plan to be followed by the Certification Body in order to verify the function of the control and protection systems as well as the dynamic behavior of the wind turbine at rated and above rated wind speed. The plan shall be enriched accordingly to the system under consideration.

10.1.1 Objectives

The inspection plan includes all critical components related to the power production, the protection system and the protective measures for personnel safety. The inspection shall include:

- wind turbine markings for the turbine identification
- main power production and protection system components
- settings of the protection system(s)
- the effectiveness of the protective measures for personnel safety

The functional test plan includes all critical functions of the control and protection system that require test verification, as described in the design documentation. The functions to be tested shall include the following:

- system behavior at emergency shutdown
- power, rotational speed and nacelle yaw control
- vibration levels and protection
- over speed protection
- system behavior at grid loss
- normal start/stop operation at wind speed levels from low to above rated

Moreover, the following case dependent items are to be considered:

- operational testing of all additional protection systems that are activated by component failure or critical events
- simulation of specific critical events or operational conditions

10.1.2 System documentation

The following items are needed for deciding the test plan as well as during the performance of the test:

- wind turbine and major component drawings (general, electrical etc)
- wind turbine technical specifications and operational parameters
- specification of components (controller, mechanical components, hydraulics, safety loop etc)
- failure mode effects, or equivalent, analyses for major systems (control and braking)

10.1.3 Test conditions

The test plan, issued for the specific system shall be submitted by the manufacturer and it is subject to approval by the certification body (CB). It shall among others include the following:

- details for the procedures to be followed during the testing

- appropriate safety measures
- identification of criteria for acceptable wind turbine system behavior

Any modifications to the test plan, that are found to be necessary during the test, shall be documented and subject to approval by the CB.

10.1.4 Test provisions

The test plan, issued for the specific system, shall include all details for the provisions needed by the manufacturer. The following are considered:

- definition of physical quantities to be measured and their tolerances
- instrumentation and calibration
- data acquisition system
- operational settings of the system
- external conditions requirements

10.1.5 Reporting and analysis

The test report, issued according to the requirements of IEC WT 01, will include the following:

- system identification tables and check lists
- inspection results
- raw data and related statistics of the measured quantities during the functional testing
- identification of overall system natural frequencies
- results acceptance criteria fulfillment

10.2 System inspection plan

The system inspection aims at the following:

- Identification of the system
- Verification of the system assembly (main components)
- Verification of the system settings (operational magnitudes, protection systems)
- Verification of the capacity of the protection systems
- Verification of the suitability of the monitoring and recording system that supports the functional tests

The plan comprises specific inspection actions that are presented in the following paragraphs.

10.2.1 Wind turbine markings

The following items are identified and recorded. The correctness and completeness of the readings are registered.

- Rated wind speed and power
- System manufacturer, model, serial number and date of production
- Ranges of operation (wind speed, temperature etc)
- IEC Wind turbine class
- Electrical terminals info (voltage and frequency)

10.2.2 Mechanical and structural components

Major component manufacturer, model, serial number and date of production

The wind turbine is checked to be representative in terms of the main mechanical components. The items for inspection are the blades, hub, main bearings, gearbox, mechanical brake, main frame, tower and the hydraulic system parts.

10.2.3 Electrical components

10.2.3.1 Major component manufacturer, model, serial number and date of production

The wind turbine is checked to be representative in terms of the main electrical components. The items for inspection are the generator, electrical power converter and the controller.

10.2.3.2 Electrical panel

The items for inspection include the accessibility and position of the main switch, the emergency button(s), the panel markings, the screening of live parts and the provision of grounded auxiliary sockets.

10.2.3.3 Lightning protection

The items for inspection include the cabling, the rails, the routing and connections of the lightning protection of the blade, main and yaw bearings, nacelle and tower. The foundation grounding system as well as any external grounding network is also inspected and the acceptance of the prescribed earth resistance measurement is to be verified.

10.2.3.4 Cabling

The items for visual inspection are the type, installation, routing and protection of cables from generator down to the electrical panel.

10.2.3.5 Over voltage and short circuit protection

The items for inspection are the location and nominal capacity of the overvoltage protection devices and the fuses.

10.2.4 Turbine settings

10.2.4.1 Blade settings

The item for inspection is the pitch setting of the blades.

10.2.4.2 Operation range settings

The items for registration, through the controller monitor, are the yawing speed, the blade pitching speed, the maximum power as well as the cut-in and cut-out wind speeds.

10.2.4.3 Fault detection range settings

The items for registration, through the controller monitor, are the over speed, overload and hydraulic system pressure operation limit settings.

10.2.5 Protective measures for personnel safety

10.2.5.1 Operating room

The items for inspection include the access/escape ways, the safety instructions, the emergency button, the working space, standing places, fire extinguishing measures, grounding system, lighting and auxiliary electrical sockets.

10.2.5.2 Tower

The items for inspection include the ladder, fall protection systems, handrails and fixing points, standing places, platforms, lighting and safety measures of lifts.

10.2.5.3 Nacelle

The items for inspection are the entrance, protection from rotating/moving parts, lighting, sockets, working space, emergency button, control buttons, grounding system, blocking devices and the emergency exit system.

10.2.5.4 Hub

The items for inspection are the access ways, the working space and the securing points.

10.2.6 Signal recording and monitoring system

10.2.6.1 Controller monitor

The item for inspection is the meteorological, wind turbine operational, power and loading magnitudes that can be monitored through the controller of the system.

10.2.6.2 External acquisition and monitoring system

The item for inspection is the capability of the external acquisition system for the collection of the necessary physical quantity measurements. The aspects for consideration (according to the approved test plan) are:

- sensor and acquisition system calibration
- location and type of sensors
- sampling rates
- monitoring and storing capabilities
- interface with the controller

10.3 Functional testing

The functional testing aims at the following:

- Verification of the functioning of the operating system
- Verification of the functioning and the capacity of the protection systems
- Registration of the behavior of the turbine systems during specific component failure conditions
- Operation of the blocking devices

The testing comprises specific actions that are presented in the following paragraphs.

10.3.1 Wind turbine at normal operation

The test aims at the determination of the turbine systems behavior at normal operation conditions.
During the testing actions the turbine response is visually registered and the following magnitudes are recorded (through the measuring system):

- turbine status
- power output
- grid current (only when system start or stop is expected)
- rotor speed
- pitch angle (when applicable)
- vibration levels

If there is an upwind met mast equipped with wind speed and direction sensors, at a proper height, the relevant magnitudes are also registered.

The following operations are considered:

10.3.1.1 Start up

The test is performed according to the following:

- *wind conditions*: close to cut-in, rated and above rated
- *wind turbine state*: normal
- *testing actions*: manual start
- *number of tests*: one per condition

10.3.1.2 Power production

The test is performed according to the following:

- *wind conditions*: close to rated
- *wind turbine state*: normal
- *testing actions*: manual start
- *number of tests*: one

10.3.1.3 Shut down

The test is performed according to the following:

- *wind conditions*: close to rated and above rated
- *wind turbine state*: normal
- *testing actions*: manual normal stop
- *number of tests*: one per condition

10.3.1.4 Emergency shut down

The test is performed according to the following:

- *wind conditions*: close to rated and above rated
- *wind turbine state*: normal
- *testing actions*: manually activated emergency stop
- *number of tests*: one per condition

10.3.1.5 Emergency shut down during turbine yawing

The test is performed according to the following:

- *wind conditions*: close to rated
- *wind turbine state*: normal
- *testing actions*: manual misalignment of 20°, normal start and emergency stop
- *number of tests*: one

10.3.2 Simulation of failure situations

The test aims to the determination of the turbine behavior at component failure conditions. During the testing actions the turbine response is visually registered and the following magnitudes are recorded (through the measuring system):

- turbine status
- power output
- grid current (only when system start or stop is expected)
- rotor speed
- pitch angle (when applicable)
- vibration levels

If there is an upwind met mast equipped with wind speed and direction sensors, at a proper height, the relevant magnitudes are also registered.

10.3.2.1 Grid loss

The test is performed according to the following:

- *wind conditions*: close to rated and above rated
- *wind turbine state*: normal
- *testing actions*: grid disconnection from main switch
- *number of tests*: one per condition

10.3.2.2 Short grid disconnection

The test is performed according to the following:

- *wind conditions*: close to rated
- *wind turbine state*: normal
- *testing actions*: manual grid disconnection and connection using main switch
- *number of tests*: one per condition

10.3.2.3 UPS failure

The test is performed according to the following:

- *wind conditions*: close to rated
- *wind turbine state*: normal operation
- *testing actions*: manual UPS output disconnection before and during start, stop and emergency stop
- *number of tests*: one per testing action

10.3.2.4 UPS failure during grid loss

The test is performed according to the following:

- *wind conditions*: close to rated
- *wind turbine state*: normal operation
- *testing actions*: manual UPS output disconnection, manual grid disconnection and emergency stop
- *number of tests*: one per testing action

10.3.2.5 Activation of protection systems at over-speed situation

The test is performed according to the following:

- *wind conditions*: below rated
- *wind turbine state*: normal operation

- *testing actions*: suitable manual overruling of low-level safety measures and/or grid connection for attaining the over speed situation
- *number of tests*: one per testing action

10.3.2.6 Pitch system failure

The test is performed according to the following:

- *wind conditions*: close to rated and above rated
- *wind turbine state*: normal operation
- *testing actions*: manual disconnection of pitch angle signal cables to the controller, manual disconnection of pitch system (motor, pump) driving signal cable from controller, cable short circuit of signals to the controller
- *number of tests*: one per testing action

10.3.2.7 Rotor speed, component temperature, wind speed and direction sensor failure

The test is performed according to the following:

- *wind conditions*: close to rated
- *wind turbine state*: normal operation
- *testing actions*: manual disconnection of signal cables to the controller, cable short circuit of signals to the controller
- *number of tests*: one per testing action

10.3.2.8 Cable twist sensor

The test is performed according to the following:

- *wind conditions*: any
- *wind turbine state*: normal operation
- *testing actions*: manual yawing, disconnection of signal cables from the controller, cable short circuit of signals to the controller
- *number of tests*: one per testing action

10.3.2.9 Excessive vibration sensor

The test is performed according to the following:

- *wind conditions*: any
- *wind turbine state*: normal operation
- *testing actions*: manual activation of sensor, disconnection of signals to the controller, cable short circuit
- *number of tests*: one per testing action

10.3.2.10 Simulation of single failure situations in all components of the safety loop (not covered by the previous)

Test is programmed according to the failure mode analysis of control and protection system provided by the manufacturer and performed according to the following:

- *wind conditions*: any
- *wind turbine state*: normal operation
- *testing actions*: manual activation of sensor, disconnection of signals to the controller, cable short circuit
- *number of tests*: one per testing action

10.3.3 Application of blocking devices

This test aims to demonstrate the clarity of the application instructions and the manageability of the blocking devices. The test is performed for blade, rotor and nacelle blocking devices.
The simulation of maintenance sequence at normal conditions follows the steps:

- apply the blocking device;
- take an action (eg release mechanical brake for a short time) to load the blocking device;
- unlock the blocking device.

11. BIBLIOGRAPHY

1. European Wind Turbine Certification EWTC Final report, ECN--C-01-059, June 2001

2. IEC 61400-1: Wind turbine generator systems. Part 1. Safety requirements, edition 2, 1999.

3. IEC WT 01: IEC System for conformity testing and certification of wind turbines – Rules and procedures, 2001

4. Guideline for independent load analysis with HawC or Flex4. DNV Internal Report, C5-CPN-BAG-2_c11, rev. 0, 2001

5. H. Gudehus; H. Zenner. Leitfaden für eine Betriebsfestigkeitsberechnung (Guideline for Fatigue Analysis), 3rd edition, Publisher: Verlag Stahleisen, Düsseldorf, 1995

6. Berechnung von Wöhlerlinien für Bauteile aus Stahl, Stahlguss und Grauguss - synthetische Wöhlerlinien (Calculation of S/N curves for steel, cast steel and cast iron - Synthetic S/N curves), VDEh-Bericht Nr. (VDEh report No.) ABF11, Publisher: Verlag Stahleisen, Düsseldorf, 1983.

7. ASME Boiler & Pressure Vessel Code, Section III Division 1 - Subsection NB, Class 1 Components NB-3216, ASME, 1995.

8. Soullié P. et al: “Guidelines for inspections and functional tests”, ECN Wind Energy, Internal Note Rep. No. 74050-C-00-04.1, 2000

Date: August 2001	**Report number:** ECN-C--01-059

Authors: F. Van Hulle (ECN), C. Nath (GL-Wind), P.H. Jensen (Risø), C. Eriksson (DNV), P. Vionis (CRES)

ECN Project number: 7.4050
Contract number: EU JOR3-Ct98-0265 Novem: 224.760-9822

Programme: Wind Energy

Principal: European Commission / Novem

Abstract:
The main objective of EWTC is to develop a common practice in order to overcome the different interpretation possibilities of the present standards used in certification i.e. the IEC 61400-1 which addresses technical and safety requirements for wind turbines and the IEC WT 01 which addresses the certification systems. The use of these documents - which contain a lot of sub-optimal compromises - in practice lead to different interpretations and hence to different conclusions in the evaluation of wind turbine design. As a result, wind turbines are not universally accepted. The ultimate objective is to work towards a uniform wind turbine certification all over Europe.
The basic method followed in the EWTC project was to identify the variation in interpretation by in parallel carrying out three “certification cases”. Based upon the differences encountered the project partners have worked out solutions for agreement. The result of this process is a set of Guidelines to be used together with the above-mentioned IEC standards and other Certification Regulations used by the Certifying Bodies.
The project was carried out by a Consortium consisting of Germanischer Lloyd WindEnergie (D), Risø National Laboratories together with Det Norske Veritas (DK), Centre of Renewable Energy Sources CRES (GR) and Energy research Centre of the Netherlands ECN together with CIWI Holland. The coordination was done by ECN. The manufacturers Enercon GmbH (D), Nordic Wind Power (S) and Jeumont Industrie (F) provided the material for the case studies in terms of design documents and access to a wind turbine for testing.
The case studies delivered a lot of discussion material and hence aspects to be clarified in Guidelines. As expected, the differences in evaluation methods between the project partners are considerable. Striking examples are the different evaluation methods of the loads and the different methods for evaluation of the wind turbine protection systems. In practice it appears that the level of detail of information required from the manufacturer is quite variable, and a similar variation of detail is visible in the evaluation reports of the Certifying Bodies.
The partners have streamlined their conclusions towards a common document: Guidelines for Design Evaluation. These Guidelines will be used on a voluntary basis by the partners who participated to the project together with the documents, which are part of the formal set of certification regulations. The implementation of these Guidelines in a formal European system should take place after some experience has been collected. However it should not be assumed that this would happen automatically without a proper external mechanism that will maintain continuity in the harmonisation process.

Key Words: Wind energy, certification, European harmonisation

Authorisation	**Name**	**Signature**	**Date**
Checked	W. Stam		
Approved	H. Hendriks		
Authorised	H. Beurskens		