Content

1. Who we are
2. Certification, what is it?
3. Standards in Wind Energy (History)
4. Certification Schemes
5. Wind Turbine Certification
6. Standards Overview
7. IEC Standards Development
8. Type Certification & Standards
9. Project Certification
Who we are
GL Group - Business Segments

**oil & gas**
- GL Noble Denton
  - Technical Assurance
  - Advanced Engineering Consulting
  - Asset Performance & Maintenance
  - Marine Operations & Consulting
  - Project Execution
  - Software Products

**maritime services**
- Germanischer Lloyd
  - Ship Newbuilding
  - Maritime Systems & Components
  - Fleet Service
  - Maritime Solutions

**renewables**
- GL Garrad Hassan
  - Engineering Consulting
  - Marine Operations
  - Measurements
  - Software Products
  - Training
  - Component Certification
  - Type Certification
  - Project Certification
  - Training & Seminars
  - Guidelines

GL Noble Denton is a world class technical service provider for the oil and gas industry.

Germanischer Lloyd is dedicated to ensuring the safety of life and property at sea, and the prevention of pollution of the marine environment.

GL GH is recognised worldwide as a provider of services at all stages of onshore and offshore wind projects.

GL RC, is a leading certification body primarily focussed on the certification of wind farms, wind turbines and their components.
GL’s History in Wind Energy (1)

• 1977
  • First activities in Wind Energy

• 1980
  • Examination GROWIAN and Small Turbines

• 1984
  • Testfield Pellworm / Kaiser-Wilhelm-Koog
  • R&D-Project for Load Calculation, Measurements and Guidelines

• 1986
  • 1st Guideline
  • Project for Test of Small Wind Turbines

• 1993
  • Regulations for the Certification of Wind Energy Conversion Systems
GL’s History in Wind Energy (2)

- 1994
  - European Offshore Study
- 1995
  - First Guideline for the Certification of Offshore Wind Turbines
- 1999
  - Regulations for the Certification of Wind Energy Conversion Systems
- 2003
  - Guideline for the Certification of Wind Turbines (Supplemented 2004)
- 2005
  - Guideline for the Certification of Offshore Wind Turbines
- 2007
  - Partnership with Helimax
GL’s History in Wind Energy (3)

• 2008
  • Three Practices:
    – Certification,
    – Turbine Measurements and
    – Consulting & Engineering

• 2009
  • New Business Segment: Renewables
  • Competence Centres:
    – Renewables Certification,
    – Renewables Turbine Measurements and
    – Renewables Consulting & Engineering
  • Merger with Garrad Hassan

• 2010
  • Guideline for the Certification of Wind Turbines edition 2010
GL’s History in Wind Energy (4)

- 2011
  - Chinese Edition of Guideline for Wind Turbines
  - Kick-off for 3rd edition of „Guideline for the Certification of Offshore Wind Turbines“

- 2012
  - Publication of the new Guideline for the Certification of Offshore Wind Turbines

- 2013
  - Technical Note on Training Systems
  - New edition of CMS-Guideline
  - ...
Our strategic answer: Joining forces

DNV GL Group

- Founded 1864
- Høvik, Norway
- 10,400 employees

Dedicated competences in:
- Tankers
- Offshore Classification
- Power & Transmission
- System certification

- To be formed in 2013
- Head office in Høvik
- 17,100 employees

A leading company in:
- Classification
- Oil & Gas
- Energy
- Business Assurance

GL

- Founded 1867
- Hamburg
- 6,700 employees

Dedicated competences in:
- Container ships
- Energy efficiency
- Marine operations
- Renewables
Our Geographical Reach – Experts in DNV GL Renewables Certification

- ~900 staff
- ~40 locations
- ~20 countries
- ~260 at DNV GL RC
Certification
What is it?
What is it? – Certification

Certification refers to the confirmation of certain characteristics of an object, person, or organization. This confirmation is often, but not always, provided by some form of external review, education, assessment, or audit.

- Professional, where a person is certified
- Product, if a product meets minimum standards
- Accreditation is a specific organization's process of certification
What is it? - Certification

**ISO / IEC 17000**

- **Certification**
  - third-party attestation related to products, processes, systems or persons

- **Attestation**
  - issue of a statement, based on a decision following the review, that fulfilment of specified requirements has been demonstrated

- **Review**
  - verification of the suitability, adequacy and effectiveness...

- in short:
  confirmation for compliance of a product or a service with defined requirements
1\textsuperscript{st}, 2\textsuperscript{nd} and 3\textsuperscript{rd} party conformity assessment

- **First-party conformity assessment activity**
  - conformity assessment activity that is performed by the person or organization that \textit{provides} the object
- **Second-party conformity assessment activity**
  - conformity assessment activity that is performed by a person or organization that has a \textit{user interest} in the object
- **Third-party conformity assessment activity**
  - conformity assessment activity that is performed by a person or body that is \textit{independent} of the person or organization that provides the object and of user interests in that object
- Wikipedia: Third-party certification involves an independent assessment declaring that specified requirements pertaining to a product, person, process or management system have been met
Evaluation, Accreditation, Certification...

- Multilateral Agreement
- Accreditation Body
- Certification Body
- Wind Turbine or Project

MLA, EA
DAkkS
GL
Manufacturer

Deutsche Akkreditierungsstelle GmbH
(former Deutsches Akkreditierungssystem Prüfwesen, DAP)

Evaluation
Accreditation
Certification
Normative environment

- Accreditation bodies operate according to ISO/IEC 17011. Accredited entities in specific sectors must provide evidence to the accreditation body that they conform to other standards in the same series:
  - ISO/IEC 17020: "General criteria for the operation of various types of bodies performing inspection" (2004)
  - ISO/IEC 17021: "Conformity assessment. Requirements for bodies providing audit and certification of management systems" (2011)
  - ISO/IEC 17025: "General requirements for the competence of testing and calibration laboratories" (2005)
Definition of Certification

Certification is to confirm the compliance of a design or a product (or a service) with defined requirements.

(GL, DNV, IEC, BSH, etc.)

GL RC is accredited to certify according to all common standards in the wind and marine industry (GL, DNV, IEC, BSH, etc.)
Standards in Wind Energy (History)
Safety is the basis for success

• Renewable energy devices had technical problems with impact on survivability and availability
• GROWIAN, ...

Certification

• Independent technical evaluation/surveillance. Risk reduction during design/realisation
• Better attention and quality in the production
• Compliance with requirements to ease international acceptance

Standardisation
Guideline & Standard Development ...

- First efforts in the late 70's (Denmark, Schleswig Holstein)

- IEA Recommended practices
  http://www.ieawind.org/Task_11/recomend_pract.html

- Focus on power performance, measurements, load analysis, safety system

- First GL Guideline in 1986

Guideline & Standard Development

- National Requirements in
  Germany- DIBt,
  Denmark - DS472
  The Netherlands - NEN6096
- Offshore requirements, Denmark 2001, Germany BSH 2004
- IEC Standardisation within TC 88
  (first standard IEC 1400-1 in 1994)
- Use of Oil & Gas industry standards in offshore
- Two main streams in development: IEC & GL
- DNV develop standards for blades and support structures
- New entrants develop certification rules based on IEC standards (ABS, BV, LR)
Certification Schemes
Certification

- Certification system:
  - defines certification bodies and their procedures, certification schemes to be applied
  - accreditation, mutual recognition, application procedure, certificates

- Certification scheme:
  - defines scope for certification, scope assessment and standards or guidelines to be considered
  - defines what is Type-, Project Certification, A-DA,..., IPE, GCC,...
  - at GL-IV-1 Chapter 1, GL-IV-2 Chapter 1, IEC 61400-22, DNV OSS-901

- Standards and Guidelines
  - define requirements to be fulfilled
  - GL-IV-1&2 Chapters 2-14, IEC61400-xx, DNV J-101,...
Wind Turbine Certification Basics

- Safety of
  - Human live
  - Environment
  - Structure

- Non-manned structures
- Safety level similar to non manned oil&gas industry structures
- Systems are both site specific as well as serial products

Support structure/cabling $\rightarrow$ Site specific $\rightarrow$ Project Certification
Machinery + $\rightarrow$ Serial product $\rightarrow$ Type Certification
IEC 61400-22: Type Certification

- Design basis evaluation
- Design evaluation
- Foundation design evaluation
- Manufacturing evaluation
- Foundation manufacturing evaluation
- Type testing
- Type characteristics measurements
- Final evaluation
- Optional module
- Type certificate
IEC 61400-22: Project Certification

Project Certificate

We hereby certify that the wind turbine(s) of the type Manufacturer - Turbine Type has been assessed by GL (Det Norske Veritas) according to the conditions of the site, the site-specific design, the surveillance of manufacturing and the execution of the installation, and commissioning in accordance with the IEC 61400-21-2012 and GL-Guidelines and IEC-Standards for certification.

The Project Certificate is based on the following:

- The site has been assessed by GL according to the IEC 61400-21-2012 standards.
- The turbine has been designed and manufactured according to the IEC 61400-21-2012 standards.
- The installation and commissioning have been carried out according to the IEC 61400-21-2012 standards.

The Project Certificate is valid for 10 years from the date of issuance.

[Diagram showing the project certification process]
# Different Certification procedures

<table>
<thead>
<tr>
<th>Service</th>
<th>GL</th>
<th>DNV</th>
<th>IEC</th>
<th>ABS</th>
<th>BV</th>
<th>LR</th>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<th>Document</th>
<th>Item</th>
<th>GL</th>
<th>DNV</th>
<th>IEC</th>
<th>ABS</th>
<th>BV</th>
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<tr>
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<td></td>
<td></td>
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<tr>
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<td>OSS-901</td>
<td>IEC 61400-22</td>
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<tr>
<td>Project certification offshore</td>
<td>IV-2</td>
<td></td>
<td>IEC 61400-22</td>
<td></td>
<td>WFPC 100</td>
<td>Guidance</td>
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</tbody>
</table>
National Requirements

- Germany: DIBt-Guideline Richtlinie für Windenergieanlagen (Guidelines for Wind Turbines)
- Denmark: Executive order on the technical certification scheme for the design, manufacture and installation of wind turbines, from the Danish Energy Authority ("Energistyrelsen") No. 651 dated 26.6.2008
- The Netherlands: Pre-Standard NVN 11400-0 Wind Turbines or IEC 61400-22 plus IEC 61400-1
- India: TAPS – 2000 Type Approval – Provisional Scheme
Requirements within BSH-release

- BSH Standard Konstruktive Ausführung von Offshore-WEA published by BSH in 2005
- A Type and a Project Certification are required. (But not defined!)
- BSH does not know IEC 61400-22
- References to DNV standards and GL Guidelines
- Certifications according to GL or DNV or IEC are accepted
- Additional requirements exist

- Standard is under review
- Additional standard for geotechnical investigation
Wind Turbine Certification
Wind Turbine Certification Basics

- Safety of
  - Human life
  - Environment
  - Structure

- Non-manned structures
- Safety level similar to non manned oil&gas industry structures
- Systems are both site specific as well as serial products

Support structure/cabling → Site specific → Project Certification
Machinery + → Serial product → Type Certification
Type Certification

Project Certification

Barge  Semi-submersible  TLP (Tension Leg Platform)  Spar buoy
buoyancy stabilised  buoyancy / ballast stabilised  mooring line stabilised  ballast stabilised

Standards and Certification, ITN MARE WINT
07/09/2013 35
Principal Certification Steps

- Principal safety of the prototype
  - Plausibility check
  - Limited parallel analysis
- Assessment of the serial product
  - Complete design assessment
  - Prototype test results
  - QM & Manufacture quality
  - Implementation of design in manufacture
- Evaluation of the power plant for a dedicated installation site including
  - Review of site assessment
Certification Components

Design Assessment

- Plausibility of the design
- Examination of drawings, assumptions and analysis
  Examination of components (design and tests)

Design Assessment and Certification of major components

Practical Test

- Test of the device
- Comparison of test results with assumptions

Inspection & Quality Control

- Examination of fabrication quality
- Witnessing of installation
Standards Overview
Actual GL Guidelines in detail

- Guideline for the Certification of Wind Turbines, GL-IV-1, 2010
- Guideline for the Continued Operation of Wind Turbines, GL-IV-1-12, 2009
- Richtlinie zur Erstellung von technischen Risikoanalysen für Offshore-Windparks, GL-IV-3, 2002
Actual GL Technical Notes in detail (Supplement to Guidelines to extend scope)

- TN for the Certification of Wind Turbines for Extreme Temperatures (here: Cold Climate), Edition 2011, Rev. 4
- GL TN 065 Grid Code Compliance (GCC) Certification procedure, Ed. 2010, Rev. 7
- GL TN 066 Grid Code Compliance (GCC) Test procedure for Low Voltage Ride Through (LVRT) , Ed. 2010, Rev. 7
- TN for the Certification of Service Providers in the Wind Energy Industry , Ed. 2009, Rev 6
DNV Offshore Standards

- A: Quality and Safety Methodology
- B: Materials Technology
- C: Structures
- D: Systems
- E: Special Facilities
- F: Pipelines and Risers
- G: Asset Operations
- J: Wind Energy

Service Specifications

Offshore Standards

Recommended Practices

Internationally recognised codes

Design

Operation

Construction
**DNV**

- Wind industry standards structure part of offshore standards
- DNV standards based on IEC procedure
- **DNV-DSS-904**, Type Certification of Wind Turbines, Jan. 2012
- **DNV-OSS-901**, Project Certification of Offshore Wind Farms, June 2012

  - DNV-DS-J102, Design and Manufacture of Wind Turbine Blades, Offshore and Onshore, Oct. 2010
  - ...
  - DNV-OS-J301, Standard for Classification of Wind Turbine Installation Units, Oct. 2010
  - ...
ABS - BV - LR

• ABS
  • Class sign (like ships etc.), reference to IEC and API
  • Includes Cyclones on very simplified manner

• BV
  • Guide on Offshore Wind Farm Project Certification (Based on IEC 61400 Series) BV-WFPC 100, Dec. 2012
  • Description how to apply IEC 61400-22
  • Classification and Certification of Floating Offshore Wind Turbines, NI 572, DTR00 E, Nov. 2010
  • Very rough guidance, reference to offshore standards and IEC

• LR
  • “Guidance on offshore wind farm certification”, April 2012
  • Basis for certification are IEC 61400-22.
  • Based on IEC 61400-1, ISO 19901-1 and ISO 19901-4
  • Reference for floating to LR Floating offshore structure rules (FOIFL)
IEC TC 88, 61400 series

- **IEC 61400-22: Conformity Testing and Certification of Wind Turbines**
- IEC 61400-1: Design Requirements
- IEC 61400-2: Small Wind Turbines
- IEC 61400-3: Design Requirements for Offshore Wind Turbines
- IEC TS 61400-3-2: Design Requirements for Floating Offshore Wind Turbines
- IEC 61400-4: Gears for Wind Turbines
- IEC 61400-5: Rotor Blades Wind Turbines
- IEC 61400-6: Tower and Foundations for Wind Turbines
- IEC 61400-11: Acoustic Noise measurement Techniques
- IEC 61400-12-1: Power performance measurements
- IEC 61400-13: Measurements of mechanical loads
- IEC 61400-14: Declaration of sound power level and tonality
- IEC 61400-21: Measurement of power quality characteristics
- IEC TR 61400-23: Full scale blade structural testing
- IEC TR 61400-24: Lightning protection
- IEC 61400-25(-1-6): Communication
- IEC TS 61400-26: Availability
- IEC 61400-27: Electrical simulation models
IEC Standards Development
Standardisation

- International Organization for Standardization (ISO)
- International Electrotechnical Commission (IEC)
  - global organization
  - standards for all electrical, electronic and related technologies
  - basis for national standardization
  - references when drafting international tenders and contracts
- European Committee for Electrotech. Standardization (CEN)
  - Comité Européen de Normalisation Electrotechnique
- National Standardization Organizations
IEC Standards

- Standardisation body: IEC, ISO, Cenelec
- IEC: international Electrotechnical Committee (www.iec.ch)
- Steering committee: TC 88, USA chair, NL secretary
- 24 participating countries
Objectives of IEC

• meet the requirements of the global market efficiently
• ensure primacy and maximum world-wide use of its standards and conformity assessment schemes
• assess and improve the quality of products and services covered by its standards
• establish the conditions for the interoperability of complex systems
• increase the efficiency of industrial processes
• contribute to the improvement of human health and safety
• contribute to the protection of the environment
### IEC Terminology

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>SMB</td>
<td>Standardization Management Board</td>
</tr>
<tr>
<td>TC</td>
<td>Technical Committee TC88 Wind Turbines</td>
</tr>
<tr>
<td>O-Member</td>
<td>Observer Member (of a TC)</td>
</tr>
<tr>
<td>P-Member</td>
<td>Participating Member (of a TC)</td>
</tr>
<tr>
<td>NC</td>
<td>National Committee</td>
</tr>
<tr>
<td></td>
<td>• Indian</td>
</tr>
<tr>
<td></td>
<td>• German</td>
</tr>
<tr>
<td></td>
<td>• ...</td>
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</tbody>
</table>
IEC Standards

- Members of IEC are national standard committees
- Individual companies can participate in the process via a selection mechanism on national level
- IEC standards are world wide
- In Europe: automatic adoption as EN standard (CEN/Cenelec) via parallel voting process
Creating an IEC standard can be very lengthy process

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
<th>Duration</th>
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<tbody>
<tr>
<td>1 proposal</td>
<td>NWP</td>
<td>-3</td>
</tr>
<tr>
<td>2 preparatory</td>
<td>preparation of WD (working draft)</td>
<td>0</td>
</tr>
<tr>
<td>3 committee</td>
<td>development and acceptance of CDV (committee draft for voting)</td>
<td>12</td>
</tr>
<tr>
<td>4 enquiry</td>
<td>development and acceptance of FDIS (final draft International Standard) or Technical Specification</td>
<td>24</td>
</tr>
<tr>
<td>5 approval</td>
<td>approval of FDIS</td>
<td>36</td>
</tr>
<tr>
<td>6 publication</td>
<td>international standard</td>
<td>48</td>
</tr>
</tbody>
</table>
Preparation Stages Int. Standards

Committee stage
- CD: Committee Draft (for comment)

Enquiry stage
- CDV: Committee Draft for Vote (five months voting period)

Approval stage
- FDIS: Final Draft International Standard (two months voting)

Publication stage
- IS: International Standard
Types of IEC Publications

International consensus products:
- International Standard (e.g. -1, -2, -3, ...)
- Technical Specification (TS)
- Technical Report (TR)
- Guide (e.g. Guide 65)
- Publicly Available Specification (PAS)

Limited consensus products:
- Industry Technical Agreement (ITA)
- Technology Trend Assessment (TTA)
## Standards in wind energy: overview

*From Frans Van Hulle: Standardisation in wind energy: role for EWEA?*

<table>
<thead>
<tr>
<th>Stage in wind turbine life</th>
<th>Design</th>
<th>Testing</th>
<th>Other</th>
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<tbody>
<tr>
<td>Design and manufacturing</td>
<td>Wind turbines</td>
<td>Power performance</td>
<td>x</td>
</tr>
<tr>
<td>(Proto)type testing</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Installation and commissioning</td>
<td>x</td>
<td>Loads and components (blades)</td>
<td>x</td>
</tr>
<tr>
<td>Network connection</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Operation and maintenance</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Decommission</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 1: Availability of international standards (mainly IEC wind energy standards of the series IEC 61400) for different aspects in the various stages in turbine life

- x = standard available.
- Gray-shaded cell = not applicable case.

Type and Project Certification

- Design Assessment
- Quality Management
- IPE
- Prototype Testing

- Site Design Conditions
- Site Specific Design Assessment
- Manufacturing Surveillance
- Commissioning Surveillance

- Type Certificate
- Transport and Install. Surveillance

- Project Certificate
- Periodic Monitoring
Type Certification
Type Certification - overview

- Design Assessment
- Quality Management
- IPE Implementation of Design Requirements in Production and Erection
- Prototype Testing

Type Certificate
Main IEC standard for Wind Turbines is IEC 61400-1 and 61400-3 for offshore

- Originally published in 2005, amendment in 2011
- Now 61400-1 ed. 4 in work. CD to be published in early 2014. Ed. 2 of 61400-3 one year later
- Main Focus on:
  - Safety System
  - External conditions and wind class definition
  - Load analysis
  - Load case definition
  - Safety factors
  - Some guidance on site assessment
- Basic requirements regarding mechanical, structural and electrical engineering, commissioning and operation
Design Assessment, GL Guideline

- General Conditions for Approval
- Safety System, Protective and Monitoring Devices
- Requirements for Materials and Corrosion Protection
- Load Assumptions
- Strength Analyses
- Structures
- Machinery Components
- Electrical Installations
- Manuals

Assessment of Loads and Safety concept

Certification Reports Load assumptions

Assessment of the Design documentation and the manuals

- Rotor blade tests
- Prototype trial of the gearbox at the test bench
- Witnessing of the commissioning

Certification Reports:
- Safety system and manuals
- Rotor blades
- Machinery components
- Tower (and foundation)
- Electrical equipment
- Commissioning
- Nacelle cover and spinner

For items still outstanding: B- Design Assessment

No items outstanding: A- Design Assessment

07/09/2013
Standards and Certification, ITN MARE WINT
GL Renewables Certification
GL Guideline, Safety Level, Limit States

- Safety level:
  - Normal safety level (unmanned structure, low influence on environment) Target $\approx 5 \times 10^{-4}$
  - Low safety level (secondary structures)
  - High safety level, manned structures only

- Requirements to the safety system
- Load case definitions
- Safety factors

Limit states:
- Ultimate Limit State (ULS/FLS)
- Serviceability Limit State
- No Accidental Limit State
GL Guideline, Safety Concept

- Analysis of safety system, protective and monitoring systems
- Basis:
  Engineering knowledge, experience or formal risk analysis
  e.g. Failure Mode and Effect Analysis (FMEA)
  - Safety system is independent from control system
  - Safety system overrides control system
  - Testing of control and safety system during commissioning
  - Single failure concept
  - Redundant safety system
  - Emergency stop
  - Special requirements possible e.g.
    - Leakage detection / Bilge pumps
    - Collision warning systems
Load Assumptions

- GL Guideline chapter 4
- IEC 61400-1, IEC 61400-3
- DNV J-101

- full flexibility and maximum options
- additionally update of load case catalogue
## Wind Turbine Classes

<table>
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<tr>
<th>Wind turbine class</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>S</th>
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<tr>
<td>$- V_{\text{ref}}$ [m/s]</td>
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example: GL IV-1
## GL Guideline, Load Cases, Basic Philosophy

<table>
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<tr>
<th>Load Group</th>
<th>Design condition</th>
<th>Environmental conditions</th>
<th>Recurrence period</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Normal operation, parked</td>
<td>Extreme</td>
<td>≤ 50 years</td>
</tr>
<tr>
<td>II</td>
<td>Operation, emergency stop, fault, parked after fault</td>
<td>Normal</td>
<td>≤ 1-year</td>
</tr>
<tr>
<td>III</td>
<td>Installation, Maintenance</td>
<td>To be defined by the designer</td>
<td>-</td>
</tr>
<tr>
<td>IV</td>
<td>Secured/Parked during installation</td>
<td>Normal</td>
<td>≤ 1-year</td>
</tr>
</tbody>
</table>
# Design Load Cases IEC 61400-3 (extract)

<table>
<thead>
<tr>
<th>Design situation</th>
<th>DLC</th>
<th>Wind condition</th>
<th>Waves</th>
<th>Wind and wave directionality</th>
<th>Sea currents</th>
<th>Water level</th>
<th>Other conditions</th>
<th>Type of analysis</th>
<th>Parti</th>
<th>safety factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Power production</td>
<td>1.1</td>
<td>NTM</td>
<td>$V_{in} &lt; V_{hub} &lt; V_{out}$ RNA</td>
<td>NSS</td>
<td>$H_s = E \left[ \frac{H_s}{V_{hub}} \right]$</td>
<td>COD, UNI</td>
<td>NCM</td>
<td>MSL</td>
<td>For extrapolation of extreme loads on the RNA</td>
<td>U</td>
</tr>
<tr>
<td>1.2</td>
<td>NTM</td>
<td>$V_{in} &lt; V_{hub} &lt; V_{out}$</td>
<td>NSS Joint prob. distribution of $H_s, T_p, V_{hub}$</td>
<td>COD, MUL</td>
<td>No currents</td>
<td>NWLR or $\geq$ MSL</td>
<td>F</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.3</td>
<td>ETM</td>
<td>$V_{in} &lt; V_{hub} &lt; V_{out}$</td>
<td>NSS</td>
<td>$H_s = E \left[ \frac{H_s}{V_{hub}} \right]$</td>
<td>COD, UNI</td>
<td>NCM</td>
<td>MSL</td>
<td>U</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td>ECD</td>
<td>$V_{hub} = V_r - 2 \text{ m/s}$, $V_r$, $V_r + 2 \text{ m/s}$</td>
<td>NSS (or NWH)</td>
<td>$H_s = E \left[ \frac{H_s}{V_{hub}} \right]$</td>
<td>MIS, wind direction change</td>
<td>NCM</td>
<td>MSL</td>
<td>U</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td>EWS</td>
<td>$V_{in} &lt; V_{hub} &lt; V_{out}$</td>
<td>NSS (or NWH)</td>
<td>$H_s = E \left[ \frac{H_s}{V_{hub}} \right]$</td>
<td>COD, UNI</td>
<td>NCM</td>
<td>MSL</td>
<td>U</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>1.6a</td>
<td>NTM</td>
<td>$V_{in} &lt; V_{hub} &lt; V_{out}$</td>
<td>SSS</td>
<td>$H_s = H_{SSS}$</td>
<td>COD, UNI</td>
<td>NCM</td>
<td>NWLR</td>
<td>U</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>1.6b</td>
<td>NTM</td>
<td>$V_{in} &lt; V_{hub} &lt; V_{out}$</td>
<td>SWH</td>
<td>$H_s = H_{SWH}$</td>
<td>COD, UNI</td>
<td>NCM</td>
<td>NWLR</td>
<td>U</td>
<td>N</td>
<td></td>
</tr>
</tbody>
</table>
Partial Safety Factors for Loads $\gamma_F$

<table>
<thead>
<tr>
<th>Source of loading</th>
<th>Unfavourable loads</th>
<th>Favourable loads</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type of design situation</td>
<td>All design situations</td>
</tr>
<tr>
<td></td>
<td>Normal and extreme N</td>
<td>Abnormal A</td>
</tr>
<tr>
<td>Aerodynamic</td>
<td>1,35</td>
<td>1,1</td>
</tr>
<tr>
<td>Operational</td>
<td>1,35</td>
<td>1,1</td>
</tr>
<tr>
<td>Gravity</td>
<td>1,1/1,35*</td>
<td>1,1</td>
</tr>
<tr>
<td>Other inertia</td>
<td>1,25</td>
<td>1,1</td>
</tr>
</tbody>
</table>

* In the event of the masses not being determined by weighing.

“Guideline for the Certification of Wind Turbines” Edition 2010
## Partial Safety Factors for Loads $\gamma_F$

<table>
<thead>
<tr>
<th>Unfavourable loads</th>
<th>Favourable loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of design situation (see Tables 1 and 2)</td>
<td>All design situations</td>
</tr>
<tr>
<td>Normal (N)</td>
<td>Abnormal (A)</td>
</tr>
<tr>
<td>1,35*</td>
<td>1,1</td>
</tr>
</tbody>
</table>

* For design load case DLC 1.1, given that loads are determined using statistical load extrapolation at prescribed wind speeds between $V_{in}$ and $V_{out}$, the partial load factor for normal design situations shall be $\gamma_f = 1.25$.

If for normal design situations the characteristic value of the load response $F_{gravity}$ due to gravity can be calculated for the design situation in question, and gravity is an unfavourable load, the partial load factor for combined loading from gravity and other sources may have the value:

$$\gamma_f = 1,1 + \phi \zeta^2$$

$$\phi = \begin{cases} 0,15 & \text{for DLC1.1} \\ 0,25 & \text{otherwise} \end{cases}$$

$$\zeta = \begin{cases} 1 - \frac{|F_{gravity}|}{F_k}; & |F_{gravity}| \leq |F_k| \\ 1; & |F_{gravity}| > |F_k| \end{cases}$$

Pretension and gravity loads that significantly relieve the total load response are considered favourable loads.
Fatigue

Compare of load levels
GL2005
GL2012
IEC61400-3
Compare of load levels
GL2005
GL2012
IEC61400-3

Extreme

Hub's Extreme Loads (% ref: GL2012)
GL Rotor coordinate

Blade Roots' Extreme Loads (% ref: GL2012)
GL Blade coordinate

GL2005
GL2012

IEC 61400-3

Tower Top's Extreme Loads (% ref: GL2012)
GL Support structure coordinate

GL2005
GL2012

IEC 61400-3

Yaw bearing's Extreme Loads (% ref: GL2012)
GL Yaw Bearing coordinate

GL2005
GL2012

IEC 61400-3

Tower Bottom's Extreme Loads (% ref: GL2012)
GL Support structure coordinate

GL2005
GL2012

IEC 61400-3
Small Wind Turbines (SWT)

- **IEC 61400-2: Small Wind Turbines**
  - Simplified requirements
  - Limit to rotor swept area smaller than or equal to 200 m², generating electricity at a voltage below 1000 V AC or 1500 V DC for both on-grid and off-grid applications
Machinery Components

- **GL Guideline** Chapter 6 and 7
- **IEC 61400-4**, Design requirements for wind turbine gearboxes
- Reference to other ISO standards
- Gears:
  - **ISO 6336** – Calculation of load capacity of spur and helical gears
  - **AGMA 2001/2101** – Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth
- Bearings:
  - **ISO 281** – Rolling bearings – Dynamic load ratings and rating live of bearings
  - **IEC 81400-4** – Wind turbines -- part 4: Design and specification of gearboxes
Drive Train Dynamics

- Load assumptions for the design of turbines are based on simulations of a global model
- Dynamic properties of e.g. drive train and internal loads are neglected

Why Drive Train Dynamics:
- Analysis of the dynamic behavior of the drive train using a detailed simulation model
- Verification of model parameter assumptions representing the drive train in global model
- Verification of design loads
- GL Guideline Appendix 7.A on Drive Train Dynamics
Gearbox – Prototype and Serial Test
Lightning Protection
The red path is ended. The energy is now feeded to the grid. What happens there you will hear from torge some more important components I will show you now.

NIFH: 10.10.2012
Lightning protection at Rotor Blades

A. Receptor
B. Down conductor
C. Down conductor
D. Metal mesh

Steel wire

IEC 61400-24
Overvoltage Protection System

LPZ: Lightning Protection Zone

IEC 61400-24
Quality Management (QM)

- Verification that requirements of ISO 9001:2008 regarding design and manufacturing are fulfilled
- Certification of QM system
Implementation of design requirements in Production and Erection (IPE)

- It has to be approved and assessed that the requirements stipulated in the technical documentations are observed and implemented in production and erection.

- One-time surveillance during production and erection (depending on quality management measures).

- Definition of important / critical production processes regarding quality requirements (resulting from Design Assessment).
Prototype Testing

- measurement of the power curve
  IEC 61400-12-1
- measurement of the noise emission
  (optional) IEC 61400-11
- measurement of the electrical characteristics
- test of wind turbine behaviour
- load measurements, IEC 61400-13
- test operation of the gearbox at the wind turbine
Power Curve

measured wind speed

$\rightarrow P_{el}$
Project Certification
Project Certification (GL IV-2)

- Type - Certificate
  - Assessment of site design conditions
  - Site-specific Design Assessment
  - Surveillance during production
  - Surveillance during commissioning
  - Surveillance during transport and erection

- Project – Certificate
  - Periodic Monitoring
Site Design Conditions

- wind & wave conditions
- soil conditions
- influence of the wind farm configuration
- other environmental conditions, such as: salt content of the air, temperature, ice and snow, humidity, lightning strike, solar radiation etc.
- electrical grid conditions…
  ... and connections

- main definitions in GL-Guideline or IEC 61400-1 and IEC 61400-3
Site-specific Design Assessment

wind park site

wind turbine

Do they match?
Site Design Conditions

• Site Assessment
  • Environmental Conditions

• Soil Investigation

• Further Items include
  • Load Case Definitions
  • Determination of Rules for materials, corrosion protection
  • Assumptions for WTG: masses, eigenfrequencies, …
  • Concept for Transport, Erection and Inspection
  • Specification of specific Analysis Methods
    ➔ leading to the Design Basis
Site-specific Design Assessment

- Load Assessment

- Assessment the support structure
  - ULS (ultimate limit state)
  - FLS (fatigue limit state)
  - Investigation of details e.g. for grouting connection, 2nd-steel

- Assessment of the turbine including
  - are the loads higher than those assumed in the Type Certificate? (in such cases: reserve calculations necessary)
  - Is the turbine design to withstand site conditions? (corrosion, temperature, ...)

Standards and Certification, ITN MARE WINT

GL Renewables Certification
Surveillance during Production

- inspection and testing of materials and components
- scrutiny of QM records, such as test certificates, tracers, reports
- surveillance of production, including storage conditions and handling
- structural steelwork, welding, inspection of NDT
- nacelle assembly
- inspection of the corrosion protection
- inspection of the electrical power system
- supervision of the final test

The general objective is to verify, that the production is done according to the approved drawings, rules and specifications.
Qualification of welders, approval of weld shops
Geometry and corrosion protection
Traceability of components
alber; 23.09.2010
Manufacturing Surveillance (2)
Surveillance during Transport and Erection

- identification and allocation of all components to the wind turbine in question
- checking the components for damage during transport
- inspection of the job schedules (e.g. for welding, installation, bolting up)
- inspection of prefabricated subassemblies, and of components to be installed, for adequate quality of manufacture, insofar as this has not been done at the manufacturers’ works
- surveillance of important steps in the erection on a random-sampling basis
- inspection of bolted connections, surveillance of non-destructive tests (e.g. welded joints)
- inspection of the corrosion protection
- inspection of the electrical installation (run of cables, equipment earths and earthing system)
Surveillance during commissioning

- functioning of the emergency stop button
- triggering of the brakes by every operating condition possible in operation
- functioning of the yaw system
- behaviour at loss of load (grid loss)
- behaviour at overspeed
- functioning of automatic operation
- visual inspection of the entire installation
- checking the logic of the control system’s indicators
- general appearance
- corrosion protection
- damages
- conformity of the main components with the certified design and traceability / numeration of the components
Thank you very much!
Present Status of CMS for Wind Turbines (1)

Application:

• Condition monitoring is used for many years in power plants and industrial facilities.

• At the beginning only little use in wind turbines due to skepticism of its advantages.

• With increasing power of wind turbines CMS is becoming more accepted.

• According to the GL RC’s Offshore Guideline CMS is mandatory for Offshore wind turbines.
Present Status of CMS for Wind Turbines (2)

Intention:

- Drive train monitoring with special focus on gears and bearings
- Detection of damages
- Condition based maintenance
- Predictable maintenance schedules
- Enhancing availability
Present Status of CMS for Wind Turbines (3)

Realization:

• Individual solutions are prevalent

• CMS are individually adapted to wind turbines as wind turbines are generally not prepared for CMS

• Monitoring by individuals, wind farm operators or Monitoring Bodies (MB)

• The CMS is independent from the control system and the safety system
Present Status of CMS for Wind Turbines (4)

Wind turbine control system

CMS

Control System and Safety System

Operator

Drive Train Monitoring

Data storage

Monitoring body

(Optional)
Thank you very much for your attention

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