New Guideline for offshore wind turbines

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Abstract: The offshore wind energy market is developing fast. Turbines, substations and offshore sites are increasing in size and they are in more challenging environments. Therefore, the industry requires vigilance in maintaining standards to keep pace with technology developments, enabling safe deployment and long term operation. Certification of wind farms, wind turbines and their components is state-of-the-art and a must in most places around the world. It helps to attract investors, satisfy insurers and to bring offshore project development on the next level. Furthermore assessment to harmonised regulations is an active support of export and eases market entries. Accompanied by certification of training systems or maintenance services it provides comprehensive backup for the whole project. Therefore it is important to know the certification processes and guidelines as well as the keystones of their development for all parties involved in a project lifecycle.

This paper puts focus on the latest guideline developments for GL 2012 and describes the outcome and latest innovations of GL Renewables Certification (GL RC) and its wind and marine energy committee for certification of offshore wind turbines and projects. Issues like load assumptions, floating wind turbines and risk based approval are some of them. A comparison to existing requirements is given and the benefits of Type and Project Certification for manufacturers, banks and insurances making use of the different certification schemes as well as guidelines will be described. The modules and procedures to obtain Type and Project Certificates are shown in detail.

The new guideline follows the main developments in offshore wind industry. One is the increase in size of turbines and the mitigation of loads using advanced, “intelligent”, control systems which sometimes are complex and thus prone to errors. As a consequence examination and testing of control systems is part of the guideline. Another issue is that turbines are installed in waters where the first generation monopile solutions are not feasible any more. New structures like jackets are used in big numbers putting additional challenges to the structure and foundation design. In the guidelines novel analysis methods are required e.g. for piles under cyclic axial loading considering the high frequency of tension cyclic loads typical for wind turbines. Finally floating wind turbines are planned for installation at several parts of the world, imposing new challenges e.g. regarding stability and mooring safety requirements. These are well known in offshore oil and gas industry but have to be adapted to consider the unmanned type of structure and the installation of the wind turbines in big numbers in farms.

Finally technical notes, accompanying the guidelines, for specific items as grouted connections are addressed. In the past grouted connections of wind turbines have shown several problems. Proposals for new analysis requirements allowing safe grouted connections for wind turbines shall be discussed in more detail in near future.
1 Introduction

The procedures to obtain Type and Project Certificates are described on the basis of GL 2012: Guideline for the Certification of Offshore Wind Turbines, Edition 2012 [15].

Type Certification comprises Design Assessment, Implementation of the design-related requirements in Production and Erection, Evaluation of Quality Management and Prototype Testing. Project Certification is based on Type Certification and covers the aspects of Site Design Conditions, Site-specific Design Assessment, Surveillance during Production, Transport and Erection as well as Witnessing of Commissioning and Periodic Monitoring. The individual modules are concluded with Statements of Compliance. Certificates are issued upon the successful completion of the relevant modules.

The most important part of the Type Certification is the assessment of the design documentation (specifications, drawings, verifications, test reports, etc.), a thorough design review with respect to the requirements defined in the a. m. guideline and other codes and standards. It is generally carried out in two sequential steps. The first part covers all aspects of the safety and control concept as well as the load assumptions and load calculations.

During the second part of the Design Assessment all components of the system are being examined. At the end of the Design Assessment manuals and procedures for transport, erection, start-up, commissioning, operation and maintenance are checked for suitability, completeness and compliance with the assumptions in the design documentation. Rotor blade testing as well as prototype testing of e.g. main gearbox and generator are an integral part of the Design Assessment. These are followed by a turbine commissioning witnessing.

In addition to this the Implementation of the design requirements in Production and Erection (IPE) shall be observed. This is shown once to the certification body by the manufacturers of the components and the offshore wind turbine. The evaluation of the designer’s and manufacturer’s quality management covers the whole range of activities necessary to confirm the quality of the product. In order to validate the design calculations, to optimise control, performance and additional optional topics like noise or Low Voltage Ride Through (LVRT) behaviour and to verify the performance of the safety and control systems the Prototype Testing is an integral part of the design and certification process. The measurements shall be based on the relevant standards and are to be witnessed by the certification body if not performed by institutes accredited according to ISO 17025 [7]. Furthermore the prototype of the gearbox shall be tested on the offshore wind turbine in addition to the test on the bench. Additional parts of certification such as personnel safety, fire protection, condition monitoring systems (and bodies), training or maintenance systems, hot and cold climate or grid code compliance may be covered, too, to support e.g. availability, safety or export of the offshore turbines.

Project Certification comprises a complete third party assessment and certification of an offshore wind farm from Site Design Conditions to (Site-specific) Design Assessment as well as surveillance of most important steps in the project and Periodic Monitoring during the operating phase. Changes in design done for one site or offshore wind farm only can easily be covered herein to complement the Type Certificate. Furthermore besides the offshore wind turbine the OSS (Offshore Sub Station) and e.g. cables within the offshore wind park are an integral part of complete project certification making it a more complex process which needs experience and know-how as well as thorough project management.
After the completion of evaluations, monitoring and witnessing, the certification body issues Statements of Compliance for the relevant steps and components / units. Certificates are being issued upon finalisation of the Component, Type and Project Certification.

In the last months of 2012 GL RC finalised the revision of its guideline which is published as GL 2012 including the state-of-the-art in certification and the actual knowledge about turbine design requirements. This paper covers the latest developments for the new offshore guideline which was published last year and will have effect on forthcoming offshore wind turbine developments worldwide. It focuses on load calculations, reporting needs and floating structures as well as further technical aspects. To learn more about Type and Project Certification in general, the international guideline history or for a complete list of all changes covered by the new onshore edition and implemented for this offshore edition see [12]. Find out all about the changes and developments to be one of the first knowing all about GL 2012.

2 Development Process

Early 2011, the existing GL-Guideline of 2005 [3] was an established and worldwide used document. At that time the first meetings were held to discuss the next edition of this offshore guideline for the certification of offshore wind turbines and farms. In fact the project was kicked off on 18th March 2011. After clarification of the main tasks and the overall time-frame for the update the detailed planning started.

The project covered:
- review and revision of all chapters and sections of the existing edition,
- clarification of new information with regard to concepts, developments and solutions of both technical and certification background,
- harmonization with existing guidelines and standards,
- harmonization with onshore guideline GL 2010 [20] which was revised short before,
- preparation of draft chapters and sections including revisions and new items,
- discussion and clarification of all drafts in the Wind and Marine Energy Committee of GL RC,
- layout, editorial office and – finally – publication.

Thus three phases were identified. Phase one, starting in the middle of 2011 to prepare the new guideline on basis of drafts. Phase two, starting early 2012 to initiate the meetings of the Wind and Marine Energy Committee and incorporate industry feedback. Phase three, coming to an end in the last months of 2012 to get to the final text and publish the new guideline.

All parts of GL 2005 have been subject to review, discussions and improvements. The procedures for Type and Project Certification have been updated and component certification was stated explicitly; modules and elements have been revised and explained in more detail or deleted if no more necessary. Experience of many certification projects on basis of the 2005-edition resulted in optimised text, new information or additional annexes and notes. All references have been evaluated and updated in case new information is available. Additionally all
Notes on Engineering Details issued by GL RC in the past years have been included. Thus the new edition represents the state-of-the-art with regard to the whole offshore wind turbine or complete offshore project.

The edition of this guideline called “GL 2012” covering offshore wind turbines and farms as well as components came into force on 1st December 2012. Once published GL 2012 replaced GL 2005 and forms a new and trend-setting basis for certification activities to ensure safety and reliability of offshore wind turbines and farms worldwide. GL 2012 will become a worthy successor of the existing guideline – thanks to all the effort of GL and external experts and especially the Wind and Marine Energy Committee with several unnamed experts of members’ companies, associations and institutions in the background.

3 The Update in detail

3.1 General

Reading and using GL 2012 you may expect updates on almost all sections and chapters. In the following find some selected topics this paper will shed some light on. Expect more detailed information on all of the items in the months to come and feel free to visit GL’s webpage (www.gl-group.com/GLRenewables) or contact the authors directly.

The updated guideline follows the main developments in the offshore wind industry, for example, it considers the increased size of turbines and mitigation of loads using advanced and complex control systems. As a consequence examination and testing of control systems is now part of the guideline. Furthermore, the new version contains novel analysis methods e.g. for piles under cyclic axial loading considering the high frequency of tension cyclic loads. In addition, requirements for floating wind turbines regarding stability and mooring safety requirements are addressed.

The guideline for offshore wind turbines was improved to fully comply with the guideline for onshore wind turbines of 2010. All improvements made therein [14] are included in the offshore version, too.

One essential addition is the inclusion of different concepts of floating wind turbines introduced including sketches and their stability principles. To achieve these tasks new requirements on design, load analysis, stability and testing were introduced. These consider the latest international (IMO and SOLAS) resolutions for floating bodies. As for onshore and fixed offshore turbines Type Certification of floating wind turbines is possible. Provision is made that the whole structure including floater can be certified once for generic conditions. In a following project the designer may show that the design complies with the site requirements. Mooring lines and anchors have to be site specific. By this option the approval procedure for projects is speeded up, compared to fixed structures where the support structure is site specific and an extra analysis is needed for every location.

Other advantages are:

- A- and B- Type Certificate introduced (allowing for non-safety relevant open items in B-type certificates)
- A- and B- Project Certificate introduced (allowing for non-safety relevant open items in B-type certificates)
- D-Design assessment included as a “feasibility check” prior the C-Design Assessment for prototypes.
- Manufacture: Improvement of Implementation of the design-related requirements in Production and Erection (IPE) and introduction of Critical Manufacturing Processes (CMP)
- Surveillance during manufacture, transport and installation for 25% of the turbines required for project certification. Commissioning witnessing for 10% of the turbines is necessary.

3.2 Risk-based approval

A departure from traditional design and certification methods is the introduction of Risk-based design and approval. Innovative concepts, not covered by guidelines so far, can become part of the certification. The method is based on developments achieved within the R&D project SAFEDOR (Design, Operation and Regulation for Safety) running in the 6th Framework Programme of the European Commission [19] and the GL “Guidelines for the Analysis of Alternative Design and Arrangements”. The certification body and the designer / owner of the innovative structure or component have to work close together: After the design preview (phase I) in which the design novelty and possible challenges of guidelines are agreed a preliminary analysis in qualitative terms (phase II) is performed. The preliminary analysis in qualitative terms consists of the definition of the analysis scope, and the hazard identification by means of a method that is commonly agreed. Hazards that are identified are ranked,
and from the ranked hazards casualty scenarios are developed for use in the quantitative analysis (phase III). This is followed by the concept refinement and construction (phase IV) during which the design requirements and risk reducing measures that originate from the results of the analysis must be implemented, analysed and tested. The system has to be brought to service and monitored in the installation (phase V) and operation phase (phase VI).

### 3.3 Load calculations

In GL 2012 no load time series are required for C- and D-Design Assessments. These are assessments of prototypes or turbines under development not asking for thorough fatigue evaluations at this stage of testing and development. The Note on Engineering Details for D-Design Assessments is included in the guideline now. This enhances the options for different types of certification and makes it easier to benefit from certified products.

In general load calculations according to IEC 61400-3 [18] are accepted as equivalent. An optional appendix can be used for detailed description on relevant parameters of control and safety system for load calculations. Doing this the options for the user of the guideline are maximised.

The complete section for the description of the external conditions was reviewed. While the principle wind description is similar to the previous version the Extreme Turbulence Model (ETM) is introduced. The intention is to capture extreme loads resulting from low probability high wind speed turbulence in the atmosphere during normal operation at medium wind speed in the same way as it is done by applying extreme (50-year) wind speed or waves to design the structure. In addition the ETM is one method to consider the increased vorticity of the wind in farms due to wake effects.

The procedure to evaluate loads for turbulent EWM (extreme wind speed model) load cases is simplified; now it consists of a sufficient number of representative seeds at $I=12\%$ instead of seeds with confirmed gust criteria at moving 3s-average. Furthermore the turbulence scale parameter $\Lambda$ for NTM (normal turbulence model) and EOG (extreme operating gust) is harmonized with IEC 61400-1 [5]. Last but not least positive and negative EWS (extreme wind shear) are to be considered for horizontal and vertical direction now.

Further on the combination of wind, wave and ice conditions is clarified and – where possible – simplified. The combination of extreme wind and wave conditions is now performed by embedding non linear extreme waves in stochastic wave time series and apply them on the structure. By this method the stochastic response of the structure is taken into account without compromising the analysis of non linear effects due to aerodynamics, control system interaction or extreme wave kinematics. The load calculations section is upgraded by extending previous descriptions e.g. in wave kinematics, adding additional information e.g. in wind-wave misalignment or wake effects as well as fully rewrite in e.g. boat impact analysis.

The design load cases (DLC) are optimized as follows:
- DLCs are divided into two groups: mandatory DLCs (DLC 1.x to DLC 8.x) in one table and optional DLC 9.x in a separate table
- Both tables are restructured
- Non-relevant load cases DLC 1.8, 1.9, 3.3, 6.1b and c, 6.2b, 6.3b, 6.6 are removed
- Transition of former DLC 1.11, 1.12, 1.14, 6.6, 6.7 into optional group DLC 9.x where designer / manufacturer decides on scope of assessment
- Merging of extreme load cases and fatigue load cases into combined extreme and fatigue load cases: e.g. DLC 1.1 + DLC 1.2 -> DLC 1.1; DLC 2.1 + DLC 2.2 + DLC 2.3 -> DLC 2.1 + DLC 2.2
- New load case DLC 1.2 with extreme turbulence
- Number of extreme storm DLC6.x (combined 1- or 50-year wind and wave conditions) load cases reduced

![Generic risk assessment process][15]
- Consideration of probably increased fatigue with lower availability in DLC 7.2
- Improved description of sea ice loading, consideration of dynamic ice loading due to locking of periodic ice break with structure natural frequency
- Mass eccentricity of rotor and all relevant components of the drive train is to be considered, e.g. eccentricity of direct drive generators

These measures will contribute to easier and faster load simulations and assessments.

### 3.4 Floating wind turbines

Floating wind turbines put an extra complexity to the design, assessment and testing of offshore wind turbines. Of course the turbine has to stay afloat and a station keeping system is needed. The different requirements have been considered:

- The safety system is extended to consider requirements for floating structures (mooring system, motions monitoring). As an example the tightness and draft, the position of the turbine and the heeling angles have to be monitored.
- In the design of the control system additional parameters like sea state and body movement have to be included. Special care is to be taken to avoid parametric excitation by interaction of the control system dynamics and the high period motions of the structure.
- Intact and damage stability requirements have been introduced. The requirements fulfil the IMO IS [16] code for intact stability and the MODU code [17] for damage stability under consideration of the wind turbine peculiarities. The freeboard e.g. shall be sufficient to avoid any contact of the rotor with water and allow safe access to the turbine at any time.
- A load case group DLC 10.x is introduced to consider damage stability and mooring line loss situations. Analysis of the motions and loads during loss of one mooring line and the redundancy case have to be performed.
- For the analysis of the hull and the mooring system reference is made to the relevant sections of the GL Rules for offshore structures. Special issues are addressed.
- Prototype testing of floating wind turbines is a special challenge. While for fixed structures testing onshore is accepted, for floating structures, at least part of the tests shall be performed offshore. This adaptation has been made to ensure testing the proper integration of the control system in the design and the loading of the structure under consideration of the body movements. Influences in turbine power curve due to large movements and heeling angles have to be considered, too.
- As an additional requirement the inclining test has been introduced.
- Requirements for towing of floating wind turbines are included.

![Fig. 7: Sketches of Floating Offshore Wind Turbines with their stability principles [15]](image-url)
3.5 Transport and installation

The transport and installation section is substantially modified to cover all operations related to installation of offshore wind turbine starting from load-out and transportation till the lifting operations and installation procedures including vessel positioning. The section is now harmonized with other GL regulations in the offshore sector. During the modification it was aimed to focus on the marine operations itself, defining procedural safety requirements. Thus Chapter 12 is now guiding part of the project certification, while structural design requirements related to the marine operations (i.e. in respect of sea-fastening) were re-located into the correspondent chapter of the guideline.

The components addressed are:
- Load-out (floating, lifted, skidded, by trailers, grounded)
- Transportation, including sea-fastening and towing (barges, floating)
  - Lifting
  - Installation of jackets, piles and topside structures
  - Vessel positioning
  - Pipe / cable laying

3.6 Reporting needs

For the annual update and in case of a re-certification, the following documents – if applicable – shall be submitted for evaluation:
- list of valid drawings and specifications (for re-certification only)
- list of current manufacturing facilities (for re-certification only)
- list of all modifications to the design of components forming a part of the design assessment or IPE and, if applicable, documents for evaluation of the modifications
- list of alterations to the QM system since the last audit (for re-certification only)
- list of all installed (offshore) wind turbines of the type (at least a statement of the type with precise designation of the variant, serial number, hub height, location)
- list of all damages to components of the installed wind turbines forming a part of the design assessment or IPE
- declaration on possible changes or additions to workshops and / or store-houses (for annual update only)

Whereas the items are clearly described it was always difficult to figure out which modifications or damages are to be reported as indicated above. What is a “major” modification or which damage is severe enough to be included? To answer these questions two tables are included in GL 2010 already and copied in GL 2012 giving a first indication. Further developments of such indications are planned.
### Table 1: Examples for modifications or damages to be reported [15]

<table>
<thead>
<tr>
<th>Component Description</th>
<th>Damage/Modification</th>
<th>Report Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor blade</td>
<td>Cracks in the laminate and adhesive</td>
<td>- list of damages - root cause analysis</td>
</tr>
<tr>
<td>Planet carrier of main gearbox</td>
<td>Change of material</td>
<td>- list of modifications - changed documentation</td>
</tr>
<tr>
<td>Bolted connection of hub/rotor shaft (multiple bolt connection)</td>
<td>Change in number of bolts</td>
<td>- list of modifications - changed documentation</td>
</tr>
</tbody>
</table>

### Table 2: Examples for modifications or damages not necessarily to be reported [15]

<table>
<thead>
<tr>
<th>Component Description</th>
<th>Damage/Modification</th>
<th>Report Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover of main shaft</td>
<td>Change of material</td>
<td>-</td>
</tr>
<tr>
<td>Fixture for control cabinet</td>
<td>Broken once</td>
<td>-</td>
</tr>
<tr>
<td>Bolted connection of tower platform</td>
<td>Change in size of bolts</td>
<td>- depending on scope of certification (see Note in Section 1.1.1)</td>
</tr>
</tbody>
</table>

Updates of turbines assessed on basis of GL 2005 or GL 2010 to the requirements of GL 2012 are possible, too. The individual scope shall be addressed and clarified in the stage of design basis.

## 4 Conclusions

The strong growth of the offshore wind energy industry and the growing size of offshore wind farms as well as turbines therein enforce financing banks and insurance companies as well as authorities to require reliability and safety assessments of these products and projects. Additionally the market for floating turbines becomes more and more important and a thorough technical review is required, too. The assessments are carried out within the certification of the types of components, turbines and the complete offshore wind farms. Within the framework of the certification of offshore wind turbines, reliability, safety, strength and fatigue are evaluated in order to guarantee safe operation. Minimising of risks and building up confidence to investors, insurers, operators and authorities are the main aspects of a third party assessment within the certification process. The described guideline GL 2012 contributes to these objectives and thus supports the whole industry.

## 5 GL Renewables Certification Company Overview

GL Renewables Certification (GL RC) is a leading certification body for renewable energy projects and the associated equipment. It offers the complete range of services for renewable energy certifications and third party
inspections as well as any kind of expertise reporting. Certification is among others carried out on the basis of the GL Guideline for the Certification of Wind Turbines (Edition 2010) and the Guideline for the Certification of Offshore Wind Turbines (Edition 2012). All GL RC guidelines are regularly updated by Notes on Engineering Details and supplemented by Technical Notes which are available on the webpage. Furthermore, GL RC is accredited to carry out certification in accordance with all relevant national and international standards in the field of wind energy. The company has offices in Germany, the U.S., Canada, India and China, and employs 185 people worldwide.

6 References