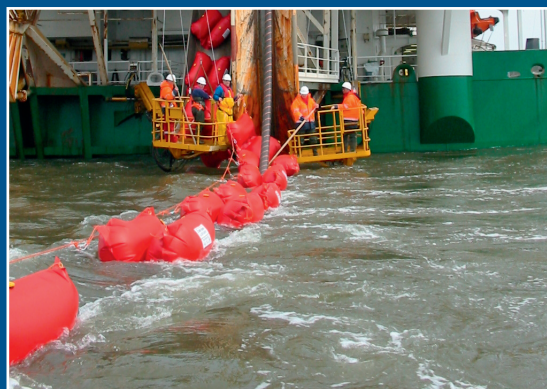
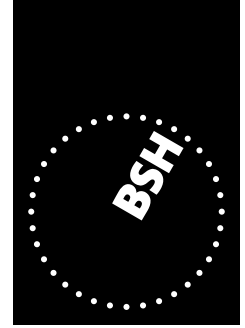


BUNDESAMT FÜR
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Standard

Design of Offshore Wind Turbines





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20 December 2007

Published by the Federal Maritime and Hydrographic Agency (BSH)
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Hamburg and Rostock 2007
www.bsh.de

BSH no. 7005

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Photos: Repower AG, H. Stehmeier

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Teil A: General

1 Introduction

This standard is intended to provide legal and planning security for development, design, implementation, operation and decommissioning of offshore wind farms within the ambit of the Marine Facilities Ordinance (SeeAnIV). It is dynamic and integrative in nature, so that it will be possible to take account of new knowledge and developments as well as the need to incorporate standards that have not been included before in order to achieve standardisation of an overall system.

A range of representatives from expert bodies and institutions have been involved in developing this standard, and played a constructive role in its development. The representatives of the classification societies Det Norske Veritas (DNV) and Germanischer Lloyd (GL) provided expert accompaniment for the process. Representatives of the business and scientific communities made valuable contributions, so that overall it has been possible to create a solid basis for constructive cooperation in terms of system security in order to protect the marine environment and maintain the safety and efficiency of navigation.

2 Fundamentals

2.1 Legal basis

Installations subject to approval under SeeAnIV shall comply with the recognised rules of technology; § 5 para. 2 SeeAnIV demands this both for the design and installation of the systems as well as for their operation.

In accordance with § 4 para. 2 SeeAnIV, approval may be subject to compliance with certain technical standards; accordingly, demonstrating compliance with the prescribed standards represents the basis for establishing the legality of the design, installation and operation of the system.

2.2 Subject matter of this standard

This standard regulates the various structural components of an offshore wind farm that differ in terms of design.

In particular, these include

- Turbine, consisting of nacelle and rotor blades
- Support structure consisting of tower and substructure, including locally fixed integration into the seabed (foundation)
- Cabling of the individual installations within the farm, including their linkage at the transformer substation
- Transformer substation including the platform
- Power export system from the transformer substation to the grid connection on land
- Additional constructional components of the offshore wind farm, if necessary.

The offshore wind farm is considered both in terms of its individual components and as an overall system. The sections to be worked through are basically divided into the following project phases which are described in more detail in [Part C](#) und [Table 2](#):

- Development
- Design
- Implementation (production, transport, installation, commissioning)
- Operation
- Decommissioning.

The specification to comply with the state of the art or, failing that, the state of current scientific progress, relates to the conclusion of each specific project phase.

2.3 Standard directives for approval practice

On the basis of § 4 para. 2 SeeAnIV, approvals granted previously for materials regulated here have contained directives specifying the project, some of which can be viewed as standardising practice, even if they are subject to continuous examination in what is currently a dynamic development process. These directives including their justifications are summarised below.

2.3.1 Construction and operation of offshore wind turbines

Number 1

The subjects of the approval are individual offshore wind turbines including ancillary facilities such as cabling within the park and a transformer substation.

Justification:

The provision outlines and defines the type and scope of the subject of the approval in terms of both space and construction.

Number 2

The precise positions of the (individual) offshore wind turbines as well as ancillary facilities shall be specified. Following completion of the installations, the approval authority shall be presented with an as-built drawing containing all construction facilities installed including the final coordinates.

Justification:

The purpose of the directive is to specify the subjects of the approval. It is not possible to present any construction plans at this stage because the method of construction of the installations has not been definitively decided, and therefore cannot be specifically represented either. These documents to be presented, in particular the as-built drawing, shall be considered as the basis for checking this approval following completion of the installations with their measured position, as well as forming the basis for further procedures, and then become the subject of this approval.

Number 3

The design and equipment of the individual installations shall correspond to the state of the art. The same applies to the erection of the installations. The development, design, implementation and inspection shall be conducted in accordance with the „Design of Offshore Wind Turbines“ standard published by the BSH. In addition, construction engineering preparation of the foundation work and subsequent inspection of the system operation shall be in accordance with the BSH standard implemented in the above publication,

namely „Standard for Geotechnical Site and Route Surveys. Minimum Requirements for the Foundation of Offshore Wind Turbines and Power Cable Route Burial Assessments“ [1] in the current version in each case; any deviations shall be applied for to the approval authority and their equivalence shall be justified.

The offshore wind turbine including the structures used for its foundation and the transformer substation as well as cabling within the farm shall be inspected by an expert institution, person or group of persons (certifier/registered inspector) recognised by the BSH on a case-by-case basis. The inspection shall be completed with a confirmation to be presented to the BSH. The confirmation shall contain an expert's declaration that the overall project, a technical system or a component of such has been configured in accordance with the generally recognised rules of technology or, failing that, the current state of scientific progress.

The owner, companies undertaking the construction and installation work as well as authorised certifiers/registered inspectors shall take suitable organisational measures to ensure that the BSH is continuously involved in the inspection process. A project plan including a chart of the milestones and suitable organisational steps for further implementation shall be presented. Construction and/or operating permits may be suspended if information or certificates are not presented in accordance with the regulations of the approval authority.

The necessary certificates shall be presented phase-by-phase in accordance with the progress of the project (see [Table 2](#), page 37).

Planning checked by the certifier/registered inspector including a draft of the system structure (provisional design basis and preliminary draft) shall be presented to the BSH for examination and approval. The design basis and the preliminary draft based on it are regular components of the application documents and, at the same time, form the basis for the environmental impact study as well as for the call for tenders. It shall contain at least the technically feasible variants of the design components that are possible at the site in question, based on qualified investigations and expert opinions.

During the course of the design phase, the design basis and the tested basic design that are updated based on the results of the call for tenders and/or specification of the individual design components shall be presented to the BSH for examination and approval in good time, however at least one year before installation of the systems. These shall contain the documents that are usual for the structures (construction and design drawings, construction phase plan, etc.). At this point, binding data shall be presented for the further cornerstones and milestones in the schedule for the implementation phase.

Following completion of the design phase, the inspected implementation planning is to be presented to the BSH for examination and approval.

Justification:

Compliance with the conditions to maintain the quality standard of the state of the art as well as certification of the systems and components guarantees structural safety of the system. The design and equipment variant that the approval holder intends to install, but which cannot however be determined at this phase, will then be checked by a third expert body to ensure that the normal quality requirements are satisfied. In this way, it will be possible to ensure that the current approval can be effectively issued without detailed construction and design drawings being available. These documents and certificates shall be presented within the named appropriate period in order to allow them to be checked before the systems are installed. Earlier presentation of the documents is not only possible but also desirable in order for additional changes to be made if necessary. The standard site survey [1] contains minimum requirements that include in particular specifications for the geological, geophysical and geotechnical site survey. The standard is currently at the status of 1 August 2003 and is being updated. The current version shall be used in each case. The approval authority shall decide on deviations on a case-by-case basis, and exclusively reserves the right to commission a test report from a classification society (§ 5 para. 2 SeeAnIV) or other suitable experts at the expense of the applicant.

Number 4

In particular, the design and configuration of the structures shall meet the following requirements:

Number 4.1

The structures shall be designed and configured in such a way that

- no avoidable emissions of pollutants, noise and light into the marine environment can occur during installation or operation in accordance with the state of the art or - if such emissions are mandatory under the safety requirements for marine and air transport and are unavoidable - the impairments shall be kept to a minimum
- in the event of collision with a ship, the hull of the ship shall be damaged as little as possible.

Number 4.2

The external paintwork in the area of the turbine and tower shall always take the form of a low-reflectivity light grey, notwithstanding regulations on aviation and shipping identification.

Number 4.3

The corrosion protection shall have the lowest possible level of pollutants. The use of TBT is prohibited. The (underwater) structures shall be provided with oil-repellent coatings in the relevant area (tidal range/ wave height).

Number 4.4

During the positioning (configuration) of the individual installations, care shall be taken to ensure that simultaneous operation of the offshore wind turbines cannot give rise to any harmful interference.

Justification:

The regulations in number 4 serve to avoid both contamination and impairment of the marine environment as well as of the safety of transport in accordance with § 3 para. 1 SeeAnIV. As shown by the formulation on emissions avoidance, it may be difficult to reconcile the requirements imposed in order to protect the natural environment and those for the safety of shipping.

The requirement to provide a design with the greatest hull-retaining properties in the event of a collision between a ship and the offshore wind turbine is intended to meet both objectives defined in § 3 SeeAnIV simultaneously, whereas the safety requirements for shipping and aviation in terms of light emissions represent a limit for essential emissions avoidance during the construction and operation phases.

The requirement in number 4.1 is closely related to the ancillary provision of number 3 and specifies continuous optimisation of the installations in terms of ecological impact in line with ongoing progress in knowledge and technology, to the extent that this is possible and reasonable based on indispensable security measures.

Linking this requirement to the state of the art is intended to ensure that the design and equipment is able to avoid or reduce any effects which cannot currently be foreseen with certainty, but which if they were to occur later would lead to the cancellation or revocation of the approval. In the event that pollution, noise and light emissions cannot be avoided, number 4.1 of the regulation includes minimisation of the incurred impairments in accordance with the precautionary principle. Examples here include the development and use of deterrent measures against animal species that are negatively affected, the use of the best available and most naturally compatible traffic safety beacon (intelligent system) that flexibly adapts the light intensity to visibility conditions, the use of the most environmentally friendly service products and the most comprehensive possible encapsulation of pipes and containers that carry pollutants.

The aforementioned purposes are also served by the specific requirements in numbers 4.2 and 4.3 for configuring corrosion protection and the colour scheme for the systems. The requirement on the colour scheme of the systems is intended to avoid any dazzle effect due to unnecessary reflections on smooth surfaces of the systems. The requirement on using oil-repellent coatings in the area that comes into contact with the sea surface ensures that drifting oil in the area of the project will not adhere to the components which would prevent the oil from being recovered. This is intended to avoid the situation in which adhering oil would be washed out into the water continuously over a lengthy period.

The expected input of sound into the body of water should be named in close connection to this, and the noise level is also subject to an imposed minimum requirement. The requirement in number 4.4 takes account of the possible powerful effect of noise input and its avoidance.

2.3.2 Construction and operation of the power export cable of offshore wind turbines

Number 1

The subject of the approval is the power export cable system in the area of the EEZ for connecting the offshore wind turbines to the power grid, including its planned location and the transfer point at the boundary to sovereign territory.

Number 2

In the engineering measures preparing for cable laying and during subsequent monitoring, compliance with the current version of the BSH standard „Standard for Geotechnical Site and Route Surveys. Minimum Requirements for the Foundation of Offshore Wind Turbines and Power Cable Route Burial Assessments“ [1] is required; any deviations shall be applied for to the approval authority and their equivalence shall be justified. Investigations for the route survey shall be applied for in good time in accordance with § 132 of the Federal Mining Act (BBergG).

Number 3

The documents examined by the certifier/registered inspector containing the specific technical specifications (manufacturer, cable design, substances used, weight per meter cable) of the cable that will be used shall be presented to the BSH for examination and approval. The current version of the BSH standard „Design of Offshore Wind Turbines“ [2] shall be observed during the development, design, implementation and inspection; any deviations shall be applied for to the approval authority and their equivalence shall be justified.

2.4 Additional standard specifications for offshore wind farms

The current version of the aforementioned standard „Standard for Geotechnical Site and Route Surveys. Minimum Requirements for the Foundation of Offshore Wind Turbines and Power Cable Route Burial Assessments“ [1] by the BSH forms part of this code of practice.

Safety and precautionary measures as defined by § 5 para. 2 clause 2 SeeAnIV are defined in a separate regulation. A corresponding standard for a protection and safety concept can be incorporated. The regulations in the „Richtlinie der WSDen und der Fachstelle der WSV für Verkehrstechniken (FVT) für die Gestaltung, Kennzeichnung und Betrieb von Offshore-Windparks“ are unaffected by this.

Generally recognised rules of technology that already exist specifically for certain individual components or systems are listed as basic standard provisions in the corresponding regulation materials. If applicable to offshore wind turbines, the valid German technical regulations take precedence. Omitted regula-

tions can be supplemented from other codes of practice if an expert reliability analysis is undertaken. It is basically not allowed for different codes of practice to be mixed together. The combination or mutual supplementing of different or competing codes of practice, or of individual provisions therein, shall always be subject to an expert reliability analysis and evaluation.

3 Deviations

Deviations from the standards established here are possible providing these are appropriate based on new knowledge in general or with regard to the specific features of the project, or serve the aforementioned protective purposes in at least an equivalent manner; these shall be applied for from the approval authority - in good time - and justified in detail based on their equivalence. The approval authority shall decide on deviations on a case-by-case basis, and exclusively reserves the right to commission a test report from a classification society (§ 5 para. 2 SeeAnIV) or - if legally possible - by an appropriate registered inspector at the expense of the applicant.

4 Updating

This standard represents the current state of the art and of knowledge. New knowledge is gathered, especially during future implementation of projects, and further technical developments are also to be expected, therefore this standard cannot be a static product, but is adapted in line with ongoing developments at appropriate intervals of time.

Part B: Certificates and approval requirements

1 Definitions

The overall mechanical system of an offshore wind turbine consists of the components of the turbine and support structure (Figure 1). The support structure can be further subdivided into the tower and substructure. The foundation elements form part of the substructure.

The turbine consists in detail of the nacelle and the rotor blades.

The components of the overall system of an offshore wind park are listed in [Part A, chapter 2.2](#).

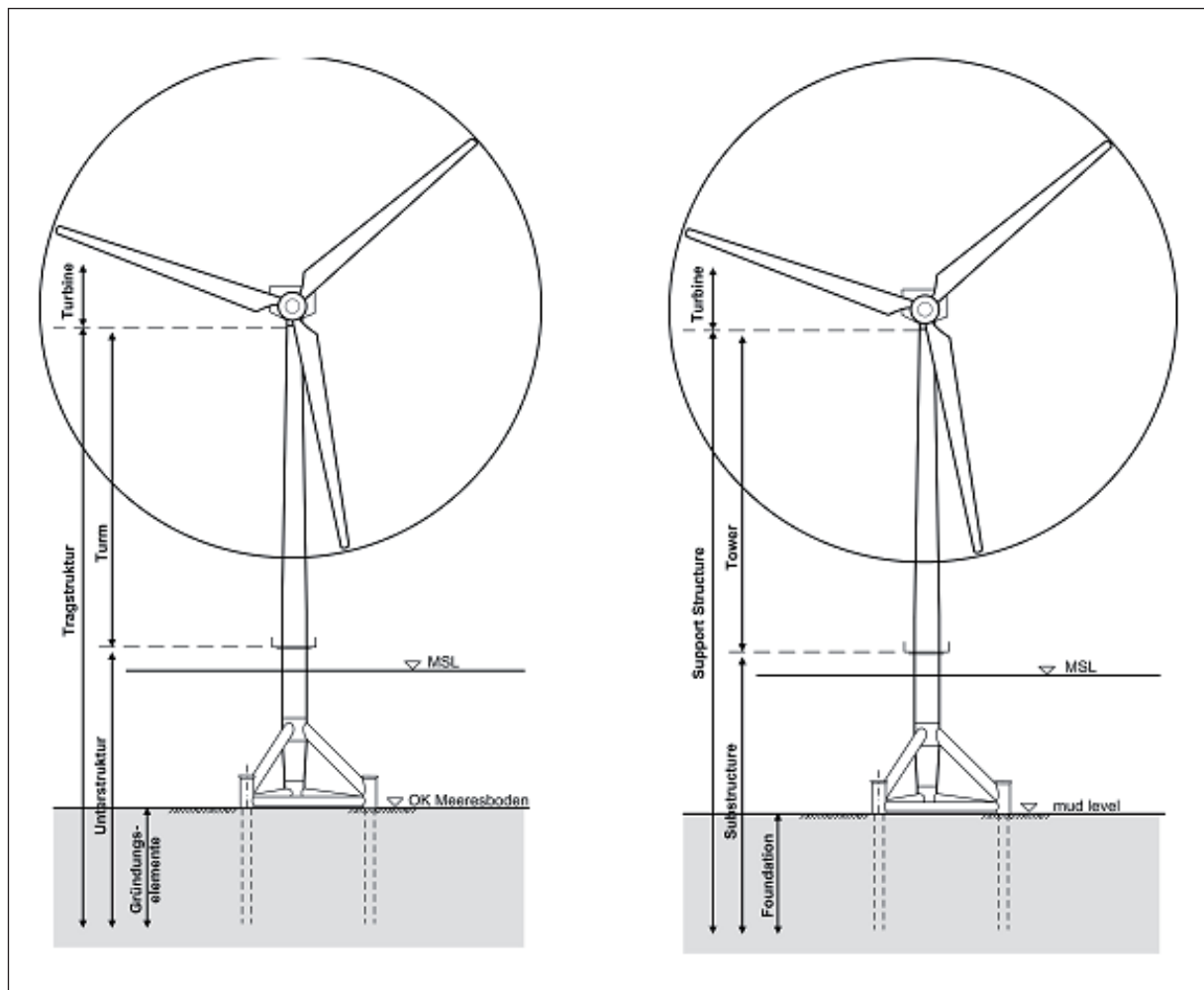


Abb. 1: Components of an offshore wind turbine

2 General

Considering the overall system of an offshore wind turbine formed by the support structure and turbine as well as of the overall system of an offshore wind farm formed by the offshore wind turbines, cabling within the wind farm, submarine cables, transformer substation and any additional elements, evidence should be provided that the already type-certified turbine together with the design of the support structure for the specific site and any of the aforementioned components of the offshore wind park are in accordance with the applicable certification directives. As such, the external conditions of the specific site (soil conditions, wind and wave distribution, tides, ice drift, stability of the electrical grid, wind farm configuration) and special features shall be considered.

Furthermore, independent inspection of the implementation (production, transport, installation and commissioning) shall guarantee that the turbine, support structure, cabling within the farm, submarine cables, transformer substation and any other components of the offshore wind park are in accordance with the certified/tested implementation documents and do not reveal any serious defects or damage.

Periodical inspections shall be made to inspect the status of the offshore wind farm during the operating phase. Periodical inspections are required in order to maintain the operating permit.

In all of the (component) certificates listed below, it is necessary to check whether the certificate or at least parts of it are to be obtained on the overall mechanical system. This is the case, for example, when measuring and checking the natural frequencies of the offshore wind farm.

The test procedure principally includes the following elements and steps:

- 1) Type certificate for the turbine;
- 2) Test of the site conditions including soil properties (site evaluation);
- 3) Test of the site-specific loading assumptions and the support structure (site-specific design evaluation); Test whether the type certificate (1) of the turbine covers all site conditions, otherwise a supplementary test of the turbine;
- 4) Certificate of conformity/test certificate for the site-specific design of the offshore wind turbine following completion of points (1) to (3);
- 5) Test and evaluation of the facilities for inspecting the offshore wind turbines as an overall system (Supervisory Control and Data Acquisition, SCADA, including the Condition Inspection System, CMS);
- 6) Testing and evaluation of sea operations and the decommissioning concept;
- 7) Production inspection;
- 8) Inspection of transport, installation and commissioning;
- 9) Certificate of conformity/test certificate for the inspection services following completion of points (5) to (7);
- 10) Project certificate;
- 11) Periodical inspections for maintaining the test certificate and the operating permit;
- 12) Testing and inspection of the decommissioning and issue of the associated test certificate/certificate of conformity.

As a rule, the type certification is applied for by the manufacturer of offshore wind turbines. Registered inspectors shall be accredited by the BSH on a case-by-case basis. It is highly recommended for registered inspectors to be involved and accredited at an early stage, as well as the information exchange with the certifier/registered inspector to commence as soon as possible.

Definition of the site conditions including the soil situation and of the directives and methods to be used in the design basis (principles for positioning) should be agreed at an early stage with the certifier/registered inspector in order to avoid problems during the subsequent phases of detailed design and evaluation.

A (pre-)evaluation of the assumptions and, if necessary of the specified design, by the certifier/registered inspector is recommended as part of the preparation of tender documents for a bidding process.

3 Site-specific design certificates

3.1 Turbine

As a rule, a type certificate shall be presented for the turbine provided. As an exceptional case, it is also possible to present another appropriate certificate for the turbine to be approved in the case of a pilot system or new development that has not yet had time to be type-certified. The purpose of the type certification as well as the exceptionally allowable other certification is to ensure expert testing and confirmation that the turbine type conforms to the basic standards and/or directives in terms of its design and documentation, and can be produced on this basis. Marine ambient conditions are to be considered in this regard. Offshore operation of the wind farm in accordance with the standard and/or directives shall be demonstrated for the type certification.

This results in the following tasks for the type certification:

- Design evaluation of the turbine type:
 - Loading assumptions
 - Management and safety concept
 - Rotor blades including static or dynamic blade tests
 - Machine
 - Optionally tower (without substructure, however including connection of the tower to the substructure and its properties, if necessary for evaluation of the other components, e.g. rigidity assumptions)
 - Electrical systems and lightning protection
 - Commissioning inspection for one of the first offshore wind turbines of the tested type
- Implementation of the design requirements in production and installation: a one-off production inspection and tour of the production process ensures that the design requirements in terms of production and installation defined in the implementation documents can be achieved in the production company.
- QM system of the manufacturer of offshore wind farms: a valid certificate of quality management in accordance with ISO 9001 shall be presented. If this is not available, the quality management may be tested based on ISO 9001 in consultation with the certifier/registered inspector.
- Prototype measurements
The following measurements/tests shall be performed on one of the first prototypes (e.g. prototype on land):
 - Load
 - Performance curve
 - Grid compatibility
 - Noise
 - System behaviour

3.2 Support structure

3.2.1 Site conditions and design basis

First of all, the site conditions and their transfer to the design basis shall be presented and evaluated by the certifier/registered inspector. The design basis shall be evaluated as early as possible prior to commencement of design considerations or preliminary considerations of the system design.

The following data shall be presented at least:

- Site and configuration of the offshore wind farm with coordinates for all offshore wind turbines, transformer substation and any additional construction components
- Soil attributes:
 - Geotechnical and geophysical programme of investigation
 - Geotechnical report and data of surveys carried out: Evaluation of pressure soundings and drilling trials, derivation of soil parameters for calculations
 - Conformity with the „Standard for Geotechnical Site and Route Surveys“ standard [1] of the BSH; the certifier/registered inspector evaluates whether the presented survey concept meets the BSH standard or, in case of deviations, whether these are sufficiently justified and acceptable
- Wind data;
- Maritime conditions (water depths/levels, wave data, tides, correlation of wind and waves, ice drift, currents, scouring, fouling, etc.)

As a rule, reports by suitable expert bodies shall be prepared for recording the aforementioned data. The certifier/ registered inspector checks the completeness of the reports and evaluates the plausibility of the data.

In order to be able to provide a catalogue of requirements for structural designs that is as complete and reliable as possible, additional data is contained in the design basis in addition to the aforementioned site conditions: These are: definition of the loading conditions used for dimensioning, definition of the standards and directives to be used for structural design, materials, corrosion protection, etc. as well as a description of special certification methods if these are not apparent from standards or directives. These points are also checked and evaluated by the certifier/registered inspector as part of the evaluation of the design basis.

3.2.2 Loading assumptions

Loading conditions relevant for design are to be defined based on the site conditions and the design basis as well as the operation and safety concept of the offshore wind turbines. The scope of the loading condition definitions shall be evaluated by the certifier/registered inspector. It is recommended for the loading conditions to be evaluated by the certifier/registered inspector before the simulation and calculation of loading assumptions starts, in order to avoid duplicating simulations. All loading conditions are to be considered that are necessary in order to demonstrate the structural integrity of the offshore wind turbines. A basic differentiation is drawn between operational stability loads for demonstrating operational stability and extreme loads for demonstrating general stability against collapse (strength, stability, external stability against collapse). The operational stability loads shall represent operation of the offshore wind farm over a service life of at least 20 years. The extreme loads shall include all events that can lead to the greatest possible loads, given consideration for the probability of simultaneous occurrence (e.g. „50-year gust“, „50-year wave“, extreme angle of approach of the rotor, collision with ship (service ship), ice pressure, etc.

The combination of external conditions and system statuses shall be represented and justified for the corresponding project and the site according to (or if necessary based on) the applicable guidelines and standards. The partial safety factors of the effects of the codes of practice used shall be taken into account. The calculation methods, e.g. simulation processes, number of implementations and combination of wind and wave loads, shall be described and any simplifying assumptions shall be justified.

Once the loading condition definitions have been defined and evaluated, load calculations shall be performed with regard to the complete structural dynamics and presented to the certifier/registered inspector for examination. The certifier/registered inspector checks the plausibility of the loading assumptions

and the results based on exemplary calculations. The comparison between parallel calculations and those in the presented load calculations forms a basis for the decision on whether to accept the loading assumptions and to issue the test report for the loading assumptions.

3.2.3 Support structure without foundation elements

Definition:

The term support structure encompasses all constructional components and systems located between the seabed and the turbine (see 3.1). In general, the support structure can be subdivided into the tower and the substructure (see [Figure 1](#)).

3.2.3.1 General

The general material characteristics and strength properties shall be listed with regard to materials (concrete, reinforcing steel, prestressing steel, steel, etc.). Generally approved construction materials shall be used in accordance with the list of regulated construction products. Approval from the BSH is required if non-regulated products are used in an exceptional case (example „grouting“). The BSH may call on the services of appropriate assessors to assess the construction product under consideration for this purpose.

3.2.3.2 Technical codes of practice

Technical codes of practice listed below (not a complete list) shall be used as the basis, taking the current version in each case. When using the structural design codes, the risks deviating from those of normal building structures are allowed to be considered to an appropriate extent. Deviations shall be indicated separately and justified. Final approval of the BSH for deviations is required; the BSH may engage the services of a suitable assessor for this purpose.

Standards and directives governing offshore wind turbines (effects):

- [3] DIN 1055-4: 2005-03,
- [4] IEC 61400-3,
- [5] API RP 2A-LRFD,
- [6] GL Guideline for the Certification of Offshore Wind Turbines.
- [7] DNV-OS-J101.

Structural design codes:

- [8] DIN 18800-1 to -4,
- [9] DIN EN 1993-1 -2:2006-10 (Eurocode 3),
- [10] DIN 1045,
- [11] DIN EN 1992-1 -1:2005-10 (Eurocode 2),
- [12] DIN EN 206-01: 2001 -07.

Remarks:

- With regard to certifying cathodic corrosion protection, refer to the current version of the GL directive „VI Additional Rules and Guidelines, Part 9 - Materials and Welding, Chapter 6 - Guidelines for Corrosion Protection and Coating Systems“ [13] and the DNV directive „Recommended Practice DNV-RP-B401. Cathodic Protection Design“ [14].

- With regard to certifying the fatigue strength of reinforced concrete and reinforced concrete components, refer to the DAST publication 439 „CEB-FIP Model Code 1990“ (Berlin 1994) [15].
- With regard to the structural design of solid structures, refer to the current version of the Offshore Standard DNV-OS-C502 „Offshore concrete structures“ [16].
- With regard to the structural design of grouted joint connections, refer to the DNV publication „Structural Design of Grouted Connection in Offshore Steel Monopile Foundations“ (Global Windpower, 2004) [17] as well as the GL Guideline for the Certification of Offshore Wind Turbines [6], chapter 5.4.4 „Grouted connections“.
- With regard to certificates using the finite element method, refer to the GL Guideline for the Certification of Offshore Wind Turbines [6], chapter 5.A „Strength Analysis with the Finite Element Method“.

3.2.3.3 Required certificates

- Certificates of dynamic properties:
 - Natural frequencies of the overall system comprising turbine, tower and substructure including the foundation elements
 - Testing compliance of natural frequencies in the load simulation with the natural frequencies calculated based on the support structure data
 - Checking of vibration amplitudes and vibration speeds as well as accelerations with regard to the functions of the offshore wind turbine
- Certificates in the ultimate limit state (ULS):
 - Strength certificates
 - Stability certificates
 - Certificates of force applications and connections
- Certificates in the fatigue limit state (FLS):
 - Certificate against fatigue (operational stability)
- Certificates in the serviceability limit state (SLS):
 - Limitation of deformation
 - Limitation of concrete compressive stresses, steel stresses and decompression
 - Limitation of crack widths
- Certificates of durability:
 - Certificate of the corrosion protection concept:
 - Cathodic corrosion protection with sacrificial anodes or by impressed-current systems and coatings
- Certificates in the accidental limit state (ALS) if such are provided.
- Evaluation of hull-retaining properties of the support structure:
 - Estimate of the potential damage to a ship's hull on collision between unmanoeuvrable ships and support structures of the offshore wind turbine
 - Evaluation of the positional security of the components of the offshore wind turbine (nacelle) under short-time effect of collision loads
- Representation of the noise emissions from the support structure, in particular the substructure:
 - Noise emissions during the construction phase and
 - Noise emissions during the operation phase
- Representation of the planned inspection of the support structure by a condition inspection system (CMS) for at least 1/10 of the offshore wind turbines

- Special aspects for certifying steel structures:
 - The stability certificate for circular cylindrical shells is allowed to be obtained in accordance with section 10.1.3 of the „Richtlinie für Windenergieanlagen - Einwirkungen und Standsicherheitsnachweise für Turm und Gründung“ (edition March 2004) [18] by the Deutsches Institut für Bautechnik
 - Certification of the fatigue limit status for driven piles (also for monopiles) shall take account of the damage proportion from the pile driving itself.
 - Certification of grouted joint connections shall be obtained in accordance with the recommendations of GL or DNV using the finite element method (FEM) and, if necessary, confirmed by laboratory tests conducted in an accredited test institute.

3.2.3.4 Structural design

- Specialties of steel fabrications:
 - The special corrosion risks shall be taken into account when using high-grade steel components.
 - The wind turbine (e.g. steel tower) and equipment (secondary steel such as boat landing, platforms and ladders) shall be connected to the lightning protection and earthing system.
 - Driven monopiles shall have a minimum ratio of diameter to wall thickness $D/t = 100$ if at all possible.
- Specialties of solid constructions:
 - Care shall be taken to route lightning protection and earth cables through the concrete structures for dissipation into the soil (e.g. connection to existing reinforcement).
 - The special corrosion risks shall be taken into account when using high-grade steel components.
 - The structural design of reinforced concrete and prestressed concrete reinforcement shall take account of the aspects of minimum and crack reinforcement, rod and edge spacings, concrete covering, bending radii, anchoring and encroachment lengths, anchoring points for the transverse force reinforcement as well as corrosion protection measures in prestressing elements.

3.2.4 Foundation elements

3.2.4.1 Preliminary remarks

Offshore wind turbines are structures with a high degree of difficulty, their foundations are to be classified in geotechnical category 3 (earth and foundation structures as well as geotechnical measures with a high geotechnical risk) in accordance with DIN 1054-2005.01 [19]. They require their foundation design to be conducted by an engineer with numerous safety certificates (stability against collapse and serviceability) on the basis of an individual soil investigation and assessment involving an expert in geotechnology with thorough knowledge and experience in this area.

Quite apart from the uncertainties of the local soil situation, it is also necessary to consider the limited possibilities of deterministic calculation models in geotechnology when drafting the foundation elements of offshore wind turbines.

The achievable „accuracy“ of numerical model calculations including the soil is significantly lower than that of design components due to the implementation of what are, by necessity, highly simplified stress deformation relationships and contact surface conditions. As a rule, therefore, variations of the significant influencing parameters shall be undertaken by means of which their influence on the draft target is limited and which indicate how the overall structure will „behave“ within these limits to a sufficient degree of probability.

This procedure is essential for all certificates

- in which soil deformations are contained as a target or influencing parameter
- in which changes in the soil properties have to be considered
- in which assumptions are made regarding model parameters due to the lack of determinability

To the extent that soil deformations are relevant in terms of the design but cannot be predicted with the necessary level of accuracy, the resulting problems shall be bypassed using suitable design measures if circumstances permit. Otherwise, the observation method is to be used.

3.2.4.2 Safety certificate concept and process, level of stability against collapse

Geotechnical certificates of the structural safety of the soil, the foundation elements and their components shall be obtained for offshore wind turbines in accordance with the following principles:

- The mechanisms of the expected interaction between the soil and the structure shall be represented and considered in the certificates for the foundation elements.
- In all cases, a certification concept with characteristic soil parameters and partial safety factors on the load side and the resistance side (load and resistance factors) shall be used. Deviations are permitted in justified cases, in particular if the interaction between the soil and the structure does not permit definitive separation between load and resistance or if the resistances are directly or indirectly dependent on external effects (e.g. shearing resistances of external loads). In such cases, a comparable level of stability against collapse shall be demonstrated.
- The applicability of the certification process used shall be documented. Violations of the documented application limits shall be evaluated and documented.
- To the extent that recognised certification processes are unavailable and a separate calculation model with calculation processes is designed, the model and the calculation process shall be presented in a way that permits it to be tested and be comprehensively documented. If the calculation results achieved through this method are not without doubt and no major safety reserves in the structure are indicated for the problem being dealt with, then the applicability of the model, the process itself and its assumptions in the application case shall be verified by a suitable measurement and observation programme on the structure. These measurements and observations form a necessary component of the certificate and shall be presented as such together with the certificate; this process corresponds to the „observation method“ in accordance with EC7 [20], its elements shall be implemented in full (see Appendix 3).
- Deviations from the level of stability against collapse in accordance with DIN 1054-2005.01 [19] are basically permitted for considering the special conditions of the offshore situation, any such deviations shall be indicated and justified. Lower deviations from this level of stability against collapse shall require the approval of the BSH, which may engage the services of a suitable assessor for this purpose. If different safety concepts and certification processes are used, equivalence of the safety statement shall be confirmed by an expert.

3.2.4.3 Technical codes of practice

The following technical codes of practice shall be used as the basis, as necessary in the updated version at the time when the design basis is defined:

- [1] „Standard for Geotechnical Site and Route Surveys“
- [20] DIN EN 1997-1:2005-10
- [19] DIN 1054:2005-01

Deviations from these codes of practice are permitted in order to consider the special conditions of offshore wind turbines. They shall be indicated as such and justified. Final approval of the BSH is required for the deviations, and the BSH may engage the services of a suitable assessor for this purpose.

The current versions of the technical codes of practice listed below (the list is not complete) can be used as an additional basis where DIN 1054 [19] does not define any regulations or cannot be used or cannot be used practically due to the special features of offshore foundations in general or offshore wind farms in particular:

- [6] GL Guideline for the Certification of Offshore Wind Turbines
- [7] DNV OS-J-101
- [21] DIBt-RiLi WEA
- [22] API RP 2A-WSD
- [5] API RP 2A-LRFD

3.2.4.4 Material designations and parameters

The material parameters used for the soil types shall in all cases be determined and designated according to the relevant DIN regulations. Deviating or supplementary processes and designations shall be indicated as such and comprehensively documented.

3.2.4.5 Soil model and characteristic soil parameters

- The „Standard for Geotechnical Site and Route Surveys“ [1] of the BSH shall be used in its current version as the minimum requirement for soil surveys.
- For each site of offshore wind turbines, the set of available survey results shall be used for deriving an individual geotechnical soil model for the site that shall be used as the basis of the certificates. For this purpose (at least) one suitable calculation profile (soil profile) shall be specified with the required characteristic soil parameters of its soil layers. If the soil is non-homogenous, it may be necessary to formulate a more complex soil model for each offshore wind farm site with several calculation profiles.
- The characteristic values and their probable bandwidths of all soil characteristics that are relevant for certification shall be defined and specified for the soil model. This data shall be based on the evaluation of a bandwidth of investigation results and on an expert's opinion based on experience, correlation and/or interpretation of direct and indirect information and investigations on the site.
- Design values of the soil parameters shall, if necessary, be derived from the bandwidth of characteristic values with regard to their significance in whichever calculation model is used. Variations in model calculations shall be provided to an appropriate extent.
- Lower and upper limits for the relevant soil parameters shall be varied in an unfavourable combination for the purposes of natural frequency analyses as well as for the load capacity and serviceability certificates.

3.2.4.6 Boundary conditions for certificates

The following boundary conditions for certificates shall be differentiated:

- Ultimate limit state (ULS)
- Fatigue limit state (FLS)
- Serviceability limit state (SLS)
- Accidental limit state (ALS), to the extent given.

3.2.4.7 Required certificates

3.2.4.7.1 Certificate of stability of the seabed

Demonstration shall be given that the soil system on which the certificates for the foundation and load calculations for the support structure are based is stable.

The following items are to be considered in particular:

- Potential reduction in stability of the seabed due to external influences such as current and wave action, influenced by the substructure; effect of earthquake; offshore operations such as pile driving or dredging, etc.
- Potential change in the geometry of the seabed due to influences such as erosion (scouring) and suffosion
- Potential change in the arrangement of foundation elements due to influences such as cyclical creep of the soil, accumulated deformation (hysteresis)
- Potential change in the mechanical properties of the soil due to influences such as pore water pressure accumulation (liquefaction), consolidation, deconsolidation.

It is necessary to demonstrate:

- that either these mechanisms do not occur
- or that these mechanisms have been adequately taken into account in the design
- or that these mechanisms will be adequately observed during installation and operation, and suitable measures will be taken to compensate for them if necessary.

3.2.4.7.2 Certificates for foundation elements

The minimum scope of investigation, documentation and provision of suitable certificates is as follows:

- Process engineering of the installation and effects of the installation process
- Description and modelling of the significant interactions between the soil and the structure as the basis and input parameters
- Demonstrations of the external load capacity of the foundation and its elements
- Demonstrations of the internal load capacity of the foundation elements
- Natural frequency analysis of the offshore wind farm
- The influence of stability properties of the seabed on the stability against collapse and on the serviceability of the foundation, the entire structure and its components
- Effects of cyclical and dynamic loading („degradation“ and „liquefaction“)
- Constraint stress on structural elements and add-on components due to permanent soil deformation
- Safety against shifting of ballast material

Special certificates are to be provided for pile foundations:

- Axial pile load capacity and safety (peak resistance and jacket friction)
- Lateral pile load capacity and safety
- Axial deformation and shifting estimates (settling, inclination and rotation)
- Lateral deformation and shifting estimates
- Pile group effects and interactions between individual foundation elements (e.g. in tripod and jacket structures)

Special certificates are to be provided for heavyweight foundations:

- Soil loading by the normal soil stress and limitation of the open gap
- External stability against collapse (safety against tilting, sliding and bearing capacity failure), if necessary with consideration for potential pore water excess pressure build-up.

Suitable structural design criteria shall be defined for the deformation and shifting certificates based on the potential static and dynamic effects on the components and on the structure (e.g. max. permitted deflection and rotation at the pile head at the level of the seabed and at the pile foot; max. exploitation of the lateral bedding reaction of the soil; minimum or maximum values for soil rigidity).

An expert assessment shall be undertaken into the effects of the following parameters and how they can practically be considered in the certificates:

- Installation of the foundation elements on the soil and foundation system (e.g. piling; driving aids)
- Positional shifts of the foundation elements

- Exceeding manufacturing tolerances
- Deviations in piling depths
- etc.

3.2.4.7.3 Certificates for special forms of foundation

- For special forms (e.g. suction anchors, bucket foundations, etc.), certificates shall be obtained in a similar way to the specified certificates for pile and gravity foundations, in consultation with the BSH. The BSH may engage the services of suitable assessors in this case.

3.3 Certificate of conformity for evaluating the site-specific configuration of offshore wind turbines

Upon presentation of the reports on site conditions, load assumptions and support structure, the certificate of conformity for the offshore wind turbines is normally issued by the certifier/registered inspector. The certificate of conformity is issued upon the completion of the design test.

Preconditions for issue of the certificate of conformity are that the turbine (management and safety system, machine, rotor, electrical engineering) are unchanged compared to the already type-certified offshore wind turbine, that the site-specific loads for the machine do not exceed the permitted loads in the type certification and that marine ambient conditions have already been taken into account in the type certification (climate control, corrosion protection, etc.).

If the site-specific loads are greater than those in the type certification, the load capacity of the components of the offshore wind turbine affected can be demonstrated by stress reserve considerations. If this proves unsuccessful, an adapted design of the components in question is required. The certifier/registered inspector checks the stress reserve considerations and conducts parallel calculations on submission of new evidence.

Additional components or tests, e.g. on-board crane or add-on and built-in components can be included in the design test. This shall be coordinated with the client and the approval authorities at an early stage (see 3.2).

3.4 Submarine cables

3.4.1 General

Cables and their accessories are to be used in accordance with the state of the art, the requirements of the relevant standards (selection see 3.4.2) or which have their suitability demonstrated by comparable tests and are appropriate for the particular application conditions/situations.

3.4.2 Technical codes of practice

3.4.2.1 Cabling within the wind farm

The following technical codes of practice in their current version are to be observed for test requirements and suitability certificates, with alternating current transmission using plastic-insulated power cables (energy distribution cables):

[23] DIN VDE 0276-620 or

[24] IEC 60502-2

- [\[25\]](#) DIN VDE 0278-629-1 or
- [\[26\]](#) IEC 60502-4
- [\[27\]](#) DIN EN 61442 (VDE 0278-442) or
- [\[28\]](#) IEC 61442

3.4.2.2 Connection to the power grid

3.4.2.2.1 Alternating current transmission

The following technical codes of practice in their current version are to be observed for test requirements and suitability certificates, with alternating current transmission using plastic-insulated power cables:

- [\[29\]](#) DIN VDE 0276-632 or HD 632 S1 or
- [\[30\]](#) IEC 60840
- [\[31\]](#) DIN VDE 0276-62067 (in preparation, status September 2006) or
- [\[32\]](#) IEC 62067

If tests on high-voltage submarine cables cannot be performed in accordance with the aforementioned standards, reference is made to the recommendations of CIGRE in their current version, published in the following Electra editions (house magazine of CIGRE):

- CIGRE: Recommendations for Mechanical Tests on Submarine Cables [\[33\]](#)
- CIGRE: Recommendations for Testing of long Submarine Cables with Extruded Insulation for System Voltage above 30 (36) to 150 (170) kV [\[34\]](#)
- CIGRE: Recommendations for Testing long AC Submarine Cables with Extruded Insulation for System Voltage above 30 to 170 kV [\[35\]](#)

3.4.2.2.2 Direct current transmission

The current version of the following CIGRE recommendation can be used for all direct current (DC) cables:

- CIGRE Recommendations for Mechanical Tests on Submarine Cables [\[33\]](#)

The following recommendations of the CIGRE in their current version can be used for plastic-insulated direct current (DC) power cables:

- CIGRE: Testing DC Extruded Cable Systems for Power Transmission up to 250 kV [\[36\]](#)

The following CIGRE recommendation can be used for cables with mass-impregnated paper insulation:

- CIGRE: Recommendations for Tests of Power Transmission DC Cables for a rated voltage up to 800 kV [\[37\]](#).

3.4.3 Environmental influences

3.4.3.1 Electrical fields

Shielded cables do not generate any electric field outside the cable. The limit value of 5 kV/m at 50 Hz in accordance with BImSchV is therefore complied with without restrictions. A certificate according to BImSchV shall be produced if using unshielded cables.

3.4.3.2 Magnetic fields

3.4.3.2.1 Alternating current

With three-conductor cables, the magnetic fields almost cancel one another out. The limit value of 100 μT at 50 Hz required by BlmSchV for areas in which people stay for long periods is thus complied with, without restrictions. The same applies for coaxially operated three-phase single-conductor cables as well as for three-phase single-conductor cables operated in a bipolar arrangement.

When non-stranded cables are used, it is necessary to demonstrate that they have been laid in accordance with BlmSchV.

3.4.3.2.2 Direct current

The magnetic fields almost cancel one another out when bipolar cables are used. The limit value of 400 μT at 0 Hz for areas in which people stay for long periods, as required by BlmSchV, is therefore complied with without restrictions.

When monopolar cables are used, it is necessary to demonstrate that they have been laid in accordance with BlmSchV.

3.4.3.3 Heat loss from power cables

The limit temperature of 2 K suggested from a natural protection perspective applies in the EEZ of the North Sea and Baltic Sea for a reference point depth of 20 cm.

A calculation method shall be used that has its starting point in the time average of the cable losses, and goes on from here to calculate the time average of reference point heating. IEC 60287 can be used as the relevant calculation method for this. To take account of full-load phases of wind farms lasting several days, transient heating is superimposed on this average reference point heating (this transient heating resulting from a jump in cable losses from the time average to their maximum value). This transient temperature curve can be calculated with reference to IEC publication IEC 60853-2 [38]. [39] demonstrates that both calculation methods suggested by IEC for cable technology are equivalent to the significantly more complex FE method for all boundary conditions in question.

When calculating the time average for cable losses, it is necessary to consider the parameters of the connected wind farm, the mean wind speed of the location and the resulting wind farm output. For three-phase cables in addition, this time average is also determined by parameters of the transmission system. For example, the length of the cable route has an influence on the capacitive currents supplied into both cable ends, while the installation of compensation systems has a decisive influence on this as well. A magnitude of 0.7 km/W ([40], [41], [42], [43]) is not exceeded as specific thermal resistance values for water-saturated soils.

3.4.4 Cable laying and construction site safety

There are no (inter)national regulations on cable laying and repair. For this reason, this standard relies on relevant experience. With regard to safety provisions, reference is made to the relevant international and national safety regulations, and in particular to strict compliance with BGV C23 [44] in particular due to the high risk potential for diving work.

The basic precondition for rapid and safe laying of submarine cables is a detailed survey of the planned cable route with regard to the soil properties of the seabed, meteorological and oceanographical conditions in the sea area as well as existing uses along the cable route.

In this regard, reference is made to the current versions of the following technical codes of practice:

- [1] Standard for Geotechnical Site and Route Surveys, in particular section B.6 and
- [45] ICPC recommendations, in particular no. 9

In addition, the following shall be observed:

- The suitable laying process shall be defined in good time on the basis of the aforementioned soil survey:
 - Simultaneous lay & burial (SL & B), i.e. laying and trenching in one working step and/or
 - Post lay burial (PLB), i.e. the cable layer and trencher operate at different times.
- Knowledge of the availability of special equipment is obtained in good time in order to guarantee reliable planning and, consequently, the shortest possible construction times
- Avoidance of cable joints wherever possible. In any event, joints are to be installed with an adequate distance from shipping lanes.

3.4.5 Cable protection

With regard to the protection of the cable and consequently the associated avoidance of cable repairs and construction sites, care shall be taken that the cables:

- are kept away from shipping lanes if possible
- cross shipping lanes with the shortest possible distance with regard to existing offshore installations (e.g. pipelines)
- shall be installed as deep as possible in the seabed with regard to environmental effects
- shall have their route length optimised in order to achieve the shortest possible installation length and therefore a short construction phase
- provided with additional mechanical protection where necessary, e.g. in the case of intersections with other existing cables
- have sufficient armouring

3.5 Additional components of the offshore wind farm

Other central components of the wind park are:

- Wind measuring mast
- Transformer substation
- Service and accommodation platforms
- Lifting gear, cranes and add-on components

The aforementioned procedure for project certification/testing shall be applied accordingly for this purpose. Certification can take place on the basis of GL guidelines for offshore structures, DNV standards or other directives (see [Appendix 2](#)).

4 Configuration, operation and decommissioning

4.1 General

All of the equipment used for offshore work shall comply with the regulations and standards of German and European standards with regard to safety, environmental compatibility and load capacity. The equipment shall be in good condition at all times. Repairs are only allowed to be performed by suitable

and certified companies. Cranes, lifting gear and tackle, including all cables, hooks, etc. shall be maintained in accordance with the regulations for safe handling. Approval by the BSH is required before equipment, processes or materials can be used that do not correspond to a recognised standard. In this case, the BSH may call on the services of appropriate assessors for assessing the procedures. The installation processes shall be selected so the work can be interrupted when necessary without endangering personnel or the equipment. Personnel are to be provided with personal protective equipment in accordance with the regulations, and which shall be worn accordingly during the work.

The installers and entities involved in the installation shall draw up an installation manual. The objective of this installation manual is to provide a clear presentation of procedures together with the general technical conditions. The presentation should describe the phases with sufficient detail so as to enable feasibility and logistics to be checked. The installation manual shall be updated and includes the following phases, amongst others:

- Implementation
- Operation
- Decommissioning

Special general conditions during installation work are documented in the installation manual. These include, amongst other items, unusual external conditions such as a heavy swell, strong winds, extreme times, ice drift, hail, lightning, earthquake.

If a helicopter link is required for connecting the construction site to the mainland, landing platforms shall be provided for this with regard to the distance from the mainland, fire protection, marking, etc. and in accordance with the relevant national and international regulations.

4.2 Technical codes of practice

In all cases, the following technical codes of practice are to be applied, amongst others, in their relevant current versions as well as the generally accepted state of the art:

- [46] prEN ISO/19901-6, after implementation,
- [47] DNV Marine Operations
- [48] GL Rules and Guidelines IV
- [5] API RP 2A-LRFD
- [6] GL Guideline for the Certification of Offshore Wind Turbines

4.3 Approvals from the responsible authorities

The required consultations shall be undertaken with the relevant authorities for all steps in implementation, operation and decommissioning or - as necessary - presented for approval.

4.4 Required certificates for the implementation phase

Detailed implementation planning is to be drawn up. Checklists and operation manuals for all planned activities shall be prepared and updated. Records shall be kept of the implementation (diary). The specified documents shall be permanently available at suitable locations (at least one at the site management offshore and another at the land base) where they can be viewed. The situation report shall be prepared after completion of the work and documents the actual situation on the soil. These documents form part of the installation manual.

During installation, the logistics of all significant components and assemblies shall be presented and certified from the production location to the installation site in order to exclude dangers to personnel and risks to equipment and the environment.

- **Planning documents**
The manufacturer of the components shall provide complete drawings, specifications and instructions for the installation procedure as well as installation and erection of the wind turbine. The manufacturer shall supply details of all loads and weights with data on the centre of gravity, lashing points, special tools and processes necessary for lashing and installing the components.
- **Takeover of the components**
Components shall be moved and stored during installation and transport in accordance with the manufacturer's instructions. Components shall be secured where there is a risk of movement and damage by wind, swell, etc.
- **Climatic conditions**
The climatic limits specified by the manufacturer shall be observed and maintained during installation. The following points shall be taken into account, amongst others:
 - Swell (wave heights),
 - Tides
 - Wind speeds
 - Visibility
 - Temperature
 - Rain
 - Lightning
 - Snow and ice
- **Certification of the transport and installation concept**
The manufacturer of the structures shall be adequately described and it shall be possible to test it with regard to feasibility of undertaking it at sea. Any danger to public safety and shipping shall be excluded.

Certifications of the significant construction phases for transport and installation in order to undertake the planned project shall be described adequately with the following sub-items, amongst others:

- Construction phase plan
 - Ancillary equipment and resources
 - Arrangement of marine vessels, buoys, lights, etc.
 - Lifting, lowering, unloading and ballasting procedures
 - Inspection of the seabed condition
 - Necessary static and dynamic certificates for performing the lifting and installation procedures
 - Regulation of responsibilities and communication priorities in all important transport and installation procedures and
 - Certification of the equipment involved such as cranes and derrick barges
- **Towing procedures and installation**
The following certificates, amongst others, shall be provided for towing and transport procedures as well as installation:
 - Buoyancy of the construction, which shall take account of not only vertical and horizontal movement but also the transition from floating condition
 - adequate buoyant force and sufficient distance from the base of the body of water, as well as
 - certification of sufficient bollard pulling force.
 - **Access to the installation site**
The installation site as well as all routes leading to it shall be secured. The following points shall be taken into account, amongst others:
 - Load capacity of the equipment
 - Access ways to the installation site

- Temporary closures and restrictions
- Prohibited areas and protection zones
- Shipping and aviation
- Installation procedure at the installation site and
- Access system to the structures

- Certificate for floating equipment
All significant floating equipment involved in the operations shall be certified/approved for operation. This can be in the form of a class approval or a special permit.

- Certification for crane and lifting equipment
Lifting equipment and facilities including all crossbeams, lashing cables, hooks and other ancillaries required for installation shall be of sufficient size and tested. Instructions and documents relating to installation and handling shall be provided by the manufacturer. All lifting equipment, cables and hooks shall be checked and confirmed for the permitted load. All floating units within a class shall be covered by a crane manual that is updated in accordance with the regulations.

- Certification for transport and installation materials
Certification of the transport and installation materials includes the precise specification of the identification features required for the product as well as transfer and positioning. These include, amongst other items:
 - Designation of the structure and assignment to the installation location
 - Manufacturer, supplier, importer
 - Designation, type
 - External dimensions of all types
 - Water depth at the installation site
 - Rated power, rotor diameter, hub height
 - Requirements for sea transport and installation
 - Designation and dimensions of all significant components with the information required for installation
 - Lashing points, lashing devices

- Procedural instructions
The instructions issued by the manufacturer for safe installation or erection shall be followed. The following points shall be taken into account, amongst others:
 - Special tools
 - Tensioning devices
 - Attachments and lifting gear
 - Transport protection devices
 - Lubrication and service instructions

- Inspection/certification of weather conditions
Weather conditions and forecasts shall be monitored regularly, in particular before major work or work which will continue uninterrupted for long periods. At least two independent weather services shall be involved.

- Certifications of product quality
The components and accessories shall be specified in accordance with the manufacturer's data. The quality shall be demonstrated by checking the supplied products and the manufacturing procedures for the products in accordance with the specifications, and includes at least the following points:
 - Material certificates
 - Delivery notes
 - Correct installation conditions
 - Lifting devices
 - Cable and bending roller diameters

- Risk assessment for the significant working phases
The risk assessment is used for estimating dangers during work phases and for preparing options for preventing danger. These include, amongst other items:
 - Analysis of possible risks and presentation of their effect on the concept
 - Presentation of dangerous situations that could occur due to deviations from the planned working procedure
 - Emergency and recovery procedures
- Required status certificates
The status report following completion of installation work or for major interruptions describes the individual changes above and below the seabed, and their composition based on layer and height. The data shall be kept continuously up-to-date in the installation manual. This serves the purpose of predictive risk observation and the decommissioning requirement.

4.5 Operation

Structures at sea shall be maintained. Detailed planning shall be drawn up and kept updated for this purpose. Changes to the situation shall be documented after completion of the work. These documents form part of the installation manual.

During maintenance in operation, all significant components and assemblies shall be presented and certified from the production location to the installation site in order to exclude dangers to personnel and risks to equipment and the environment. This is done in the same way as the necessary certificates during the implementation phase.

4.6 Decommissioning

Following final cessation of use, offshore structures shall be removed. Detailed planning shall be drawn up for this in good time prior to the start of decommissioning. Changes shall be documented and become part of the installation manual.

During the decommissioning, all significant components and assemblies shall be certified from the decommissioning site to the place of their ecologically sound disposal in order to exclude dangers to personnel and risks to equipment and the environment. The certificates are provided in the same way as the necessary certificates during the implementation phase.

5 Other approval requirements

Additional appraisals are required in addition to the inspections stipulated in the previous chapters, in particular:

- Evaluation of the protection and safety concept for the wind farm (safety of shipping, identification, illumination, emergency plans, etc.) according to the BSH standard „Schutz- und Sicherheitskonzept“ (in preparation)
- Safety of personnel (e.g. for helicopter landing decks and airdrop platforms, manned transformer substation, boat landing stages, ladders and stairways, etc.),
- Noise emissions
- Use of substances that may have a polluting effect in water
- Possible pollutant discharge

These assessments are not dealt with in this „Design of Offshore Wind Farms“ standard.

6 Inspection services

6.1 Preliminary remarks

Inspection services are provided by experts of the certifier/registered inspector or, if necessary, by other experts recognised by the BSH, and are used to ensure that the design requirements derived from the design documents have been implemented and complied with, as well as compliance with the basic standards and directives governing production, transport, installation, commissioning and operation. A plan for the extent of production inspection shall be worked out in consultation with the certifier/test expert. This planning shall define which components require inspection, which random sample level is to be selected and how to proceed if the inspection result is unsatisfactory.

In detail, the relevant applicable standards and directives shall be taken into account.

The following sections 6.2 to 6.4 focus on structural safety. Safety of personnel, lifting gear, cranes, transformer platforms, cable laying and add-ons shall be considered separately.

6.2 Production inspection

The following considerations on production inspection principally apply to welded structures; however, they shall be applied accordingly to components produced by other means.

Prior to the start of production or work on site, the following documents shall be presented for viewing and inspection by the certifier/registered inspector:

General

- Valid QM certificate according to ISO 9001
- Quality management:: QM handbook, QM procedural and working instructions

Steel fabrication

- Operating permit for the welding company, welding suitability certificate of the welding company according to DIN 18800 Teil 7 [\[49\]](#).
- Qualification certificates of the welding personnel (welder test, e.g. EN 287 [\[50\]](#) or ISO 9606 [\[51\]](#)),
- Qualification certificate of the welding supervisory personnel (SFI or SFM)
- Qualification certificate of the personnel and provision of the necessary equipment for non-destructive testing
- Welding process tests (Welding Procedure Quality Requirements, WPQR)
- Certificates for welding fillers
- Welding instructions (Welding Procedure Specifications, WPS) and
- Implementation drawings as provided

Concrete construction

- Suitability test of the concrete provided
- Provision of external inspection for inspection classes 2 and 3
- Implementation drawings as provided (implementation drawings shall be checked for conformity with the implementation documents presented for the design test)

Implementation drawings and welding instructions shall be checked for conformity with the implementation documents presented for the design test (drawings and provisional welding procedure specifications (pWPS)).

The following checks are to be performed as part of regular inspection by the certifier/registered inspector during production in the welding company/on site/in the prefabricated concrete plant:

Steel fabrication

- Inspection of the material certificates according to DIN EN10204 3.2 [52] of the steel manufacturer
- Inspection of the non-destructive testing reports
- Inspection of the production process and undertaking of non-destructive testing
- Final check on finished components:
- Checking dimensions and tolerances
- Checking coat thicknesses of the corrosion protection
- Checking the general condition
- Checking for damage
- Checking the audibility and traceability of components and the materials/semi-finished parts used
- Checking of other quality records and goods outgoing check

Concrete construction

- Checking the concrete delivery notes
- Checking the strength samples (sample cubes)
- Checking the external inspection reports according to DIN 1045-3 [53],
- Checking the reinforcement
- Checking the concrete cover
- Checking the dimensions of the structure
- Checking the prefabricated components
- Checking other quality records

6.3 Transport- and installation inspection

The certifier/test expert shall conduct the following inspection procedures for offshore wind farms and support structures during transport and installation:

- Inspection of loading and lashing for sea transport
- Inspection of compliance with weather conditions for sea transport
- Inspection of installation of the support structure including lifting work
- Inspection of installation of the machine and rotor blades

This involves checking:

- Correct undertaking of loading, lashing, transport and installation in accordance with the implementation documents
- Checking for damage
- Checking for corrosion or damage to the corrosion protection
- Traceability and numbering of the components
- General appearance of the components after installation
- Reports by the companies undertaking the work which document the testing that is performed under their own responsibility

6.4 Commissioning inspection

Commissioning takes place after installation and grid connection. The following checks are performed as part of inspection of commissioning:

- Conformity of the main components with the certified/checked design documents and traceability/numbering of the same
- General appearance

- Functional tests and test of the safety system
- Corrosion protection
- Check for damage

A test report shall be prepared after completion of the commissioning inspection¹⁾.

6.5 Periodical inspections

6.5.1 General

The entire system (turbine and support structure) shall be inspected in detail as part of the periodical inspections. A specific checklist for the facility and site shall be prepared for the test on the basis of the technical documents, and shall also contain the evaluation criteria. The intervals for recurrent tests shall be defined. Periodical inspections shall be performed annually on 25% of the offshore wind farms of an offshore wind farm, so that all offshore wind turbines will have been inspected after each block of four years. Central structures such as the transformer substation shall be inspected annually, whilst deviation from the annual inspection is permitted for other individual structures. The inspection shall be performed by suitable experts.

6.5.2 Evaluation criteria for the periodical inspections

The evaluation criteria for periodical inspections shall be defined with regard to the structure and site.

6.5.3 Documents of the offshore wind turbines to be tested

The following documents at least shall be inspected as part of the periodical inspections:

- Test reports or certification reports with all appendices and supplements
- Construction approval
- Operating permit
- Operating instructions
- Commissioning report
- Filled-in technical maintenance specifications for the offshore wind farm including the support structure and scour protection (maintenance logs)
- Reports on previous recurrent tests or condition inspections
- Certificate of the oil quality
- Documentation of modifications/repairs made to the installation and, if necessary, approvals

6.5.4 Scope of the periodical inspections

A visual inspection of the installation shall be performed involving inspection of the individual installation components including the rotor blade and the underwater structure as well as the scour protection from immediate proximity, the underwater structure shall be inspected by divers or with a camera mounted on a remotely operated vehicle (ROV). The points to be inspected shall be cleaned or exposed as required.

1) Note: Commissioning inspection is important not just from the perspective of reliability and safety of the offshore wind turbine. Following commissioning, the standard procedure is for ownership and responsibility to be transferred from the manufacturer to the operator/owner. Checking the condition of the system provides a certificate from an independent body stating that the offshore wind turbine is in correct condition.

At the same time, the stability of the installation against collapse, including the machine, and the function of both the safety system and the brake systems shall be tested. The items covered by periodical inspections are specified in Table 1.

Assembly	Test item
Rotor blade	Damage to the surface, cracks, structural inconsistencies of the blade body (inspection from a lifting platform or climbing device: Visual assessment and inspection of the structure using suitable processes (e.g. knocking, ultrasound)). Tightening torque of screw connections. Damage to the lightning protection equipment.
Driveline	Leaks, unusual noises, condition of the corrosion protection, lubrication condition, tightening torque of screw connections. Condition of the gear unit (oil sample if necessary).
Nacelle and components that carry force and torque	Corrosion, cracks, unusual noises, lubrication condition, tightening torque of screw connections.
Hydraulic system, pneumatic system	Damage, leaks, corrosion, function.
Support structure (tower, underwater structure, foundation)	Corrosion, cracks, tightening torques of screw connections, unacceptable scouring, position.
Safety equipment, measuring sensors and brake systems	Function checks, compliance with limit values, damage, wear.
System control and electrotechnical components including transformer, station and switchgear	Connections, attachment, function, corrosion, contamination.
Documents	Completeness, compliance with regulations, implementation, test documents, regular undertaking of maintenance, undertaking of any modifications/repairs according to authorisation.

Table 1: Recurrent test items

Part C: Time sequence

1 General

The time sequence of a project generally extends through the following sections (see Table 2):

- Development phase
- Design phase
- Implementation phase (production, transport, installation, commissioning)
- Operating phase
- Decommissioning phase

The required documents shall be presented to the approval authority for inspection and approval in good time during the individual project phases (see Table 2). Furthermore, the body responsible for the project shall ensure that the approval authority is continuously included in the project phases.

Prior to the issue of an approval, it is necessary to conduct a preliminary survey of the site in order to record all site conditions relevant for the design, this forming the starting point for a design basis and a preliminary study. The purpose is to establish whether the site meets the technical criteria for installation and operation of an offshore wind park.

The design basis that also has to be prepared and presented at regular intervals in the approval process during the development phase generally contains the initial technical requirements. This contains all data and figures required for the particular element of the offshore wind park at its relevant site as well as certification methods that are required for drafting a stable and serviceable construction in accordance with the generally recognised state of the art or, failing that, the state of current scientific progress. It is based on qualified investigations and expert reports. The design basis as well as the preliminary draft prepared from it form part of the application documents that are used as the basis for assessing the approval preconditions within the scope of the decision on whether the project may be approved.

A certifier/registered inspector performs a plausibility check of the design basis and a preliminary draft based on it. This involves the certifier/registered inspector testing both the plausibility of the site conditions and their data sources as well as the plausibility of the preliminary draft and the methodology used. The test report shall be presented to the approval authority.

2 Development phase

The site data shall be assembled based on qualified reports in order to ascertain the design basis and the basic design, this site data including for example:

- Meteorological and oceanographical reports (wind, waves, currents, bathymetry, etc.)
- Geotechnical report
- Other reports, e.g. on icing, scouring, etc.

The correlation between individual site conditions shall be presented, in particular the correlation of wind and waves. The survey concept for preparing the geotechnical report shall be agreed with the certifier/registered inspector and the approval authority on the basis of the „Standard Baugrunderkundung“ [1] of the BSH in its current version before the start of the survey. Deviations from the „Standard Baugrunderkundung“ [1] shall be applied for to the BSH, presenting their equivalence, and justified.

The „collision friendliness“ (see Appendix 1) shall be documented in a report for the draft of the support structure prepared on the basis of the site conditions, and included in the design basis and the preliminary draft.

The major configuration parameters as well as the configuration standards and directives to be applied shall be named in the design basis.

The object of certification/testing of the design basis and the basic design is to ensure reliable site and configuration conditions so as to minimise potential errors in the subsequent detail design at an early stage. In doing so, it is necessary to ensure that the particular offshore wind turbine or offshore wind farm is considered as an overall system. The certifier/registered inspector shall conduct an in-depth plausibility check of all site conditions and their correlations for this purpose, and shall evaluate all relevant configuration conditions.

3 Design phase

Detailed evidence, design diagrams and specifications shall be prepared in the design phase. This applies to support structures, the transformer substation with grid connection, measuring mast and any additional components of the offshore wind farm. As a rule, the turbine has a type certification, therefore certification that it is suitable for use at the site is sufficient. The design phase is accompanied by the site-specific design evaluation.

At least 1 year before the start of installation of the systems, the certified/reviewed design documents shall be presented to the BSH in the form of the design basis and the basic design. Successful completion of evaluating the design documents shall be documented by the certifier/registered inspector with a certificate of conformity as well as associated test reports.

Following presentation of the certificate of conformity for the design evaluation and after a concluding test, the BSH shall issue the approval for installation, if necessary with the assistance of a recognised expert institution, person or group of persons.

4 Implementation phase

Production, transport, installation and commissioning shall be followed by the certifier/registered inspector through independent inspections. Prior to the commencement of production, the qualification of the production companies shall be checked, and an inspection plan agreed by the project designer, manufacturers and certifier/registered inspector. The agreed inspection plan shall be sent to the BSH prior to the start of production.

The certifier/registered inspector shall immediately inform the client and the BSH if serious deviations from the requirements specified in the checked and approved design documents become apparent during production, transport and installation.

Completion of production, transport, installation and commissioning shall be documented with corresponding certificates of conformity that group together all issued inspection reports. Following presentation of the certificates of conformity for production, transport, installation and commissioning and, if necessary, a concluding test, the BSH shall issue the approval for operating the offshore wind farm, with the assistance of a recognised expert institution, person or group of persons.

5 Operating phase

Annual periodical inspections shall be performed during the operating phase. The certifier/registered inspector shall issue inspection reports on the inspected systems. The certificate of conformity for the periodical inspection shall be issued if the inspected systems are operated in accordance with the standards on which they are based and are maintained in accordance with the certified/reviewed maintenance plan. This groups together the results of the individual inspection reports.

6 Decommissioning phase

A decommissioning plan shall be drawn up in good time prior to completion of the operating phase and applied for to the BSH. This plan shall be based on the decommissioning concept that was checked as part of the design evaluation.

In the event that statutory requirements or the state of the art have changed between the design phase and the end of the operating phase, appropriate adaptations to the current state of the art shall be included in the preparation of the decommissioning plan.

The decommissioning plan agreed with the certifier/registered inspector shall be presented to the BSH, which reserves the right to have it checked by an independent assessor. The decommissioning shall be inspected by the certifier/registered inspector. The certifier/registered inspector shall issue regular inspection reports during the decommissioning phase. Successful completion of the decommissioning phase shall be documented with a corresponding certificate of conformity grouping together the individual inspection reports, which shall be presented to the BSH. The decommissioning phase terminates with a declaration from the BSH that the measure has been completed.

Table 2: Schematic representation of the time sequence for realisation of an offshore wind farm project

Phase	Measure	Responsible for the project	Certifier/ registered inspector	Approval authority
Development	Clarification of details for the site	Geotechnical survey in accordance with the BSH standard in its current version, ascertaining meteorological and oceanographical parameters	Test report and certificate of conformity for the design basis	Inspection by the BSH * 1st release
	Planning with preliminary draft of the installation structure	Ascertaining the effects depending on the planned offshore wind turbine, preparation of the design basis and the preliminary draft	Opinion on the preliminary draft	
	Call for tenders	Compilation of the call for tenders documents and evaluation		
Design	Basic design	Calculation of definitive effects depending on the selected system, definition of the necessary certifications including procedure, basic design and associated calculations	Test reports and certificate of conformity for the basic design	Inspection by the BSH * 2nd release (at least 1 year before installation of the systems)
	Implementation planning	Undertaking of detailed calculations, preparation of implementation documents (drawings, specifications, etc.), preparation of a logistics and decommissioning concept	Test reports for loading assumptions, support structure, submarine cables, transformer substation, measuring mast, logistics and decommissioning concept, etc. Certificate of conformity for the site-specific design evaluation	Inspection by the BSH * 3rd release
Implementation	Production	Manufacture of all components of the offshore wind farm on land	Inspection reports and certificate of conformity for production monitoring	Inspection by the BSH * operations release (with constraints if necessary)
	Transport	Land and sea transport from the production site to the planned installation site	Inspection reports and certificate of conformity for transport monitoring	
	Installation	Erection and installation of all elements of the offshore wind farm **	Inspection reports for erection and installation monitoring	
	Commissioning	Commissioning of all elements of the offshore wind farm Application for operating permit	Inspection reports for commissioning monitoring Certificate of conformity for the installation and commissioning monitoring Project certificate	
Operation	Operation, maintenance and monitoring	Management of maintenance and repair, logs, reports and evaluations, with any necessary measures	Recurrent tests, inspection reports and certificates of conformity	Inspection by the BSH * upholding or temporary withdrawal of the operating permit
Decommissioning	Decommissioning planning	In good time before completion of the operating phase, undertaking calculations, preparing the implementation documents for the selected decommissioning, updating the decommissioning concepts	Test report for the decommissioning plan	Inspection by the BSH * approval (possibly with constraints)
	Undertaking the decommissioning	Implementation of the planned measure with detailed checking and monitoring to accompany the decommissioning	Inspection reports and certificate of conformity for the decommissioning	Inspection by the BSH * declaration of completion of the measure by the BSH

* Inspection by the BSH, if necessary with the involvement of a specifically engaged assessor,

** i.e. offshore wind turbine, cabling within the wind farm, submarine cables, transformer substation and other elements

Hull-retaining configuration of the substructure

The following evaluations are required:

- Hull-retaining behaviour of the substructure
Evaluation of the hull-retaining behaviour of the substructure shall be provided as part of a risk analysis. The method of the risk analysis is described in [54], for example. The method should be based on the Hazardous Incident Ordinance (Störfallverordnung), the British Safety Case Regulations for offshore installations [55] and the IMO regulations.
- Quantitative risk analysis.

The quantitative risk analysis evaluates the dangers according to their probability of occurrence and the extent of the damage that could be occasioned by this danger. The following or equivalent safety analytical methods should be used:

- 1) Hazard analysis.
Possible danger statuses are identified and their consequences and effects ascertained and evaluated based on a failure effect analysis.
- 2) The ascertained danger statuses are compared to the probabilities of occurrence. This is used for preparing a risk matrix linking the categorised occurrence frequencies with categorised consequences (Table 3). A combination of probability and consequence is evaluated. Permitted areas are shown here in light grey and encompass numbers 1 - 3.

Catastrophic	4	5	6	7
Serious	3	4	5	6
Considerable	2	3	4	5
Not significant	1	2	3	4
Frequency of occurrence of the consequence	Extremely rare	Rare	Occasional	Frequent

Table 3: Risk matrix with risk priority numbers

Quantitative correspondences between frequencies of occurrence and their consequences are defined in Tables 4 and 5.

qualitativ [1/a]	Offshore Wind Turbine / Ship	Environment	Safety
Frequent	$H > 10^{-1}$	$H > 2 \cdot 10^{-1}$	$H > 10^{-1}$
Occasional	$10^{-1} \geq H > 10^{-2}$	$2 \cdot 10^{-1} \geq H > 2 \cdot 10^{-2}$	$10^{-1} \geq H > 10^{-2}$
Rare	$10^{-2} \geq H > 10^{-3}$	$2 \cdot 10^{-2} \geq H > 2 \cdot 10^{-3}$	$10^{-2} \geq H > 10^{-3}$
Extremely rare	$10^{-3} \geq H$	$2 \cdot 10^{-3} \geq H$	$10^{-3} \geq H$

Table 4: Frequency of occurrence: Number of cases per year

Qualitative	Offshore Wind Turbine / Ship	Environment	Safety
Not significant	Offshore wind turbine can continue to be operated (if necessary following extensive repair)	No or minor environmental pollution	No injuries
Considerable	Offshore wind turbine defective	Considerable environmental pollution: Service products from side tanks*/ double floors flow into the water (double hull and double floors not fully penetrated)	Few injuries
Serious	Offshore wind turbine destroyed	Major environmental pollution: Loading tanks leaking, leakage of content (double hull/floor fully penetrated)	Serious injuries, small number of fatalities
Catastrophic	Nacelle or large parts of the nacelle crash down on the vessel	Ship breaks apart/ sinks	Large number of fatalities

* Normally, ballast water is carried in the side tanks

Table 5: Consequences

- 3) Determining the frequency of occurrence of various scenarios:
The probability of occurrence of the scenarios identified in step 2 should be determined using error tree analyses and model calculations.
- 4) Collision calculation:
The mechanical estimation of collision safety (consequence analysis) can be calculated using suitable simulation programmes. These include FE programmes with an explicit solution algorithm for dynamic questions, e.g. LS-Dyna, MSC.Dytran, Abaqus Explicit, Pam Crash to name only a few. Furthermore, processes have been developed for evaluating the collision safety of offshore platforms that are based on yield hinge theory. These are implemented, for example, in the USFOS calculation programme. The selection of calculation method is left to discretion. Proof of applicability is to be provided.

In connection with a risk analysis, it should be demonstrated that there will be no major environmental pollution incidents because

- a) either the entire collision energy can be absorbed by the ship and the offshore wind farm structure or
- b) the offshore wind farm fails during the collision procedure without ripping open the ship's hull.

The following general conditions shall to be met:

- 1) When using a simulation, the offshore wind turbine is to be idealised in a suitable way for a contact problem (shell elements when using FE method).
- 2) The offshore wind turbine structure is to be represented at least up to the deck height of the ship plus 5 m, as shown in point (1). The masses and the inertias of the parts further above (tower, nacelle, rotor, etc.) shall also be considered.

- 3) The bedding conditions shall be applied to the foundation elements at least as elastic springs (dynamic bedding module). Clamping at the level of the top edge of the uppermost weight-bearing ground layer is permitted as an alternative, because it leads to an increase in the overall rigidity of the offshore wind farm and therefore to conservative results.
- 4) Grouting may be considered as a rigid connection or a linear-elastic material.
- 5) The calculations should be performed with the model of an accident assessment ship. It is possible to use a single-hulled tanker with 160,000 tdw. If it is possible to establish that a ship type of this size cannot reach the wind farm (e.g. due to inadequate water depth) then a different ship can be found as the accident assessment ship and used. Data on shipping movements is required for this. This shall be provided by the BSH.
- 6) The calculation shall assume a ship drifting sideways at 2 m/s. At the moment of collision, the ship does not have its own propulsion, longitudinal speed is 0 m/s.

If a simplified process (yield hinge method, etc.) is used, the energy absorbed from the ship's structure shall be used for calculating the degree of damage to the ship and therefore the (environmental) threat.

The calculated damage scenarios shall be incorporated in the risk analysis. The damage shall be evaluated according to [\[56\]](#) (see chapters 6 and 8) of the relevant regulations issued by GL, DNV, IMO, etc.

If the substructure has been demonstrated as „collision friendly“ at another point, it is possible to make reference to this fact providing assurance is given that the general conditions used there are of an equivalent or greater degree of severity to those of the structure requiring certification or of these requirements.

Technical codes of practice and literature

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- [24] IEC 60502-2: Power cables with extruded insulation and their accessories for rated voltages from 1 kV ($U_m = 1,2$ kV) up to 30 kV ($U_m = 36$ kV) - Part 2: Cables for rated voltages from 6 kV ($U_m = 7,2$ kV) up to 30 kV ($U_m = 36$ kV).
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At present, no further codes of practice and standards have been named. Following evaluations of the initial experience with this standard, additional codes of practice and bibliographical references shall be included in this list as part of the process of updating this standard.

Use of the observation method according to EC 7 and DIN 1054

The observation method in accordance with EC 7 is provided in DIN 1054 [18] as a method for certifying stability against collapse. It is a combination of the normal investigations and certifications (forecasts) with ongoing measuring checks of the structure, in which critical situations are controlled by using suitable prepared technical measures. This method represents the recognised state of the art for structures whose foundation design is not based on secure engineering experience. The observation period for offshore wind turbines shall be extended to the operating phase. Boundary conditions that can neither be calculated with sufficient accuracy nor recognised in good time through observation shall be avoided by conducting work on the safe side and through design measures. Where possible, computer forecasts shall be supplemented by experience in comparable construction measures. The following preparations shall be made prior to the start of construction in order to use the observation method:

- The limits of structural and ground behaviour to be maintained shall be defined.
- The area in which the structural behaviour will probably take place shall be ascertained based on existing survey results.
- It shall be demonstrated that the structural behaviour shall stay within the limits to be maintained, with an adequate degree of probability.
- A measuring programme shall be prepared using significant parameters to check whether the actual structural behaviour is within the limits that are to be maintained.
- A plan of suitable countermeasures shall be developed for every possible eventuality in which measurements indicate that limits to be maintained have been exceeded; this plan forms part of the certificate of stability against collapse. It shall be possible for the planned countermeasures to be taken at any time.
- The measuring intervals and measurement results shall be capable of indicating the need for countermeasures at a sufficiently early stage for the countermeasures to be taken in good time.
- During construction work and operation, the measurement programme and its timely evaluation shall be carried out as scheduled and shall be documented. Deviations from the plan shall be documented.

Numerical models for geotechnical certificates

Preparing certificates of stability against collapse using numerical methods in geotechnology is not the recognised state of the art in Germany. Building blocks for standardised procedures have been worked out in the form of recommendations by working group AK 1.6, Numerical Systems in Geotechnology of the Deutsche Gesellschaft für Geotechnik (DGGT).

Numerical models using the FE method make it possible to use continuum mechanical calculation models on complex structures even when taking account of the ground, although with major simplifications; they do not necessarily produce more accurate calculation results.

Special ground properties, interactive processes and complex procedures can be studied in principle and qualitatively using numerical models, however quantitative studies cannot necessarily be reproduced or represented reliably. System changes due to cyclical processes cannot be represented with sufficient reliability as a rule.

Plausibility checks represent a significant element in assessing numerical calculation results, e. g. by comparing them with areas of experience. Where adequate experience with foundations for comparable offshore wind farms is not available, particular value shall be placed on formulating simple analytical models and on making a critical and cautious evaluation of the results when designing of the foundation elements and assessing their interaction with the support structure.

Glossary

General

Implementation plan

This contains the planning documents that are ready for implementation on the basis of the basic design approved by the BSH for realising an offshore wind farm. The main emphasis of implementation planning lies in preparing works plans, usually on a relatively large scale. The objective of implementation planning is to achieve a set of plans that can be released for construction. The tested implementation plan approved by the BSH concludes the design phase.

Basic design

This contains the definitive basis for taking planning decisions when realising an offshore wind farm. The objective is to achieve a coherent and achievable planning concept that takes account of all project-specific issues. The checked basis design approved by the BSH concludes the first subsection of the design phase.

Design basis

This contains all data and figures required for the particular element of the offshore wind farm at its particular location that are necessary for designing a structurally stable and serviceable construction in accordance with the generally recognised state of the art or, failing that, the state of current scientific progress. It is based on qualified investigations and expert reports.

Conformity

This refers to a match with defined requirements.

Preliminary draft

This contains several planning variants which are already significant parts of the realisation of an offshore wind park. The checked preliminary draft approved by the BSH forms the conclusion of the development phase.

Foundation elements

Ground

This is the system consisting of one or more layers of soil.

Soil (loose rock)

This is the general material designation for the various layers of the ground.

Characteristic values of the soil parameters

These are carefully selected mean values of a typical bandwidth of these values for the particular soil type under the circumstances to be considered, the magnitude of which is to be viewed as assured for the service life of the foundation. The geotechnical engineering model in which they are to be used shall also be taken into account when defining them.

Design values of the soil parameters

These are values derived from the characteristic values of the soil parameters by reduction (if necessary by augmentation) with safety factors. It is necessary to use them in calculations in which the safety factors cannot be used or cannot be exclusively used on the loading values (calculated with characteristic values of the soil parameters). In each case, they shall be defined with reference to the geotechnical engineering model in which they are to be used.

Dynamic loadings of the ground

These result from high-frequency periodical (vibration) or intermittent transient effects (shocks) that create such a high stress modification rate in the ground that inertia forces cannot be neglected, and which principally establish small deformations of a constant volume with a quasi-elastic nature.

Ultimate limit state (ULS)

This is reached when the augmentation of resistances results in intolerably large stresses on the ground, the foundation elements or their components.

Serviceability limit state (SLS)

This is reached when the augmentation of impacts (usage loads) would result in intolerably large overall shifts or permanent dislocations of the ground, the foundation elements or their components.

Fatigue limit state (FLS)

This is reached when the total loadings of the ground have resulted in a reduction either in the rigidity or the strength of the ground or parts thereof, with the effect that stability against collapse and/or serviceability of the foundation can no longer be guaranteed for the structure.

Foundation elements

These are all design components by means of which the support structure (generally speaking the substructure) is placed on or anchored in the ground. They carry the necessary force effects durably and safely into the ground.

Static loadings or quasi-static loadings of the ground

These result from impacts which principally have magnitudes with a monotonic structure and only change insignificantly or which only occur rarely (as maximum magnitude).

Cyclical loadings

These result from effects with a large number of regular or irregular, low frequency magnitude changes, with or without changes of direction.

List of abbreviations

AC	Alternating Current
API	American Petroleum Institute
BBergG	Bundesberggesetz (Federal Mining Act)
BGV	Berufsgenossenschaftliche Vorschriften für die Sicherheit und Gesundheit bei der Arbeit (German accident prevention regulations)
BImSchV	Bundesimmissionsschutzverordnung (Federal Immission Control Act)
CEP	Comité Euro-International du Béton (Euro-International Concrete Committee)
CIGRE	Conférence Internationale des Grandes Électriques (International Council on Large Electric Systems)
DAST	Deutscher Ausschuss für Stahlbau (German committee for steel construction)
DIBt	Deutsches Institut für Bautechnik (German institute for construction technology)
DC	Direct Current
DGGT	Deutschen Gesellschaft für Geotechnik (German geotechnical society)
DIN	Deutsche Industrienorm (German industrial standard)
DNV	Det Norske Veritas
EC	Eurocode
EEZ	Exclusive Economic Zone
EN	Euro-Norm (European standard)
FE	Finite Elemente
FIP	Fédération International de la Précontrainte (International Federation for Prestressing)
FLS	Fatigue Limit State
GL	Germanischer Lloyd
ICPC	International Cable Protection Committee
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organization
ISO	International Standardization Organization
K	Kelvin
PLB	Post Lay Burial
SeeAnIV	Seeanlagenverordnung (Marine Facilities Ordinance)
SL & B	Simultaneous Lay & Burial
SLS	Serviceability Limit State
TBT	Tributyltin
ULS	Ultimate Limit State
VDI	Verein Deutscher Ingenieure
WSD	Wasser- und Schifffahrtsdirektion (Regional Waterways and Shipping Directorate)
WSV	Wasser- und Schifffahrtsverwaltung (German Federal Waterways Administration)
μT	Mikrotesla