STANDARD

DNVGL-ST-0054 Edition June 2017

Transport and installation of wind power plants

DNV GL AS

FOREWORD

DNV GL standards contain requirements, principles and acceptance criteria for objects, personnel, organisations and/or operations.

Any comments may be sent by e-mail to *rules@dnvgl.com*

CHANGES – CURRENT

This is a new document.

CONTENTS

SECTION 1 INTRODUCTION

1.1 General

1.1.1 Introduction

This standard provides general safety principles, requirements and guidance for the transport and installation (T&I) of onshore and offshore wind power plants.

The development of the standard has been based on long term experience in DNV GL with issuing standards to help the wind turbine (WT) industry in evolving. Due to the importance of offshore activities (mostly due to intensive costs of substructures, foundations and of offshore activities) the standard is predominantly oriented towards (but not limited to) T&I of the offshore wind parks.

The standard contains requirements for the design of assets (components) resulting from the planning of their transport and installation as well as requirements for the execution of their transport and installation. These requirements are given as guidance text or by reference to further specific standards.

1.1.2 Objective

The objective of the standard is to provide the approach ensuring the structural integrity of the wind power plant assets and components during transport, installation and decommissioning operations.

Further objectives of this standard are:

— to serve as a guidance for designers, suppliers, purchasers and regulators for safe design and execution of T&I procedures based on a risk-based approach
— to serve as a contractual reference document between suppliers and customers.

1.1.3 Scope

The standard provides the requirements aimed to ensure structural integrity of assets/components, including:

— requirements for T&I planning
— requirements for T&I execution
— requirements for evaluations and checks upon finalization of T&I.

The standard may be applied as part of the technical basis for carrying out a DNV GL certification and for verification services.

Guidance note:

The certification scope is defined in the service specifications, among others:

— DNVGL-SE-0073 *Project certification of wind farms according to IEC 61400-22*
— DNVGL-SE-0074 *Type and component certification of wind turbines according to IEC 61400-22*
— DNVGL-SE-0190 *Project certification of wind power plants*
— DNVGL-SE-0441 *Type and component certification of wind turbines*

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

The standard does not provide the requirements for the design and manufacturing of the installation vessels, lifting appliances and sea fastening.

Guidance note:

Requirements relevant for marine warranty survey (MWS) may be found in:

— DNVGL-SE-0080 *Noble Denton marine services – marine warranty survey*
— DNVGL-ST-N001 *Marine operations and marine warranty*

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

1.1.4 Application

The standard is applicable to the planning, compilation and execution of transport and installation procedures and summarizes essential T&I aspects to be observed within different project phases:

— during the development of the assets or components: influences of T&I on the structural integrity
— during the development of T&I documentation (method statements, procedures, drawings): information to be considered in T&I documentation
— prior to start of the particular T&I works: tests and checks to be carried out
— during the execution of T&I operations: working steps and parameters to be monitored (processes, sequences, limiting values, timing)
— upon completion of T&I: evaluation of possible impacts on the structural integrity of the assets during T&I, procedural deviations (in sense of sequences, timing, limiting values, etc.).

The standard is applicable to the assets associated with wind energy projects located onshore and offshore (see Figure 1-1 and Figure 1-2), including:

— wind turbines and their support structures
— substation(s) along with accommodation platform(s) including topside(s) and support structure(s)
— meteorological masts
— power cables
— control station(s).

The principles, requirements and guidance of this standard shall be applied within the development phase of the assets beginning with the design basis through the detailed design. Necessary updates of the design may be required during the manufacturing as well as prior or even during the T&I phase.

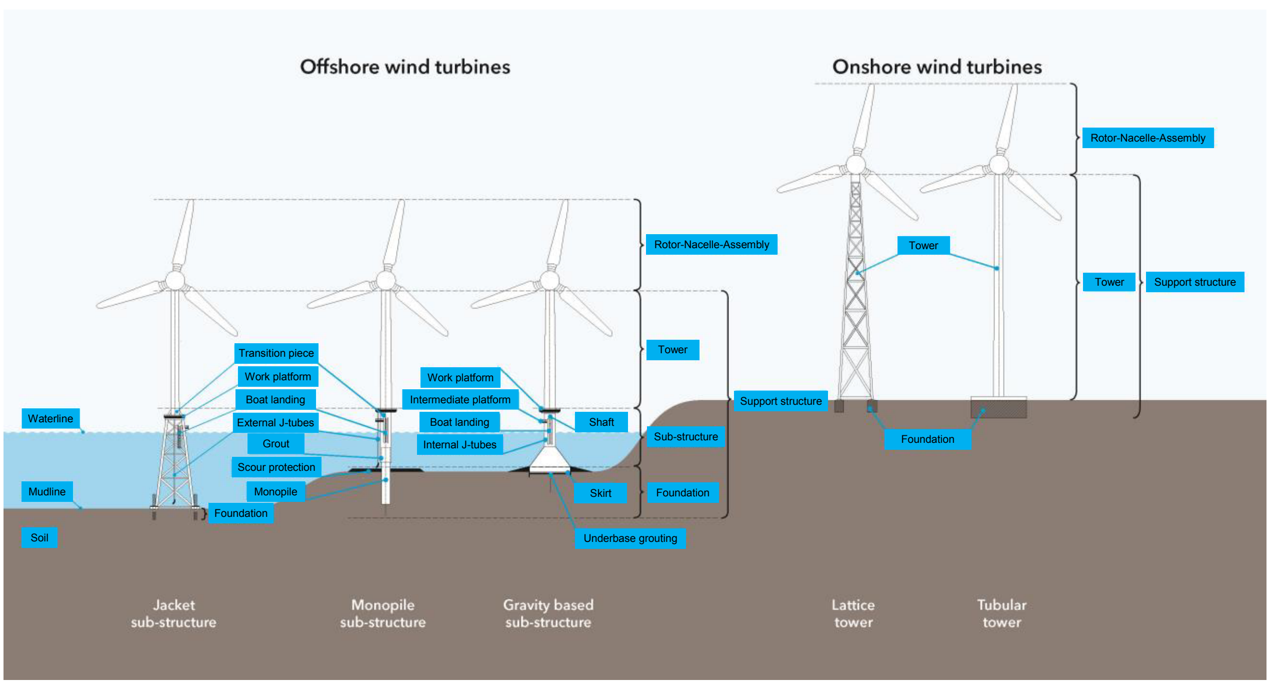


Figure 1-1 Offshore and onshore wind turbine components

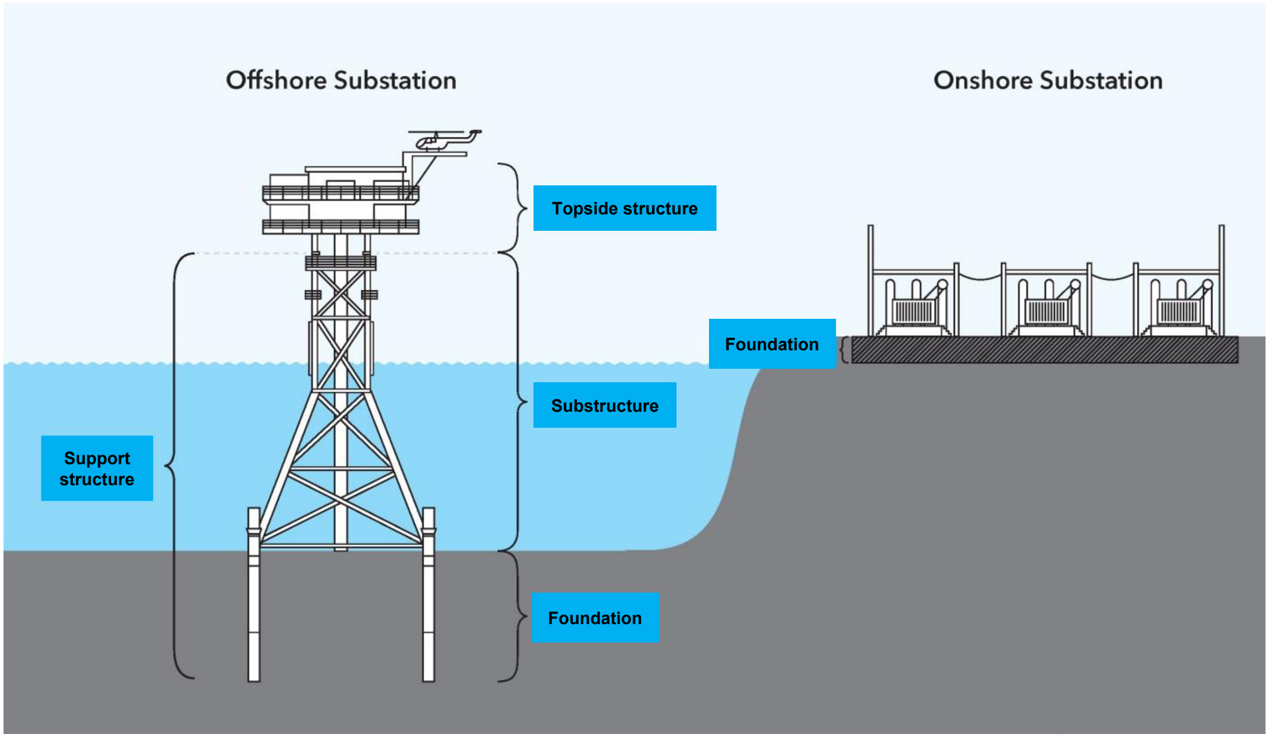


Figure 1-2 Offshore and onshore substation components

The standard has been prepared for general worldwide application. Locally applicable legislation may include requirements in excess of the provisions of this standard depending on type, size, location and intended service of the installation.

Implementation of prescriptive requirements given in this standard together with responsible operation are intended to result in an acceptable and targeted level of safety for the asset of the wind power plant.

The prescriptive requirements are based on experience and safety studies and attempt to generalize with respect to design and application. In the cases if this generalization may not be appropriate to a specific design, alternative planning and design may be assumed to be of an acceptable level of safety when the risks are assessed and managed, supported and complemented by other prescriptive guidance.

1.2 References and definitions

1.2.1 Standards and guidelines

This standard makes reference to relevant international, DNV GL and other standards and recommended practices. Unless otherwise specified in the certification agreement or in this standard, the latest valid revision of each referenced document applies.

Table 1-1 Standards and guidelines

Reference	*Title*
DNVGL-OS-C101	Design of offshore steel structures, general – LRFD method
DNVGL-RP-0360	Subsea power cables in shallow water

Reference	*Title*
DNVGL-RP-0416	Corrosion protection for wind turbines
DNVGL-RP-0419	Analysis of grouted connections using the finite element method
DNVGL-SE-0073	Project certification of wind farms according to IEC 61400-22
DNVGL-SE-0074	Type and component certification of wind turbines according to IEC 61400-22
DNVGL-SE-0080	Noble Denton marine services – marine warranty survey
DNVGL-SE-0190	Project certification of wind power plants
DNVGL-SE-0420	Certification of meteorological mast
DNVGL-SE-0441	Type and component certification of wind turbines
DNVGL-ST-0126	Support structures for wind turbines
DNVGL-ST-0145	Offshore substations
DNVGL-ST-0359	Subsea power cables for wind power plants
DNVGL-ST-0361	Machinery for wind turbines
DNVGL-ST-0376	Rotor blades for wind turbines
DNVGL-ST-N001	Marine operations and marine warranty
EN 50522	Earthing of power installations exceeding 1 kV a.c.
IEC 61400-1	Wind turbines – Design requirements
IEC 61400-3	Wind turbines – Design requirements for offshore wind turbines
ISO 29400	Ships and marine technology – Offshore wind energy – Port and marine operations

1.3 Definitions

1.3.1 Verbal forms

Table 1-2 Verbal forms

Verbal form	*Definition*
Shall	verbal form used to indicate requirements strictly to be followed in order to conform to the document
Should	verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required
May	verbal form used to indicate a course of action permissible within the limits of the document

1.3.2 Definitions

Table 1-3 Terms

Term	*Definition*
asset	term used in the context of wind power plant projects to describe the object to be developed, manufactured and maintained In this standard the term refers either to “wind turbines”, the “substation”, the “power cables”, “meteorological mast” or “control station”.
component	main part of an asset In this standard the term refers to rotor–nacelle-assembly (RNA), part of the support structure of the wind turbine (tower, sea ice substructure and foundation), topside equipment, and parts of support structure for substation (topside structure, substructure and foundation). The term main component is used for example to describe the main transformer, converter, switchgear, cables, rotor blade, rotor hub, main bearing, gearbox and generator of a wind turbine or substation.
fixed offshore installation	non-buoyant construction that is founded on/in the seabed at a particular offshore location, transferring the loads acting on it into the soil
foundation	part of the support structure, structural or geotechnical component, or both, extending from the ground level or the seabed and downwards
grout	cementitious material including the constituent materials; cement, water and admixture, used to connect steel parts as e.g. substructure and transition piece
intermediate T&I phase	interruption of the assets and components transfer from one defined safe condition to another In this standard the term refers to an unsafe state of a component (asset) due to interruption of the planned T&I sequence for a period of time exceeding allowed limits (e.g. set-down of wind turbine jacket without consequent execution of grouted connection with its piles within several days/weeks).
load-out	sub-operation within the transport phase, during which the object is transferred from the quay onto the deck of a barge, vessel or other watercraft
method statement	T&I document designed for a specific procedure, component or sub-operation explaining how the work is conducted, which inputs are required and which outputs and results are expected
offshore installation	collective term to cover any structure, buoyant or non-buoyant, designed and built for installation at a particular offshore location
offshore substation	collective term for high voltage AC (transformer) and high voltage DC (converter) platforms as well as associated accommodation platforms located offshore
rotor	component of the wind turbine consisting of multiple rotor blades attached to a hub
rotor nacelle assembly	includes all components/systems located above the tower top flange
sub-operation	operation that forms a specific phase of transport or installation
substation	see offshore substation

Term	*Definition*
substructure	part of the support structure for a wind turbine which extends upwards from the soil and connects the foundation and the tower The term is also used to designate the part of the support structure for a substation which extends upwards from the soil and connects the foundation and the topside or platform.
T&I planning	all design and organisational activities to be regarded during design and planning of transport and installation sequences within the development and construction phase of the wind power plant with the target to manage the risks and ensure structural integrity of the assets and components
topside	structures and equipment placed on a supporting structure to provide some or all functions of an offshore substation
tower	structural component, which forms a part of the support structure for a wind turbine, usually extending from somewhere above the ground level or still water level (for an offshore wind turbine) to just below the nacelle of the wind turbine
wind power plant	energy producing facility, comprising all its main assets to produce power and transfer it into the power grid Typically also known as wind farm. In this service specification the term wind power plant is associated with the main assets wind turbines and substation(s) including their support structures, power cables and the control station.

1.4 Acronyms, abbreviations and symbols

1.4.1 Acronyms and abbreviations

Table 1-4 Acronyms and abbreviations

Abbreviation	*Definition*
COF	consequence of failure
CRP	carbon fibre reinforced plastic
DAF	dynamic amplification factor
FLS	fatigue limit state
GRP	glass fibre reinforced plastic
H	high
HH	very high
L	low
LL	very low
M	average
MWS	marine warranty survey
NDT	non-destructive testing

Abbreviation	*Definition*
OSS	offshore substation
PLL	potential loss of life
POB	people on board
PPE	personnel protective equipment
SHL	static hook load
SKL	skew load factor
SLS	serviceability limit state
SPMT	self-propelled modular transporter
TDR	time domain reflectometer
T&I	transport and installation
TP	transition piece
ULS	ultimate limit state
WT	wind turbine

SECTION 2 PLANNING AND DESIGN APPROACH

2.1 Planning

2.1.1 Strategy and risk management

Planning of transport and installation sequences (T&I planning) within a wind power plant project shall incorporate the risk management process with the target to ensure during T&I the transfer of assets and components from one defined safe state to another, see Figure 2-1.

Wind power plant life-cycle phase	**Development**			**Construction**	
Certification phase	**Concept**	**Design basis**	**Design**	**Manu-facturing**	**Transport and installation**
T&I planning tasks	• Selection of T&I, decommissioning and transport methodology on conceptual level • Feasibility assessment of T&I, decommissioning and transport concept	• Definition of the site conditions and the basis for T&I planning and design • Preliminary (high level) risk assessment to provide input to detailed design, definition of the safety objective	• Consideration of site-specific design results during T&I planning • Design concept of the sea fastening, installation tools and equipment • Iterative development of preliminary T&I documentation based on detailed (low level) risk assessment	• Update of T&I documentation due to modifications of the assets and components within the manufacturing phase	• Update of T&I documentation due to modifications of ships chartering, sea fastening adaptations, etc. • Final verification of the assets (components) structural integrity upon ships chartering, sea fastening adaptations, etc. • Amendment of T&I documentation due to lessons learned, necessity of modifications of design and procedures

Figure 2-1 Transport and installation planning in a project pipeline

Adequate T&I planning shall be started on the early stage of the project to have a sufficient basis for the engineering and ensure safe, workable and economical transport and installation of a wind power plant. Preliminary (high level) risk assessment should aim at ensuring that a safe, practicable concept is carried forward to further T&I planning.

The process of T&I planning shall aim at the reduction and elimination of the potential risks by means of continuous adaptations during every single project phase, see Figure 2-2. Where safety objectives were not achieved, design modifications are required. The updated design shall be rechecked to avoid introduction of new hazards.

A systematic review shall be carried out at all phases to identify and evaluate hazards and the consequences of single failures.

Safety objectives are the criteria to be met to ensure safe execution of transport and installation of a wind power plant. The safety objectives may be quantified by key figures such as:

— personnel health and safety risk
— financial losses, among others due to disturbances of the timeline, damage or losses
— impact on the environment.

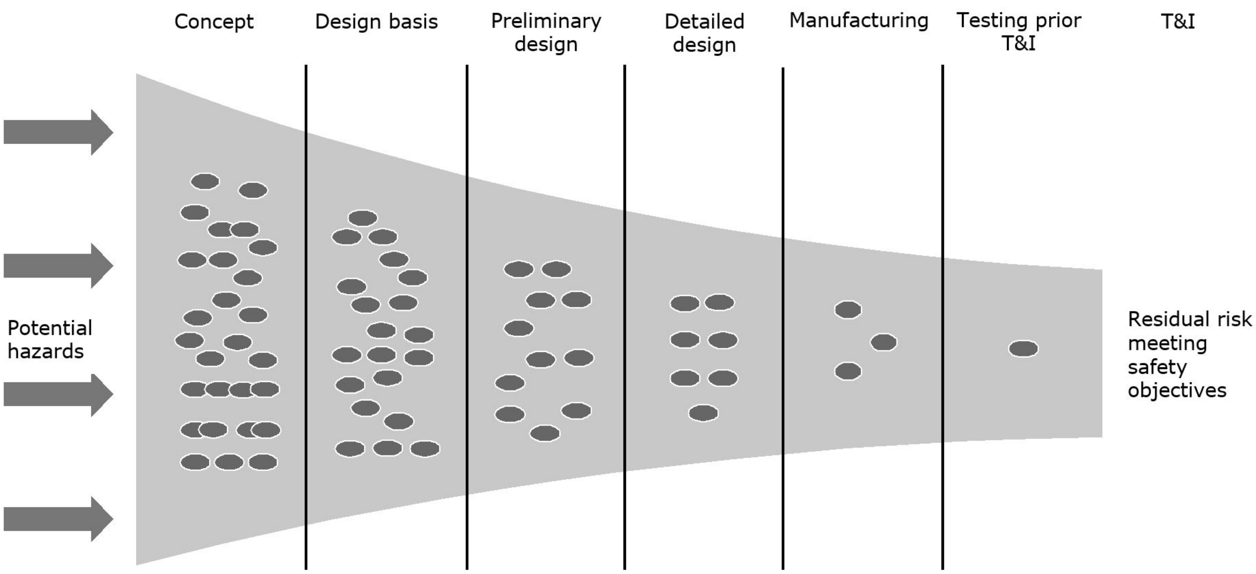


Figure 2-2 Achievement of the safety objectives

Risk management shall be applied to the project to reduce the effects of hazards and to limit the overall risk. This objective may be achieved by addressing the following functions in turn:

— identification of potential hazards
— assessment of risk potential
— prevention to avoid hazards wherever possible
— control to reduce the potential consequences of unavoidable hazards
— measures to mitigate the consequences of an incident, should one occur.

(Ref. ISO 29400)

App.A provides an approach for the identification of potential hazards and the assessment of the risk potential.

Guidance note:

Management of risks associated with T&I is an essential task during the design development and certification of

— assets/components manufactured in series (e.g. wind turbines, their components)
— project specific assets/components.

[1.1.3] provides references to DNV GL service specifications defining certification scopes within type and project certification accordingly.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

2.1.2 Contingency planning

The contingency planning is a backup plan describing how the consequences shall be handled, should a hazard for any reason be unavoidable.

Means of adequate handling of contingencies identified within risk management process shall be provided, including

— adequate redundancy (design contingency) covering single failure(s)
— back-up of the equipment
— supporting personnel.

Following potential deviations from the transport and installation methodology, sequence and duration should be considered in contingency planning in general:

— exceedance of allowable weather conditions
— failure of T&I equipment (among others crane hydraulic system, hydraulic hammer, ballast pump, grouting mixer)
— congestion of a piping (grouting system, hydraulic line of jacket sleeve gripper)
— failure of compressed air, water or electrical power supply
— anchor line, mooring malfunction and other structural failures
— failure of communication
— loss of vessel or barge control
— loss of onshore installation crane control
— collision, impact, grounding, stranding
— fire, explosion, pollution, leakage
— personnel accidents, illnesses, injuries, man overboard
— presence of unauthorized persons, vandalism
— unexploded ordnance.

Contingency planning considerations specific for particular sub-operations and components are observed in Sec.3 and Sec.4.

2.2 Design approach

Within the design process of a wind power plant the integrity of the structure or its components exposed to temporary conditions (i.e. during load-out, transport, lifting and other T&I sub-operations) shall be ensured.

The influence of intermediate T&I phases on the structural integrity (i.e. interruption of the process of transport or installation of the asset or component), that are not planned but have a high probability, shall be investigated.

Following shall be worked out in a general case:

— proves of structural integrity of the asset and components (including lifting points) during T&I as well as during intermediate T&I phases
— definition of limiting values, environmental conditions, allowable durations and other operational limits.

Following limit states shall be investigated depending on the transport or installation sub-operation to be applied:

— ultimate limit states (ULS)
— fatigue limit states (FLS) depending on the transport distance, time of exposure, road condition, installation method
— serviceability limit states (SLS)

In case that similar sub-procedures shall be performed repeatedly at different locations or within different T&I phases (e.g. pile lifted load-out from quay onto a barge followed by the load-out onto an installation vessel on site), the structural integrity shall be at least proven for the most unfavourable/critical case.

Required safety factors for design loads and design resistance shall be applied for the chosen method of transport/installation in accordance with the relevant applicable standard for the asset (component).

Guidance note:

DNVGL-SE-0073, DNVGL-SE-0074, DNVGL-SE-0190 and DNVGL-SE-0441 provide references to ruling standards relevant for the different assets and components.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Wherever necessary, protection measures (protecting caps, anti-vortex devices, environmental protective coverage, guards or locking devices, etc.) shall be assigned. Aspects (including loads and necessary protections) relevant for particular T&I sub-operations and assets/components of a wind power plant are specified in Sec.3, Sec.4 and Sec.5.

SECTION 3 SUB-OPERATIONS DURING TRANSPORT AND INSTALLATION

3.1 General

This section provides a general overview of the sub-operations typical for the transport and installation of wind power plants. As these sub-operations are applicable with respect to different components of a wind power plant, aspects specific for particular components are handled in Sec.4.

3.2 Pre-assembly and intermediate storage

Pre-assembly of components is an approach applied in order to limit the duration and, correspondingly, the costs of installation work. Pre-assembly shall be referred to the installation processes rather than the manufacturing processes. It may include (but is not limited to) tower assembling (i.e. connection of tower segments), mounting of blades to the hub (“rotor star assembling”), mounting of the hub and two rotor blades (“bunny”) to the rotor nacelle assembly.

The pre-assembly processes can be performed:

— in the vicinity of the onshore installation site
— on the quay in due time prior to load-out (quayside pre-assembly for offshore projects).

Intermediate storage areas are locations for temporary storage of asset, components and main components, taking place between different transportation stages.

Following shall be worked out within the development phase:

— proof of structural integrity of the asset and the components within the pre-assembly processes and intermediate storage periods
— definition of lifting points
— definition of limiting values for lifting speed, environmental conditions, allowable duration and other operational limits.

During T&I planning as well as prior to start and during pre-assembly and intermediate storage the following shall be ensured:

— sufficient working and manoeuvring area, absence of obstacles for all foreseen movements in horizontal and vertical directions, suitability of area for turning
— acceptable surface condition (purity, plane, inclinations, dryness, availability of drainage)
— sufficient load bearing capacity of the pre-assembly and intermediate storage areas
— availability of suitable and working lifting appliances, equipment, tooling
— availability of fresh water, compressed air, electric power supply necessary to carry out the pre-assembly or to maintain intermediate storage period
— sufficient lighting and light distribution
— sufficient personnel qualification
— availability of protective measures required for the asset and components (e.g. wood cribbing, covering sheets, caps, grease, heaters) and monitoring of the conditions (including humidity control inside hub and nacelle)
— availability of personnel protective equipment (PPE) where relevant.

3.3 Onshore transport

Multiple factors shall be considered during selection of the onshore transport method and route, among others:

— distance
— dimensions

— weight of the components to be transported
— vehicle turning radii
— obstructions and constraints, among other road and railroad bridges, power transmission lines, trees, urban furniture
— strength and stability of the temporary roadways, consideration of muddy areas
— costs of the overall transport
— permissions required from authorities.

Transport documentation shall include the description of all working steps. Auxiliary equipment and tools shall be specified exactly (e.g. transportation adapters, securing and protections). Transport documentation shall refer to relevant necessary drawings, specifications or instructions.

The execution of all checks and working steps of the onshore transport shall be documented. For each check and working step, there shall be appropriate cells in the documentation template to be filled in, together with fields for recording measurement values and test results.

3.3.1 Road transport

Within the design of components the influence on structural integrity (e.g. bending stress due to dead weight of the (main) component) caused by the lifting tools geometry, position of the attachment / application points and vehicle movements, shall be considered.

It shall be demonstrated by proper means that the fatigue effect caused by the loading situation during transport is insignificant and can be neglected in the structural verification of the blade. Special attention shall be paid to influence of the vehicles design during:

— transports of rotor blades with segmented design
— transports of e.g. tower segments or blades over distances of more than 100 km by means of combined vehicles consisted of several separated modules, see Figure 3-1
— transports of blades in inclined condition by means of vehicles with blade lifting adapter.

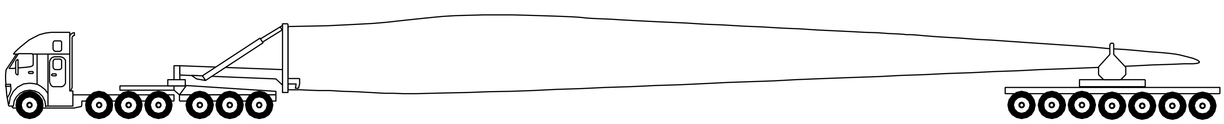


Figure 3-1 Road transport by separated modules (blade transport)

In the documentation for road transport following information shall be provided:

— weight and dimensions of the (main) components to be transported
— minimum requirements on road widths and curves
— required minimum load bearing capacity of the roads
— manufacturers' fastening provisions
— measures against vibration
— maximum inclination angles
— minimum allowable road slope and grade
— required minimum overhead clearance
— required minimum lay-by length and width
— adjustment capability of the vehicle against road camber and elevations.

During planning of the transport a road survey shall be carried out to ensure a safe execution of the transport. Following aspects shall be considered:

— geometries of roads, bridges and tunnels including width, slope, curves radius, junctions, traffic circles
— road condition including dips, installed bumps, functional drainage, traffic situation
— restrictions of roads and bridges on height, length and allowable loads

— widths and heights under bridges and viaducts
— availability of lay-by areas for provisional parking
— conformity of operations with transport permits issued by national authorities
— condition and restrictions of the roads at the installation site (site roads)
— sufficient working and manoeuvring area at the transport's destination (at installation site or intermediate storage area)
— dimensional restrictions passing toll areas and borders
— condition of temporary roads at the site.

Carrying capacity of the vehicles shall be approved for the weights of the assets/components to be transported.

All cranes used for lifting of the components onto the vehicles:

— shall be appropriately rated for safe handling of the intended weights and dimensions
— shall be able to work within the environmental limits.

It shall be ensured that a route survey is carried out to prevent interference during transportation with potential obstacles (slopes, grades, curves, clearance to bridges etc.).

In the documentation following information shall be provided:

— maximum allowable wind speed for loading of the components
— other criteria for the interruption of loading (rainfall, lightning hazard, change of wind direction, etc.).

Requirements on warning flags, lights, signs and marking, as well as days and hours allowable for transport operations shall be considered in accordance with the national and local regulations.

During road transport the position of the components on the vehicle as well as the condition of the lashing points on the vehicle shall be regularly visually inspected.

Components that require a power supply during transport (e.g. nacelle) shall be provided with a suitable power supply system.

3.3.2 Railway transport

Requirements in [3.3.1] shall be considered where applicable.

Railcars shall be suitable for transport of the (main) components and approved by the relevant authorities for this type of transport.

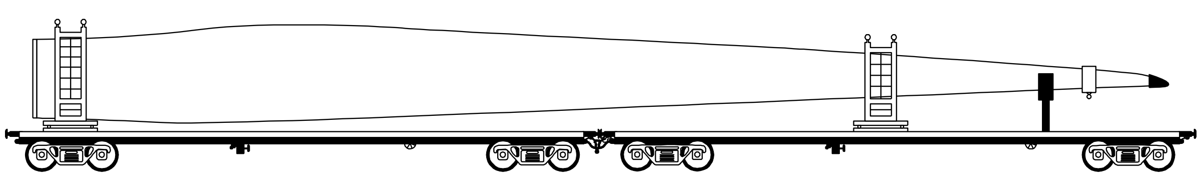


Figure 3-2 Railcar transport (blade transport on two railcars)

It shall be ensured that a route survey is carried out to prevent interference during transportation with potential obstacles (slopes, grades, curves, loading gauge, space between the tracks, etc.).

If two railcars are used for the transport due to the length of the component, it shall be ensured that the component is not endangered by railcars' relative motion in the curves.

3.3.3 Aircraft transport

Within the design of components the influence on the component's structural integrity caused by an airplane, helicopter, or hybrid air vehicle during the take-off, landing as well as flight in turbulence condition shall be considered where relevant.

In the documentation for the aircraft transport following information shall be provided:

— maximum allowable wind speed for loading of the components onto/into the aircraft
— maximum allowable wind speed and direction for landing
— maximum allowable transportation distance and time
— other criteria for the interruption of loading (precipitation, lightning hazard, change of wind direction, etc.).

3.4 Onshore installation

Within the design of the wind turbine foundation and tower following influences shall be considered, if applicable:

— influence on the structural design of the foundation from cranes with a possible footprint influencing the WT's foundation's affected zone
— influence on the structural design of the tower from attachments of the erecting crane
— influence on the structural design of tower and foundation from pulling up the nacelle along the erected tower.

In the onshore installation documentation, all prerequisites for the execution of the erection work shall be stated, among other

— requirements for the weather conditions (limiting wind speeds, temperatures, rainfall)
— requirements for site access and working area and/or adequate curing of the foundation
— precise designations and dimensions of all plant components to be assembled and erected together with all data needed for erection, such as weights, lifting points etc.
— special tools or hoisting equipment necessary for the erection considering the loads and weights during erection
— requirements for these tools or equipment e.g. testing or regular inspections
— maximum admissible delay between erection of the wind turbine tower and mounting of the nacelle
— required qualifications for the technical erection personnel shall be defined in the erection documentation.

In the onshore installation documentation all working steps needed for erection shall be described in format and level of detail that the qualified technical erection personnel performing the required tasks are able to understand the instructions. This means among others:

— auxiliary equipment and resources shall be specified exactly (e.g. lubricants, oil for filling up the gearbox) shall be specified
— references to drawings, specifications or instructions necessary for the erection shall be stated
— work instructions including all working steps for bolted and welding connections to be carried out during erection shall be included
— all necessary tests and checks shall be listed
— procedures for energizing electrical equipment shall be provided.

In the onshore installation documentation hazardous situations which may arise through deviations from the planned erection sequence shall be named and countermeasures shall be specified. Such situations may include:

— lightning, snow, icing, visibility, extreme temperatures, very high winds, prolonged periods of the substructure and/or the support structure standing without rotor nacelle assembly at critical wind speeds
— hazardous situations which may arise due to unintended motion or rotation.

In the onshore installation documentation safety and accident-prevention measures shall be specified which are necessary before or during assembly, installation and erection, e.g. use of personal protective equipment, guards or locking devices. For personnel entering any enclosed working space such as the hub or blade interior, safety provisions shall be stated, e.g. standby personnel. Emergency procedures and rescue operations shall be described.

In the onshore installation documentation the execution of all checks and working steps within the erection process shall be duly documented. For each check and working step, there shall be appropriate cells in the documentation template to be filled in, together with fields for recording measurement values and test results. All adjustment settings and set values as well as the expected measurement results shall be specified. The following fields shall be provided in addition:

— type identification of the assets and components (manufacturer, supplier or importer, designation, type and if applicable type variant)
— serial number, operator and installation site of the wind power plant
— version numbers of all software and parameter lists which are installed
— weather conditions, if the weather is able to influence the quality of work
— checklist of the execution of all working steps, tests and checks.

3.5 Nearshore transport

Definition "nearshore transport" in this standard includes water transport via inland waters as well as nearshore transport via vessels or barges near to coast.

Within T&I planning of nearshore transport the sheltered character of inland waterways and nearshore areas shall be duly considered. Among other the following shall be taken into account:

— wind speed, significant wave heights specific for the selected transport route
— water depth, wind induced water level changes, high water cable and bridge overhead clearance, tidal variations
— currents (speed and direction)
— turning circle of long components in narrow areas
— dimensional limitations through bridges, locks, etc.

3.6 Offshore transport

Within the conceptual phase of the wind power plant development the following shall be worked out based on the risk assessment:

— selection of a proper method of offshore transport ("wet" towing of floating components or "dry transport", i.e. transport of the components on the deck of a barge or vessel)
— selection of an adequate vessel type
— selection of a suitable period for transportation, considering typical weather conditions (e.g. tropical or northern winter storms)
— selection of a proper transport route.

Multiple factors shall be considered during selection of the offshore transport method and route, these are among others:

— dimensions, weight, centre of gravity of the components
— environmental conditions (wind, waves, current)
— transport loads and sensibility to weather changes
— distance and weather window constraints
— narrow waterways, obstructions (e.g. bridges, drafts restrictions, locks, cables)
— project schedule
— availability of safe haven/sheltered areas
— potential necessity for routine inspections and, consequently, availability of access to the transported component and escape in the case of emergency.

Offshore transport documentation shall at least provide following information:

— intended route and duration of sea transport
— environmental limits

— requirements to the transport vessels (including tug power, arrangement of vessels, navigation equipment etc.) and other equipment used (floating cranes etc.)
— references to drawings, specifications and instructions necessary for the sea transport
— required qualifications of the technical personnel.

Routine inspections of components and sea fastening conditions may be required during transport, e.g. after a period of bad weather. The records shall document the execution of all checks and working steps of the offshore transport. For each check and working step, there shall be appropriate cells in the documentation template to be filled in, together with fields for recording measurement values and test results.

Requirements with respect to different offshore transport sub-operations starting from the load-out of the components are outlined in [3.6.1] to [3.6.3].

3.6.1 Load-out

Within the development of wind power plant the following load-out-relevant aspects shall be worked out:

— proof of the structural integrity of the components subject to load-out including consideration of tolerances and specific operational conditions
— definition of the limiting environmental conditions and maximum allowable load-out duration.

Guidance note:

Guidance on loads acting onto the component during specific load-out sub-operations is provided in DNVGL-ST-N001 Sec.10 *Load-out*.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

In the contingency plan for load-outs the following shall be considered:

— hydraulic system failure
— hose rupture/leakage
— tire puncture and tire pressure
— steering irregularities, failure of steering system
— traction failure
— ballast pump failure
— mooring line failure
— conservatively estimated duration of repair work
— tools and back-up equipment required.

3.6.1.1 Trailer-transported load-out

Trailer-transported load-out is a load-out performed by means of self-propelled modular transporters (SPMT), see Figure 3-3.

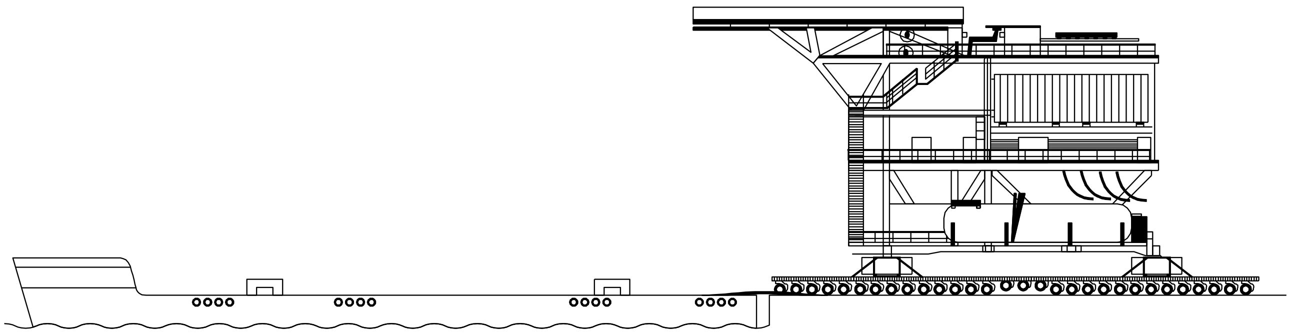


Figure 3-3 Trailer-transported load-out of a topside (offshore substation)

Structural integrity of the component during trailer-transported load-out shall be verified under consideration of a three point support condition caused by possible deflections, e.g. due to:

— trailer inclinations due to improper co-ordination in operation of the hydraulic suspension system
— ground surface conditions
— overturning effects due to horizontal loads
— behaviour of a link span bridge between the quay and the vessel (due to vessel mooring and ballasting, distance between the vessel and the quay, securing the link span to vessel and quay).

During T&I planning as well as prior to start of trailer-transported load-out following aspects shall be considered:

— water depth, water level
— local environmental conditions, especially the possibility of sea and swell waves, currents, tides, wind induced water level changes
— sufficient load bearing capacity of the quay
— quays surface condition and absence of obstructions on the trailer path
— sufficient linkspan bridge capacity
— appropriate linkspan bridge securing
— barge, linkspan bridge and quay alignment tolerances
— influence of the linkspan bridge slope on the component
— slope change and movements of the linkspan bridge due to wave or swell action
— manoeuvring capabilities and hydraulic lifting capacity of the trailers
— reaction loads from wind
— inertia due to accelerations during start and stop
— differential traction, steering inaccuracies, improper co-ordination in the operation of the hydraulic suspension
— adequate braking capacity at any time
— soil bearing capacity (in case of grounded load-out i.e. where the barge or vessel is supported at the sea bottom during the load transfer phase).

Following tests and checks shall be carried out prior to start of trailer-transported load-out:

— functional test of the ballast systems including back-up ballast system
— operational check of the trailers (SPMT)
— check of availability of the fuel for the power pack.

Within the execution of trailer-transported load-out following shall be duly monitored:

— environmental conditions
— duration of the load-out
— structural deflections
— elevation of the barge or vessel against the quay, movements of the linkspan bridge and other tolerances defined in the load-out method statement.

3.6.1.2 Skidded load-out

Skidded load-out may be performed by means of pulled or self-propelled skid-shoes moving the component over low-friction blocks laid onto skid-ways.

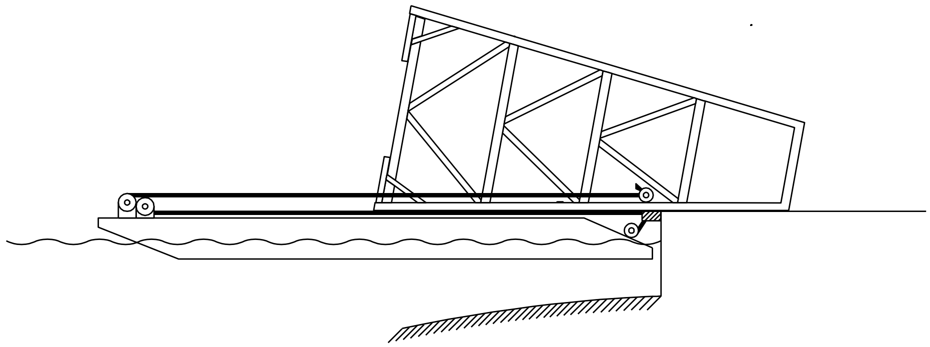


Figure 3-4 Skidded load-out of a jacket onto a barge

Requirements in [3.6.1.1] shall be observed where relevant.

During T&I planning as well as prior to start of the skidded load-out following aspects shall be considered:

— skidding shoes, rails, wires and anchor points strength capability as well as sufficient flexibility of skid shoes to compensate the level and slope changes
— condition of skid beams (skid rails), lateral guides, wires and anchor points
— levelness tolerances of the skid beams (skid rails)
— limiting operating values and allowed tolerances
— adequate braking capacity of the system at any time
— barge/link-beam relative movements
— availability and functionality of retrieval system.

Following tests and checks shall be carried out prior to start of skidded load-out:

— visual checks of the wires skidding shoes, rails, lateral guides, wires, anchor points
— operational checks of the push-pull unit (functioning of the remote control, lifting of hydraulic cylinders, transport motion, where relevant)

Within the execution of a skidded load-out following shall be duly monitored:

— motions of the barge or vessel against the quay, seabed clearances and other tolerances defined in the load-out method statement.

Load-out analyses of the skidded component shall consider the elasticity, alignment and as-built dimensions of the shore and vessel skidways. Verification of structural integrity of the component during skidded load-out shall be carried out for the following deflections:

— deviation of any single component “corner” support with respect to the other “corner” supports by 25 mm
— deviation of any single component support with respect to the other supports by 15 mm.

3.6.1.3 Lifted load-out

Lifted load-out is a lifting operation performed by land- or vessel-based cranes for the purpose of load-out onto a barge or transportation vessel, see Figure 3-5.

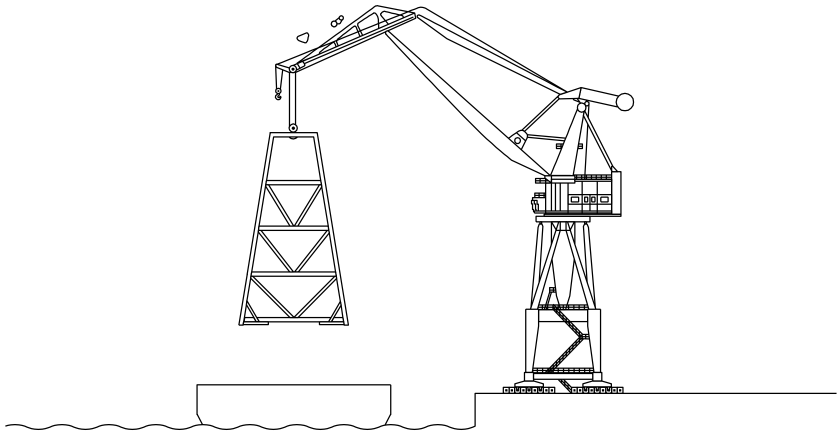


Figure 3-5 Lifted load-out of a jacket onto a barge

During T&I planning as well as prior to the start of a lifted load-out the following aspects shall be considered:

— water depth
— local environmental effects, especially the possibility of waves, swell, current, tide
— sufficient load bearing capacity of the quay
— soil bearing capacity (in case of grounded load-out, i.e. where the barge or vessel is supported at the sea bottom during the load transfer phase)
— limiting operating values (hoisting velocity, tilt, relative motions, environmental conditions)
— vertical clearance between the underside of the component and the top of the barge (vessel), considering any possible heel, trim, motion
— horizontal clearance between the component and any other previously loaded-out structure
— under-keel clearance i.e. vertical distance between the lowest part of the barge (vessel) hull and the seabed – before and after load-out.

Verification of the lifting points and lifted structure design shall be carried out in accordance with App.B.

Following tests and checks shall be carried out prior to start of a lifted load-out:

— check of the sling conditions
— non-destructive test (NDT) of the padeyes and their connection to the structure of component.

Within the execution of lifted load-out the following shall be duly monitored:

— environmental conditions
— duration of the load-out
— application of protection bumpers, guides and their support points
— component deflections
— motions of the barge or vessel against the quay, seabed clearances
— tilt of lifted components especially for multi-hook lifts or statically indeterminate conditions
— relative motions of lifted component
— hoisting velocity
— position and orientation
— other tolerances defined in the load-out method statement.

3.6.1.4 Float-out

Float-out as a load-out performed for components fabricated in a dry dock, brought afloat due to their own buoyancy or additional temporary buoyancy tanks and towed from the fabrication site.

During T&I planning as well as prior to start of float-out the following aspects shall be considered:

— influences of local environmental conditions and dock water inlet arrangement
— consideration of intact and damage stability cases, definition of allowable duration for the critical conditions
— sufficient load bearing capacity of the dry dock
— provision of guiding and fendering arrangements.

Guidance note:

Further guidance on loads acting onto the component during float-out sub-operation is provided in DNVGL-ST-N001 Sec.12 *Tow out of dry-dock or building basin*.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Following tests and checks shall be carried out prior to start of float-out:

— visual checks of guiding and fendering arrangements
— visual checks of temporary buoyancy tanks, connection points to the component
— functional test of temporary buoyancy (collapsible rubber bags)
— visual checks of dry-dock area, piping outlets/inlets, filter boxes, plugs to avoid blockage due to debris, etc.
— visual check of mooring, positioning and towing systems, wires, quick release hooks, winches, etc.

Within the execution of the float-out the following shall be duly monitored:

— environmental conditions
— duration of the float-out
— draughts of the self-buoyant component, bottom clearance
— position and orientation of the component
— lateral clearance during passage of float-out channel.

3.6.2 Wet towing

Wet towing assumes wet transport to the offshore site of a floating structure (e.g. gravity base structures, monopoles, jacket substructures) supported by their own buoyancy buoyancy (and possible temporary bouyancy) and pushed/pulled by tugs, see Figure 3-6.

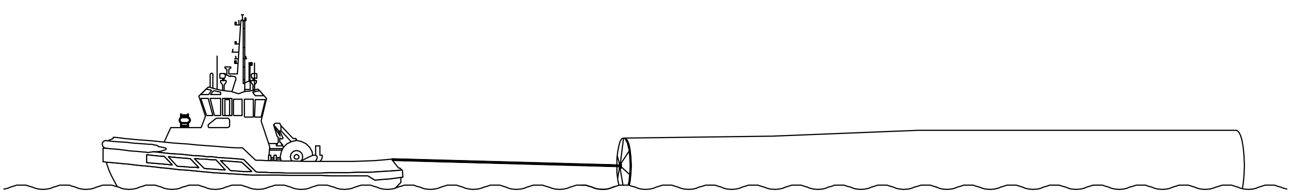


Figure 3-6 Wet towing of a monopile

During the design of the component the structural strength shall be verified. All relevant loads shall be taken into account, among other (where relevant):

— hydrostatic loads due to external water pressure on submerged structures or internal water pressure in water filled compartments
— wave slamming loads, normal wave and current induced loads
— aero- and hydrodynamically induced vortex shedding and the risk of vortex induced vibrations (especially when transported vertically)
— interaction between the towed component and the propeller race
— increased draught due to interaction between the seabed and the towed component

— channel effects in narrow passages.

The buoyancy of the self-floating component shall be estimated on the basis of an accurate geometric model. The buoyancy shall be estimated for all relevant draughts. The position of the centre of buoyancy shall be estimated accordingly. Effect of possible variations in buoyancy shall be considered.

Auxiliary and permanent buoyancy tanks, similar buoyant structures and attachments to the towed component shall be designed to withstand the loads.

Rubber diaphragms (plugs) shall have sufficient strength to withstand internal and external water head or air pressure including loads due to temperature changes after assembly. The rubber diaphragms shall also be capable of withstanding relevant hydrodynamic drag and inertia forces during towing. Rubber diaphragms shall be protected against wear, heat, and frost after assembly.

Monitoring of hydraulic pressure and/or water leakage inside the floating component shall be foreseen to recognize sinking. Contingency plan shall be worked-out for the case of sinking.

In case of towing of piles bundles:

— bundle towing connections and wires should be designed based on dynamic analysis of the launch, towing and holdback forces
— bundle break-out forces shall be conservatively estimated; the effects of launch track slope/settlement, mechanical resistance, launch bogie/roller conditions and other relevant parameters that influence the break-out force shall be considered
— the stability of the total bundle and tow heads/structures shall be calculated for all stages of the launch, tow installation and flooding; side current forces, hydrodynamic effects during tow and free surface effects during flooding operations shall be considered
— bundle behaviour during tow should as far as possible be estimated during design. Inline structures should as far as possible be designed in a way that will minimize the generation of hydrodynamic drag, inertia and lift forces that could cause an instable/fluctuating bundle configuration during tow
— sensitivity studies shall be carried out for essential parameters such as weight, ballast, buoyancy, salinity, cross current, towing speed, back tension, internal pressure loss etc. for relevant phases.

Guidance note:

Further guidance on loads acting on the component during wet towing sub-operation is provided in DNVGL-ST-N001 Sec.11 *Sea voyages*.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

3.6.3 Dry transport

Dry transport (dry towing, vessel transport) assumes transport of component(s) loaded onto a flat top cargo barge, general purpose cargo carrier, submersible heavy lift vessel or jack-up vessel, see Figure 3-7.

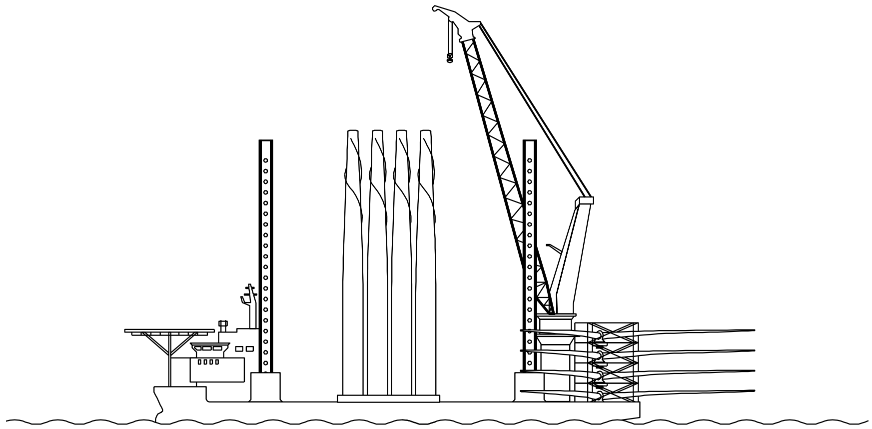


Figure 3-7 Dry transport of wind turbine components

The grillage elements (including shimming plates) shall be used to distribute a concentrated deck load to a sufficient number of load carrying elements. Sea fastening shall be used to secure the transported components from rotations (e.g. overturning) and translations in all directions. The sea fastening, grillage and shimming plates design shall duly reflect structural strength limitations of a component to be transported. Effects of global loads on local strength shall be considered.

Grillage and sea fastening shall be designed and erected taking into account all physical limitations implied by the load transfer procedures/methods both to and from the transport vessel(s).

Typical physical limitations may be related to:

— available heights
— strict tolerances, etc. imposing requirements to erection/welding sequence
— load-out trailer layout
— space needed for (operation of) load-out systems, e.g. pumps, hoses, pull/push units
— set down tolerances and shimming requirements
— aero- and hydrodynamically induced vortex shedding and the risk of vortex induced vibrations (especially when transported vertically)
— cutting/handling offshore
— securing of components before lifting
— possible need to set down the component again and re-instate sea fastening offshore.

During the development of the component to be transported positioning tolerances on the grillage including, if applicable, effect of vessel hull beam deflections shall be considered.

Verification of the components structural design shall be carried out in accordance with App.B.

Sea fastening design for offshore installation operations should allow easy release and provide adequate support and horizontal restraints until the component may be lifted clear of the vessel, or launched as applicable.

Before departure an inspection of the sea fastening and the component shall be carried out to confirm compliance with above stated requirements.

Tow-out criteria shall be established and agreed for all towing operations. The towing criteria shall consider all limitations imposed by weather restricted transports.

The crew of the towing vessel(s) for the towed component(s) shall be familiar with the equipment and installations which may be used during the voyage. The crew shall be instructed whether regular inspections of the sea fastening and the component(s) are necessary and which actions are to be undertaken in case of any deviation from the approved conditions.

Adequate contingency shall be provided for sailing in narrow areas and/or in areas with heavy traffic.

3.7 Offshore installation

3.7.1 Documentation

All prerequisites for the execution of the erection work of an asset (component) of the wind power plant shall be stated in the offshore installation documentation, among others:

— requirements for the weather conditions (limiting wind speeds, temperatures, precipitation, wave height, water level and current speed, visibility, etc.)
— requirements for site access and working area or adequate curing of the foundation or any grouted connections
— precise designations and dimensions of all components to be assembled and erected, together with all data needed for erection, such as weights, lifting points etc.
— special tools or equipment necessary for the installation with due consideration for the loads and weights during installation
— requirements for these tools or equipment, e.g. testing or regular inspections
— maximum admissible time between installation of the substructure and erection of the rest of the support structure, and the maximum admissible delay until mounting of the topsides structure or the RNA of the wind turbine
— requirements for the vessels (tug power, navigation equipment etc.) and other equipment used (floating cranes etc.)
— quantities of all equipment and material necessary for the installation (e.g. grouting material, bolts, mooring and fastening equipment, special tools)
— required qualification of the technical personnel.

In the offshore installation documentation all working steps needed for erection shall be described in format and level of detail that the qualified technical erection personnel performing the required tasks are able to understand the instructions. This means among other provision of the following information:

— auxiliary equipment and resources (e.g. lubricants, grouting materials, oil for filling up the gearbox)
— references to drawings, specifications or instructions necessary for the offshore installation
— arrangement of installation vessels, buoys, lights etc. including the mooring / positioning equipment
— lifting, lowering, touchdown and ballasting procedures including admissible draft(s) and / or bottom clearance(s)
— work instructions including all working steps for bolted and welding connections to be carried out during erection
— all necessary tests and checks
— procedures for energizing electrical equipment and de-energizing in case of emergency requirements
— necessary monitoring of seabed conditions (including condition of the scour protection, condition of the installed gravel beds below a gravity base foundations).

In the offshore installation documentation hazardous situations which may arise through deviation from the planned erection sequence shall be named and countermeasures shall be specified. Such situations may include:

— lightning, snow, icing, visibility, extreme temperatures, very high winds, waves or currents during installation, prolonged periods of the substructure and/or the support structure standing without topsides structure at critical wind speeds and/or wave frequencies
— hazardous situations which may arise due to unintended motion or rotation.

Safety and accident-prevention measures which are necessary before or during assembly, installation and erection, e.g. use of personal protective equipment, guards or locking devices shall be specified in the offshore installation documentation. For personnel entering any enclosed working space such as the hub or blade interior, safety provisions shall be stated, e.g. standby personnel. Emergency procedures and rescue operations shall be described.

The execution of all checks and working steps within the erection process shall be duly documented in the offshore installation documentation. For each check and working step, there shall be appropriate cells in the documentation template to be filled in, together with fields for recording measurement values and test results. All adjustment settings and set values as well as the expected measurement results shall be specified. The following fields shall be provided in addition:

— type identification of the offshore asset (where applicable: designation, type, type variant, rated power, identification and position at the offshore site, water depth, manufacturer, supplier, importer)
— weather conditions, if the weather is able to influence the quality of work (e.g. temperature, rain, snow, lightning, visibility, ambient light, average wind speed, gust wind speed, wave height and tidal condition)
— version numbers of all software and parameter lists which are installed
— checklist of the execution of all working steps, tests and checks.

3.7.2 Launching

Launching is a process of sliding of the component into the sea from the ballasted barge or other floating unit, see Figure 3-8.

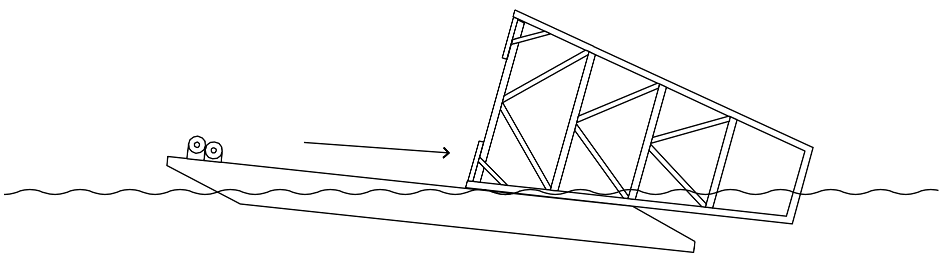


Figure 3-8 Launching of a jacket

During T&I planning following aspects relevant for launching shall be considered:

— water depth at the launch site as well as the seabed condition
— launch barge submergence behaviour
— weight and CoG of the object
— influences of skidway friction and tilt beam motion on the structure of the component
— minimization of sea fastening to simplify launching process
— positive pressure in intact/sealed compartments.

When the component to be launched has sufficient floating capability, the barge shall be separated from the structure by appropriate additional ballasting to avoid unwanted impacts.

Documentation for launching shall include the following information:

— limiting environmental conditions
— contingency plan for failure of operational systems
— description of the necessary checks of the barge, operational systems and equipment
— description of tightness tests for compartments, seals, closures.

The following tests shall be carried out before the start of transport to the launching location:

— tightness test of compartments, seals, closures
— checks of the barge, operational systems and equipment (operational systems and closures shall be in the proper condition and orientation).

During the launching following parameters shall be duly monitored:

— position of the barge and launch direction
— environmental conditions including wind and current (both speed and direction)
— draught, heel, trim and stability of the launched component
— clearance of the component.

3.7.3 Lifting

Elements which may be subjected to shock loading during the lifting and lowering procedure shall be especially considered and duly strengthened. Protection by guides and in special cases fendering may be necessary.

Lift points should be configured such that the risk of damage and/or accidental release of slings (due to possible impact loads) are negligible. Lift point layout and rigging design shall ensure adequate stability and acceptable tilt of the component during all phases.

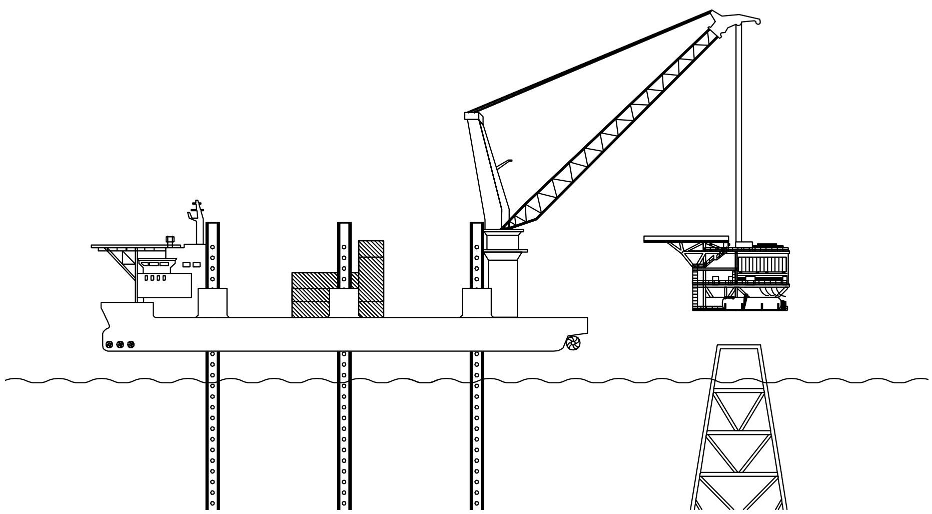


Figure 3-9 Lifting of a topside

Adequate stability of the component shall be ensured considering:

— all possible unfavourable combinations of sling loads (especially during upending), buoyancy (and changes of buoyancy), inaccuracy in the determination of the centre of gravity or its shift (especially during lowering into the water)
— vertical wave loads
— horizontal (differential) wave loads
— current loads
— lift dynamics
— tolerances of weight from manufacturing
— motions of the lifting vessel.

Dynamic loading shall be considered to account global dynamic effects resulting from vessel motions, boom, wire and rigging stiffness, boom tip location and motions, crane movements and wind loading.

Verification of the lift points and lifted structure design shall be carried out in accordance with App.B.

3.7.4 Set-down

Set-down is a process of unloading the hook upon lowering of the lifted component onto the sea bed or on the substructure.

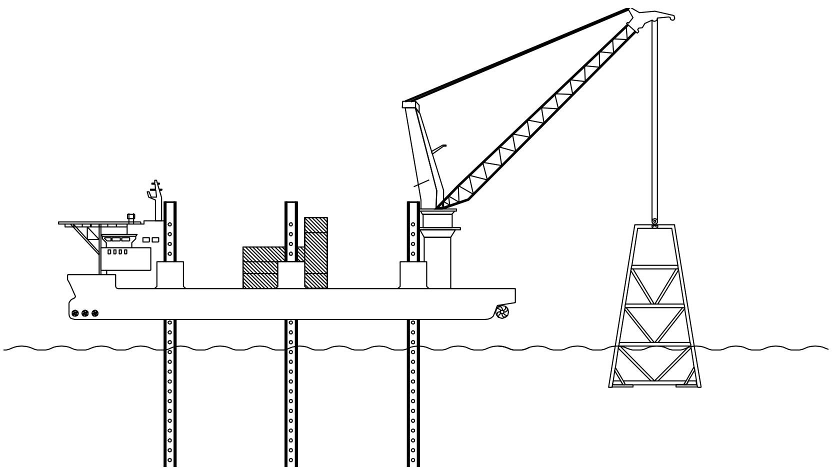


Figure 3-10 Set-down of a jacket

Allowable maximum set-down velocity shall be determined during development phase based on impact analysis. It shall be ensured that this set-down velocity is not exceeded. It may be necessary to use a heave compensator to ensure that the actual set-down velocity is less than or equal to the maximum allowable set-down velocity.

The component shall be set-down smoothly and with minimal delay to avoid exposure to high waves, wind gusts or low-cycle fatigue. It is recommended to incorporate tolerances of the initial positioning into the structure.

It is recommended that the set-down speed is limited to a maximum value of 0.5 m/sec and impact loads to no more than 3% of the (submerged) weight (including added mass).

The component set-down onto seabed shall be capable of being levelled if there is a sloping or uneven seabed surface. Levelling procedure for set-down component shall be duly described in the T&I documentation and shall include acceptance criteria (deviation from verticality).

3.7.5 Piling

Design of pile foundations shall comply with DNVGL-ST-0126 (for foundations of wind turbines), DNVGL-OS-C101 (for other offshore steel structures).

Following aspects shall be considered during T&I planning and development of the piling procedure:

— soil characteristics
— pile driving method
— sizes of driving and reserve hammers
— lifting equipment for hammers and piles
— lifting/upending procedure for piles
— noise mitigation.

Piles shall be equipped with penetration markings showing the pile penetration in the soil.

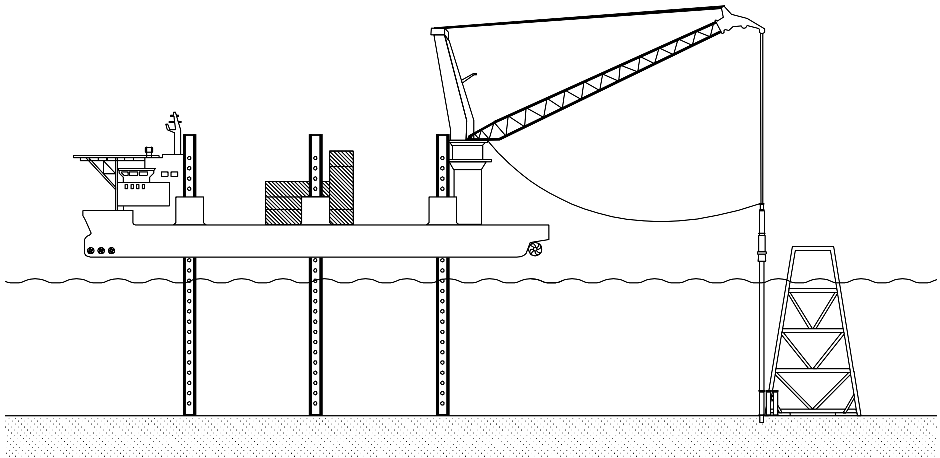


Figure 3-11 Piling of a jacket pile

Following aspects shall be duly investigated during the development of the pile driving procedure:

— feasibility of the pile installation shall be proven by a drivability study or an equivalent analysis
— structures with piled foundations shall be assessed with respect to stability for both operation and temporary design conditions, e.g. prior to and during installation of the piles
— if subsea templates shall be applied during piling, the on-bottom stability of the template shall be verified under consideration of environmental loads both on template and pile(s), duration of piling and expected soil conditions
— pile driving refusal criteria shall be defined and evaluated for the selected hammers
— the hammer shall be selected based on site specific drivability analysis under consideration of soil characteristics and hammer properties
— noise mitigation approach (e.g. by means of bubble curtain, sound dampers) shall be calculated and evaluated on effectiveness, where required
— followers should be used for the installation when it is not possible or not preferred to directly drive the pile's tip
— to avoid driving on the water column, vent holes shall be provided in the pile or in the follower; it shall be considered that holes in the pile reduce pile's yield strength
— total pile stresses (static plus dynamic) shall not exceed the pile's yield strength.

If for the positioning of a pile a template (base frame) is used, its on-bottom stability shall be verified within the development phase. To prevent sliding the pile installation sequence should be started with the installation of two piles in diagonal corners.

Jacket piles shall be installed in a sequence which achieves stability of the jacket in all stages of the installation. A proper arrangement for locating and guiding the piles into the pile sleeves shall be established. This requirement is of particular importance for subsea operation. Horizontal clearances between hammer, pile or follower and the jacket structure shall not be less than 1 m.

Fabrication tolerances, clearances, deflections and pile sway have to be considered.

The following risks, means of their mitigation and contingencies, as well as relevant limiting values, method of their measurements/monitoring and acceptance criteria shall be described in the T&I documentation:

— failure of hydraulic system
— failure of electrical system
— soil plug rise during piling
— failure of mechanical components of the hammer (including due to fatigue reasons)
— pile refusal due to unexpected soil properties or pile set-up after piling interruption

— pile running (unexpectedly too high driving progress)
— failure of the remotely operated vehicle (ROV) used for the monitoring of piling process
— influence of noise mitigation on the hammer efficiency
— sticking of the follower in the pile
— exceedance of noise limits
— welding equipment failure, should the pile be extended at the offshore site by an additional part welded to the pile’s tip
— unacceptable inclination of the driven pile
— unacceptable deformation (including dents, pile ovalization)
— additional or oversized shear keys, and the clearance of the hammer guides.

Upon completion of the pile driving the influences on the pile structure shall be verified in accordance with DNVGL-ST-0126 (foundations of wind turbines), DNVGL-OS-C101 (other offshore steel structures).

All deviations from the approved procedure identified on site (including all damages, design modifications, deviations from sequence and timing) as well as their reasons (if known) shall be duly recorded and analysed on impact on the structural integrity.

During T&I planning following options for reducing of the pile driving resistance may be considered in the case the pile reaches refusal before the target penetration:

— plug removal inside the pile e.g. by drilling or jetting and air lifting to reduce pile driving resistance
— soil removal below the pile toe by means of similar technique
— drilling an oversized hole under the pile toe with consequent grouting of the annulus between the pile and the drilled hole.

During pile installation pile-driving-records shall contain blow counts and hammer energy for every pile.

T&I documentation for drilling remedial action shall describe following risks, means of their mitigation and contingencies, as well as indicate relevant limiting values, method of their measurements/monitoring and acceptance criteria:

— failure of hydraulic system
— failure of crane, lifting equipment
— failure of ROV used for the monitoring of drilling process
— hose rupture and oil spillage
— pile or pile toe damage by the drilling equipment.

After pile installation the pile fatigue assessment shall be carried out based on pile-driving records. Influence of the deviation from verticality (as defined in the design documentation) and any kind of pile deformation (including pile ovalization) shall also be evaluated for acceptance.

3.7.6 Float-over

Float-over operation is a possibility for the installation of topsides of OSS or accommodation platforms. The following manoeuvres are carried out during the float-over operation:

— positioning of the barge in order to align the topside structure with the substructure
— ballasting of the barge to submerge and connect the topside with the substructure (set-down/transfer).

Planning of the float-over operation shall ensure that:

— the structural integrity of the topside due to load effects during float-over (hydrostatic pressure, deflections, environmental conditions including waves and wind) is not endangered
— the topside has adequate static and dynamic floating capability and stability
— adequate clearance between the topside and substructure (considering motions of the platform and tidal effects) is provided
— the legs of the substructure are duly protected from impact by the barge by means of fenders

- vertical and horizontal forces during topside's set-down onto the substructure are damped and equalized by polyester lines attached to winches on the barge, by correspondent protective pads or shock-absorbers installed on the legs.

Methods shall be considered to minimize the risk of striking contact between the barge and the topside, immediately following set-down (e.g. due to wave impact or incorrect ballasting).

During float-over careful consideration of the prevalent currents, waves and swell (height, period, direction) is required.

Guidance note:

Further guidance on float-over operations is provided in DNVGL-ST-N001 Sec.15 *Lift-off, mating and float-over operations*.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

3.7.7 Jacking-up

Jacking-up is the method of topside elevation onto the offshore substructure (jacket) by means of temporary hydraulic jacking system.

All lifting equipment (hydraulic strand jacks) used for the installation shall be designed for sufficient safe working limits.

Strand wires shall be kept clean all the time. During onshore preparations (assembly at the manufacturing yard) any works above or nearby the installation equipment that may potentially affect the strand wires (sandblast, weld, grind, cut) shall be prevented, relocated or isolated by covering with sheets or blankets. Special care shall be taken to prevent twisting or kinking of the strands.

Any seawater contact with the strand jacks placed on the head legs shall be prevented.

In the T&I documentation following information shall be stated:

- environmental criteria for the installation (among other significant wave height, wind speed, rain- or snowfall limitations)
- uncovered maximum strand wire exposure time
- expected duration of the overall lifting (shall be in-line with the weather forecast window)
- description of lifting speed control.

Environmental limits may not be exceeded during installation and shall be duly monitored.

Prior to the start of the installation the following checks shall be performed:

- availability of functions of the central computer responsible for control of hydraulic lifting equipment
- pressurization and absence of leakages of the hydraulic system
- cleanliness of every strand jack
- level checks of the engine (fuel, oil) and in the hydraulic aggregates (hydraulic fluid).

Once the topside is elevated it shall be levelled e.g. by lifting by the correspondent strand jacks. Levelling criteria shall be stated in the T&I documentation.

3.7.8 Welding connections

During design of steel structures, accessibility of the welding areas during offshore activities (including installation and repairs) shall be considered (e.g. by installation of temporary scaffolding and protection required for welding).

All welding carried out on the construction site shall be carefully planned; shelter, lighting and weather protection shall be planned depending on the welding process. It should be aimed at conditions that are equivalent to workshop conditions.

Procedures and test specifications for all welding and tests shall be available at the construction site.

Tests which are required for the respective structural category or execution class shall be carried out; welding parameters shall be applied according to specifications. Qualification of welders and NDT operators shall also be confirmed before start of welding operations.

Preparation of working area, storage of welding consumables, cleaning and joint preparation, pre-heating, welding, waiting time, NDT testing, coating, coating inspection shall be monitored during execution.

The influence of the pile driving fatigue on the welding shall be analysed and compared with the design assumptions.

3.7.9 Bolted connections

Design of the bolted connections shall comply with DNVGL-ST-0126.

Installation documentation shall provide instruction for the execution of the bolted connection. This instruction shall contain at least the following information:

— pre-treatment or checks of the surfaces to be joined (including coating thickness, flatness, roughness)
— if additional activities at the flanges (e.g. underpinning) during the connecting work are already intended in the design, these shall be described together with the necessary materials. If these activities only become necessary when certain criteria are exceeded (e.g. maximum gap widths), the criteria and measurement procedures shall be stated
— lubrication condition of thread and bolt/nut
— tightening procedure and all data needed for the manufacturing (e.g. preloading, torque required, tightening tool)
— tightening sequence.

3.7.10 Grouted connections

Design of the grouted connections shall comply with DNVGL-ST-0126 and DNVGL-RP-0419.

The grouting procedure shall be defined in detail by the manufacturer of the grouted connection in a method statement. The method statement shall contain at least the following information:

— responsibilities and qualification of personnel
— materials applied
— storage of materials (grout, binder, mixing water) during transport and installation
— equipment (mixing plant, pump, grout lines, cranes, testing lab) definition of required environmental conditions
— specification of required environmental conditions (air temperature, water temperature, wind and wave conditions, weather window, temperature of mixing/pumping equipment, temperature of relevant steel parts)
— detailed description of working steps during grouting procedures
— specification of measures to be taken for grouting at low temperatures (if applicable)
— detailed description of measures to be taken in case of interruptions of the grouting process
— specification of the maximum duration of the grouting process (specifically, how long should the grouted structures be supported)
— detailed description of quality control (material tests etc.)
— specification of requirements for health/safety.

The following checks shall be performed before starting the grouting process:

— check of permissible environmental conditions as per method statement
— inspection of components and structural details (dimensions, geometry, surface quality, corrosion protection, cleanliness, marine growth, state and condition of grout seal)
— check of materials: grout material (type, batch, manufacturing date, data sheets, storage conditions), mixing water (storage conditions, fresh water)
— check of mixing/pumping equipment (visual check of mixer, pumps and grout lines and coupler elements)
— check of implementation of quality control as per method statement.

The following checks shall be performed during the grouting process:

— check of permissible environmental conditions as per method statement
— check of mixing procedure (minimum/maximum water content, mixing process)
— check of maximum duration for grouting process as per method statement
— visual inspection of the mixed grout and check of relevant grout properties (consistency, air void content, sampling for compression tests)
— documentation of any irregularities and deviations to method statement
— check of grout overflow, visual inspection of overflowing grout.

The following checks have to be performed after the grouting process:

— check of permissible environmental conditions as per method statement and relevant documentation
— analysis of test results performed on grout properties and accordant documentation.

In case that the grouting process had to be interrupted and no procedure had been defined how to continue the grouting process in the method statement, DNV GL shall be involved before continuation of the grouting process in order to agree on a suitable procedure to continue the work.

SECTION 4 TRANSPORT AND INSTALLATION OF ASSETS AND COMPONENTS

4.1 Foundations and substructures

Foundations and substructures, see Figure 4-1, form the subsea part of the asset's structure. This standard covers fixed substructures rigidly connected to the seabed by means of pile foundation, under the effect of own weight (gravity base structure) and negative pressure (suction bucket).

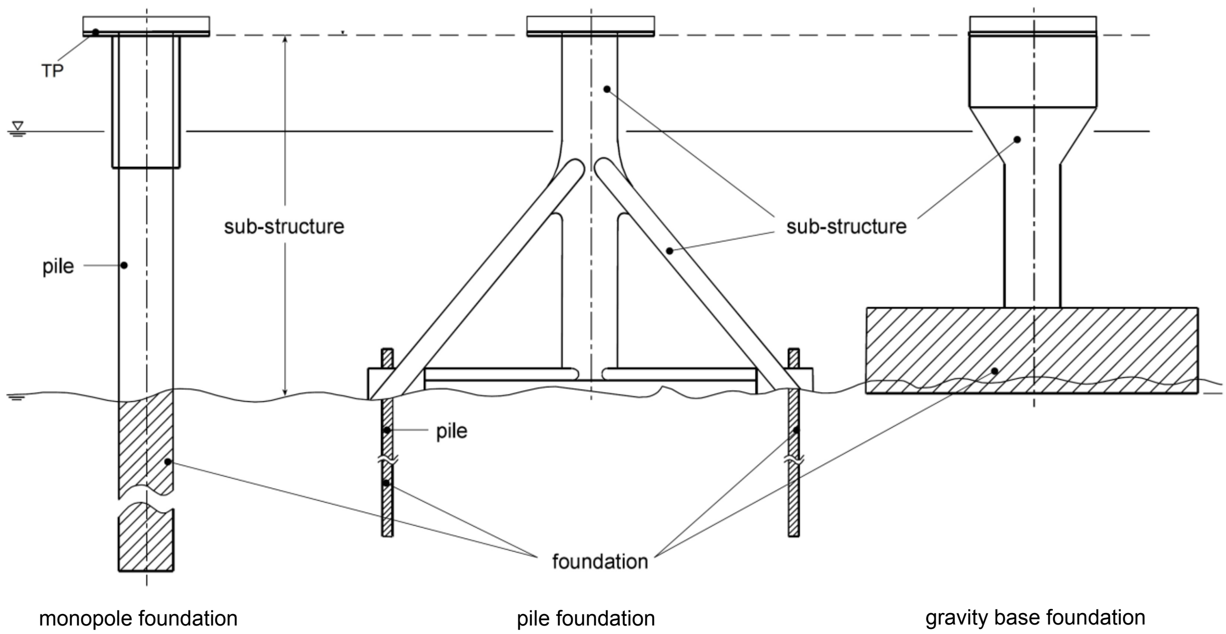


Figure 4-1 Offshore foundations and substructures

Design of foundations and substructures shall comply with DNVGL-ST-0126 (foundations of wind turbines) and DNVGL-OS-C101 (other offshore steel structures).

Requirements of Sec.3 shall be considered as relevant.

Within the execution of foundation (substructure) installation it shall be ensured that the installation location does not deviate from the coordinates indicated in the design documentation limits. In case that such deviations exist, assessment shall be carried out to ensure that the deviations do not endanger

— the structural integrity of the asset over the life-time of the asset (among others due to new specific environmental conditions e.g. depth, sea bed properties, currents, wind turbulences)
— the power cable system design
— ship navigation and environment
— the existing assets (crossing of other cables, pipelines) and un-exploded ordnances.

4.1.1 Gravity base structure

Offshore gravity base structures are substructures held in place by gravity. They may be built using concrete as well as precast element solutions and are typically constructed onshore and towed (floating) to their final position offshore. Tanks or cells inside the gravity base structure may be used to control buoyancy during transportation. By flooding the cells with water the gravity base structures are set down. In order to have sufficient ballast, cells are typically filled with sand, rock or other materials.

During T&I planning all loads which may occur due to effects such as hydrostatic pressure, impacts, mooring, guiding, pulling by tugs and winches, etc. should be considered in the design of the gravity base structure.

Prior to dry-dock flooding and prior to transport to the installation site the following shall be carried out prior to dry-dock flooding:

— check of blockage of the installation systems: piping for flooding, grouting, skirt water evaluation, etc.
— the weight of the gravity base structure should be calculated on the basis of accurate specific weights and volumes and/ or weighed or estimated weights of parts of the component, equipment, etc.
— the buoyancy of the gravity base structure should be estimated on the basis of an accurate geometric model and weight limits
— the position of the center of buoyancy should be estimated accordingly.

Trial-ballasting test should be performed prior the start of the transport.

For float-out the requirements of [3.6.1.4] shall be considered.

During the transport of gravity base structures afloat the following shall be monitored:

— draught, trim, and under-keel clearance
— position and orientation of the component
— environmental conditions including tide
— air pressure in air pressurised compartments
— air leakage
— water plug (preventing escape of the air from the compartment inside the gravity base structure providing buoyancy), if relevant.

4.1.2 Monopile and transition piece

Requirements for transport in [3.6] and piling procedure in [3.7.5] shall be considered.

The inside of the transition piece (TP) shall be inspected prior to start of the transport to the installation site. Special attention shall be paid to the grout seal.

Prior to the installation of TP the navigational lights previously temporarily installed on the monopile shall be removed. The monopile surface shall be duly cleaned to ensure proper execution of grouting connection.

Inclination of the monopile and TP shall be in acceptable range depending on defined total tolerance for the tower axis. Reference is made to DNVGL-ST-0126.

Earth connection between TP and monopole shall be ensured to fulfil the requirements of IEC 61400-24, EN 50522. Tests shall be carried out upon complete installation.

Installation of a TP-cover is required to ensure suitable condition of TP till the commencement of tower (segment) installation.

4.1.3 Jacket

Requirements for piling and grouting in [3.7.5] and [3.7.10] shall be considered.

During T&I planning a contingency plan shall be evaluated for the case of congestion/blockage of the grouting pipe. Double redundancy shall be provided on jackets, i.e. in case that the primary grouting pipe fails there shall be two additional options provided (e.g. supplemental grouting pipe and stinger connector for grouting with the involvement of a ROV).

Earth connection between jacket and piles shall be ensured to fulfil the requirements of IEC 61400-24, EN 50522. Tests shall be carried out upon complete installation.

Depending on the design and method of installation, e.g. pre-piling, post-piling, use of mud-mats a proper sea bed preparation is required.

If temporary support is foreseen for holding the jacket during curing of the grout, it shall be removed (released) after curing of the grout to transfer the load through the grouting connections. The removal and retraction of temporary supports shall preferably be tested onshore, before load-out.

An adequate weather window shall be chosen and sufficient temporary support of the jacket shall be guaranteed during grouting and grout curing to prevent early-age cycling of the grout material.

Guidance note:

Further guidance on jacket installation operation is provided in DNVGL-ST-N001 Sec.13 *Jacket installation operations*.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

4.1.4 Suction bucket

The driving force for the suction bucket to penetrate the soil is the hydrostatic pressure related to the depth at the installation site and the vacuum established inside the bucket.

During T&I planning a contingency plan shall be worked out for the case of congestion/blockage of the concrete route. Double redundancy shall be provided i.e. in case if the primary route fails there shall be two additional options provided (e.g. supplemental hose connector and stinger vent hole for concreting with the involvement of a ROV).

Installation of the suction bucket should be monitored by a ROV at all times (penetration sequences, grouting).

Once the suction buckets are flooded and setdown on the seabed (or scour protection) is completed, it shall be ensured that the openings in the bucket (e.g. concrete overflow holes) are closed to enable the pumps to create the required negative pressure for penetration into the soil by pumping out the water from the bucket.

For substructures with several suction buckets the penetration process shall be carried out on all suction buckets simultaneously. The inclination of the substructure shall be constantly monitored. In case that levelling is required this shall be achieved by decreasing or increasing the suction pumping rate specifically on every single suction bucket.

Acceptance criteria for the penetration depth and inclination shall be stated in the T&I documentation.

Within the development phase it shall be confirmed that during filling the bucket with the concrete, any uplifting piston-effect from the concrete pressure may not occur. The level of concrete inside the bucket and flow rate of the pumped concrete shall be monitored. The overflow holes will be prepared and be open during this procedure.

Upon the completion of concreting, all openings in the bucket shall be sealed.

4.2 Scour protection

Within the development of a wind power plant the following shall be prepared concerning scour:

— procedures, contingency plan
— investigation of influence (punch-through) of the scour protection on the substructure.

In the T&I documentation dimensions of the different layers (filter, armour) of the scour protection around the foundation (substructure) shall be defined, including layer height, radius, side slopes, vertical and horizontal tolerances, gravel specifications. Timescale for the installation duration as well as limiting environmental conditions shall be provided.

Prior to start of the transport and during the installation of the scour protection the following shall be ensured:

— sufficient quantity of appropriate scour materials and all necessary deployment equipment shall be prepared for mobilisation
— the anti-scour material shall be transported and installed with the specifications in the design documentation (including gravel material, weight, grading in mm, coefficient of uniformity)
— care should be taken when laying scour protection to ensure that bad weather and/or high currents during the installation phase do not cause damages to the lower layers.

During the installation of the scour protection (and especially during current direction change) regular intermediate check surveys shall be carried out to verify the touchdown point, the building up progress and the quality of the work.

After completion of the work an as-built report shall be issued including comparison of original design of the scour protection with the as-built configuration.

Guidance note:

Cables should be trenched or otherwise protected in scour-prone areas. Additional precautions may be required close to J-tubes or I-tubes at a substructure, especially immediately after laying of the cable.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

4.3 Corrosion protection

Within the development of a wind power plant the following shall be considered with regard to the corrosion protection:

— the mechanical integrity of anode fastening devices during installation
— cathodic protection is mandatory for the submerged zone and shall serve jacket and jacket piles (where relevant); sufficient electrical connectivity between them shall be provided
— installation procedure including drawings of the detailed design showing location of individual anodes, requirements for preparation, specification of materials and equipment to be used, information on handling and storage of anodes and materials for anode installation, reference to welding and/or brazing procedure specifications and qualification of personnel carrying out welding/brazing, inspection and testing of anode fastening
— the splash zone coated areas not covered by the anodic protection, to avoid further unnecessary damage during T&I, or to ensure that repairs where necessary are implemented before installation.

Guidance note:

Reference is made to DNVGL-RP-0416 *Corrosion protection for wind turbines*.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

4.4 Power cables

Detailed design of the transport and installation steps for the cable system and its interfaces is a process that shall address all possible scenarios such as the following:

— cable storage, load-out and transport
— cable laying, e.g. offshore, in landfall area and/or at infrastructure crossings
— cable pull-in at offshore units and landfall
— cable burial, including burial tools and their characteristics
— cable protection by non-burial methods
— cable jointing
— contingencies.

Risk assessments shall be carried out for each step of the installation process. An overall installation manual shall be developed. The installation manual shall include detailed procedures for the individual installation steps, including the relevant operational parameters and limiting weather conditions established in the installation analyses.

The installation method chosen shall facilitate control over the cable configuration at all times.

Detailed requirements related to T&I of the power cable system with a focus on offshore, landfall and, where applicable, onshore construction are specified in DNVGL-ST-0359.

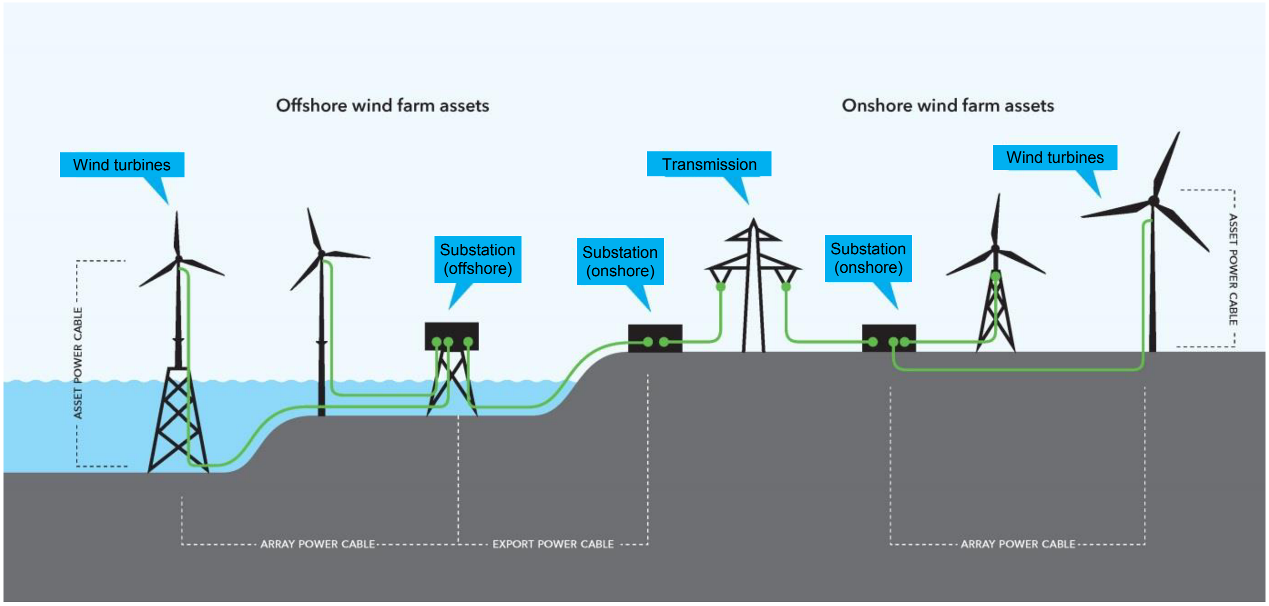


Figure 4-2 Power cable system

4.5 Tower

A common tower design for both onshore and offshore wind turbines is a tubular steel tower, which is manufactured in sections of typically 20-30 m length with flanges at both ends. The tower will typically have circular cross-sections.

In segmented steel and concrete towers the cross-sections are divided into a number of panels which typically are assembled by bolts. A major advantage for a segmented tower design is the facilitation of transportation.

Lattice towers are typically manufactured by means of welded or bolted tubular steel profiles or L-section steel profiles. The lattice towers are typically three- or four-legged and consist of corner chords interconnected with bracings in a triangulated structure. A major advantage of a lattice tower design is the abundance of experienced lattice tower designers and manufactures from other industry sectors.

During T&I planning the following shall be considered for towers and tower segments/panels:

— manufacturers T&I manuals
— requirements of Sec.3 (as relevant), as well as of App.B
— relevant conditions from the WT Type Certificate.

During T&I planning it shall be considered that tubular towers shall be designed so that resonance with the frequencies of vortex shedding will not occur during transport and installation. Vortex-induced vibrations may be prevented by designing for an arrangement of special protection (temporary wind spoilers otherwise known as strakes, vortex ropes) and/or by designing for arranging the structural components and their temporary supports appropriately.

Transportation method and arrangement (including necessary supports inside tower segments) shall be described and match with the assumptions of the component design.

For both, concrete and steel tower segments, the following is valid:

— wooden cradles with at least 10 cm thickness shall be applied for the intermediate storage, on the transport vehicle (or ship) and onsite preassembly works
— wooden cradles shall have either spacing or geometry suiting the radius of the tower segment/panel

— alternative solutions to wooden cradles can be applied if their effectiveness is justified
— for the load-out the number of lifting loops, their material and breadth shall be chosen in such way that the structural integrity is not endangered due to dead weight of a segment, accelerations during lift up, movements during load-out excited by environmental conditions
— proper levelling and centering of the segments shall ensure that the limits set within the design are not exceeded.

Tower weight shall be compared with the theoretical assumptions made during the development phase.

If grout connections shall be performed (e.g. for joining concrete towers segments/panels) sampling and tests are required to assure integrity of the joints. Reference is made to [3.7.10].

Before installation commences, the pre-installation inspection shall be carried out according to the manufacturer's instructions, which shall include the following:

— check whether elements inside the tower (e.g. pre-installed ladders, switching cabinets) are distorted or bent, whether signs of cracks and dents (outside the design limits) are not considered
— in the pre-assembled tower segments – whether all bolts are marked as torqued and no turning is considered
— check whether flanges of tower segments are even and free of foreign elements ensuring parallel joining of the flange surfaces (since a gap in the flange connection leads to a strong increase in loading of the bolts) and correctly coated
— inspect the bolt holes in the flanges as well as flanges themselves for corrosion and cracks
— check whether bolts are free of damages and impurities, free of any sign of corrosion, scratches, bents and crack-development
— check whether the bolts are handled as per manufacturer's requirements; this includes their lubrication and temperature requirements.

If applicable, tightening/torqueing procedure (including sequences and values) shall be carried out in accordance with the manufacturer's instructions. Calibration of the bolting equipment used for tower segment installation shall be applied to check the output torque (tightening moment) of the tool within acceptable tolerance.

Once the installation is completed, the following checks and tests according to the erection manual shall be performed:

— condition of grounding and bonding wires as well as their terminations (including at ladder assembly)
— bolts marking indicating as-torqued position
— condition of the top flange joint/bottom flange joint with respect to damages or irregularities (inspection to be performed on both sides)
— condition of lights, lighting cables and light switches, power sockets, power supply cables and cable support system to be inspected visually
— condition of pre-installed ladders including fall arrest system.

All deviations (items missing, damages found) as well as the cause of the damages (if known) shall be duly recorded. Deviations and damages identified upon installation of the tower shall be analyzed for impact on the structural integrity of WT.

4.6 Nacelle

During T&I planning the following shall be considered for nacelles:

— manufacturers installation manuals
— requirements of Sec.3 (as relevant), as well as of App.B
— relevant conditions from WT type certificate

Influences of T&I conditions and of the transport arrangement on the structural integrity of the nacelle shall be considered during T&I planning. Lifting points shall be adequately dimensioned.

Transportation method and arrangement shall be described and match to the assumptions of the component design.

Transport fastening in the nacelle shall be described and weather protection shall be ensured (i.e. maintenance of atmospheric conditions inside the nacelle).

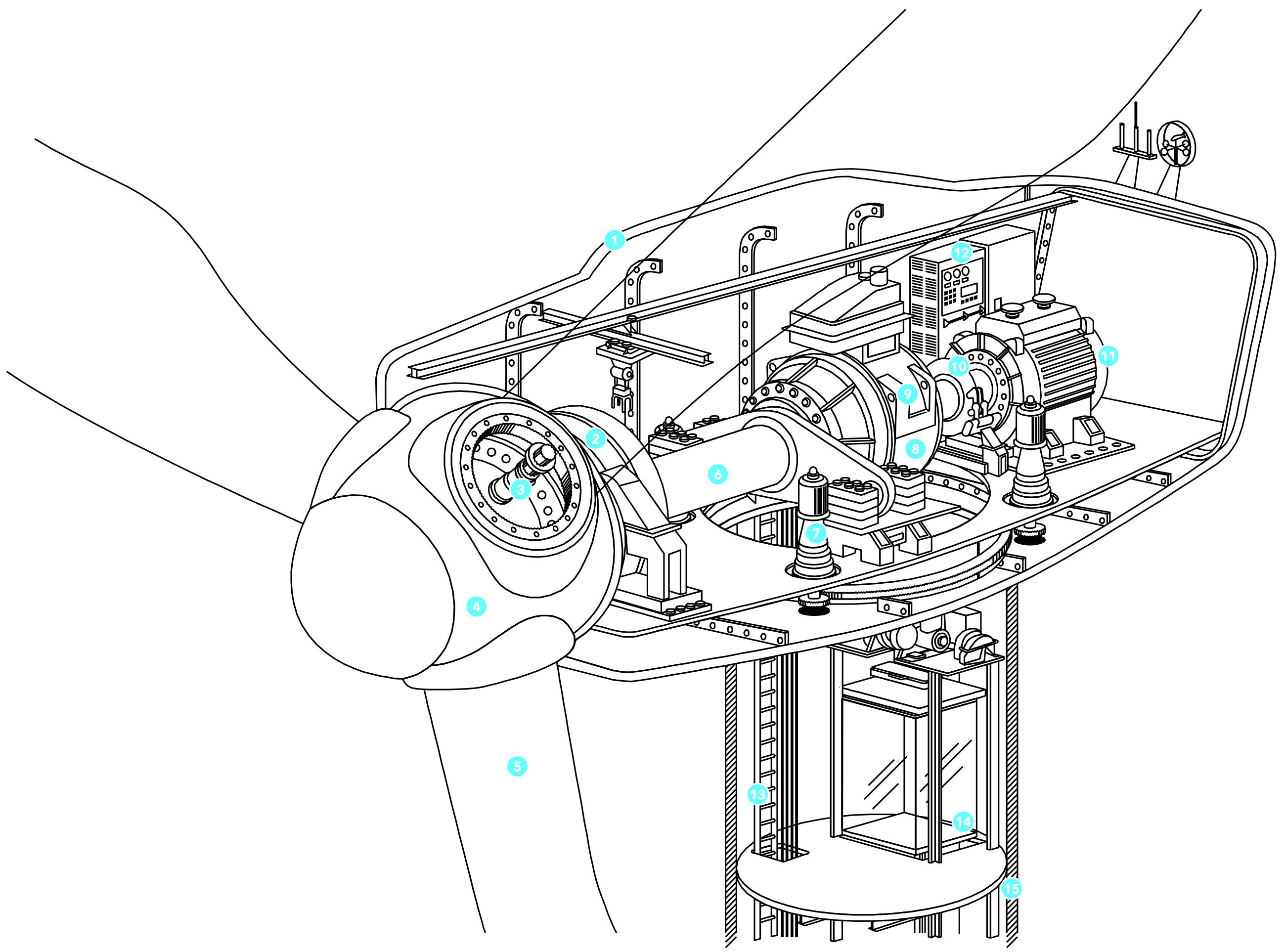
Corrosion protection of machined surfaces (e.g. flanges) shall be guaranteed e.g. by wax-based corrosion inhibitors. Upon assembly, the temporary corrosion protection shall be duly removed.

Handling of components shall be described and protection against mechanical damage shall be foreseen (e.g. protection against contact of nacelle with securing transport chains).

In case that extended duration of nacelle storage or transport is expected, regular rotation of the drive train shall be ensured in accordance with the manufacturer’s requirements.

Furthermore during long stand still / idling periods, e.g. caused by missing grid when the turbine is erected and installed, regular rotation of drive train and sufficient lubrication shall be ensured in accordance with the manufacturer requirements.

Nacelle weight shall be compared with the theoretical assumptions made during design development. Reference is made to App.B.



1 – nacelle cover; 2 – main bearing; 3 – pitch drive; 4 – hub; 5 – rotor blade; 6 – main shaft; 7 – yaw drive; 8 – gearbox; 9 – lift point; 10 – disk brake; 11 – generator; 12 – electrical cabinet; 13 – ladder; 14 – elevator; 15 – upper tower segment

Figure 4-3 Rotor-nacelle-assembly and upper tower segment of a wind turbine

NDT testing for surfaces and volumetric flaws shall be carried out on load carrying metallic components in accordance with DNVGL-ST-0361.

Following tests and checks shall be carried out prior to start of T&I:

— Visual inspection of the hook-on points (pad eyes, trunnions), clamping points (e.g. yaw bearing)
— check for absence of damages, holes, scratches on fiber glass surfaces
— check the condition of the seals and hatches
— check of the paintwork inside the nacelle
— visual inspection for damages and deviations: main shaft, gearbox fans, gearbox and its oil pipes, brakes, generator and generator fans, yaw drives, cabinets and other components
— check whether loose parts (tools, instruments, fire extinguishers, personal protective equipment, mobile ladder, etc.) are secured or removed
— check whether the transport covers are applied where required, are intact and correctly positioned.

Limiting values for accelerations and vibrations of sub-components and other parts (e.g. electrical cabinets, switchboards, etc.) should be obtained from the component manufacturer and be considered accordingly.

Lifting points (clamping points or hook-on points) where the consequences cannot be predicted or the usage exceeds the intended function or deviates from the intended load-path shall be confirmed by the component manufacturer. Examples: Hook-on points located on the main gearbox, clamping of yaw bearing during transport.

All deviations (items missing, damages found) as well as the cause of the damages (if known) shall be duly recorded. Deviations and damages identified upon installation of the nacelle shall be analyzed for impact on the structural integrity of WT.

4.7 Rotor

During T&I planning the following shall be considered for WT rotors:

— manufacturers installation manuals
— requirements of Sec.3 (as relevant), as well as of App.B
— relevant conditions from the WT type certificate.

In addition, for blades DNVGL-ST-0376 shall be applied.

In order to ensure the integrity of all bolted connections of the blades and rotor star to the sea fastening (pedestal) all tightening elements (bolts and nuts) are to be visually inspected after each transport phase.

During the transport the connection shall be regularly inspected for movement. If nuts indicate turning from the original position, the bolted connection shall be retightened using proper equipment to the specified preload condition.

Before the installation of the rotor commences and upon finalization of the installation all necessary checks shall be carried out in accordance with the manufacturer’s instruction, including:

— check of the nose cone parts for scratches, other signs of damage
— check that the hatch is undamaged and closes properly
— check that the handrails (if any) are undamaged and installed and secured properly
— inspection of the hub (both outside surfaces and internal steel structure and equipment) for cracks, scratches and other signs of damage
— inspection of the flanges for signs of corrosion or damage
— check of the pitch drives for damage
— check of the connecting cables visually for damage and secure contacts
— check whether the hub entrance has been delivered including star-like ladder, platforms, ladder support, connectors and bolts, nuts and washers.

If for the installation of single blade or of the pre-assembled rotor turning of the WT main shaft is required, operability of relevant equipment shall be tested in advance before the start of T&I including the turning actuator, control unit, gearbox oil heating. Blades bearing openings should be equipped with the safety nets.

All deviations (items missing, damages found) as well as the cause of the damages (if known) shall be duly recorded. Deviations and damages identified upon installation of the rotor shall be analyzed for impact on the structural integrity of the WT.

4.8 Topside

Requirements of Sec.3 (as relevant), as well as of App.B, shall be considered.

During T&I planning

— weather window (i.e. environmental conditions and allowable time frame) for T&I procedures shall be defined
— transport conditions shall be assessed to investigate whether additional support or temporary bracing for the equipment installed inside the topside as well as on its open decks is required.

Transport and lifting arrangement (e.g. overall geometry of rigging) shall comply with the assumptions made in the design of the topside. Verification of the topside structure design including lift points shall be carried out in accordance with App.B.

Machinery, components and systems and electrical installations should be designed to withstand the maximum inclinations and accelerations due to roll, pitch, yaw, surge, sway, heave motions of the barge (vessel) during transport. Limiting values (accelerations, vibrations) shall be obtained from the manufacturers (electrical cabinets). If required, additional support, temporary bracing shall be provided. Following equipment may potentially require additional support or temporary bracing:

— transformers
— converters
— shunt reactors
— external coolers or radiators
— tanks containing liquids (e.g. transformer conservator tanks, fuel storages, daily tanks, water tanks intended for firefighting, sanitary needs, etc.)
— gas bottles
— diesel generators
— switchgears and switchboards
— containers on open decks
— gas bottles.

It shall be ensured that additional support or temporary bracing will not damage steel structure of the topside.

Following additional measures may be required:

— physical protection, lifting or fixture for gratings, ladders, handrails, doors, electrical panels, substation cranes hoisting
— removal and transport in a transport container of fire extinguishers, furniture etc. potentially subject to drop during T&I with subsequent their installation upon completion of the topside installation
— lowering of masts, antennas, ventilation units etc. potentially subject to damage during load-out, lifting.

Prior to the start of the topside transport the following shall be duly checked:

— application and condition of additional supports, temporary bracings, physical protection, fixtures
— removal of unsecured or unstable objects (tools, instruments)
— sealing of the venting tubes in tanks containing liquids
— theoretical design weight shall be compared with results from physical weighing.

Transportation method and arrangement shall be described and matched with the assumptions of the component design. Description of process for connection between topside and jacket, e.g. by welding shall include process, qualification of personnel, welding process specification, testing.

Following working steps and parameters shall be considered and monitored during installation:

- weather restrictions
- lowering speed, accuracy, stabbing of topside
- execution of offshore welding, connection between jacket and topside

  condition of hook on points (pad eyes, trunions) – by NDT and visually, preferably after each lift (also yard lift).

4.9 Meteorological mast

The meteorological mast (met mast) consists normally of a foundation (for offshore met mast – gravity base, monopile or jacket), on which a lattice tower is mounted, see Figure 4-4.

Requirements of Sec.3, [4.1], [4.3] and [4.5] (as relevant), as well of App.B shall be considered.

Further aspects of T&I relevant for the certification are specified in DNVGL-SE-0420.

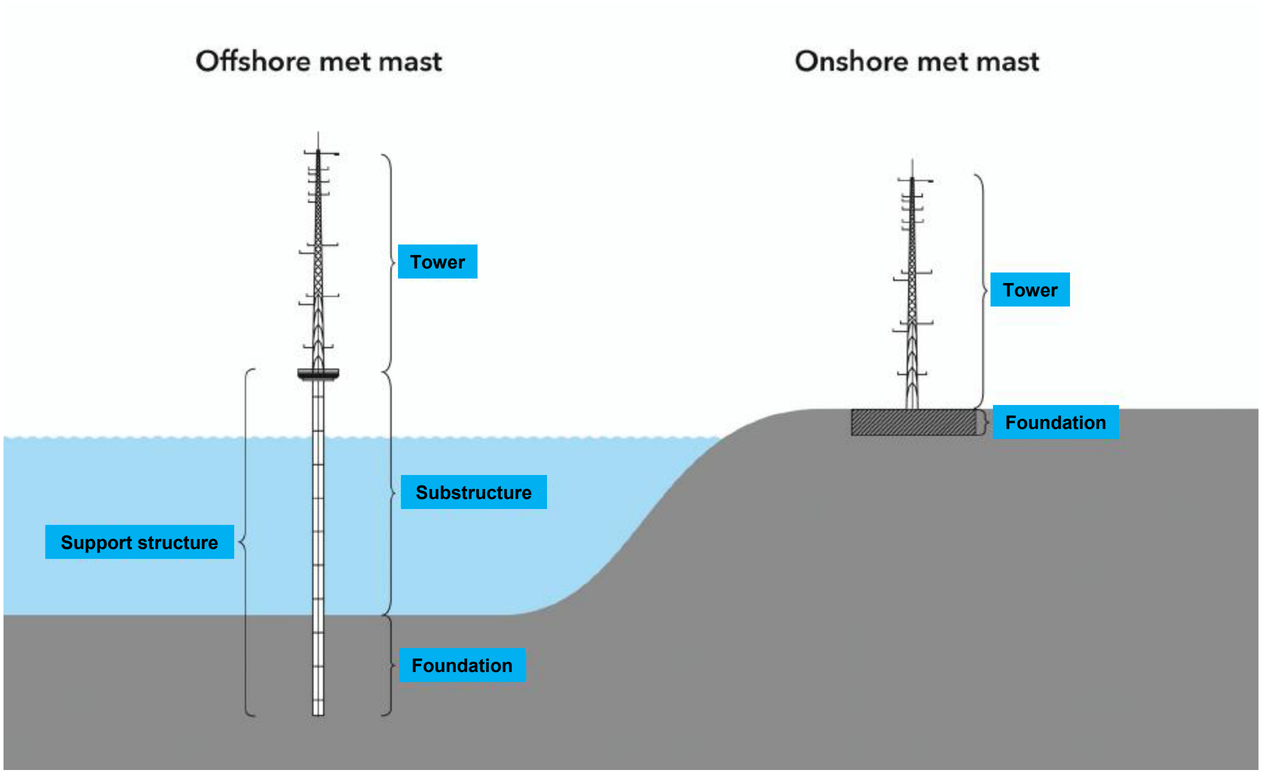


Figure 4-4 Offshore and onshore met mast structural components

SECTION 5 DECOMMISSIONING TRANSPORT OF A WIND POWER PLANT

5.1 General

The removal, i.e. deconstruction and transport of the wind power plant assets including all equipment from the site may be enforced by law or may be performed for economic, environmental or for reasons of reputation.

However before commencing the construction of the wind power plant the deconstruction and transport concept should be developed. It shall contain the assessment of the feasibility of the selected deconstruction and transport methodology. Deconstruction should in general be achieved by reversing of the installation processes. Where reversing of the installation and transport processes is not realistic, the feasibility of the method of the deconstruction and transport intended to be applied upon decommissioning shall be supported by the proven examples from offshore industry.

The detailed decommissioning and deconstruction manuals should be developed at latest during operational phase of the project and shall be adapted continuously where necessary to meet the actual conditions and circumstances of the power plant and its environment.

The decommissioning and deconstruction manual shall document at least the following:

— methodology and description of all working steps of the decommissioning of all the wind power plant assets
— methodology and description of all working steps of the deconstruction of all decommissioned assets
— methodology and description of all working steps of the transport of all deconstructed assets.

Guidance note:

Further guidance on deconstruction and disposal transport of the wind power plants is provided in DNVGL-ST-N001.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

5.2 Substructures and foundations

For both onshore and offshore projects national regulations shall be considered with regard to

— allowance that the assets remain at their location
— definition of allowable heights of parts of the substructures and foundations left in the ground
— allowable method of the removal.

The following should be considered in the case of absence of correspondent national and local regulations:

— potential effects on the safety of surface or subsurface navigation and other uses of the sea
— rate of deterioration of the material and its present and possible future effect on the marine environment including wildlife
— risk that the material will shift from its position at some future time
— costs, technical feasibility, and risks of injury to personnel associated with removal of the assets
— determination of another application purpose and reasonable justification allowing the substructure/ foundation or parts thereof to remain on the site.

Guidance note:

Reference is made to the following regulations:

— IMO "Guidelines and Standards for the Removal of Offshore Installations and Structures on the Continental Shelf and in the Exclusive Economic Zone"
— Guidance notes for industry "Decommissioning of offshore renewable energy installations under the Energy Act 2004", Department of Energy & Climate Change (UK)

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

If removal of a foundation and/or substructures is required, investigations shall be carried out regarding, e.g.:

— method and phases of removal
— environmental conditions
— risks involved
— necessary equipment to be provided during operations
— structural arrangements and mechanical devices (pipes, fittings etc.) to be provided already during construction phase, and measures required to ensure that removal operations will be possible at the expected time.

If removal is anticipated, this should be assessed by analyses of the ground reactions generated during the removal procedure. This should be carried out in order to ensure that the resistance may be overcome with the means available. The analysis shall be based on upper bound ground parameters.

Guidance note:

Regarding skirted foundations (e.g. suction buckets), suction forces tend to develop at the foundation base and the tips of skirts. These forces may be overcome by sustained uplift forces or by introducing water into the confined base compartments to relieve the suction.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Setup effects, consolidation effects, uneven separation from ground surface, possible drop-off of ground or under base grout, weights of accumulated debris and marine growth should be considered.

Suction installed foundations may be removed by reversing the installation process and applying overpressure in the bucket instead of under pressure.

Reference is made to DNVGL-ST-0126 and DNVGL-OS-C101 for further details.

5.3 Power cables

Cables that are planned to be removed should be classified by their destination, i.e. "scrap" or "re-use". This classification will to some extent define the failure modes, limit states and acceptance criteria which shall be checked.

Decommissioning of power cables intended for "re-use" should be planned, conducted and documented in such a way that degradation mechanisms are reduced and the cable may be re-commissioned and put into service again.

The decommissioning concept, including the withdrawal from service and abandonment / removal options, shall cover the following:

— relevant international, national and local regulations
— natural environment (benefits of not disturbing the seabed, possible pollution, future affects)
— obstruction of surface navigation, also in comparison to existing installations, wrecks and debris
— possible motions of sediments
— future management of an out-of-service cable system
— procedure and technical feasibility of cable removal.

Guidance note:

Reference is made to DNVGL-RP-0360.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

APPENDIX A ASSESSMENT OF RISK POTENTIAL

A.1 General

This appendix provides an approach for the identification of potential hazards and the assessment of the risk potential.

A hazard is a potential source of harm. Harm may be related to human injury, negative environmental impact, damage to asset/component or a combination of these. An incident which occurs when a hazard is realised is a hazardous event or a failure.

Risk is the likelihood of a specified undesired event (hazard, see [A.2]) occurring within a specified period or in specified circumstances. Risk may be expressed as the combination of:

— consequence of that event (see [A.3]), and
— probability (see [A.4]).

A.2 Hazard identification

Hazard is a deviation (departure from the design and operating intention) which may cause damage, injury or other form of loss. Hazards may potentially affect the execution of the transport and installation of wind power plants causing:

— injuries of the personnel or fatality
— increase of T&I costs (due to delay, further complication or additional steps)
— losses of asset, components, equipment
— impact on reputation and public relation
— a combination of these.

Table A-1 provides examples for hazards (deviations, irregularities, undesired events) to successful and safe execution of the transport and installation, possible causes and consequences. Potential consequences are given for personnel health and safety, environmental and economic consequences.

Table A-1 Hazard identification

Number	*Hazards (deviations, irregularities, undesired events)*	*Possible causes*	*Possible consequences*
1 Asset design/T&I equipment design			
1.1	Failure of asset or component, due to — structural damage — loss of component's buoyancy — loss of anchor line, mooring — congestion of a piping (grouting system, hydraulic line of jacket sleeve gripper) — fire, explosion	a) unreasonable dimensioning and design b) lack of protection c) insufficient scope or performance of checks and tests before and during T&I d) wrong weather forecast	Personnel health and safety consequences (injury, fatality) Economic consequences (loss of asset, components, equipment; increase of T&I costs; reputation) Environmental consequences (waste, pollution)

Number	*Hazards (deviations, irregularities, undesired events)*	*Possible causes*	*Possible consequences*
1.2	Failure of T&I machinery and equipment e.g. — loss of vessel or barge control, collision, impact, grounding, stranding — failure of crane or SPMT hydraulic system, hydraulic hammer, ballast pump, grouting mixer — failure of compressed air, water or electrical power supply — failure of communication	a) unreasonable selection of lifting appliances, hydraulic hammers, bolts tightening equipment b) decrease of equipment efficiency, ability and reliability due to cooling and lubrication state, rusting, eroding, wear c) inappropriate maintenance and repair of machinery and equipment	Personnel health and safety consequences (injury, fatality) Economic consequences (damage, collapse, reputation) Environmental consequences (waste, pollution)
1.3	Delays, schedule conflicts	a) late appointment of installation ships and equipment b) complex access for maintenance and repair of the installation equipment c) design issues relevant for asset/component	Economic consequences (costs, reputation)
2 Methods and procedures			
2.1	Failures or damages within the execution of T&I procedures	a) asset and components design faults b) unreasonable selection of T&I methods, absence of necessary protections c) application of a new or non-proven technology d) unreasonable selection of onshore transport route, quay, berth, installation vessel, barges, sea fastening, preassembly or intermediate storage area	Personnel health and safety (injury, fatality) Economic consequences (damage, collapse, reputation) Environmental consequences (waste, pollution)
2.2	Collision, impact, grounding, stranding	a) unreasonable transport route selection (length and duration, lack of safe havens, etc.) b) unreasonable selection of T&I methods c) application of a new or non-proven technology	Personnel health and safety (injury, fatality) Economic consequences (damage, collapse, reputation) Environmental consequences (waste, pollution)

Number	*Hazards (deviations, irregularities, undesired events)*	*Possible causes*	*Possible consequences*
2.3	Delays, schedule conflicts	a) unreasonable selection of T&I methods b) unreasonable selection of quay, berth, installation vessel, barges, sea fastening, preassembly or intermediate storage area c) lack of redundancy, unavailability of contingency plan	Economic consequences (costs, reputation) Environmental consequences (waste, pollution)
3 Materials and substances			
3.1	Failures or deviations within the execution of T&I procedures, e.g. — failure of crane or SPMT hydraulic system, hydraulic hammer, ballast pump, grouting mixer — congestion of a piping (grouting system, hydraulic line of jacket sleeve gripper) — failure of compressed air, water or electrical power supply — structural failures of anchor line, mooring and other	a) unreasonable selection of materials for design of assets, components, b) unreasonable selection of materials for design of sea fastening, T&I equipment	Personnel health and safety (injury, fatality) Economic consequences (damage, collapse, reputation) Environmental consequences (waste, pollution)
3.2	Delays, schedule conflicts	a) unavailability of water, compressed air, electrical power supply etc. at pre-assembly or intermediate storage area, installation site	Economic consequences (costs, reputation)
4 Measurements and tests			
4.1	Failures or deviations within the execution of T&I procedures	a) unreasonably selected measurement or test methods (e.g. during check of location coordinates, verticality of substructures, check of limits and target values within bolting, grouting, NDT of padeyes, welded joints, etc.) b) inappropriate accuracy of measurements and tests c) low reliability of measurements and tests d) poor readability of the results	Economic consequences (costs, reputation)

Number	*Hazards (deviations, irregularities, undesired events)*	*Possible causes*	*Possible consequences*
4.2	Delays, schedule conflicts	a) failure or damage of measurement and testing equipment	Economic consequences (costs, reputation)
5 Environment			
5.1	Pollution, waste at the installation site, preassembly or intermediate storage area (oil, fuel release from generator, day tanks, storage tanks, gearboxes)	a) fire, explosion due to incorrect securing of the components containing hazardous goods: flammable liquids, explosive substances, pressure vessels	Environmental consequences (waste, pollution) Economic consequences (costs, reputation) Personnel health and safety (injury)
5.2	Excessive noise disturbance level	a) failure of noise protection b) unexpected properties of the sea bed	Personnel health and safety (injury) Economic consequences (costs, reputation)
5.3	Delays, schedule conflicts due to unexpected deterioration of weather conditions	a) unreliable weather forecast b) unexpected detection of unexploded ordnance c) unexpected properties of the sea bed	Personnel health and safety (injury, fatality) Economic consequences (costs, reputation)
6 Personnel and organizational issues			
6.1	Occupational physical hazards — personnel accidents — illnesses — man overboard — unauthorized intervention — terrorism	a) geometric limitations within transport b) inappropriate (sea) fastening and securing of assets c) adverse weather and sea states d) inappropriate or insufficient equipage with tooling, personal safety equipment e) insufficient POB	Personnel health and safety (injury, fatality) Economic consequences (costs and reputation)
6.2	Dropped object, swinging load	a) inappropriate lifting b) human error c) adverse weather d) sling whole or partial failure e) mechanical failure	Personnel health and safety (injury, fatality) Economic consequences (damage, collapse, reputation) Environmental consequences (waste, pollution)
6.3	Ship collision, impact, grounding, stranding	a) insufficient qualification of the staff b) hilarity, human error c) equipment failure	Personnel health and safety (injury, fatality) Economic consequences (damage, collapse, reputation) Environmental consequences (waste, pollution)
6.4	Epidemic disease	a) food poisoning b) bio hazard c) seasickness	Personnel health and safety (injury)

Number	*Hazards (deviations, irregularities, undesired events)*	*Possible causes*	*Possible consequences*
6.5	Delays, schedule conflicts	a) insufficient qualification of the staff b) poor management and coordination c) onshore transport delays d) non-availability of the barges, installation vessels, T&I equipment e) financial issues e.g. bankruptcy of T&I subcontractors f) absence of the permissions, certificates	Economic consequences (costs and reputation)

A.3 Consequences evaluation

A.3.1 Personnel health and safety consequences

Personnel health and safety consequences evaluation should consider important factors such as:

— fatality
— injury
— illness
— man over board

Safety consequences should consider the potential death and injury of personnel and are commonly expressed in terms of potential loss of life (PLL).

An example of a safety consequences scale is shown in Table A-2 with ranges from very low (LL) to very high (HH).

Table A-2 Safety consequences scale

Category	*PLL*	*Description*
HH	> 1	multiple fatalities
H	1	single fatality
M	10^{-1}	major injury, permanent disability
L	10^{-2}	minor injury
LL	10^{-3}	slight injury

A.3.2 Environmental consequences

Environmental consequences analysis requires estimation of factors such as:

— pollution through discharge of liquids
— gas releases, also regarding greenhouse potential
— loss of highly toxic chemicals

— excessive noise.

Environmental consequences should be limited to local and global damage to the environment alone; not including safety and economic aspects.

An example for an environmental consequences scale is shown in Table A-3. The definition of units (monetary, volumetric) depends on environmental incident severity coupled with the design philosophy of the asset (component) and materials applied.

Table A-3 Environmental consequences scale

Category	*COF (litres of oil)*	*Description*
HH	> 16 000	massive effect
H	10 000 – 16 000	major effect
M	1000 – 10 000	local effect
L	100 – 1000	minor effect
LL	< 100	slight effect, negligible

A.3.3 Economic consequences

Economic consequences should include all financial matters in relation to a potential incident including:

— repair costs
— costs due to delays and schedule conflicts
— clean-up costs
— value of lost production
— fines
— reputational losses.

Economic consequences should be expressed in monetary terms (cost of failure, COF) using appropriate currency units.

An example of an economic consequences scale is shown in Table A-4, assuming an installation value of 25 M €.

Table A-4 Economic consequence scale

Category	*COF (€)*	*Description*
HH	> 5 M	massive effect
H	500 k – 5 M	major effect
M	50 k – 500 k	local effect
L	5 k – 50 k	minor effect
LL	< 5 k	slight effect, negligible

The economic consequences of business interruption may be estimated from duration and extent of production downtime, multiplied by the value of production.

A.4 Probability of failure

Probability of failure (POF) is the probability of an event occurring per unit time (e.g. annual probability).

An example of a probability of failure scale is shown in Table A-5.

Table A-5 Probability of failure scale

Category	*POF / year*	*Description*
HH	$> 10^{-2}$	failure expected
H	10^{-3} to 10^{-2}	high probability of failure
M	10^{-4} to 10^{-3}	Medium probability of failure
L	10^{-5} to 10^{-4}	Low probability of failure
LL	$< 10^{-5}$	failure not expected

A.5 Risk matrix

Risk may conveniently be represented by means of a risk matrix. A separate matrix for each consequence category should be established.

The common risk matrices shall be harmonised and standardised at the beginning of the design process and used for all risk assessments related to the installation under review.

To achieve adequate resolution, a 5 × 5 matrix is recommended as shown in Figure A-1. All matrices should use the common probability scale on one (normally the vertical) axis and individual consequence scales on the other (normally the horizontal) axis.

The risk is commonly divided into three or four (pictured) categories which should be the same for safety, environmental and economic aspects:

— H: High risks are unacceptable and actions shall be taken to reduce the risk level
— M: Medium risk may be further divided into tolerable (upper) and broadly acceptable (lower) regions to focus on efforts for risk control
  a) Risks are tolerable once all reasonably practicable actions have been taken to reduce them. Further reduction action is needed, unless the costs are grossly disproportionate to the benefits.
  b) Risks are broadly acceptable if most people would not be concerned by them. Further action is appropriate where cost-effective, or where needed to ensure that risks do not increase.
— L: Low, negligible risks do not require actions to be taken.

A matrix with three categories may be divided into H = unacceptable, M = tolerable with action required and L = broadly acceptable with no action required.

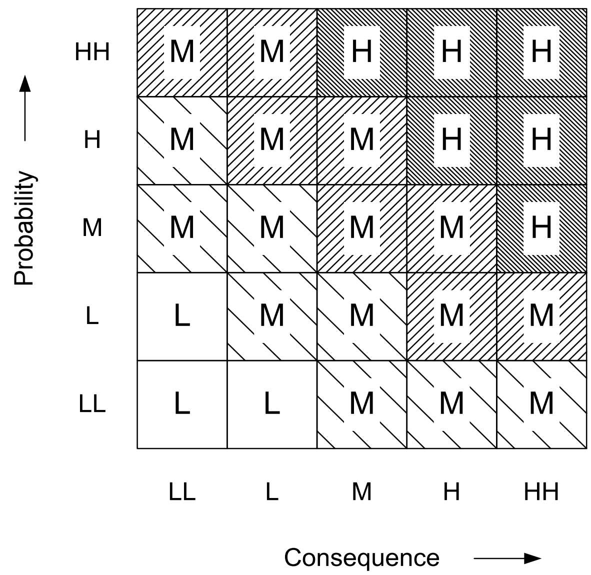


Figure A-1 Example of a risk matrix

APPENDIX B VERIFICATION OF STRUCTURAL INTEGRITY

B.1 General

Appendix B provides references to DNV GL standards containing methodology structural integrity verification of assets/components under consideration of loads introduced into the structure by other elements (lifting points, supports, sea fastening).

B.2 Lifting acceptance criteria

B.2.1 Lifting points

B.2.1.1 General

The analysis of the lifting points and attachments to the structure shall be performed, using the most severe load. For the derivation of hook, lifting point and rigging loads reference is made to DNVGL-ST-N001 Sec.16 [3].

B.2.1.2 Arrangement of padeyes

General considerations and requirements for the design of padeyes are given in DNVGL-ST-N001 Sec.16 [9.5]. Guidance on padeye design calulations is given in DNVGL-ST-N001 App.P [2].

B.2.1.3 Arrangement of trunnions

General guidance and requirements regarding trunions are given in DNVGL-ST-N001 Sec.16 [9].

Through-thickness loading of the trunnions and their attachments to the structure shall be avoided if possible. If such loading cannot be avoided, the material used shall be documented to be free of laminations, with a recognized through-thickness designation.

The trunnion stub shall generally be welded to the shell by means of a full penetration weld.

The shell and the substructure are also subject to strength investigation with the local loads, especially when the shell is unstiffened.

B.2.2 Assets and components

The structure to be lifted shall be designed according to the principles laid down in the following standards (under consideration of loads introduced into the structure by others elements, among other by lifting points):

— support structures for wind turbines: DNVGL-ST-0126
— other offshore steel structures: DNVGL-OS-C101
— nacelle and hub of wind turbines: DNVGL-ST-0361
— rotor blades of wind turbines: DNVGL-ST-0376
— offshore substations: DNVGL-ST-0145.

B.3 Transport acceptance criteria

The structure to be transported shall be designed according to the principles laid down in the following standards (under consideration of loads introduced into the structure by others elements, among other by fastening and support):

— support structures for wind turbines: DNVGL-ST-0126
— other offshore steel structures: DNVGL-OS-C101
— nacelle and hub of wind turbines: DNVGL-ST-0361
— rotor blades of wind turbines: DNVGL-ST-0376

— offshore substations: DNVGL-ST-0145.

For onshore transport the influence of the vehicles design and road surface condition on the fatigue state of the components shall be analysed, see [3.3.1].

For offshore transport the influence of the distance and duration of the transport on the fatigue state of the components shall be analysed for transports over 500 nautical miles.

During the development phase motion criteria may be applied according to DNVGL-ST-N001 Sec.11 [3]. For the verification of motion influences during offshore transport, loads for the relevant environmental conditions shall be determined by motion analysis.

CHANGES - HISTORIC

There are currently no historical changes for this document.