GL Noble Denton

TECHNICAL POLICY BOARD

GUIDELINES FOR OFFSHORE WIND FARM INFRASTRUCTURE INSTALLATION

0035/ND

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PREFACE

This document has been drawn with care to address what are considered to be the primary issues in relation to the contents based on the experience of the GL Noble Denton Group of Companies ("the Group"). This should not, however, be taken to mean that this document deals comprehensively with all of the issues which will need to be addressed or even, where a particular matter is addressed, that this document sets out a definitive view for all situations. In using this document, it should be treated as giving guidelines for sound and prudent practice, but guidelines must be reviewed in each particular case by the responsible organisation in each project to ensure that the particular circumstances of that project are addressed in a way which is adequate and appropriate to ensure that the overall guidance given is sound and comprehensive.

Reasonable precaution has been taken in the preparation of this document to seek to ensure that the content is correct and error free. However, no company in the Group

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This document must be read in its entirety and is subject to any assumptions and qualifications expressed therein as well as in any other relevant communications by the Group in connection with it. Elements of this document contain detailed technical data which is intended for analysis only by persons possessing requisite expertise in its subject matter.

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1 SUMMARY

1.1 These guidelines have been developed for the installation of offshore wind farms of various types. They mainly refer to other GL Noble Denton guidelines developed for similar operations, but giving alternatives which may apply to offshore wind farm installations.

1.2 They are intended to show clients the requirements for obtaining approval by GL Noble Denton. This approval may be needed where an operation is the subject of an insurance warranty, or where an independent third party review is required.

1.3 A description of the Marine Warranty approval process is given together with practical advice on current best practice in offshore wind farm installation.

2 INTRODUCTION

2.1 SCOPE

2.1.1 This document provides guidance for installation of offshore wind farms, in particular:

- Foundations including monopiles, steel jackets, gravity bases, suction bases, floating bases including spars, TLPs and semisubmersibles.
- Turbines and other equipment on pre-installed foundations.
- Offshore substations, transformer, control and other platforms, including those on jack-up platforms.
- Array and Export cable laying, protection and installation onto foundations and offshore substations.

2.1.2 In particular it identifies factors that need to be addressed as wind farm installation moves into deeper water and more exposed locations.

2.1.3 The guidelines and calculation methods set out in this document represent the views of GL Noble Denton and are considered to be in accordance with offshore wind farm industry good practice. Operators should also consider national and local regulations, which may be more stringent.

2.2 OTHER GL NOBLE DENTON GUIDELINE DOCUMENTS

2.2.1 This document refers to, and should be read in conjunction with other GL Noble Denton Guideline documents, particularly:

- 0001/ND – General Guidelines for Marine Projects, Ref. [1]. In particular this covers
  a. The approval process for marine warranty
  b. Health Safety and Environment
  c. Organisation, planning and documentation
  d. Metocean criteria (design and operating) and forecasts
  e. Weight Control
  f. Structural Strength
  g. Building /construction basins
  h. Tow-out from dry-dock /building basin
  i. Temporary ballasting & compressed air systems
  j. Use of Dynamic Positioning (DP) vessels
- 0009/ND – Guidelines for Elevated Operations of Jack-Ups, Ref. [2]
- 0013/ND – Guidelines for Load-Outs, Ref. [3]
- 0015/ND – Guidelines for Concrete Gravity Structure Construction & Installation, Ref. [4]
- 0016/ND – Seabed and Sub-seabed Data Required for Approvals of Mobile Offshore Units (MOU), Ref. [5]
- 0021/ND – Guidelines for the Approval of Towing Vessels, Ref. [6]
- 0027/ND – Guidelines for Marine Lifting & Lowering Operations, Ref. [7]
- 0028/ND – Guidelines for Steel Jacket Transportation & Installation, Ref. [8]
- 0030/ND – Guidelines for Marine Transportations, Ref. [9]
- 0031/ND – Guidelines for Float-over Installations /Removals, Ref. [10]
- 0032/ND – Guidelines for Moorings Ref. [11].

2.2.2 Electronic versions of GL Noble Denton Guidelines are available on:

http://www.gl-nobledenton.com/en/rules_guidelines.php

Care should be taken when referring to any GL Noble Denton Guideline document that the latest revision is being consulted.

2.2.3 Designers and installers of innovative designs or installation methods are recommended to discuss the procedures and design with the relevant GL Noble Denton office at an early stage of the project to ensure that it will be approvable without changes.

2.2.4 Please contact the Technical Policy Board Secretary at TPB@nobledenton.com with any queries or feedback.

2.3 EXCLUSIONS

2.3.1 **Diving operations** are not generally subject to a Marine Warranty and so are normally excluded, except in so far as they may cause delays to weather-sensitive operations. In particular delays may be caused by waiting for slack tide to allow divers to work safely. Where possible, weather sensitive operations should be planned to be achieved without the use of divers.

2.3.2 **Grouting operations** are normally covered by the Certifying Authority rather than the Marine Warranty Surveyor (MWS). Agreement will need to be made with the client at an early stage to define the boundaries between the involvements of the Certifying Authority and the MWS. However the timing of grouting operations that could delay a monopile or piled jacket being able to resist a 10 year seasonal storm is of concern to the MWS. In particular any damage to grout seals before grouting will be a concern (see Section 5.3.2 d) as it could delay grouting.

2.3.3 **Structural strength and operability** of completed installed structures and equipment are covered by the Certifying Authority rather than the MWS. The MWS is only concerned with the strength during installation, including transportation and load-out. GL Noble Denton will accept a statement from the Certifying Authority that the structure can safely withstand the required accelerations and loads for the load-out, transportation and installation provided that the load paths /allowable local forces for seafastening, lifting or load-out forces are given. Alternatively the relevant calculations may be reviewed by GL Noble Denton.

2.3.4 **Un-exploded ordnance UXO** disposal is not generally subject to a Marine Warranty and is normally excluded. However it is recommended that it will be managed in accordance with the requirements of ‘Risk Management Framework’ provided in CIRIA C681, K Stone, et al. (2009), or Unexploded Ordnance (UXO) - A Guide for the Construction Industry, or similar.

3 DEFINITIONS & ABBREVIATIONS

Referenced definitions are underlined.

Term or Acronym	Definition
ALARP / As Low As Reasonably Practicable	A philosophy used in Risk Assessment to find acceptable risk levels.
AMS	Anchor Management System.
Approval	The act, by the designated GL Noble Denton representative, of issuing a Certificate of Approval.
Array Cable(s)	Generic term collectively used for Inter Turbine Cables and Collector Cables.
Barge	A non-propelled vessel commonly used to carry cargo or equipment. (For the purposes of this document, the term Barge can be considered to include Pontoon, Ship or Vessel where appropriate).
BAS / Burial Assessment Survey.	A survey to assess the expected burial depths on a cable route using purpose built sledges equipment with bottom penetrating sonar equipment or by towing a miniature plough.
Bend restrictor	A device with several interlocking elements that lock when a design radius is achieved.
Bird Caging	A phenomenon whereby armour wires locally rearrange with an increase and/or decrease in pitch circle diameter as a result of accumulated axial and radial stresses in the armour layer(s).
BPI / Burial Protection Index	A process to optimise cable burial depth requirements based on a risk assessment of threats to the cable and the soil strengths in the location of each risk.
Cable Burial	A submarine power cable is trenched into the seabed and covered with soil providing complete burial of a cable (see Cable Trenching below)
Cable Trenching	A submarine cable is lowered beneath the mean seabed level into an open cut trench. The trench is left open and any subsequent cover of the cable is by natural reinstatement of the seabed.
Cats-paw	An extreme type of loop thrown into cables where a combination of low tension and residual torsion forms a twisted loop. Commonly seen at repair Final Splice locations where the Final Splice is lowered too quickly.
Certificate of Approval	A formal document issued by GL Noble Denton stating that, in its judgement and opinion, all reasonable checks, preparations and precautions have been taken to keep risks within acceptable limits, and an operation may proceed.
Cable Grips	Cable Grips are used to pull or support cables and pipes. They work on the principle of the harder the pull, the tighter the grip.
Chinese Fingers	Also known as pulling socks, are used to pull or support cables and pipes. They work on the principle of the harder the pull, the tighter the grip.
CLB	Cable Lay Barge
CLV	Cable Laying Vessel. Main cable installation vessel.

Term or Acronym	Definition
CLV (SE)	Cable Laying Vessel (Shore End).
Collector Cables	Submarine power cables that 'collect' power from strings of Array Cables and deliver that power to an offshore substation.
Competent person	Someone who has sufficient training and experience or knowledge and other qualities that allow them to assist you properly. The level of competence required will depend on the complexity of the situation and the particular help required.
Crane vessel	The vessel, ship or barge on which lifting equipment is mounted. For the purposes of this document it is considered to include: crane barge, crane ship, derrick barge, floating shear-leg, heavy lift vessel, semi-submersible crane vessel (SSCV) and jack-up crane vessel.
CSA / Cross Sectional Area	Normally presented as the CSA of a single conductor in a submarine power cable x 3. For example a submarine power cable with 3x600mm2 in its designation would be a cable with three conductors each of 600mm2.
DP	Dynamic Positioning or Dynamically Positioned
Export Cable(s)	Submarine power cables connecting the offshore wind farm to a landfall connection point and hence the onshore distribution network.
FAT	Factory Acceptance Tests
Final Splice	The location where a second joint is inserted into a cable system during a repair and includes the excess slack in the cable where the two ends of the final splice come to the surface.
FMEA or FMECA	Failure Modes and Effects Analysis or Failure Modes, Effects and Criticality Analysis
GBS	Gravity Base Structure (foundation)
GL Noble Denton	The legal entity trading under the GL Noble Denton name which is contracted to carry out the scope of work and issues a Certificate of Approval, or provides advice, recommendations or designs as a consultancy service.
Grommet	A single length of unit rope laid up 6 times over a core, as shown in IMCA, Ref. [17], to form an endless loop
HDD	Horizontal Directional Drilling
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
HPR	Hydro-acoustic Positioning Reference. A through water acoustic link between a vessel and a seabed beacon. Used to locate and track vehicles in the water column and can be used as a DP reference.
IACS	International Association of Classification Societies
ICPC / International Cable Protection Committee	A trade body representing and lobbying on behalf of subsea cable owners. For historical reasons membership is predominately telecom companies.
ITP / Inspection Test Plan	A plan in which all test, witness and hold points for all aspects of a cable installation are listed.

Term or Acronym	Definition
IVB	Independent Verification Body. The wind farm certification agency.
I-tube.	A vertical tube fitted to offshore structures to install submarine cables between the seabed and the structure topsides.
Installation Analysis.	An analysis of the impact the installation methods will have on the cables to be installed. Focusses on the cable tension for each stage of an installation and should include an analysis of the seabed stability of the cable for surface laid sections especially when the cable will be laid in a curve or around an alter course.
Insurance Warranty	A clause in the insurance policy for a particular venture, requiring the approval of a marine operation by a specified independent survey house.
Inter Turbine Cables	Submarine power cables connecting two turbines.
J-tube	A J shaped tube fitted to offshore structures to install submarine cables between the seabed and the structure topsides.
LCE / Linear Cable Engine	An industry term commonly used to refer collectively to cable lay tensioners.
Lift point	The connection between the rigging and the structure to be lifted. May include padear, padeye or trunnion
Load-out	The transfer of a major assembly or a module from land onto a barge e.g. by horizontal movement or by lifting
MBR / Minimum Bending Radius	The minimum allowable radius of a bend in a cable (to prevent damage)
MP / Monopile	Common tubular structure used as foundation for offshore wind turbine generator.
MPI / Magnetic Particle Inspection	A Non-Destructive Testing (NDT) process for detecting surface and slightly subsurface discontinuities in ferroelectric materials such as iron.
MWS	Marine Warranty Surveyor (see Section 4.1 of 0001/ND, Ref. [1]).
Nacelle	The part of the wind turbine on top of the tower, where the hub, gearbox, generator and control systems are located.
Net weight	The calculated or weighed weight of a structure, with no contingency or weighing allowance
NTE weight / Not To Exceed weight	sometimes used in projects to define the maximum possible weight of a particular structure.
NDT / Non Destructive Testing	Ultrasonic scanning, magnetic particle inspection, eddy current inspection or radiographic imaging or similar. May include visual inspection.
Operation Duration	The planned duration of the operation **excluding** a contingency period from the Point of No Return to a condition when the operations /structures can safely withstand a seasonal design storm (also termed “safe to safe” duration).
Operation, marine operation	Any activity, including load-out, transportation, offload or installation, which is subject to the potential hazards of weather, tides, marine equipment and the marine environment,

Term or Acronym	Definition
Operational reference period	The Operation Duration, **including** a contingency period.
OWF	Offshore Wind Farm
Padear	A lift point consisting of a central member, which may be of tubular or flat plate form, with horizontal trunnions round which a sling or grommet may be passed
Padeye	A lift point consisting essentially of a plate, reinforced by cheek plates if necessary, with a hole through which a shackle may be connected
PLIB / Post Lay Inspection Burial.	The use of a WROV to survey the installed cables. WROVs are often used with a cable burial module in order that an attempt can be made to increase the burial depth in areas where the burial depth is non-conforming.
PLGR / Pre Lay Grapnel Run	The use of grapnels to clear linear debris that might have fallen onto the cable route after RC operations. Normally done immediately before cable lay and burial operations.
PNR / Point of No Return	The last point in time, or a geographical point along a route, at which an operation could be aborted and returned to a safe condition.
Pull Back Method	A J-tube pull-in operation where the pull-in winch is mounted on the installation vessel and the end of the pull-in wire connected to the cable runs from the vessel to the J-tube bottom end up and over a sheave and back to the installation vessel pull-in winch.
Quadrant	A structure, usually with rollers, to limit the MBR as the cable travels over or though it and changes direction, typically during loading or laying during second end J tube pull in operations.
RC / Route Clearance.	The use of grapnels and other methods to clear debris from the planned cable routes. Normally done well in advance of cable operations to allow adequate time to remove debris.
Rigging	The slings, shackles and other devices including spreaders used to connect the structure to be lifted to the crane
Rigging weight	The total weight of rigging, including slings, shackles and spreaders, including contingency.
Rotor	Configuration consisting of the complete set of blades, connected to the hub.
RPL / Route Planning List.	A tabularised list of the co-ordinates defining the route along which a submarine cable is to be installed and the planned installation slack. A post installation RPL will record the as-built cable route co-ordinates, installed slack and burial depths.
Seafastenings	The system used to attach a structure to a barge or vessel for transportation
Scour pit	The result of scour around a pile, leg etc. See Ref. [21].
SE / Shore End	The section of submarine cable installed between the landfall connection point and the offshore set up position of the CLV or CLB.

Term or Acronym	Definition
SIMOPS / Simultaneous Operations	Operations usually involving various parties and vessels requiring co-ordination and definitions of responsibilities.
Slack Management	A generalized term used by the submarine cable installation industry to refer to the control of cable pay-out out against a pre-defined installation plan.
Spreader beam or bar	A spreader beam or bar is a structure designed to resist the compression forces induced by angled slings, by altering the line of action of the force on a lift point into a vertical plane. The structure shall also resist bending moments due to geometry and tolerances.
Spud	A large metal post which penetrates the seabed under its own weight and is used to prevent lateral movement of a barge. A dredge barge will typically have two spuds in guides near its stern.
Structure	The object to be lifted
Survey	Attendance and inspection by a GL Noble Denton representative. Other surveys which may be required for a marine operation, including suitability, dimensional, structural, navigational and Class surveys.
Surveyor	The GL Noble Denton representative carrying out a survey. An employee of a contractor or Classification Society performing, for instance, a suitability, dimensional, structural, navigational or Class survey.
SWL / Safe Working Load	SWL is a de-rated value of WLL, following an assessment by a competent person of the maximum static load the item can sustain under the conditions in which the item is being used.
Tensioner	A winch used for handling submarine power cables to pay out and pick up or to provide hold back tension in the cable during installation operations.
TD / Touch Down	Seabed location at which a submarine cable touches down on the seabed during installation.
Tower	The tubular element from the top of the flange on the foundation to the bottom of the flange below the nacelle, generally built up of several sections.
TP / Transition Piece	A tubular structure on top of a monopile to provide a horizontal foundation for the tower.
Trunnion	A lift point consisting of a horizontal tubular cantilever, round which a sling or grommet may be passed. An upending trunnion is used to rotate a structure from horizontal to vertical, or vice versa, and the trunnion forms a bearing round which the sling, grommet or another structure will rotate.
UNCLOS	United Nations Law of the Sea
UXO	Unexploded Ordnance
Vessel	A marine craft designed for the purpose of transportation by sea or construction activities offshore. See Barge

Term or Acronym	Definition
Weather restricted operation	A marine operation which can be completed **within the limits** of an operational reference period with a favourable weather forecast (generally less than 72 hours), taking contingencies into account. The design environmental condition need not reflect the statistical extremes for the area and season. A suitable factor should be applied between the operational weather limits and the design weather conditions (see Section 7.3.3 of 0001/ND, Ref. [1]).
Weather unrestricted operation	An operation with an operational reference period **greater than** the reliable limits of a favourable weather forecast (generally less than 72 hours). The design weather conditions must reflect the statistical extremes for the area and season. The design weather is typically a 10 year seasonal storm, but subject to Section 7.2.2 of 0001/ND, Ref. [1].
WLL / Working Load Limit	The maximum force which a product is authorized to sustain in general service when the rigging and connection arrangements are in accordance with the design. See SWL.
WTG	Wind Turbine Generator
WROV	Work class Remotely Operated Vehicle.
XLPE / Cross Linked Polyethylene	A type of AC cable conductor insulation commonly used on submarine power cables.

4 THE APPROVAL PROCESS

4.1 GL NOBLE DENTON APPROVAL

4.1.1 See Section 4 of 0001/ND “General Guidelines for Marine Projects”, Ref. [1] for more details.

4.1.2 See Section 4.6 of 0001/ND, Ref. [1], for details of the approval of repetitive operations.

4.2 SCOPE OF WORK LEADING TO AN APPROVAL

4.2.1 The scope of work of each phase of installation, apart from cable installation, is covered in the relevant guidelines described in Section 2.2.

4.2.2 The scope of work for cable installation will depend on the insurance warranty but may typically cover:

a. Attendance at Factory Acceptance Tests (FAT) at the factory.

b. Approval of land transport to the loading port.

c. Approval of load-out onto a transport vessel, CLV or CLB and any subsequent inter-vessel transfer. This may include continuous attendance witnessing the load-out.

d. Approval of transport of cables to offshore site.

e. Approval of cable route and method(s) of protecting the cable along the route.

f. Approval of cable installation including trenching, burial or other protection and terminations at either end.

g. Review and appproval of the Installation Manual, Installation Procedures, Task Plans, HAZID, HAZOP and Contingency Procedures.

h. Review of Installation Analysis, vessel motion analysis and other relevant analyses to ensure all criteria stated in the Installation Manual and other installation procedural documents are supported by valid calculations.

i. Approval of CLV, CLB and CLV (SE) cable installation equipment on them.

j. Approval of attending tugs and other construction support vessels.

k. Approval of submarine cable Installation Analysis.

l. Approval of CLV, CLB and/or CLV(SE) limiting sea states for each stage of the cable installation operationApproval of weather-restricted operations.

m. Issuance of Certificates of Approval for towing/transport and installation of cables on a cable by cable basis. Issuance of Statements of Acceptablity for operations that no longer require GL Noble Denton attendance, includes setting of conditions that must be followed for the Statements of Acceptablity to remain valid..

4.2.3 In order to issue Certificates of Approval, GL Noble Denton will typically require to consider, as applicable, the following topics:

a. Operating manuals, including procedures and contingency procedures.

b. The management structure for multi-contracting projects for the operations, and Management of Change procedures.

c. Site zone control, including Simultaneous Marine Operations (SIMOPS).

d. Design criteria and geotechnical, bathymetric and environmental /meterological data.

e. Risk assessments, HAZOP /HAZID studies involving all parties.

f. Operation-specific requirements described later in these guidelines.

g. Vessels suitability and certification.

h. Suitability of all jack-up operating locations (including soils, obstructions, survival air gap, and suvivability of the jack-up in the design environmental conditions).

i. Procedures, calculations and equipment certification for:

- All significant (as determined by the insurance warranty) load-outs
- All significant towages or transportations
- All significant lifts and installation operations
- Cable laying and termination at either end.

4.2.4 Surveys carried out as part of GL Noble Denton's scope of work typically include those in the following Table.

Table 4-1 Typically Required Surveys

Survey	Time	Place
Sighting of inspection/test. Certificates for slings and shackles	Before departure of structure from shore	GL ND / client's office or fabrication yard
Survey of barge /transport vessel	Before load-out	As available
Survey of towing vessel(s)	Before tow	
Suitability survey of installation vessel and installation /handling tools. This will include witnessing function tests of new or adapted handling /lifting tools	Before start of marine operations	
Survey of load-out site and equipment, and issue of Certificate of Approval	Before load-out	Fabrication yard
Sighting of inspection /test certificates or release notes for lift points and attachments	Before departure of tow /transport	
Inspection of rigging laydown, seafastening, securing of all items, tow /transport preparations, and issue of Certificate of Approval		
Jack-up Crane vessel mooring and/or jack-up for installation activities	Before start of marine operations	At lift site
Installation vessel in-field DP trials		
Inspection of preparations for lift, and issue of Certificate of Approval	Immediately before cutting seafastening	

4.2.5 The survey frequency for repetitive operations is specified in Section 4.6 of General Guidelines 0001/ND, Ref. [1].

4.3 END OF MWS SCOPE OF WORK

4.3.1 The end of the scope of work is typically when the installation (or stage of installation) can safely withstand a design storm. Agreement should be reached at an early stage of the project as exactly when this is. It will depend on the warranty wording and agreement with the client and Certifying Authority (see Section 2.3.3).

4.4 LIMITATION OF APPROVAL

4.4.1 See Section 4.5 of General Guidelines 0001/ND, Ref. [1].

5 GENERAL

5.1 COORDINATION

5.1.1 The owner or operator of a wind farm has a duty to provide In-field Management to co-ordinate the operations of vessels and helicopters in the field and communications between them. In general there will be many more vessels working in a wind farm during construction than in an oil or gas field of comparable value.

5.1.2 The following figure shows the main interaction between parties that is required at an early stage of the installation project to ensure success.

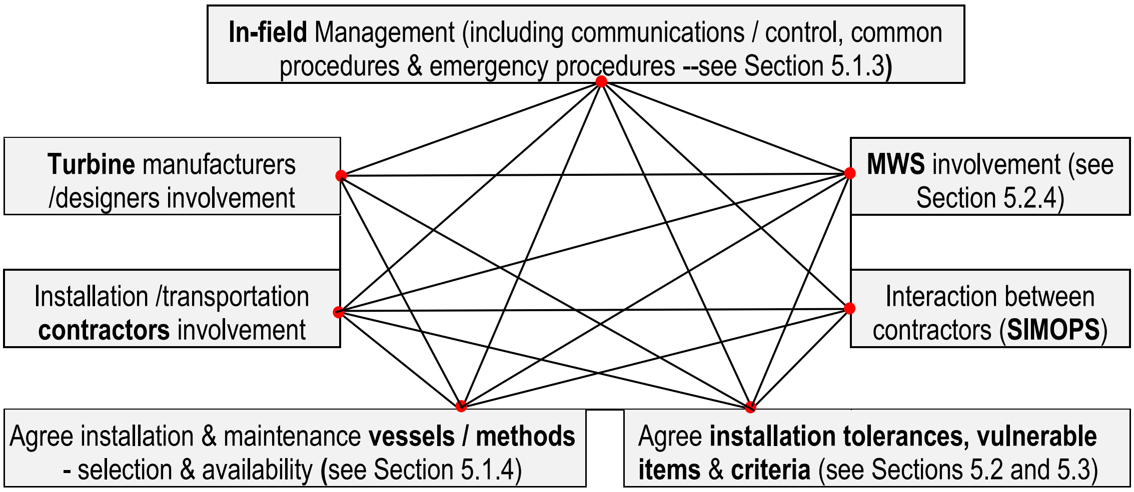

Figure 5-1 Simplified Required Early Interaction Flow-Chart

5.1.3 **In-Field Management**. This will include:

a. Scheduling contractors, vessels and helicopters to avoid congestion /collisions.

b. Co-ordinating communication and control between all parties to reduce conflicts and risks.

c. Managing common logistic arrangements and scheduling for key operations, especially SIMOPS,

d. Providing a framework for developing and enforcing common procedures, including emergency procedures, which define the responsibilities at all times.

e. Ensuring that adequate mooring systems can be laid to avoid damaging cables or subsea structures, or interfering with other operations. This may involve installing prelaid pile anchors if the anchor holding is poor or there are too many power or control cables on the seabed.

f. If jack-ups are used, ensuring that footprints and cable routes will not prevent other jack-ups operating subsequently

g. Ensuring that all positional, bathymetric, soil and current surveys are performed using the same datum and coordinate system, are of sufficient accuracy and that the results are disseminated to all relevant parties as required. See Section 5.5.

h. Identifying particularly vulnerable items or areas that are at risk from operations by other parties. See Section 5.3.

5.1.4 **Vessels.** Working alongside offshore structures for installation and maintenance may involve use of many different types of vessel during the life of the structure, including:

- Jack-up barges or ships which leave “footprints” into which subsequent jack-ups (especially with different leg spacing) may slide, causing leg damage, or stand on cables that are laid in the incorrect locations. The planning for installation and maintenance must allow for the use of different jack-ups during the life of the wind farm.
- Moored vessels with anchors that can drag and cut cables on the seabed.

- DP vessels with the potential to lose position after a DP failure and hit the structure.
- Vessels bringing repair and maintenance personnel, often with sophisticated transfer systems.

The main advantages and disadvantages of these different types are given in the following Table 5-1.

Table 5-1 Relative Advantages of Different Installation Vessels & Positioning Systems

Vessel /system	Advantages	Disadvantages
Jack-up (of adequate design) – see Note 1	Provides a relatively stable operating platform above the waves (reducing crane hook movements). Can stay on location during storms. (For some short operations in good weather, the jack-up may not jack-up out of the water to save time but use its legs to stay on location).	1. Needs good weather (typically <1 to 2 m sig wave height) to jack-up or down to move to a new location. 2. Normally needs moorings or DP to move onto location (tugs may sometimes be used alone if locational accuracy is not required and there are no collision risks or strong currents) 3. "Footprints" from previous jack-ups may cause severe structural problems due to legs sliding into them (especially if of different leg geometry. 4. Jack-ups may not be suitable with some seabeds (e.g. very soft or rocky). Legs may be vulnerable to scour & punch-through. Adequate leg length required to maintain safe air gap in storms. 5. Limited number of jack-ups presently available with adequate design especially for deeper exposed locations. 6. Cables on seabed (especially if not located accurately) may restrict operating positions
Floating vessel – (not DP)	Generally cheaper to operate than jack-ups or DP vessels Do not leave footprints or tread on /damage cables (apart from with anchors)	1. Vessel motions limit crane and other operations. 2. Need moorings to stay on location (see below).
Mooring system		1. Anchors may drag causing loss of position leading to collision, or cable /subsea structure damage. 2. In some locations some anchor cables will require be slackened to avoid damage to structures between vessel and anchor. Care needed when re-tensioned. 3. Mooring systems need redundancy. 4. Moorings must be laid to avoid damaging cables. 5. Generally moorings will not be designed to survive a storm so the vessel needs to initially move away from a structure when weather deteriorates and then out of the field if it gets worse.
DP (for vessel or jack-up)	Faster to mobilise or demobilise and more flexible than if moored. DP vessels can operate in deeper water than jack-ups	1. Risk of "run-off" or "drift-off" after DP failure or if environmental conditions occur beyond the DP System capacity. (For jack-ups this is for the approach only, reducing the time at risk).
Sheerlegs	Often have high lifting capacities	1. As for floating vessels (moored or DP) 2. Less adaptable as cannot slew lifted objects 3. Usually designed for inshore or coastal use (small waves) 4. Class limitations may prevent use offshore.
Grounded vessels /barges	(May be required in shallow water for cable landfall)	1. Must avoid any prelaid cables unless well protected. 2. Generally requires a good weather window or sheltered water. 3. Cohesive soils may hold the hull down when trying to refloat.

Note 1: Jack-ups that are not designed for ongoing seasonal operations for that location may need to "cut and run" for a safe location before the weather exceeds that required for safely jacking down into the water.

5.2 TOLERANCES & CRITERIA

5.2.1 The selection of many installation tolerances and criteria will be an economic trade-off between reducing the cost of manufacture and reducing the costs of delays waiting for good weather in consequence. Manufacturers often prefer tighter installation tolerances which require better weather criteria for installation. It is generally beneficial to select the transportation /installation contractors before such tolerances and criteria are fixed as they may significantly affect the installation methods, risks and costs.

5.2.2 Such tolerances may include:

a. Position and orientation of monopiles, pile templates, jackets and other structures.

b. Pile or structure verticality.

c. Clearances between piles inside pile sleeves, including allowances for weld beads and grout keys.

5.2.3 Such criteria may include:

a. Wind speeds (at specified heights and gust durations) for critical lifts.

b. Any restrictions on current speeds or wave heights (and how they will be measured) for specific operations. These could include stabbing piles or jackets into templates.

c. Degree of acceptable damage to grout keys during piling.

d. Any restrictions on helicopter or vessel movements within the field in bad visibility or other adverse conditions.

e. Any restrictions on transfer of people and equipment onto fixed or floating installations by various means.

f. Requirements for disposal of any dredged materials, drilling cuttings or soil plugs removed from piles (to comply with national or international laws or conventions, and to avoid problems with other contractors).

g. Piling operations – sound effects on sea life.

5.2.4 GL Noble Denton will also have an input to such selection in so far as the tolerances and criteria must not be so severe that there is a possibility that the equipment may never be able to be installed without taking unacceptable risks. If installation environmental criteria are set too high then there is also a higher probability of damage.

5.3 VULNERABLE ITEMS OR AREAS

5.3.1 Due to the many parties and vessels working in close proximity it is necessary that each party understands what items are particularly vulnerable to actions by others. These items need to be identified at an early stage so that they can be considered in the relevant risk assessments. The list of vulnerable items needs to be updated and promulgated as required during the life of the wind farm.

5.3.2 Typical vulnerable items or areas may include:

a. J-tube entry holes being covered with soil or debris

b. Changes in seabed level (from scour, dredging, jack-up footprints, drill cuttings etc) varying the natural frequency of foundations.

c. Scour can also affect jack-up foundations, cables, anchors etc. Scour model tests may be required in areas with high current speeds and soft or sandy seabeds.

d. Damage to grout seals and back-up seals.

e. External fittings (including anodes, J-tubes) being damaged by dropped objects, vessel collision or mooring lines.

f. Operations of divers (vulnerable to propellers and propeller wash, noise and blast, bubble curtains, cables and dropped or lowered objects).

5.4 PLANNED MOORINGS

5.4.1 Geotechnical and bathymetric surveys should determine at an early design stage if the seabed will provide good anchor holding and may determine the type of anchors that will be needed. If anchor holding is poor (leading to a high probability of dragging anchors damaging cables) then prelaid or piled anchors may be very cost effective. Allowable anchor locations should be agreed at the same time as the cable routes.

5.5 SITE & ROUTE SURVEY REQUIREMENTS

5.5.1 As well as ensuring that all positional, bathymetric, soil and current surveys are performed using the same datum and coordinate systems, various requirements to ensure sufficient accuracy like the frequency of survey equipment calibration (for salinity, temperature etc) must be agreed. There should be an agreed procedure for ensuring that all survey results are disseminated to all relevant parties as required.

5.5.2 The “as built” locations of structures, cables and subsea equipment must be recorded accurately on charts using a common survey datum used by all parties. These charts must be kept updated, including all jack-up footprints as soon as they are made and issued to all vessels operating in the field. “No anchoring” zones must be well marked.

5.5.3 In advance of the final detailed design being carried out for the foundations, the seabed material, and geophysical and geotechnical surveys of the sub-bottom profile should have been carried out, as well as magnetometer surveys for ferrous objects. The Cone Penetrometer Test results and other appropriate survey details for each foundation location should be issued, or made available, to jack-up vessel operators. This will allow them to carry out site-specific assessments in accordance with ISO 19905-1, Ref. [20], and to assess the possibility of scouring around jack-legs and spud-cans.

5.5.4 Additional requirements for the cable route surveys are given in Section 10.5.

5.6 HEALTH SAFETY & ENVIRONMENT

5.6.1 Section 5 of 0001/ND, Ref. [1], describes the requirements for most offshore construction /installation projects.

5.6.2 For marine operations that are planned to carried out in close proximity to fixed or moored installations, appropriate risk assessments and vessel audits shall be carried out prior to issue of a Certificate of Approval.

5.6.3 Risk assessments, HAZOP / HAZID studies shall be carried out in the presence of the client, GL Noble Denton and the contractor’s operational personnel. These studies shall be completed at an early stage so that the findings can be incorporated into the operational procedures.

5.7 ORGANISATION & COMMUNICATION

5.7.1 Section 6.2 of 0001/ND, Ref. [1], gives suggestions for the type of organisation and communications that is usual for efficient offshore projects.

5.7.2 Sufficient management and resources shall be provided and documented to carry out the operations efficiently and safely.

5.7.3 Where the installation operations are carried out using a multi-contracting strategy, the organisation and management of these marine operations shall be defined by organisation charts with reporting lines and definition of roles and responsibilities of key personnel.

5.8 PROCEDURES AND MANUALS

5.8.1 The management structure for each operation, including reporting and communication systems, and links to safety and emergency services shall be shown. They should include:

a. The anticipated timing and duration of each operation, including contingencies.

b. The limiting wave states, wind speeds and currents, and where applicable any visibility/day-light, temperature and precipitation limits, as well as the site-specific equipment or methodology prescribed for measuring each limit-state.

c. The arrangements for control, manoeuvring and mooring of barges and/or other craft alongside installation vessels.

d. Effects on and from any other simultaneous operations (SIMOPs – see IMCA Ref. [18]).

e. Contingency and emergency plans.

f. Requirements from the relevant GL Noble Denton guidelines for each individual phase.

5.9 WEIGHT CONTROL

5.9.1 The requirements in Section 8 of 0001/ND “General Guidelines for Marine Projects”, Ref. [1], will apply.

5.9.2 Additionally for lifting, the weight contingency factors of Section 5.2 of 0027/ND – Guidelines for Marine Lifting & Lowering Operations, Ref. [7] will apply.

5.9.3 The manufacturer shall supply a weight statement with tolerance and CoG envelope for all weight-sensitive items.

5.9.4 When a large number of virtually identical items are built with very good quality control, reduced weight contingency factors may be agreed with GL Noble Denton based on the standard deviation from weighing of initial items, with random subsequent weighing used to confirm consistency of manufacture.

5.9.5 Weighing of each item may not be required if the quality control and predictions of final weights in initial weighings are shown to be good enough and a reduced requirement for weighing may then be agreed with GL Noble Denton.

5.10 WEATHER-RESTRICTED OPERATIONS & WEATHER FORECASTS

5.10.1 See Section 7 of 0001/ND “General Guidelines for Marine Projects”, Ref. [1] for more details.

5.10.2 For areas with high tidal currents there may be additional restrictions on operations due to the need to wait for slack (or slacker) tides for current-sensitive operations such as:

- Moving jack-ups on or off location
- Stabbing piles or installing jackets, substructures or equipment on the seabed
- Bringing cargo barges alongside installation vessels.
- Diving operations.

5.10.3 When high currents are combined with shallow water then additional current forces will be caused by “blockage” effects. These shallower conditions also lead to increased seabed turbulence due to wave action, and additional contingency measures may be necessary to make allowances for accelerated scouring around jack-legs and spud-cans.

5.10.4 However suitable moorings, stabbing guides and other aids may help to reduce the sensitivity to currents and decrease downtime waiting for slack tide.

5.10.5 A weather forecast of at least 48 hours duration, from an approved source, predicting that conditions will be within the prescribed limits, shall be received prior to the start of any weather-sensitive operation, and at not more than 12 hourly intervals (but preferably 6 hourly and on issuance of a bad weather warning) thereafter, until the operation is deemed complete, i.e. with all equipment and vessels in a safe condition even if the weather deteriorates.

5.10.6 Weather forecasts for wind speed should specify the height (to be agreed in advance) and wind speeds measured on site should be corrected to that height for direct comparison. The swell height, direction, and period should also be included, as well as the probability of precipitation, fog and lightning within the next 24 hours. The time of sunrise and sunset, and the phase of the moon may be advantageous though these will normally be found in nautical almanacs.

5.10.7 In field monitoring of waves (height, direction and period) should be considered to enhance the forecast for each specific lift operation.

5.10.8 For subsea lifts in areas where it is known that high currents exist in the water column, in-field monitoring of currents (speed and direction) should be considered to enhance the regular forecasts. The monitoring of sub-sea currents with acoustic Doppler or similar systems should be considered when the operational limits of ROVs, and drag on piles during stabbing can lead to operational delays.

5.10.9 Current and wave monitoring may also be used to reduce contractual disputes when operating in a specific current speed or wave height is a contractual requirement. However contractual requirements must not be allowed to over-ride safety or to increase risk.

5.11 SCOUR PROTECTION

5.11.1 See Sections 5.5.3 & 5.10.3 for information that will help in prediction of scour. "Dynamics of scour pits and scour protection", Ref [21] gives the results of research into scour on early UK offshore wind farms.

5.11.2 If scour is a possible problem then procedures or contingency procedures shall be prepared and anti-scour materials stockpiled and deployment equipment prepared for mobilisation.

5.11.3 Scour around jack-up legs may also make them more vulnerable to punch-through.

5.11.4 Care should be taken when laying scour protection to ensure that bad weather and/or high currents during the installation phase do not cause damage to the lower layers.

5.11.5 Cables will generally be trenched or otherwise protected in scour-prone areas. However additional precautions may be required close to J-tubes or I-tubes at monopiles or platforms, especially immediately after laying.

6 VESSELS

6.1 BACKGROUND

6.1.1 Many existing wind farms are in shallow sheltered waters. This has allowed use of coastal and inshore vessels that are not designed or classed for operating in exposed waters. In turn, this has often required vessels to remain within a limited distance from a port of shelter and for jack-ups to jack down and seek shelter on a bad weather forecast. This approach exposes the operations to a high risk of accidents from unforecast bad weather and being caught on a lee shore.

6.1.2 The risk is further increased if the national administration and/or class restrictions require the unit to remain within a certain distance from land (which may be a lee shore) but where there is no safe port or sheltered jacking location. However some national administrations and classification societies may be prepared to agree specific direct routes in advance which are shorter and entail less risk but exceed the normally required distance from shore.

6.1.3 Installation in deeper and more exposed locations requires a different approach, such as is used in the oil and gas industries, in which vessels typically have to be designed to survive in 50 to 100 year design storms without seeking shelter. Although the initial costs are higher, the greatly increased productivity and decreased risk make this approach much more attractive financially.

6.2 MOORINGS

6.2.1 Almost all installation vessels, unless operating on DP, will require suitable moorings to keep them on station when working alongside a structure, or when preparing to jack-up or jack-down.

6.2.2 These moorings should be designed to the requirements of 0032/ND, Ref. [11], using the agreed design criteria corresponding to the proposed operating criteria modified by the relevant Metocean Reduction Factors described in Section 7.3 of 0001/ND, Ref. [1].

6.3 DP VESSELS

6.3.1 A vessel with a minimum DP Class 2 will generally be required though a few operations, e.g. rock-dumping and cable-laying when not close to high value structures, may use DP Class 1 if the consequences of any DP failure are low. Further requirements are in Section 13 of 0001/ND, Ref. [1].

6.3.2 Jack-ups with DP shall have procedures to determine at what stages during installation or departure from a location they will operate in DP mode. As a general rule (subject to the risk assessment for the specific operation) jack-ups need to be on manual control once the seabed develops a certain level of lateral resistance during installation, and at all stages during departure. See also Section 13.7 of 0001/ND, Ref. [1].

6.4 JACK-UPS – UNRESTRICTED OPERATIONS

6.4.1 Jack-ups that are designed and classed for elevated operations in conditions in excess of those at the installation site (either all year or for particular months) shall, as a minimum, comply with the requirements of BWEA /RenewableUK Guidelines for Jack-Ups, Ref.[12].

6.4.2 The jack-up may operate at a lower air gap than required for survival in a design storm as long as it is able to jack-up to a safe air gap for a design storm before bad weather. If a breakdown prevents jacking up then the crew may need to be evacuated.

6.5 JACK-UPS – WEATHER-RESTRICTED OPERATIONS

6.5.1 Jack-ups that cannot comply with Section 6.4 above for a specific location and season shall comply with the requirements for Weather-Restricted Operations in Section 5.3 of BWEA Guidelines for Jack-Ups, Ref. [12]. This is summarised as:

a. Agree procedure documents which include limiting criteria for relevant decision points and identify suitable alternative jack-up locations between the site and safe ports. These criteria shall take into consideration the Metocean Reduction Factors described in Section 7.3 of 0001/ND, Ref. [1].

b. The jack-up is only to leave a safe location to go to the installation site on receipt of a confident good weather forecast to cover the time (including a contingency for delays) from departure to return to a safe location.

c. The jack-up is to leave the installation site unless there is a confident good weather forecast to cover the remaining time on site and to return to a safe port or to elevate to a safe air gap at a suitable stand-by location, including a contingency for delays.

d. If the jack-up cannot reach a safe port or location before meeting bad weather (above the laden jacking limits of the jack-up, typically about 1 to 1.5 m significant wave height), then it should jack-up to survival air gap at a suitable shallow water location and evacuate the crew if necessary.

6.5.2 The procedures and criteria described in Section 6.5.1 above shall be the subject of a risk assessment in which GL Noble Denton participates and agrees that the risks are acceptable.

6.5.3 Jack-ups may also operate when moored afloat, or partly elevated, to save time jacking up and down and preloading. These operations will require good weather and need to follow the Weather-Restricted Operations requirements of Section 7.3 of 0001/ND, Ref. [1].

6.6 CRANE VESSELS (SEAGOING)

6.6.1 Any seagoing crane ship operating in an area for which it is classed should be able to survive in bad weather unless it is carrying vulnerable cargo. However any lifting and mooring operation needs to be done in good weather and these design and operating criteria need to be agreed with GL Noble Denton taking Metocean Reduction Factors into account.

6.6.2 Carrying a suspended load on a crane hook in transit offshore is not generally considered good practice, unless it is for very short distances in calm weather. In bad weather the load may be very difficult to control, stability is reduced and the crane may be overloaded. Approval of such operations will require agreement from the Classification Society and a risk assessment in which GL Noble Denton participates and agrees that the risks are acceptable.

6.7 INSHORE CRANE VESSELS AND BARGES

6.7.1 Inshore crane vessels and barges shall only be used if allowed by their class notation and:

a. GL Noble Denton has agreed procedure documents which include limiting criteria for relevant decision points and identifies safe ports or locations. These criteria shall take into consideration the Metocean Reduction Factors described in Section 7.3 of 0001/ND, Ref. [1].

b. The vessel is only to leave a safe port or location to go to the installation site on receipt of a confident good weather forecast to cover the period from departure to safe return, including a contingency for delays.

c. The vessel to leave the installation site unless there is a confident good weather forecast to cover the remaining time on site and to reach a safe port or location, including a contingency for delays.

6.8 GROUNDED INSTALLATION VESSELS AND BARGES

6.8.1 Some vessels working in shallow water may need to be grounded at low water or over one or more tidal cycles. This may only be approved provided that:

a. The vessel's classification society allows such operations.

b. The seabed is such that the barge will not be damaged and it will not hold the barge down when attempting to refloat.

c. There is a method (e.g. moorings or "spuds") for holding the vessel on location when grounding and floating off in the design conditions agreed with GL Noble Denton at the design stage without damaging any cables or other structures or equipment..

d. A confident good weather forecast is obtained before grounding to cover the period (including a suitable allowance for delays) until float-off without exceeding the design conditions in c. above modified by the Metocean Reduction Factor.

6.9 TRANSPORTATION SHIPS, TUGS & BARGES

6.9.1 The requirements of 0030/ND Guidelines for Marine Transportations, Ref. [9], apply for all tows and transportations. For short voyages the relaxations in Sections 6.3 and 6.4 of 0030/ND may apply.

6.9.2 If towing vessels are currently registered in the GL Noble Denton Towing Vessel Approval Scheme (TVAS) – see 0021/ND, Ref. [6], then suitability surveys will not be required, though a check will be required before a Certificate of Approval is issued.

6.10 CABLE LAYING BARGES

6.10.1 Moored CLBs are standard industry equipment for installing submarine power cables in relatively shallow waters in close proximity to land. Moored CLBs are equipped with four or more mooring winches and one 'pull-ahead' winch. They are usually flat top pontoons with a cable laying spread added.

6.11 CABLE LAYING VESSELS

6.11.1 Cable ships are generally purpose built (or converted permanently) and typically use DP rather than moorings. They can generally lay faster than barges and in deeper waters as they are not so restricted by the time taken to adjust moorings.

6.12 OTHER VESSELS

6.12.1 Crew transfer or accommodation vessels with proprietary crew access arrangements.

6.12.2 Escort and standby vessels may be needed in some areas to warn off other vessels, especially during sensitive operations or transports.

6.12.3 Bubble curtain deployment and energising vessels may be needed if regulations on piling noise pollution apply (see Section 13.3 of 0028/ND, Ref [8]).

7 LOAD-OUT

7.1 LIFTED, SKIDDED AND TRAILER LOAD-OUTS

7.1.1 Lifted, skidded and trailer load-outs are covered in 0013/ND, Ref. [3]. However the following special cases may apply.

a. Special consideration will be given to purpose-built lifting appliances for blades. The lifting tool Certificate should specify the maximum load and any limits regarding the overall dimensions of the lifted item and any environmental limitations (e.g. maximum wind speed).

b. In the event of structural modifications to an item of lifting equipment it shall be re-approved by an IACS member before further use.

c. Bolts used for removable lifting lugs shall generally be used one time only. In special cases re-use may be accepted as described in Section B5 in Appendix B of 0001/ND, Ref. [1], but only if initial pretensioning does not exceed 60% of the bolt yield strength and the loads during lifting have not exceeded the maximum design values. For re-use of bolts, a detailed inspection plan with regular NDT including rejection criteria and exchange intervals should be submitted for review by GL Noble Denton. As a minimum, bolts should be visually inspected after each lift and with MPI (Magnetic Particle Inspection) after every 3 lifts unless fatigue calculations accepted by GL Noble Denton show that less frequent inspections are acceptable.

d. Re-useable lifting lugs shall be tested in accordance with Section 8.6 of 0027/ND, Ref. [7].

7.2 FLOAT-OVER

7.2.1 Float-over load-outs are covered in 0031/ND, Ref. [10]. However pre-ballasting floating structures must be avoided unless adequate local structural checks show that loads produced by the ballast do not exceed the capacity of the structure.

7.3 CABLE LOAD-OUT

7.3.1 Before start of load-out the cable ends must be sealed against water ingress in accordance with the cable manufacturer's procedures.

7.3.2 Before shipping, drummed cable ends must be sealed and the cable protected from external damage by use of wooden planks, or similar, securely fitted between the drum flanges.

7.3.3 Electrical and optical tests are normally done after cables are loaded into carousels or cable tanks only when the responsibility for the cable transfers from one party to another, for example when the cable manufacturer and the cable installation contractor are different companies.

7.3.4 Otherwise post load-out tests are a discretionary requirement and the client will choose whether or not to specify full or partial post load-out electrical and optical tests.

7.3.5 However if there is an incident during cable loading then tests should be done to establish whether or not the cable suffered damage. The scope of the tests can be agreed at the time of an incident and will depend on the type of incident.

7.3.6 Depending on the post load-out test scope it might be necessary for both ends of the loaded cable to be accessible for testing. The test protocol should be taken into account in the transport or lay vessel tanking plans and loading procedures.

7.3.7 Post load-out test results should be compared with the FAT results and abnormallities investigated.

7.3.8 In high fibre count cables it is acceptable to test an agreed percentage of the fibre optics unless there is an incident during load-out that might have damaged the cable.

7.3.9 When post load-out testing is finished, end seals and pull-in arrangements must be properly fitted to the cable ends by competent technicians in accordance with the manufacturer's procedures.

7.3.10 Pre-installed cable pull-in heads with integrated end seals can be fitted at the manufacturer's premises on drum-loaded cables and approriate certificates must be supplied. Drum-loaded cables are normaly only tested at FAT stage, after loading onto drums, and tested again after the cable has been installed offshore.

7.3.11 Pull-in heads or cable grips must be of adequate strength (i.e. stronger than the cables) for the transfer operation.

7.3.12 Typically pull-in head designs will be type-tested, removing the need to load test and certify every pull-in head.

7.3.13 Loaded drums should be inspected for signs of physical damage on arrival at the delivery location. If a drum is damaged then the cable in the damaged area should be inspected and, if deemed necessary, the cable should be tested.

7.3.14 **Cable types.** Submarine power cables can be torsion balanced or non-torsion balanced. Torsion balanced cables can only be stored in carousels or on drums. Non-torsion balanced cable can be stored in cable tanks.

7.3.15 Submarine power cable armour layup can be 'S' lay, 'Z' lay or 'SZ' lay which is a combination of the two. Cables might need to be coiled in a specific direction depending on the type and direction of armour layup. Loading procedures shall specify the coiling direction.

7.3.16 Submarine power cables can be constructed as wet, dry or semi-dry cables. Wet cables allow water to enter the body of the cable as far as the conductor outer sheath which is sealed against water ingress. Dry cables have a water-blocking sheath normally under the armour wire bedding layer. The water-blocking sheath prevents water from entering the body of the cable. Each conductor in a dry cable will have a swellable tape sheath encasing the conductor which swells in contact with water and keeps the conductor XLPE (Cross Linked Polyethylene) insulation dry. Some dry cables have a lead water-blocking sheath under the armour bedding. Typically HVAC cables are constructed as dry cables. Some manufactureres build semi-dry HVAC cables.

7.3.17 **The cable pathway** from the cable factory storage location to the quayside cable loading tower must be inspected for non-conforming bends (less than the cable MBR), loose /stiff rollers, sections where the cable can jump off the cable pathway and sections that are out of sight. Preferably the complete cable pathway will be monitored by CCTV during cable loading.

7.3.18 Non-conforming bends, excessive side wall pressure and shear forces are a cause for concern and can damage the cable metallic laminate and metallic sheaths and allow moisture ingress which can reduce cable insulation life.

7.3.19 Loading procedures must define a clear and concise chain of command and communications protocol and must include a command and communication interface between the onshore load-out team and CLV / CLB team.

7.3.20 Load-out must be preceded by a pre-load meeting at which the task, chain of command, control station command priorities, radio and communication protocols, emergency procedures and source of back up communications faciities must be communicated to all personnel involved in supervising the load and personel operating loading machinery and winches.

7.3.21 Responsibility for managing the load-out catenary between onshore and the CLV or transport vessel must be clearly defined.

7.3.22 If necessary a watch shall be maintained to ensure that the wash from passing vessels cannot endanger the cable loading operation.

7.3.23 All loading equipment controls, sensors and monitoring devices shall have in date calibration certificates.

7.3.24 **Swivels** must be used at the cable ends and between segments to enable residual torsion to leave the cable.

7.3.25 Cable loaded into a cable tank or a carousel must be tightly packed together to minimise gaps. Wooden paddles should be used to lever the incoming cable into place. Gaps should be packed out with wood or plastic to prevent movement at sea and to prevent overlying cable being forced into gaps between cables in underlying layers.

7.3.26 **Vertical carousels**. Submarine power cables loaded onto vertical carousels must be wound onto the carousel under tension to prevent the cable 'falling' down the carousel. The calculations to justify the back tension required to prevent the cable 'falling' down the already loaded cable should be submitted for GL Noble Denton review.

7.3.27 **Damage**. All parts of the load-out operation must be observed. Any damage to the cable outer serving must be made good. Any signs of bird-caging armour wires, kinks and buckling in the cable and a tendency for the cable to try to form loops in the catenary between the load-out gantry and the CLV load-out chute are causes for concern and should be investigated.

8 MARINE TRANSPORTATION

8.1 TRANSPORTATION OF COMPONENTS ON VESSELS OR BARGES

8.1.1 The requirements of 0030/ND Guidelines for Marine Transportations, Ref. [9], apply for all tows and transportations. For short voyages the relaxations in Sections 6.3 and 6.4 of 0030/ND may apply.

8.1.2 Seafastening of blades and other fragile components will normally need special care to avoid damage from welding or locating guides. Where friction is required to resist some or all of the seafastening forces then the coefficients of friction shall be shown to be adequate in both the wet and dry states.

8.1.3 If towing vessels are currently registered in the GL Noble Denton Towing Vessel Approval Scheme (TVAS) – see 0021/ND, Ref. [6], then suitability surveys will not be required, though a check will be required before a Certificate of Approval is issued.

8.1.4 The requirements of Appendix B of 0001/ND, Ref. [1], will apply for bolted connections used for seafastening.

8.1.5 Minimum clearance between cargo items to be lifted is given in Section 9.2 and 9.3 of 0027/ND, Ref. [7].

8.2 TRANSPORTATION OF COMPLETE ROTOR

8.2.1 Rotors with diameters of well over 100 meters may be transported horizontally (rotor axis vertical) on vessels or barges of only about 30 to 40 m beam. However the blades will generally be very vulnerable to wave slam, especially when the vessel rolls and/or pitches into a wave.

8.2.2 A successful transportation will rely on:

a. The rotor being designed to safely withstand the accelerations (from 0030/ND, Ref. [9]) during transport.

b. Reducing to negligible the probablility of wave slam on the blades by securing them well above the still water level.

c. Selecting vessels that can be ballasted to reduce the motions in likely wind and wave combinations.

d. Doing motion response calculations to optimise the loading and ballasting arrangments so as to minimise the probablity of wave slam on the blades in likely wind and wave combinations.

e. Weather routing the transport to avoid any weather that could cause wave slam on the blades. (This may not always be practicable for some seasons and longer routes between suitable shelter ports).

f. Developing procedures to avoid blade collision damage when coming alongside loading quays, entering ports of shelter (as part of the weather routing) and coming alongside the offshore lifting vessel. These procedures must include advance liaison with any suitable shelter ports (to agree the conditions under which the transport may enter, e.g. problems when meeting other vessels in the approach channel, clearances at harbour entrance and mooring at a quay). Escort vessels may also be required to reduce the probability of collision with other shipping, especially at night.

g. The rotor will normally be upended (so that the rotor axis is horizontal for installation) before coming alongside the installation vessel.

8.2.3 In some respects a transportation with the rotor in a vertical plane (as installed) may be easier, especially if fully assembled on a tower. However the required accelerations may be higher though wave slam and collision problems should be reduced

8.3 TRANSPORTATION OF TALL VERTICAL CARGOES

8.3.1 Seafastening of the TP flanges on barges or ships is often critical for many projects. The design of the bolted connection should be “gap free” to avoid self-loosening of the bolts. All gaps due to imperfections should be filled in with shim plates but not more than 2 shim plates should be used at a time. Pretension bolts in seafastenings shall be used only once due to fatigue during transportations.

8.3.2 Seafastenings must be designed to allow safe removal offshore without endangering the cargo or personnel. See also Section 9.2.1 b.

8.3.3 Clearance (air draught) under any bridges or power cables must be considered. The safe distance from live power lines shall be allowed for. The power line catenary will change if power is shut off.

8.4 CONCRETE GRAVITY STRUCTURES & OTHER WET TOWAGES

8.4.1 Larger Concrete Gravity Structures will generally be built in a dry-dock, with construction often completed afloat. The requirements for float-out, towage and installation will generally be covered by 0015/ND – Guidelines for Concrete Gravity Structure Construction & Installation, Ref. [4].

8.4.2 Smaller gravity structures may be built on barges and floated off or lifted off by crane or sheerlegs. They may also be lowered to the seabed by purpose-built installation units. Where these are not covered by existing GL Noble Denton guidelines, suitable criteria can be developed by GL Noble Denton at an early design stage.

8.4.3 Other wet towages (floating on their own buoyancy) may be launched from a slipway using standard ship launch procedures which will depend mainly on the location and slope of the launchways.

8.4.4 It will often be impracticable to provide 1 compartment damage stability for floating piles, transition pieces and suction anchors with temporary bulkheads. In this case a formal documented risk assessment, with participation from GL Noble Denton, will be required to determine the major causes of flooding and to reduce the probability to ALARP (As Low As Reasonably Practicable) as described in Section 10.7.3 of 0030/ND, Ref. [9]

8.4.5 Procedures shall be established for reconnecting a towline to a towed object in the event of a failure of any part of the towline, pennants or connections.

8.5 CABLES

8.5.1 A fundamental requirement during transport of submarine power cables is protection of the mechanical, electrical and optical properties of the cable achieved by careful and proper loading into cable tanks or rotating carousels.

8.5.2 Crush loads imparted by overlying cable must within limits set by the cable manufacturer.

8.5.3 Calculations confirming crush loads are within set limits shall be developed and shall include the effects of vessel motions which should not be less than the design storm conditions in Section 6 of 0030/ND, Ref. [9].

8.5.4 Cable tank design calculations shall be checked to ensure the cable tank structure can withstand 'racking' loads imparted by the cable stack into the cable tank structure. The conditions used for the calculations should not be less than the design storm conditions in Section 6 of 0030/ND, Ref. [9].

8.5.5 Carousel and cable tank seafastening and grillage calculations shall be checked for approval by GL Noble Denton. The conditions used for the calculations should not be less than the design storm conditions in Section 6 of 0030/ND, Ref [9].

8.5.6 The requirements for loading and stowing cable on transport vessels are the same as for a CLV /CLB as described in Section 7.3.

8.5.7 **Trans-spooling** operations between the transport vessel, CLVs or CLBs shall always be carried out in sheltered waters where both vessels can be safely moored with the minimum relative movement between the vessels.

8.5.8 The requirements for trans-spooling cables between transport vessels and CLVs are the same as for loading cables onto a CLV at the cable manufacturer's facility. Special care and attention should be given to managing the cable catenary between the two vessels especially if there is relative movement between the two vessels. Mooring lines should be checked on a regular basis and the checking period should be in accordance with the prevailing environmental conditions and passing marine traffic. Mooring line checks and adjustment shall be recorded in the cable loading log (in addition to the vessel bridge log).

9 INSTALLATION

9.1 GENERAL

9.1.1 Installation of components on wind farms are generally covered as follows:

a. Concrete or steel gravity platforms, foundations or complete integrated platforms by 0015/ND, Ref. [4], and 0028/ND, Ref. [8].

b. Monopiles and jackets by 0028/ND, Ref. [8], including piling and un-piled (storm safe) stability.

c. Lifted turbines, transition pieces, decks and modules (including substations, control stations, transformers, HVDC converter platforms, etc) by 0027/ND, Ref. [7]

d. Decks floated over jackets or gravity bases by 0031/ND, Ref. [10]

e. Jack-up platforms (construction and containing Wind Farm permanent equipment) by 0009/ND, Ref. [2], 016/ND, Ref. [4] and BWEA Guidelines for Jack-Ups, Ref.[12].

f. Cables in Section 10 of this document.

However special cases for offshore wind farms are covered in the following sections. Where special considerations apply, the requirements need to be agreed In advance with GL Noble Denton.

9.2 MONOPILES AND TRANSITION PIECES

9.2.1 Special considerations may apply for

a. Position and orientation tolerances (See Section 5.2).

b. Release of seafastenings which will normally require a specific procedure, especially for tall objects transported vertically.

c. Sea bed soil condition and scour protection requirements.

d. Levelling arrangements for the transition pieces.

e. Grippers, handling & upending equipment.

f. On-bottom stability of the unpiled Monopile in the pile gripper.

g. Stability of the TP on the MP prior to grouting (see Section 7.2.2 of 0001/ND, Ref. [1], for the environmental criteria).

h. If drilling is required for installing piles then:

1. Disposal of cuttings (see Section 5.2.3)
2. Contingency plans & equipment (e.g. fishing tools) for a broken drill string.

9.3 PILING TEMPLATES

9.3.1 Piling templates are often used to help locate piles before driving and to ensure that piles are driven vertically or at the right inclination.

9.3.2 They are normally placed on the seabed but may be attached to the side of a jack-up, with the facility to be lowered or raised and may use the jack-up legs as a positioning guide.

9.3.3 If transported attached to a jack-up then the template and its attachment must be able to withstand the design accelerations from Sections 7 and 8 of 0030/ND Ref. [9]. Its effect on trim and stability must also be checked.

9.3.4 Special transit procedures may need to be developed to reduce the risk of collisions or grounding if the attached template increases the combined draught or beam, especially if not visible above water.

9.3.5 The template will need to be capable of being levelled if there is a sloping or uneven seabed. Mud mats may also be needed for a soft seabed.

9.3.6 When templates are liable to settle in clay or silt, provision should be made for jetting or other means to overcome adhesion during subsequent extraction.

9.4 SUCTION BUCKET FOUNDATIONS

9.4.1 The requirement for any seabed preparation before installation shall be determined at any early stage.

9.4.2 Equipment and procedures shall be provided to ensure that:

a. the foundations can be safely lowered to the seabed and located within tolerances

b. there is no "piping" through the soil between outside and inside, or between individual compartments, if any, during installation

c. that any out of verticality can be corrected to within the required tolerances (possibly using crane assistance)

d. there is sufficient redundancy to allow installation to continue after flooding of any compartment or breakdown of any item of equipment. If there is insufficent compartmentation to allow this then a risk assessment must show that therre are sufficient safegaurds in place that the risk of such flooding is acceptable to GL Noble Denton

9.5 J-TUBES AND I-TUBES

9.5.1 J-tubes and I-tubes provide an installation guide and long term protection to submarine cables installed onto offshore structures. Typically the hang-off mounting flange will be welded to the top of the J-tube /I-tube.

9.5.2 J-tubes guide the cable from or near seabed level usually via a bellmouth into a bend conforming with the cable MBR and vertically to an upper level of either the foundation, substation or other structure.

9.5.3 Internal J-tubes are normally sealed where they pass through the foundation wall to prevent water exchange between the sea and the inside of the monopile.

9.5.4 I-tubes are vertical tubes with an opening facing down toward the seabed. I-tube pull-ins can be problematical if the correct installation tension is not maintained throughout the pull-in operation and over tension during pull-in operations can damage cable if the cable is pulled over the lip of the open I-tube.

9.5.5 J-tube and I-tube internal diameters should be sufficiently large to minimise friction induced tension in the cable during pull-in operations and shall be smooth with no snagging points that can snag pull-in rigging.

9.5.6 Installing cables through J-tubes and I-tubes is covered in Section 10.11

9.6 TURBINE INSTALLATION

9.6.1 Fully erected turbines have already been installed from floating craft and there will soon be jack-ups designed to do this.

9.6.2 Existing guidelines should apply unless novel installation techniques are proposed.

9.7 TOWERS

9.7.1 Installation of towers is generally carried out by a crane vessel using conventional lifting methods, often with a custom-designed lift-beam arrangement.

9.7.2 Towers can be installed in sections. If installation of the tower is planned in sections then these sections are connected together, often using bolts, before de-rigging the upper tower section.

9.7.3 Installation requirements for towers are covered in 0027/ND, Ref. [7]. However the following special cases may apply:

- Access for de-rigging
- Partial bolting
- Lifting points certification for multiple use (loadout, installation, maintenance, decommissioning)
- Verification that there will be no ovalisation due to local seafastening forces in higher seastates
- Transport frames
- Requirements and criteria for upending from the horizontal to vertical mode.

9.8 NACELLES

9.8.1 Installation of nacelles is carried by conventional lifting techniques often with spreader beams connected to grommets and trunnions. Installation requirements is covered in 0027/ND, Ref. [7]. However the following special considerations may apply:

- Lift points
- Access for de-rigging
- Partial bolting

9.9 BLADES

9.9.1 Installations of blades have generally been carried out with the hub in the horizontal position. Historically, the “bunny-ears” method has been commonplace, in which there is a single blade installed offshore with the blade inserted into the hub in the vertical direction

9.9.2 Blade handling tools are used in order to ensure a correct orientation for the integration of the blade to the hub and to permit safe rigging up and de-rigging. Blades are then bolted to the hub.

9.9.3 Installation requirements for blades is covered in 0027/ND, Ref. [7]. However the following special considerations may apply:

- Infra-red release systems which must be shown to be reliable in releasing and, more importantly, not liable to early release from any cause.
- Limiting criteria. See Section 5.2
- Boom tip motions, See Section 11.4.2 of 0028/ND, Ref. [8]
- Partial bolting

9.9.4 If the design of the blades is so confidential that the client, manufacturer or designer is unwilling to submit transport or handling calculations to GL Noble Denton then the approach in Section 9.6.3 of 0001/ND, Ref. [1], may be taken.

9.10 COMPLETE ROTOR INSTALLATION

9.10.1 Installations of completely assembled rotors (blades and hub) are carried out with the rotor axis horizontal. If the rotor is transported horizontally (rotor axis vertical as described in Section 8.2), the rotor is normally upended on board the vessel using a bespoke lifting device before coming alongside the installation vessel.

9.10.2 Installation requirements for complete rotors is covered in 0027/ND, Ref. [7]. However the following special considerations may apply:

- Upending and lifting devices
- Partial bolting
- Horizontal and vertical movement during positioning
- High windage area effect on dynamical loads

9.11 LIFTING OPERATIONS AND LIFTING TOOLS

9.11.1 Lifting operations and Lifting Tools are covered in 0027/ND, Ref. [7]. However the following special considerations may apply to wind farms:

a. Blade lifting tools (usually proprietary designs)
b. Wire slings and grommets
c. Fibre Slings (Dyneema, Aramid or HDPE)
d. Certification
e. Inspection / recertification
f. Discard criteria

9.12 INNOVATIVE INSTALLATION METHODS

9.12.1 Requirements for new methods of installation of any equipment should be agreed with the relevant GL Noble Denton office in advance, preferably at an early design stage when is more economical to comply with any recommendations.

10 CABLE INSTALLATION

10.1 BACKGROUND

10.1.1 A successful offshore wind farm cable laying operation will normally be preceded by:

a. Desk Top Study
b. Environmental Impact Assessment
c. Liaison with third party stakeholders such as fishing industry representatives and other marine users
d. Seabed route surveys
e. Burial Protection Index study
f. Route development and cable engineering
g. Cable protection selection
h. Out of service cables identified
i. In service cables identified and cable crossing agreements established with cable owners in which the crossing construction method is agreed
j. Assessment of the physical risks to the cable
k. Selection of suitable installation resources
l. Installation Analysis including J-tube /I-tube pull-in, laying around curves and when cable will be surfaced laid but not immediately buried
m. Interface management plan
n. Other items covered in Section 10.6.1, as applicable.

10.2 MAJOR CHALLENGES /CONSIDERATIONS FOR ALL CABLES

10.2.1 **Minimum Bend Radius (MBR)**. The minimum bend radius shall be protected at all times. Suitable measures should be taken to protect the MBR, particularly during high-risk operations such as pull-in, overboarding and laydown operations. Protection can be ensured with the use of quadrants, bend restrictors or rollers, etc. See Section 10.17.

10.2.2 **Turn-overs.** The cable supply contract must state the maximum number of times a cable can be turned over and the contract maximum turn-overs must exceed the planned operational turn-overs.

10.2.3 **Lead sheathing**. Some submarine power cable designs use lead sheathing as a water-block. Lead sheathing can be prone to micro cracking cause by excessive bend reversals. Micro cracking reduces the lead sheathing water-blocking properties. The installation procedures must take account of this and aim to reduce bend reversals during installation of lead-sheathed submarine power cables which must always be less than the design limit.

10.2.4 **Compression Forces.** Submarine power cables have maximum allowed compression forces that must not be exceeded during handling and installation operations. The maximum allowed compression force must be provided by the cable manufacturer and must be presented as load per unit length of cable. Cable handling machinery such as LCEs (Linear Cable Engines - tracked and wheeled types) exert compression forces on cables (see Section 10.10.3).

10.2.5 **CSA (**Cross Section Areas) have increased to accommodate offshore wind farm generating capacities. Handling of ever larger cables requires new techniques and skills to lay the cable properly and safely. When cable sizes push installation technologies it becomes increasingly important that the installation methodologies are considered at the cable selection /design stage.

10.2.6 **Direction of lay** is an important consideration and will be driven by a number of factors such as cable congestion around an offshore substation, location of installation joints and prevailing marine environment conditions.

10.2.7 **Varying ground conditions** may require different cable burial technologies to achieve acceptable levels of protection against identified threats throughout the length of the cable route. This may be a bigger problem for export cable routes due to their longer length resulting in a greater variation of ground conditions along their routes.

10.2.8 **Jack up vessel operations**. Jack up legs can be a major threat to cables if they are placed on or near a cable. Jack up legs placed on a cable will damage the cable as will ground-heave from a jack up leg placed too close to a cable (cable protection should not be relied on as protection from jack up legs). Leg penetration and ground-heave studies should be done to ensure there is sufficient space between jack up legs and cable positions.

10.2.9 **External aggression** leading to higher risk of damage. The increased risk of damage by anchors and fishing gear will influence the BPI and subsequent installation costs. In particular export cable routes will increasingly cross shipping lanes, anchorages and areas where bottom trawling is done, presenting increased challenges when designing export cable routes and installing cables.

10.2.10 **Burial.** Achieving required burial in difficult ground conditions.

10.2.11 **Lay barge mooring capability** in marginal laying conditions, cross currents, variable anchor holding ground conditions and shallow water.

10.2.12 **Laying around curves**. Cables must be laid around obstacles and approaches to offshore structures require laying around curves to line up with J-tube orientations. This may be a bigger problem for export cable routes due to major seabed obstacles at landfall areas.

10.2.13 **Bend restrictor and protection at J-tube approaches.** J-tube bell mouths can be raised above the seabed. The cable MBR must be protected in the free span between the J-tube bell mouth and the cable touch down point. The free span must be protected from ocean current induced vibration which, over time, can damage cable armour wires and can also reduce the electrical life of a cable. Cables must be protected against dropped objects at the approach to offshore structures. Scour pits might need to be crossed. All of these require bend restrictors and cable protection to be attached to the cable, usually on board the installation vessel before the cable is installed into the J-tube.

10.2.14 **J-tube /I-tube pull-in.** Protection of cable MBR; potentially high tension due to friction of pulling cable across the seabed into a J-tube; subsea handling and timely release of pull-in quadrant; cable protection /bell-mouth interface; scour pits; control of pull-in tension and MBR monitoring, observation and surveying of pull-in (visibility & tides) and correct engagement into the J-tube /I-tube of cable protection systems.

10.2.15 **J-tube pull-in limiting sea state.** A number of factors need to be considered to establish Array and Export Cable pull-in operational limiting sea states and other limiting conditions. These include:

a. offshore structure access /egress for cable pull-in personnel
b. vessel motions and impact on crane operations for transferring pull-in aids and other equipment to offshore structures
c. Cable tension caused by CLV / CLB accelerations.

10.2.16 **Laying away from the J-tube / I-tube.** Tension due to ploughing/trenching pull-off forces; cable protection/bell-mouth interface; scour pits. Control and observation of pull-in tension and MBR monitoring, observation and surveying of pull-in.

10.2.17 **Installation of cable protection.** Selection, installation monitoring and correct engagement into the J-tube/I-tube of suitable cable protection systems at the J-tube /I-tube seabed interface.

10.2.18 **Congested cable routes.** Wherever possible submarine power cables should be installed with sufficient space between cables to allow future repair operations to be carried out.

10.2.19 **Crossings.** Cable or pipeline crossings normally require a constructed crossing (mattresses, rock dumping, polyurethane products or small concrete bridges). The design and installation must be approved by the owners of the product being crossed. Wherever possible crossing points should keep the heading of the two products as close to 90 degrees as possible. Typically plough burial will not be allowed within 500m of the crossed product; therefore other means of protecting cables in this no-plough zone must be provided.

10.2.20 **Installing cables in bundles.** Cables are sometimes installed in bundles (HVDC circuits for example). Bundled cables are more difficult to handle than single cables and careful consideration must be given to the burial technology to ensure the cables are not damage by the burial /trenching tool.

10.2.21 **DP or mooring system failures** may lead to excessive tension or slack in the cable during cable laying operations. For moored barges the Mooring Analysis shall include line failure modes and an excursion analysis considering failure of each mooring line. The outcome of the Mooring Analysis will contribute to setting the limiting sea states and/or the number of attending tugs required.

10.3 SPECIFIC CHALLENGES /CONSIDERATIONS FOR EXPORT CABLES

10.3.1 **Installation durations** often exceed reliable weather forecast durations. Therefore it is difficult to set time limited weather windows.

10.3.2 **Cable route lengths** often result in installation joints in export cables. Installation joints take up to seven days to install, exceeding reliable weather forecast durations.

10.3.3 **Route development and cable engineering** at the landfall site are critical to ensure cables are secure for the life time of the project. Landfalls often have complex seabed physical environments where the influence of waves breaking in the surf zone can cause a poorly installed cable to fail within months of installation. Cable repairs in the surf zone cost substantially more than a repair undertaken at sea. Repairs done in the surf zone are more likely to fail again as protecting a cable repair in the surf zone can be very difficult.

10.3.4 **Grounding of export cable laying barges for landfall installation**. At some landfall sites the water depths prevent CLBs from getting close enough to the landfall to remain afloat during a landfall pull-in operation.

10.3.5 **Landfall sites with sea defence systems.** Normally consent conditions prevent sea defences from being breached by open cut trenches and must be crossed by HDD ducts. Ducts result in increased cable pull-in tensions and must be designed to accommodate the export cable maximum tensions and the cable design must accommodate the expected pull-in tensions.

10.3.6 **Landfall sites with extensive shallow water** will require a bespoke solution adapted to the challenges of each landfall. A range of methods have been adopted including very shallow draft vessels and tracked vehicles with cable drums mounted on the vehicle. The combination of HDD and ducts and extensive shallow water adds a high level of construction risk.

10.3.7 **Laying cables close to or over existing cables and pipelines.** Export cable routes can cross the routes of existing telecommunication cables, power cables and pipelines. Crossings typically require a constructed crossing point to maintain vertical separation between cables or between cables and pipelines. See Section 10.23.

10.3.8 **Constructed crossing** points must be designed to ensure the construction materials and methods do not cause scour to undermine the protection materials and potentially cause the crossing materials to put weight onto the crossing export cables and/or the crossed submarine plant.

10.4 SPECIFIC CHALLENGES /CONSIDERATIONS FOR ARRAY CABLES

10.4.1 **Cable installation time.** Array cables are typically installed end to end in around 36 hours. However the installation program should be based on the actual expected installation time for each cable.

10.4.2 **Weather windows.** Array Cable installations typically have different limiting sea states for crew access and egress to foundations and offshore substations, J-tube pull-in operations and Array Cable installation.

10.4.3 **Proximity to other structures** increases the risk of collision and damage to and from the CLB mooring lines and anchors. This applies particularly during pull-in operations.

10.5 CABLE ROUTE SURVEY AND POSITIONING

10.5.1 **Survey grid.** A survey should be performed covering the grid of proposed cable routes. The seabed survey shall be specified to determine seabed bathymetry, topographical features, surface soil conditions (soil type, presence of boulders etc), surface objects and UXO. Ordinarily this will be performed in the years preceding the construction phase. This survey should be repeated in the months prior to cable-laying to ensure no change in the suitability of routes. All surveys shall be performed to the same geographical datum and should be tied into existing known points and levels. A BAS (Burial Assessment Survey) is recommended for export cable routes where the ground conditions will typically vary along the export cable route.

10.5.2 **Jack-up footprints** Areas with existing jack-up footprints should be identified and new footprints should be accurately plotted when jack-ups are deployed.

10.5.3 **Plough routes** should be based on surveys and should avoid wrecks, substantial obstacles, UXO (with a defined exclusion zone), environmental sensitive areas (e.g. Sabellaria worm habitats), and difficult soil conditions. Small objects may be removed, but should be avoided if practicable.

10.5.4 **Route clearance & UXO.** Cable routes should be surveyed for potential UXO prior to choosing cable routes. Suspected UXO should be investigated or avoided. A grapnel run should be performed prior to cable laying, to ensure a clear cable route.

10.5.5 **Exclusion zones** should be adhered to when laying cable to consider future repair operations, and the possibility of using anchored vessels or grapnel assisted cable recovery. Current guidance suggests 250m exclusion from other cables, UXO, wrecks etc. Site specific assessments should be made to determine exclusion distances.

10.5.6 Wherever cables are to be installed close to an existing telecom cable consideration should be given to the additional required clearances for the telecom cable. Telecom cable repair procedures often require more space around the telecom cable in order that the repair vessel can deploy grapnels to locate, snag and recover the telecom cable. ICPC Guidelines, Refs. [14] to [16] should be referred to.

10.5.7 Cable route selection should also take account of the telecom cable owners' right to repair and maintain their cables as granted by UNCLOS (United Nations Law of the Sea).

10.5.8 A detailed bathymetry of the site resulting from a recent underwater survey should be available when assessing minimum clearances within the seabed contour, and survey inaccuracies should be accounted for.

10.5.9 Normally, two independent on-board positioning monitoring systems (PMSs) shall be utilized for operational monitoring and control purposes. Both systems shall be in operation at any time, each serving as the back-up for the other. Each should be fed by an independent power source.

10.5.10 Where underwater accuracy is important, at least one PMS shall be an underwater, hydro-acoustic reference system.

10.5.11 **As-laid surveys.** As-laid information must be compiled to enter the as-built documentation. Post-lay surveys may be required to determine burial levels and accurate locations for post-lay burial measures. If this is not required, due to recorded successful burial levels, monitoring of vessel location may be sufficiently accurate for as-built records. Required accuracy of location will be project specific.

10.6 PROCEDURES

10.6.1 An Installation Manual with Procedures, Story Boards, Task Plans and other supporting documents should be produced to cover the following as appropriate to the specific cable installation operations, incorporating solutions to the various problems identified in Sections 10.2 to 10.4:

a. General

1. Measures taken to ensure the protection of cable's MBR. See Section 10.17
2. UXO Survey. See Section 10.5.4
3. ITP (Inspection Test Plan)

b. Cable Route Development and Cable Engineering

1. Cable Route Survey. See Section 10.5
2. Route Development and Cable Engineering. See Section 10.3.3 for landfall site
3. RPL (Route Planning List). See Section 10.10.8
4. BPI (Burial Protection Index) Study to establish burial depths that will provide protection against the identified risks in the given soil conditions. See Section 10.8.

c. Route Clearance to remove old cables and large debris from the cable routes

d. **Pre Lay Grapnel Run (PLGR)** to remove linear debris immediately before the cable installation operation from the cable routes

e. **Cable Transport**

1. Cable Loading. See Section 7.3
2. Cable Transport. See Section 8.5
3. Cable Trans-spooling. See Section 8.5.7 onwards

f. **Cable Laying**

1. Cable End Sealing. See Section 7.3.1 onwards
2. Offshore Structure Topside Pull-in Preparation
3. CLV and/or CLB Suitability Analysis
4. CLV and/or CLB Vessel Motions Analysis
5. Cable Installation Analysis
6. Slack and Catenary Management. See Section 10.16
7. J / I-Tube Pull-in. See Section 10.11.
8. Cable Protection at J / I-TubeCable trenching and/or burial. See Section 10.8.
9. Cable and/or Pipeline Crossing Protection. See Section 10.23
10. Cable Emergency Abandonment and Recovery. See Section 10.19.
11. Cable Jointing or Repair. See Section 10.24.
12. PLIB (Post Lay Inspection Burial), often with a WROV to rectify any areas with inadequate burial.

g. **Landfall Preparation and Shore End Cable Installation** (see Section 10.22)

1. HDD and Duct Installation
2. Landfall Site Preparation
3. Open Cut Trenching
4. Direct Shore End Installation
5. Pre-installed Shore End Installation
6. Cable Protection Landfall to Main CLV

h. **Marine Logistics**

1. Anchor Handling
2. DP Trials. See Section 13.5 of 0001/ND, Ref. [1].
3. DP Manoeuvring and Close Proximity work
4. Crew Transfer and Access / Egress
5. Pull-in Aids Transfer

i. **Risk & Continency Planning**. See Section 5.4 of 0001/ND, Ref. [1].

1. HIRA, HAZID and HAZOPS
2. Operational Activity and Contingency Planning
3. SIMOPS
4. Risk Management Plan

10.7 PROJECT INSTALLATION MANUALS

10.7.1 **Procedures** shall include close proximity operations, laying cable around curves and laying cable along straight sections of cable routes whilst in DP mode (if applicable). Installation Manuals shall include story boards showing each step required by the installation vessel to complete all cable installations including:

a. Vessel position for each operation, mooring, anchor handling, stability, WTG /Substation setup, lay-away, laying, overboarding, burial, deburial, pull-in, cable protection systems).

b. Step-by-step written instructions for the more complex processes during cable installation (i.e. pull-in /lay away /laydown /recovery /overboarding). These shall be used to explain the methodology engineered for the operation and for the site teams to follow.

c. Limiting weather criteria, control and monitoring measures used to ensure cable integrity, surveys,

d. Calculations, contingency plans, hold/stop points, equipment descriptions and electrical testing programmes as appropriate.

e. Use of divers and ROVs

10.7.2 **Live anchors** may be used to manoeuvre a CLB in close proximity to offshore structures and to maintain the CLB position along the planned cable route. Live anchor operations shall be carefully planned and a Live Anchor Handling Procedure shall be written by the installation contractor and approved by GL Noble Denton. The Anchor Handling Procedure must include Anchor Position Drawings showing the planned positions of anchors for all phases of live anchor operations.

10.7.3 **TD position** when laying in curves must take account of the tendency for tension in cables during lay operations to pull the TD point closer to the installation vessel track line. Curves laid in surface-laid submarine power cables must be planned carefully and must be supported by Installation Analysis and Seabed Stability Analysis.

10.7.4 **Operating weather**. Computational analysis and modelling can be undertaken to assess the ability of a vessel to maintain position and heading during high risk cable handling operation and to evaluate the weather criteria for operability of the moored vessel and suitability of its moorings in a site.

10.7.5 **Risk Assessments** including HAZOPs etc. These should be attended by all appropriate project staff including the Contractor, GL Noble Denton, project H&S staff, and others as required to cover all project interfaces

10.7.6 **ROV operations**. ROVs are often used to monitor subsea activities, perform subsea work (such as attaching/detaching wires, lifting anchors etc.). Such work is often limited by visibility and currents. ROV dependant activities should therefore consider recent weather (rough weather reduces visibility), tidal schedules and predicted tidal current speeds. If visibility is an issue for ROVs, it is recommended to also use sonar surveying instruments to identify objects and cables during operations. ROV test dives should be performed to test conditions prior to activities involving cable handling. A clear and descriptive commentary/narrative should be submitted alongside any surveying video /screenshots to ensure the viewer understands and can interpret what is being presented.

10.7.7 **Messenger lines**. Messenger lines, shackles and other rigging should be fully certified and graded for predicted loads. The site specific tidal and weather conditions should also be considered when specifying such rigging. Pre-installation of messenger wires prior to pull-in should consider as-left conditions and the risk of entanglement /damage.

10.8 CABLE PROTECTION

10.8.1 All cables will require protection to some extent from scour, anchors, trawl equipment, ocean current induced vibration and dropped or sinking objects. This can be achieved through a number of techniques. Burial of cables can be carried by a number of machines or by divers. For post laying protection, accurate geophysical survey data is required to identify the cable location accurately which is intended for protection. In some cases it may be necessary to apply a tone to cables so they can be located in case of partial backfill or natural burial.

10.8.2 **Cable Protection Systems**. Cable protection systems are generally employed at the interface between the seabed and foundation, or where cable burial is not possible. Cable protection systems should be designed to protect the MBR, protect against abrasion, and minimise dynamic movement which could cause fatigue damage. Due account should also be taken of scour predictions. Key considerations for protection systems are installation methodology, friction with seabed during pull-in, the interface with the bell-mouth, and protection of the cable during pull-in /lay-away as well as over the course of the cable life-time.

10.8.3 **Cable Burial**. Cable burial targets are informed by site specific risk assessments of potential damage to the cable (inputs such as types of fishing activity). Achieved burial levels should be recorded for as-built documentation and assessment of conformity. Post-lay measures may be required to achieve target burial depth (such as rock-dumping, mattress laying or jetting). Proof of achieved depth of burial can be important to any project for presentation to the necessary stakeholders. This can be provided by video and sonar surveying equipment attached to the devices carrying out the work or immediately after burial to identify the depth of burial prior to backfill.

10.8.4 **Burial depth –** The intended depth of burial will be specified for the site and based on a number of site specific parameters such as regulatory requirements, other marine users & their activities, geotechnical & seabed conditions onsite and tidal conditions of the site. It is most likely that the seabed and geotechnical conditions for the site will determine which burial methods are most suitable and feasible. The correct burial depth will ensure cables are protected from other marine users and also are not exposed by mobile seabed features such as sand waves.

10.8.5 **Burial –** Typically jetting tools do not bury cables, most jetting tools do not reinstate the seabed over the cable so that the cable is not buried. Jetting tools fluidise the seabed leaving an open trench into which the cable will fall. The cable is subsequently buried by natural re-instatement of the seabed.

10.8.6 **Ploughing** – ploughs are towed or self-powered devices that cut a slot into the seabed. The cable passes through the plough body and exits at the bottom of the slot. The soil is then placed over the cable to provide immediate full depth burial. Towed ploughs require high bollard pull vessels to overcome the seabed cutting forces while self-powered ones will normally require power from the surface via an umbilical.

10.8.7 **Trenching –** is the process whereby a trench is opened and a cable is placed in the trench, back fill is by natural processes over time.

10.8.8 **Post Lay Jetting** – Protection can be provided by lowering cables below the mean seabed level using high pressure jetting tools operated by ROVs or divers. It is important the pressures and forces being applied to any cable are acceptable or within the allowable limits for the cable to withstand. As previously mentioned, cables may be partially buried and to find and track a cable a tone may need to be applied.

10.8.9 **As-laid Jetting –** It is becoming increasingly common to lower cables into the seabed using tracked jetting vehicles operating a few meters behind the cable TD point.

10.8.10 **Mechanical Trenching** equipment, using rock wheels or chain cutters, can be used to open trenches in hard ground conditions. Mechanical trenching tools normally open cut a trench and the cable is post trench laid into the trench when the trenching machine has completed its work. Post lay mechanical trenching machines provide protection to the cable from the mechanical cutting device.

10.8.11 **Rock Dumping –** If the required burial depth is not achieved during installation, subsequent rock dumping can provide the necessary protection he characteristics of the material being placed and the design of the rock berm will be specific to the site and the protection required. Rock is placed by rock dumping specific vessels which have sophisticated survey equipment to ensure rock is placed directly on the intended area.

10.8.12 **Mattresses and/or rock dumping** can be used to provide protection to cables especially in areas where cables are most exposed, i.e. close to bell-mouth and WTG/substation foundations. Mattresses are placed by cranes using necessary lift beams to ensure placement directly over the intended area.

10.8.13 **Articulated Pipe (also known as 'split pipe')** is a type of cable protection that protects against high impact forces and chafing where cables pass over exposed bedrock. The pipe is fitting around a cable in two halves and clamped together with two bolts at each end. The pipe ends form a ball and socket joint between pipe sections allowing the pipes to form a bend wherever required. Due to the weight of the pipe sections (spheroidal cast iron) and the necessity to use divers to fit to cables, articulated pipes are normally only used over rocks or in high currents at shore ends and over shallower water rocks.

10.8.14 **Survey** – Following cable protection operations, confirmation of the operations success is required. Survey of cable route, burial depth, depth below seabed, sonar images of protection can all provide the necessary confirmation of what is achieved.

10.9 PLOUGH OPERATIONS

10.9.1 If ploughing is used to bury the cable during laying then ploughing trials are recommended to ensure that the selected plough types and sizes are suitable and to show that the support vessel can provide sufficient bollard pull or power supply to penetrate the seabed to the required burial depth across the site.

10.9.2 Towed ploughs have limited steering which must be considered when developing cable routes with curves and alter course points.

10.9.3 Ploughs should carry HPR acoustic beacons to monitor plough seabed position and to plot the cable as-laid cable co-ordinates.

10.9.4 Ploughs can be towed or supported by DP vessels operating either in 'auto-track' or manual mode or by moored barges using a pull-ahead winch with sufficient pull. Consideration must be given to the impact of a DP runaway happening during plough operations.

10.9.5 Towed ploughs require high bollard pulls which can require more power from the DP vessel main propulsion than during normal DP operations. Consideration must be given to the impact this might have on the ability of the DP vessel to support plough operations with wind, wave and current on the vessel beam.

10.9.6 Plough burial depths of 3m are often required. In some seabed types bollard pulls or traction forces in excess of 150 tonnes will be required.

10.10 VESSEL MOVEMENT AND CABLE PAY-OUT

10.10.1 The installation vessels suitability and limiting criteria should be checked at an early stage in the project lifecycle.

10.10.2 **Tension Monitoring** – During laydown, cable recovery, pull-in and pay-out operations the loads exerted on cables must be constantly monitored to ensure forces exerted on the cable do not exceed forces and loads specified by the manufacturer. The tensile limit specified by the manufacturer should not be exceeded during installation. Load cells shall be used to monitor and record tension levels throughout installation. This monitoring can be carried by instruments such as tension meters or load cells.

10.10.3 **Compression Forces Exerted by Cable Handling Machinery**. The maximum compression force the cable handling machinery can exert must be set and calibrated at a load point that ensures the maximum allowable compression force cannot be exceeded. GL Noble Denton must:

a. be provided with a written statement from the cable manufacturer confirming the maximum allowable compression force,

b. witness calibration of the cable handling machinery compression force setting, measurement and display functions and

c. witness setting of the maximum compression force.

10.10.4 CLV /CLB movements when laying cable must comply with pre-defined plans recorded in the Installation Manual and the Installation Procedures.

10.10.5 When planning cable-lay operations for curves and alter courses, consideration must be given to the vessel track required to lay the required curve and/or alter course.

10.10.6 TD position by WROV monitoring is recommended when surface-laying submarine power cables around curves and/or altering course.

10.10.7 TD monitoring is also recommended in locations where a cable must be laid within a defined corridor or when cable length tolerances are tight.

10.10.8 **A Route Planning List** (RPL) shall be provided. The RPL shall include the cable route co-ordinates, planned burial or trenching depths and slack cable required along the cable route.

10.10.9 Well planned and managed cable installation operations deploy continuous Slack Management and Catenary Management techniques to provide real time monitoring and input to vessel position and speed decisions and to maintain the correct cable pay out speed and tension. These topics are addressed in greater detail in Section 10.16 (Catenary Management).

10.10.10 A CLV / CLB should never be allowed to drop back onto the cable catenary unless the operation is planned and the LCE can recover cable from the seabed at least at the same speed as the CLV / CLB drops back onto the cable. This type of movement, when unplanned and therefore uncontrolled, will reduce TD tension and will increase the risk of loops being thrown in the cable.

10.10.11 If the CLV / CLB does drop back over the cable and the movement is unplanned then the cable must be inspected at the seabed to ensure no loops have been thrown before the CLV / CLB moves off to re-establish the catenary and commence laying cable. If there is doubt over the condition of the cable then the cable should be tested before laying operations are re-commenced.

10.10.12 If an uncontrolled drop back occurs when plough burying cable the cable must be inspected for loops before re-commencing plough operations. If a loop enters a plough the loop will be closed by the plough body to such an extent that the conductors, sheaving and fibre optics will fail and the plough might be damaged.

10.10.13 **Contingency plans** must address action required in event of a DP malfunction and must include the actions required by the cable installation equipment operators.

10.11 PULL-IN AND TRANSFER TO STRUCTURES

10.11.1 **Planning.** CLV / CLBs typically approach close enough to offshore structures to transfer pull-in aids using the CLV / CLB crane. The Installation Manual and the Installation Procedure must show careful planning of close proximity operations and must include contingency plans to be implemented in the event that the CLV / CLB vessel moves out of control toward or away from a structure.

10.11.2 **J-tube/I-tube pull-in winch locations.** There are two types of J-tube /I-tube pull-in methods:

1. Pull-in winches mounted on the WTG or the offshore substation
2. Pull-in winches mounted on the CLV / CLB with a sheave arrangement mounted on the WTG or the offshore substation (pull back method).

In both cases the pull-in winch must have a render setting so that excess tension in the pull-in rigging caused by CLV movements does not over tension the pull-in rigging. Design calculations must be provided for GL Noble Denton review for all components in the pull-in rigging system. Wherever pull-in aids attach to an offshore structure, the suitability of the structure to support the pull-in aids shall be confirmed by the structure designer.

10.11.3 **Second end pull-in operations**. There are two methods commonly adopted to implement second end J-tube /I-tube pull-in operations:

1. A bight of cable is lowered toward the seabed using a quadrant. When the quadrant is close to the seabed as defined in the Installation Procedures, the quadrant is tipped and the bight of cable placed on the seabed. This method requires careful co-ordination between control stations to prevent a loop being thrown in the cable. The J-tube bell mouth lead angles must be capable of accepting the vertical off-lead angle required without jeopardising the cable MBR.
2. The cable end is laid on the seabed in an ‘omega’ loop in close proximity to the J-tube and pulled into the J-tube. This requires a seabed survey covering the whole of the lay down area to ensure there are no snagging points against which the cable could snag. The pull-in tensions using this method are influenced by seabed friction and soil build up where the omega loop is dragged across the seabed during pull-in and must be accounted for in the Installation Analysis. The J-tube bell mouth off-lead angles must be capable of accepting the anticipated horizontal lead angle without jeopardizing the cable MBR.

10.11.4 **Messenger wires** are normally pre-installed into J-tubes /I-tubes before foundations go offshore and a system that allows rapid messenger replacement offshore should be considered. Messenger wires and fittings will normally be a marine grade stainless steel.

10.11.5 Messenger wires occasionally fail due to corrosion and/or chafing over edges. The messenger wire design should take account of these failure modes and ensure the risk of messenger wire failure is minimised.

10.11.6 It is advisable that J-tubes /I-tubes are marked top and bottom to ensure the right messenger wire is connected to the pull-in winch wire.

10.12 CABLE LAYING MOORING

10.12.1 **Mooring Analysis**. Limiting environmental conditions as stated by the vessel owner must be verified by a mooring analysis to confirm the ability of the mooring system to hold and manoeuvre the CLB at the stated limiting conditions.

10.12.2 A Mooring Analysis must be done by competent persons and reviewed by GL Noble Denton and used as an input to the setting of the barge limiting conditions. Criteria for moorings are in 0032/ND, Ref. [11]. The Mooring Analysis shall include mooring line failure conditions and shall present the expected barge excursion in case of each mooring line failure mode.

10.12.3 Mooring system and pull-ahead anchors shall be selected to provide the required holding capability at the limiting operating conditions in the ground conditions expected at any part of a cable route.

10.12.4 Limiting conditions should be established by analysis for single mooring line failure cases for each mooring line. The number, type and power of the AHT(s) should be used when considering the limiting conditions GL Noble Denton might require for the CLB mooring operations. Excursion distances and excursions speed of the CLB for the single mooring line failure modes must be included in the Mooring Analysis.

10.12.5 Contingency Plans shall mitigate potential impact on the cable in the case of a mooring line failure. GL Noble Denton shall assess the risks to the cable in event of a mooring line failure and set the operating limitations.

10.12.6 **Close proximity operations.** CLBs must set anchors with the CLB as far from other assets as the mooring system will safely allow.

10.12.7 CLBs must test each anchor on deployment at an agreed mooring line tension for an agreed period of time before moving in for close proximity operations. GL Noble Denton shall agree the required test tension and duration and this shall be recorded in the CoA if required and will be a pre-condition to start close proximity operations.

10.12.8 **A mooring control system** and equipment FMEA must be done by competent persons and reviewed and approved by GL Noble Denton.

10.12.9 Mooring system spare parts holding must be reviewed and spares sighted. The spares holdings must take account of the FMEA findings.

10.12.10 Mooring winches shall be controlled from a mooring control station. The mooring control station shall be equipped with an open communications system to all relevant control points and shall have monitors with feeds from the survey suite and the AMS (Anchor Management System).

10.12.11 Mooring winches shall have line out recorders and tension monitors with read outs at the mooring control station. Mooring winches shall be monitored by CCTV with screens installed at the mooring control station.

10.12.12 Mooring and anchor handling operations shall be monitored and controlled with an AMS continuously logging anchor positions. The CLB control station and the AHT navigation bridge shall be equipped with screens showing anchor positions. The AMS shall be capable of showing when an anchor has slipped from its deployed position.

10.12.13 The CLB survey display and the AMS shall be integrated to provide real time position displays of the CLB barge, the anchor locations and installed cables including third party cables.

10.13 PULL-AHEAD ANCHOR & WINCH

10.13.1 Pull-ahead winches and anchors provide the force to move a CLB along the cable route. Pull-ahead winch and anchor capacity must be sufficient to move the CLB ahead within the limiting environmental conditions. When supporting plough operations the pull-ahead winch and anchor system must have the capacity to overcome the plough resistance and the tension required to overcome the limiting environmental conditions.

10.13.2 Pull-ahead winch, rope and anchor must have valid certification. Winches must be well maintained with especial attention paid to the condition of the fairlead, winch wire and its end connections and fittings.

10.13.3 The pull-ahead winch wire must be of adequate length and strength for the planned anchor placements. There must always be sufficient turns of mooring wire on the winch barrel when the pull-ahead anchor is run out to its maximum planned extent.

10.14 CAROUSELS AND FIXED CABLE TANKS

10.14.1.1 Submarine power cables are stowed in rotating carousels or fixed cable tanks. Both types will have centre cones to protect the cable MBR.

10.14.2 Carousels (either vertical or horizontal) rotate to load and discharge cable. The carousel grillages and sea fastening must be approved by GL Noble Denton.

10.14.3 Fixed cable tanks do not rotate to load and discharge cable. Fixed cable tanks have rotating cable arms to position the cable over the touch down point in the cable tank.

10.14.4 In vertical carousels the cable is wrapped around the centre cone of the rotating carousel and the loading arm moves vertically up and down the height of the centre cone to position the cable. They are loaded and unloaded with the cable under tension. The cable coils can slip down if there is insufficient tension in the cable.

10.14.5 In horizontal carousels the cable is placed on the floor of the rotating carousel and the loading arm moves horizontally across the width of the carousel.

10.14.6 Cable tank floors must be smooth with no ‘steps’ that could damage cable when the cable tank is fully loaded. It is common to line cable tank floors with ply wood sheets to protect the cable against irregularities in the cable tank floor.

10.14.7 Drums are sometimes used to transport and install shorter length cables. Special handling equipment is required to lay cable from a drum. Drum-loaded cables are usually delivered cut to the length required for a single cable segment. It is common to pre install a combined pull-in head and end seal arrangement before the loaded drum is delivered.

10.14.8 Drum-loaded cable lengths must be carefully calculated during the route development stage and precisely measured to ensure sufficient cable is loaded onto each drum.

10.15 LIFTING CABLES

10.15.1 See 0027/ND, Ref. [7], for all lifting equipment and operations.

10.16 CATENARY MANAGEMENT

10.16.1 The catenary is the cable suspension formed between the lay chute and TD at the seabed. Effective Catenary Planning and Management reduce the risk of cable damage during installation.

10.16.2 Poorly planned and implemented Catenary Management can lead to:

a. Excessive cable tension:
   - During pull-in operations can:
     - threaten the cable MBR at J-tube/I-tube entrances.
     - cause cable damage near the pull-in head or pull-in stocking.
   - Can prevent cable from dropping into the trench.
   - Can cause excessively long suspensions to form between the J-tube/I-tube entry points and the seabed.
   - Can pull cable off route when laying in curves.
   - Can prevent cable from being pulled to the surface for a repair operation.
   - During ploughing, can result in excessive tension through the plough body and in the ground after the plough has buried the cable.

- Can leave the cable in suspension over undulating seabed.

b. Excessive cable slack
- During J-tube/I-tube pull-in operations can:
  - Cause loops to be thrown in the cable especially at the second end when a quadrant is deployed to lower the cable to the seabed.
  - Cause cables to be laid in no cable zones.
  - Make trenching operations difficult or impossible if the excessive slack cable results in curves that cannot be followed by a burial vehicle.
- Can result in excessive cable ahead of the plough, resulting in the plough running over the cable.

10.16.3 The installation contractor shall provide a Catenary Management Plan for acceptance. The Catenary Management Plan must be supported by an Installation Analysis. The Catenary Management Plan must include the lay back distances and top tensions required to maintain a safe seabed tension at all water depths when laying cable in straight lines and in curves.

10.16.4 When laying cables from a DP vessel care should be given to catenary management in conditions where the DP reference system becomes unreliable and/or a DP dropout might occur. A momentary drop out of the DP reference signal can result in the CLV dropping astern enough for a loop to form in the cable.

10.17 CABLE RADIUS CONTROL SYSTEM

10.17.1 Submarine power cables have a range of allowable MBRs for different cable handling situations. For example the following would typically have different MBR for the same cable:

a. coiling into a carousel or a fixed cable tank

b. loading cable under tension onto a drum or a vertical carousel

c. whilst laying cable.

10.17.2 The cable MBR must be protected at all times during all cable handling operations. Protection of the MBR must be provided by the design of the cable storage areas, cable coiling arms, cable highways, cable handling quadrants, J-tube curves, cable tensioners, over boarding chutes/sheaves, Catenary Management Procedures, cable trenching and cable burial tools and WTG and offshore substation cable pathways.

10.17.3 If cable passes over rollers whilst under tension then the distance between the rollers must be approved by the cable manufacture to ensure that micro bending will not occur over rollers that are too far apart.

10.18 LAY CHUTE AND LAY SHEAVE

10.18.1 Cable passes overboard via a Lay Chute or a Lay Sheave. A Lay Chute is a fixed plate shaped to protect the cable MBR. A Lay Sheave is a sheave of at least the same radius as the cable MBR.

10.18.2 Lay Chutes and Lay Sheaves must have ‘whiskers’ to protect the cable MBR in cases where the cable ‘lead’ angle is not in line with the Lay Chute or Lay Sheave plan view centre line. Whiskers must accommodate the maximum lead angle expected during cable installation operations for example when a CLV might need to weather vane or ‘crab’ along a cable route to overcome the influence of wind, waves and current.

10.18.3 Whisker lead angles must take account of the impact of cross currents on the cable lead angle.

10.18.4 If the CLV stands by with cable deployed over the Lay Chute or the Lay Sheave then the cable must be picked up or paid out a few metres at set periods of time to prevent cable damage where the cable is stationary on the Lay Chute or Lay Sheave – ‘freshening the nip’.

10.19 TEMPORARY ABANDON PROCEDURE

10.19.1 There shall be a temporary abandonment procedure (giving weather and/or motion criteria for initiation). The abandonment procedure shall include a procedure to restart the installation operations. The abandonment procedure must include and forecast periods and conditions for initiating the abandonment procedure. For moored barges the forecast period might need to include the time to transit to sheltered waters.

10.20 ARRAY CABLES

10.20.1 **MBR** Inter-array cable MBR are ordinarily in the range of 1 – 1.5 m. Measures should be taken to monitor and protect the MBR throughout installation activities. Measurement of the MBR is not ordinarily practicable, and can only be ensured to any level of accuracy with cable handling tools (such as a quadrant, shoe-in tool, bend restricting cable protection). Where MBR is most at risk, bend restriction methods such as quadrants should be used. If this is not possible, careful monitoring of the cable bend geometry should be ensured.

10.20.2 Instances in which the MBR are most at risk include (but are not limited to) entry /exit to I /J-tubes, lay-away, over-boarding and touchdown, use of a quadrant, support of over-length on TP during pull-in, handling on deck.

10.20.3 **Cable protection and bend restrictor fitting to Array Cables**. Cable protection and bend restrictors must be fitted at the correct location on the cable and following the manufacturer's installation instructions to ensure the interface with the J-tube /I-tube engages properly. Careful measurements and calculations are required to establish the position at which bend restrictors and cable protection are to be attached to an Array Cable. The calculations must be verified by an approved and proven QA/QC check process on-board the installation vessel.

10.20.4 The attached position of the bend restrictor and cable protection onto the cable must be confirmed and recorded before the Array Cable pull-in operation commences. GL Noble Denton shall witness an agreed number of calculations, bend restrictor and cable protection fittings and deployments of first-end pull-in operations.

10.20.5 **Ploughed or free laid.** Cable ploughing is usually performed where possible – simultaneous lay and burial being an efficient method. Cable plough equipment should be specified for the target burial, taking consideration of soil conditions, topography and variability across the site.

10.20.6 **1st end Installation** is performed using a messenger wire installed inside the J-tube/I-tube and connected to the cable end. Pull-in operations shall ensure protection of MBR and tension limits. Particular care should be taken at touchdown to avoid jeopardizing the cable MBR, and at the bell-mouth to avoid snagging. Careful consideration should also be given to the engagement of cable protection systems with the bell-mouth, and how this allows movement and protection of the cable.

10.20.7 **2nd end laydown.** A bight (curved length of slack cable) may be laid on the seabed or a second end deployment quadrant might be used in order to facilitate pull-in using a messenger wire. The length at which the cable is cut shall allow for the design position of the cable, the final catenary from seabed into foundation based on water depth, the required over-pull for cable termination, potential scour pit development. Calculations shall be submitted by the contractor to show due consideration of these factors. A pre-defined number of calculations shall be witnessed offshore by GL Noble Denton. The cable must be lowered to the seabed in a controlled method, normally by taking up the tension in the messenger wire from the TP.

10.21 EXPORT CABLES

10.21.1 **MBR** – For all operations which involve the handling of export cables such as offloading, trans-spooling, laydown, overboarding and abandonment, measures shall be undertaken to ensure the protection of the cable MBR. Such measures can include the use of quadrants, cable highways onboard the vessel, tension meters and bend restrictors. The use of such equipment should be outlined in the procedural documentation for each operation including:

a. Ploughed or free laid

b. 2nd end laydown at substation

c. Back tension

d. Grounding lay barges

e. Floating installation

f. Positioning

g. Tides

h. Surveys of grounded areas.

10.22 EXPORT CABLE LANDFALL

10.22.1 **Cable landfall - direct**. If a CLV / CLB can approach close to the landfall position, cable can be floated ashore using a pulling wire from the landfall with floats attached to the cable. Detailed marine planning is required to ensure the main CLV / CLB can set up close enough to the landfall position for the duration of the landfall operation. Care must be taken in cross currents which can cause excessive tension in the cable leading to loss of control of the pull-in operation.

10.22.2 It is common to float the CLV in on a rising tide until the CLV is close enough to the landfall for a direct pull-in operation. The CLV is allowed to bottom out during low water phases of the tidal cycle. Careful planning is required to ensure the seabed is flat with no obstructions that might in anyway cause damage to the CLV hull. Adequate pre-set mooring must be provided. Often anchors must be placed on land due to the close proximity to land of the CLV set up position.

10.22.3 The work must be carefully planned and timed to ensure the vessel does not become trapped by falling tides. A pull-ahead anchor should be deployed offshore of the CLV and a stand-by AHT (Anchor Handling Tug) should be on site to assist the CLV if it needs to pull off the set-up position in an emergency. It would be normal for an operation where the CLV needs to bottom out for the CLV to approach the landfall site with minimum cable on-board. That means to lay cable from the offshore structure toward the landfall. Consideration should be given to seabed suction forces when re-floating the CLV.

10.22.4 **Cable landfall – pre-installed.** A small low draft vessel can be used to pre-install a separate shore end cable when the main CLV / CLB cannot approach close enough for a direct landfall operation. There are two methods for implementing a pre-installed shore end installation:

1. A shore end cable is laid by a CLV(SE) between the landfall and a position where the main CLV / CLB can set up for jointing operations or,
2. The cable is ‘turned-over’ from the main CLV / CLB onto a CLV(SE). The CLV(SE) lays the cable toward the landfall location. This method presents complications at the landfall end as the cable will need to be turned-over a second time to bring the landfall cable end to the top of the cable tank.

10.22.5 **Selecting landfall sites.** Good landfall sites are rare. They allow the CLV / CLB to approach to within a few hundred metres of land and float the cable ashore or, in some locations, pull the cable ashore without floats into an open cut trench or through a short HDD duct.

10.22.6 Wind farm export cables are more often installed at sites requiring challenging and complex civil engineering solutions than would be required at ideal landfall sites.

10.22.7 Sea defences and environmentally sensitive foreshore areas must often be crossed using HDD ducts. The physical nature of some landfall sites requires HDD lengths at the extreme end of what is currently possible.

10.23 CABLE AND PIPE-LINE CROSSINGS

10.23.1 Detailed planning is required to ensure a safe crossing for both the crossing and the crossed submarine plant (pipeline or cable). The crossing point construction must ensure the crossed submarine plant is safe from physical or other interference that could be caused by the crossing export cable(s). This could include prevention of physical contact, prevention of galvanic action and electrical interference with the crossed submarine plant.

10.23.2 The crossing design must allow for future maintenance of the crossed submarine plant and the export cable. The crossing angle should be as near to 90 degrees as is possible. Typically owners of the crossed submarine plant will require that plough operations cease 500m before and restart 500m after the crossing point location. Jetting is normally allowed within the agreed no-plough zone.

10.23.3 Crossings are often constructed using concrete mattresses and/or rock dumping to provide separation between the submarine plant and to provide stability and protection to the crossing export cable(s). The export cable can also be encased in a cable protection product although this is a decision for the cable owner. Construction methods, crossing angles and operational zone dimensions will need to be agreed between the respective submarine plant owners and recorded in a formal Crossing Agreement.

10.23.4 When export cables are to be installed close to other submarine plant then due consideration should be given to maintenance requirements of each of the respective items of submarine plant. For submarine cables it is typical to allow at least three times the water depth clearance to ensure that a repair operation can be done. Clearance from pipelines will need to be agreed with the pipeline owner.

10.24 CABLE JOINTING AND REPAIR

10.24.1 Array and export cable post-installation faults are rare and most faults to date have occurred as a result of incidents during installation. Wind farm cable repairs will either be by complete replacement of a cable or repair by cutting out the damaged /faulty cable and inserting a new section of cable. Replacement is most likely to be used for array cables whereas inserting a new segment will most likely apply to export cables.

10.24.2 Repair Vessels must provide a stable working platform, have fine control when manoeuvring and be capable of holding station over the repair location for the time required to insert a joint into a cable.

10.24.3 Repair vessels must be configured for two ends of a cable to be handled both in the water and on the vessel.

10.24.4 An enclosed jointing space is required with sufficient length and space for the ends of a cable to be bought together so a joint can be inserted into the cable.

10.24.5 Repair joints must be qualified and type tested in accordance with CIGRE, Ref. [13].

10.24.6 Jointing personnel must be qualified jointers and jointers qualifications must be submitted for GL Noble Denton approval.

10.24.7 It is recommended that repair joint kits are opened in a clean environment onshore and all parts are checked against the repair joint contents list and a dummy assembly of the joint should be done to prove the procedures are correct. The shelf life of compounds and/or resins should be checked and shown to be valid.

10.24.8 Submarine power cable repair operations involve a number of complex manoeuvres that must be carefully planned and procedures written. The selected repair vessel must be capable of supporting all phases of a cable repair operation.

10.24.9 A typical cable repair will include

a. locating the cable at the fault location,
b. recovering the cable to the surface, cutting the cable and attaching a buoy to one end,
c. deploying the buoyed off end to the seabed, recovering cable until into good cable,
d. jointing sea cable onto spare cable on the repair vessel,
e. laying cable to buoyed off cable end, recovering buoy and buoyed off cable end,
f. jointing the spare cable to the sea cable and deploying the Final Splice to the seabed.

10.24.10 If cable tension prevents the cable from being lifted to the surface the cable will need to be cut on the seabed. If the cable is not a water-blocked design then there is a risk of flooding the cable. Submarine power cables are either wet, dry or semi-dry designs and each has different levels of tolerance to water ingress. The cable manufacturer should be consulted if the repair strategy involves cutting the cable on the seabed.

10.24.11 The cable end should be secured to the seabed to prevent movement due to ocean currents. Typically this is achieved by attaching chain, steel reinforced ground rope and a clump weight to the cable end. If a buoy is used to aid location and recovery of the ground tackle the buoy should have sufficient buoyancy to remain at the surface in all anticipated current conditions. The rope, wire or chain attaching buoys to the clump weight should have sufficient strength to ensure it does not fail.

10.24.12 The cable end(s) will need to be stoppered to secure points on the repair vessel. The stopper type must be approved by the cable supplier. The stopper deck attachment point must be in line with the cable line to prevent the stopper from exerting non-conforming forces on the cable.

10.24.13 The first joint will be deployed over the lay chute or sheave in line with the spare cable to be laid out to the Final Splice location. The repair joint load mechanical properties should be confirmed as adequate for the repair chute/sheave diameter and cable tension during deployment. Extreme tensions can be generated in the cable where it enters the joint housing as the joint 'tips' over the repair chute / sheave. Consideration should be given to using a spreader beam and crane to deploy the joint over the repair chute / sheave.

10.24.14 An Installation Analysis is required for the time the repair joint is in the water column until the joint is on the seabed. If there is insufficient cable tension as the joint approaches the seabed the cable MBR will be jeopardised.

10.24.15 At the Final Splice location the end of the good cable must be recovered to the repair vessel until there is sufficient overlap with the spare cable laid from the first repair joint location for the cable ends to be taken into the jointing facility and the joint to be made.

10.24.16 The cable catenaries formed during the Final Splice jointing operation must have sufficient tension to ensure the cable MBR is not jeopardise at the seabed TD point but not so much tension that the repair vessel imparts load in the cables.

10.24.17 Final Splice operations insert an additional cable length of approximately 3 times the water depth into a cable system.

10.24.18 Final Splice deployment is a cable- hazardous operation during which a combination of cable slack and residual torsion in the cable can cause loops, 'catpaws' and standing sections of cable.

10.24.19 During Final Splice deployment the joint and cable must be supported using a spreader beam. The repair vessel must be manoeuvred away from the cable line as the Final Splice is lowered to the seabed. The joint lowering speed and the repair vessel speed must be co-ordinated to ensure the Final Splice is laid down on the seabed without jeopardizing the cable MBR, without throwing loops or leaving sections of the cable standing proud of the seabed.

10.24.20 Deployment rigging must be removed from the cable to ensure the rigging does not become entangled with cable jetting equipment.

10.24.21 The repair vessel must have sufficient manoeuvring and position keeping capability to undertake the manoeuvres required to support the operations described herein.

10.24.22 The whole of the repair section should be trench into the seabed. The Final Splice layout should be surveyed using an inspection ROV and any loops, standing loops and/or cats-paws should be recorded and if necessary an alternative protection to jetting should be developed.

10.24.23 The repaired cable should be tested and the cable repair vessel should remain on site until the tests are complete and the cable repair is shown to be acceptable.

10.24.24 The damaged and/or faulty cable should be kept and taken ashore for investigation into the cause of the failure. If the cause is an inherent defect then the costs to repair might be recoverable as a warranty claim against the cable manufacturer.

REFERENCES

[1] GL Noble Denton 0001/ND – General Guidelines for Marine Projects

[2] GL Noble Denton 0009/ND – Guidelines for Elevated Operations for Jack-Ups

[3] GL Noble Denton 0013/ND – Guidelines for Load-Outs

[4] GL Noble Denton 0015/ND – Guidelines for Concrete Gravity Structure Construction & Installation

[5] GL Noble Denton 0016/ND – Seabed and Sub-seabed Data Required for Approvals of Mobile Offshore Units (MOU)

[6] GL Noble Denton 0021/ND – Guidelines for the Approval of Towing Vessels

[7] GL Noble Denton 0027/ND – Guidelines for Marine Lifting & Lowering Operations

[8] GL Noble Denton 0028/ND – Guidelines for Steel Jacket Transportation & Installation

[9] GL Noble Denton 0030/ND – Guidelines for Marine Transportations

[10] GL Noble Denton 0031/ND – Guidelines for Float-Over Installations /Removals

[11] GL Noble Denton 0032/ND – Guidelines for Moorings

[12] BWEA Guidelines for the Selection and Operation of Jack-ups in the Marine Renewable Energy Industry, June 2009 (Note that “BWEA” is now “RenewableUK” and updates will be in this new name)

[13] CIGRE, Recommendations for Mechanical Tests on Submarine Cables published in Electra No 171 April 1997

[14] ICPC (International Cable Protection Committee) Recommendation No 2 - Recommended Route and Reporting Criteria for Cables in Proximity to Others

[15] ICPC Recommendation No 3 - Criteria to be Applied to Proposed Crossings Between Submarine Telecommunications Cables and Pipelines/Power Cables

[16] ICPC Recommendation No 13 - Proximity of Wind Farm Developments & Submarine Cables

[17] IMCA M 179 – Guidance on the Use of Cable Laid Slings and Grommets - August 2005.

[18] IMCA M 203 – Guidance on Simultaneous Operations (SIMOPS)

[19] ISO 7531:1987 - Wire Rope slings for General Purposes - Characteristics and Specifications.

[20] ISO 19905-1 - Petroleum and natural gas industries -- Site-specific assessment of mobile offshore units -- Part 1: Jack-ups

[21] (UK) Department of Energy and Climate Change - Dynamics of scour pits and scour protection – Synthesis report and recommendations Final Report 2008 http://mhk.pnnl.gov/wiki/images/9/91/Dynamics_of_Scour_Pits_and_Scour_Protection.pdf

All GL Noble Denton Guidelines can be downloaded from http://www.gl-nobledenton.com/en/rules_guidelines.php.

APPENDIX A - INITIAL INFORMATION REQUIRED FOR APPROVAL

A.1 GENERAL INFORMATION REQUIRED

A.1.1 Where approval is required, the following shall be submitted to GL Noble Denton for information and/or review, consisting of:

a. The project management structure, including contractors and subcontractors as in Section 6 of 0001/ND, Ref. [1].

b. Proposed project drawing and document register including risk assessments and marine manuals /procedures

c. Proposed timetable of events.

A.2 STRENGTH, MOTION RESPONSE & STABILITY (ALL PHASES)

A.2.1 Information to cover the topics in Sections 7 to 9.

A.2.2 Information on weight control of weight-sensitive items as in Section 8 of 0001/ND, Ref. [1].

A.3 CONSTRUCTION IN DRY-DOCK OR BASIN (IF APPLICABLE)

A.3.1 Information to cover the topics in Section 10 of 0001/ND, Ref. [1].

A.4 MOORINGS FOR CONSTRUCTION AFLOAT (IF APPLICABLE)

A.4.1 See Appendix A of 0032/ND, Ref. [11]

A.5 FLOAT-OUT & TOW TO INSHORE CONSTRUCTION SITE (IF APPLICABLE)

A.5.1 Information to cover the topics in Section 11 of 0001/ND, Ref. [1].

A.6 CONSTRUCTION / OUTFITTING AFLOAT (IF APPLICABLE)

A.6.1 Information to cover the topics in Section 9 of 0015/ND, Ref. [4].

A.7 HEAVY LIFTS (IF APPLICABLE)

A.7.1 See Appendix A of 0027/ND, Ref. [7]

A.8 TEMPORARY BALLASTING AND COMPRESSED AIR SYSTEMS (IF APPLICABLE)

A.8.1 Information to cover the topics in Section 12 of 0001/ND, Ref. [1].

A.9 DECK MATING (IF APPLICABLE)

A.9.1 See Appendix A of 0031/ND, Ref. [10].

A.10 TOW /TRANSPORTATION TO INSTALLATION SITE

A.10.1 See Appendix A of 0030/ND, Ref. [9].

A.11 INSTALLATION

A.11.1 Information to cover the topics in Section 9.

A.12 CABLE INSTALLATION

A.12.1 Information to cover the topics in Section10.