FLOATING OFFSHORE WIND CENTRE OF EXCELLENCE

Delivered by CATAPULT Offshore Renewable Energy

FLOATING OFFSHORE WIND – APPLICATION OF STANDARDS, REGULATIONS, PROJECT CERTIFICATION & CLASSIFICATION – RISKS AND OPPORTUNITIES

MAPPING REPORT – DELIVERABLE D1

In partnership with

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NOMENCLATURE

ABS	American Bureau of Shipping
ACI	American Concrete Institute
ACoPS	Approved Codes of Practice
AIP	Approval in Principle
ALARP	As Low As Reasonably Practicable
ALS	Accidental Limit State
API	American Petroleum Institute
AUV	Autonomous Underwater Vehicle
BEM	Boundary Element Method
BSH	Bundesamt für Seeschifffahrt und Hydrographie (German Federal Maritime and Hydrographic Agency)
BSI	British Standards Institution
BV	Bureau Veritas
BWM	Ballast Water Management
BWE	Ballast Water Exchange
CDM	Construction Design & Management
CEN	European Committee for Standardization
CoE	Centre of Excellence
COG	Centre of Gravity
CP	Corrosion Protection
CPR	Construction Products Regulation
CTV	Crew Transfer Vessel
DAF	Dynamic Amplification Factor
DEA	Drag Embedment Anchor
DFF	Design Fatigue Factor
DLC	Design Load Case
DNV	Det Norske Veritas
DOF	Degree of Freedom
DP	Dynamic Positioning
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EOG	Extreme Operating Gust
ETA	European Technical Assessment
EU	European Union
FEED	Front End Engineering Design

FLS	Fatigue Limit State
FOW	Floating Offshore Wind
FOWT	Floating Offshore Wind Turbine
FPSO	Floating Production Storage and Offloading Unit
HELCOM	Convention on the Protection of the Marine Environment of the Baltic Sea Area
HMPE	High-modulus polyethylene
HSE	Health, Safety and Environment
HSEx	Health and Safety Executive
HV	High Voltage
HVAC	High-Voltage Alternating Current
HVDC	High-Voltage Direct Current
IALA	International Association of Lighthouse Authorities
ID	Identification
IEC	International Electrotechnical Commission
ILA	Integrated Loads Analysis
IMCA	International Marine Contractors Association
IMO	International Maritime Organization
ISO	International Organization for Standardization
JIP	Joint Industry Project
LCoE	Levelized Cost of Energy
LOLER	Lifting Operations and Lifting Equipment Regulations
LR	Lloyd's Register
LRFD	Load and Resistance Factor Design
MAIB	Marine Accident Investigation Branch
MCA	Maritime and Coastguard Agency
MHWS	Mean High Water Spring
MIC	Microbiologically Influenced Corrosion (corrosion by bacteria present in some soil)
NavAids	Navigational aids (e.g. lighting)
NCR	Non-conformity report
O&G	Oil and Gas
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturer
OSDR	Offshore Safety Directive Regulator
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
OSS	Offshore Substation
OWF	Offshore Wind Farm

PLF	Partial Load Factor
PSF	Partial Safety Factor
RCS	Recognised Classification Society
R&D	Research and Development
RNA	Rotor Nacelle Assembly
ROV	Remotely Operated Vehicle
RP	Recommended Practice
SHM	Structural Health Monitoring
SLS	Serviceability Limit State
SOV	Service Operation Vessel
T&I	Transport and Installation
TLP	Tension Leg Platform
TRL	Technology Readiness Level
UK	United Kingdom
UKCA	UK Conformity Assessed
ULS	Ultimate Limit State
US	United Stated of America
VAWT	Vertical Axis Wind Turbine
VIV	Vortex Induced Vibration
WSD	Working Stress Design
WTG	Wind Turbine Generator

1 INDUSTRY ENGAGEMENT

A crucial element of this work has been industry engagement. Members of the Floating Offshore Wind Centre of Excellence have provided critical input and review. This report has also received detailed input from classification societies, substructure designers, project developers and insurance companies to support the identification and review of existing relevant technical standards, specifications, practice, law, regulation and guidance; and to identify risks and opportunities associated with the application of existing relevant technical standards.

We would like to thank the following companies for their input into this study, as well as any additional stakeholders who contributed but chose to stay anonymous (in alphabetical order):

- ABS
- Aqua Ventus (University of Maine)
- Bureau Veritas
- DNV
- Dr. techn. Olav Olsen
- Eolfi, a member of Shell group
- Equinor
- GICON
- Glosten PelaStar
- Hexicon
- Lloyd's Register
- Ocean Winds
- Saitec Offshore Technologies
- Stiesdal Offshore Technologies
- Swiss Re

The following organisations are the industrial partners in the Floating Offshore Wind Centre of Excellence:

2 INTRODUCTION

2.1 PROJECT BACKGROUND

There are ongoing FOW industry activities aimed at standardising design requirements for floating offshore wind structures (e.g. development of IEC TS 61400-3-2). However, these are based on limited operational experience available from the FOW industry and as it grows rapidly, they will evolve in line with experience gained. Outwith the core scope of the guidance referenced, there are a range of floating offshore wind technology functions and activities which are not addressed, or only to a limited extent. Furthermore, in contrast to bottom-fixed offshore wind foundations, the floating nature of floating offshore wind turbines opens up the potential for the application of a range of technical regulation aimed at the maritime and navigation sector, specifically, vessel classification and certification.

As such, the project "Application of Standards, Regulations, Project Certification & Classification", aims to review the relevant floating offshore wind standards, provide a general overview to stakeholders less familiar with the standardisation framework in floating wind, map existing relevant standards onto a FOW farm project, and to identify risks and opportunities for a project developer and other stakeholders, with a focus on the UK market.

This project is being delivered by Ramboll as the Lead Consultant with support and guidance from ORE Catapult and the FOW CoE partners.

2.2 SCOPE, OBJECTIVES AND ASSUMPTIONS

The objectives of the underlying project are to:

- Outline the governing technical standards relevant to the development, design, manufacture, assembly, installation, commissioning, operation, maintenance and decommissioning of FOW in the UK, considering FOW turbines, substructures, mooring and anchoring systems and all electrical infrastructure including floating substations.
- Identify and outline differences between standards and regulations of different certification and classification organisations (e.g. American Bureau of Shipping, Bureau Veritas, Det Norske Veritas, Lloyd's Register).
- Outline the certification process for FOW (technology, project etc), in commercial projects in the UK.
- Identify and outline differences between certification of different foundation and mooring typologies (with consideration of material type) including for designs that are not based directly on O&G substructure designs.
- Outline other technical regulation (for example vessel classification and certification schemes) required for commercial projects in the UK.

The results of this project are summarised in this public mapping report to provide an overview of currently existing standards relevant to FOW, to show what areas each of the standards cover and to highlight subjects that are not covered. A full report is available only to FOW CoE partners and contains full details of the main similarities and differences between key technical standards and regulations, and identified gaps, risks, opportunities and innovations.

The document review focuses on hull and mooring system and floating-specific aspects of WTG, electrical infrastructure and floating offshore substations (OSSs). Relevant operational phases of an offshore wind project are addressed in Section 1.7. Environmental, permitting and consenting, contractual and other non-technical aspects are not considered. In this study, the below governing standards with relevance in the UK have been reviewed:

Class Society	Name	Title	Revision Date
International Electrotechnical Commission	IEC TS 61400-3-2	Wind energy generation systems – Part 3-2: Design requirements for floating offshore wind turbines	April 2019
American Bureau of Shipping	195	Guide for Building and Classing Floating Offshore Wind Turbines	July 2020
Bureau Veritas	NI 572 DT R02 E	Classification and Certification of Floating Offshore Wind Turbines	January 2019
Det Norske Veritas	DNVGL-ST-0119	Floating wind turbine structures	July 2018
Det Norske Veritas	DNVGL-RU-OU-0512[1]	Floating wind turbine installations	October 2020
Lloyd's Register	LR GN[2]	Guidance Notes for Offshore Wind Farm Project Certification	July 2019

Table 1-1: Selected governing standards for floating wind projects in the UK, as analysed in detail in the study

The first level of referenced standards based on the governing standard (level 0) has been included in the study.

2.3 STAKEHOLDER ENGAGEMENT

Feedback from FOW CoE partners and external stakeholders was gathered during this project to support the identification and review of existing relevant technical standards, specifications, practice, law, regulation and guidance; and to address risks and opportunities associated with the application of existing relevant technical standards. Types of stakeholders engaged with in this study include wind farm project developers, floating substructure developers, classification societies and insurance companies. The primary concepts offered by the interviewed substructure developers cover different main materials – i.e. steel and/or concrete – and concept types – i.e. spar, semi-submersible, TLP and novel technologies like suspended counterweight, weathervaning (single point mooring) systems, multi-rotor concepts and inclined tower concepts. See Section 1.6 on technical explanations and Section 6 on acknowledged stakeholders.

A proven approach was followed to contact the stakeholders via email, providing them the key questions and sufficient background information. Then, interviews were performed to obtain as much input as possible to a variety of these key questions. Main statements and key takeaways from the stakeholder feedback were identified, categorised with respect to technical topics and, finally, fed into this report in an anonymised way.

1 DNVGL-RU-OU-0512 is not a technical standard but a rule (RU) and was included on OREC request.
2 LR GN is not the official name of this document. LR GN is used in this document to ease readability.

The key questions to obtain third party input for this study addressed the following topics:

- Maturity of standards and guidelines for FOW
- Gaps and risks related to technical aspects in standards, and to the classification and certification process
- Need for additional guidance/research
- Approach to handle novel technologies not fully covered by existing standards
- Appropriateness of current safety levels and implied conservatism
- Decision process behind selecting a specific standard framework
- UK specific regulations driving the technical design for FOW projects
- Legal/regulatory status of a FOWT
- Key takeaways from floating wind projects

2.4 PRECEDENCE AND HIERARCHY

A given order of precedence must be followed in case of conflicting requirements. An exemplary hierarchy for an offshore wind project is shown below. Requirements from a lower level of the hierarchy shall only apply when not in conflict with the requirements from a higher level of the hierarchy.

1. Authority laws, rules and regulations (national and regional)
2. Project specific requirements and specifications, e.g. design basis
3. Owner's technical and professional requirements, e.g. for design, construction, T&I etc.
4. Codes and standards
   a. Overruling status, e.g. by IEC
   b. Governing status, e.g. by DNV
   c. Mandatory status ("shall" regulations), e.g. by ISO or API
5. Other codes and standards, see also Section 2.7 and Appendix B
6. Industry best/recommended practices

The documents of items 2 & 3 typically refer to codes and standards in item 4. Depending on the developer, stricter requirements can be defined in item 2 & 3 than are required in item 4, such as for HSE. Item 4 represents a set of standards agreed between the developer and the classification society/ certification body. Item 5 refers to codes and standards referenced in item 4 as well as additional standards that cover specific design aspects.

2.5 PHILOSOPHY OF APPLICATION OF STANDARDS

In the most general terms, a technical standard is an established norm or requirement for a repeatable technical task. It is usually a formal document that establishes uniform engineering or technical criteria, methods, processes, and practices. In summary, technical standards in Offshore Wind provide an explicit set of requirements for the material, component, system, service, performance and other items. The general intention is to:

- Establish a defined target level of safety for the system to ensure human health and safety is not compromised, as well as ensure performance (such as energy production) and the structural integrity of the installations fulfil the target safety and reliability levels.
- Create uniformity across manufacturers, designers, utilities, government agencies, and other relevant parties regarding terminology, product specifications, protocols, processes and more.
- Formalize the technical aspects of a procurement agreement or project contract, e.g. exact material and performance requirements.

In offshore wind, technical standards are developed by classification bodies or by national or international consensus-based groups such as IEC, ISO or API. Furthermore, companies may also develop company-specific standards as is common practice for O&G companies for example.

Standards may be mandatorily enforced through government legislation. In offshore wind this is often the case related to fulfilment of electrical grid code compliance if offshore wind farms feed into the national grid. For the floating substructure and mooring specifically addressed in this document, in the UK there are no specific complete standards or standard suites enforced by law and only few laws/regulations that are impacting the design (see Section 5).

The intention of standards is not to limit innovation by implying that only items specifically covered in standards should be used in designing new systems. Typically, standards use language which already provides flexibility and room for interpretation in terms of the specific technical solutions covered under it. If a specific design aspect or new innovation is not explicitly covered by a specific standard within the existing (floating) offshore wind standard framework, it is common practise that the designer together with the responsible classification body identify other standards which could be applicable (in floating wind, often this relates to O&G standards). If this is not possible, individual solutions to ensure the safety level of novel design solutions not explicitly covered by standards may also be developed by the designer and agreed upon with the responsible classification body, which may also include testing. In some cases, such individual solutions also become part of standards.

Further there exists the option to not certify certain elements according to a standard and, if not mandatorily enforced by local regulations or law, be accepted by the project in terms of risk. Depending on the type of project, the developer may also choose to not certify the overall wind farm and only comply with the mandatory country specific laws and regulations. Such approaches may be followed for one-off technology demonstrators or if the floating wind farm does not feed into the public electrical grid but only powers proprietary assets (e.g. an oil and gas production platform). However, in such cases the design typically still follows common standards in the design, but their application is not embedded in a formalized certification process (see also Section 4). Furthermore, for technical innovations and products there exist frameworks for technical qualification. A typical example in the floating wind context is a project specific qualification for a novel material for mooring lines or a specific cable. Section 3 provides some additional information on this topic.

In summary, standards should not be considered to be a rigid framework which limits innovation or outlines explicit design methodologies or approaches, but rather a tool to establish common design criteria and ensure a defined target safety level.

2.6 TECHNICAL COMPONENTS OF FOWTs

This section briefly outlines the technical components of a FOWT addressed in standards.

FOWT System: A floating wind turbine comprises the following main components:

- RNA with rotor blades, hub and nacelle, housing drivetrain, generator, yaw mechanism, blade pitch mechanism, control and power electronics, brake, lubrication, and cooling systems
- Tower and transition piece[3]

Not considered in detail in this report.

- Floating substructure with secondary structures such as boat landing, guard rails, deck fittings
- Stationkeeping system (mooring or tendon system, connecting interface structure, anchor)
- Electrical system power cable (dynamic and static part)

Substructure: In most standards, FOWTs are categorised into general substructure types based on their means of establishing stability, as displayed in Figure 1-1. Specific rules may apply for each type:

- Semi-submersibles (column stabilised systems)
- Spar foundations (ballast stabilised systems, incl. suspended counterweight designs)
- Barge-type foundations (waterplane area stabilised systems)
- Tension-leg platforms (tendon stabilised systems)

Some concepts are hybrid versions combining the stability principles of the four main categories.

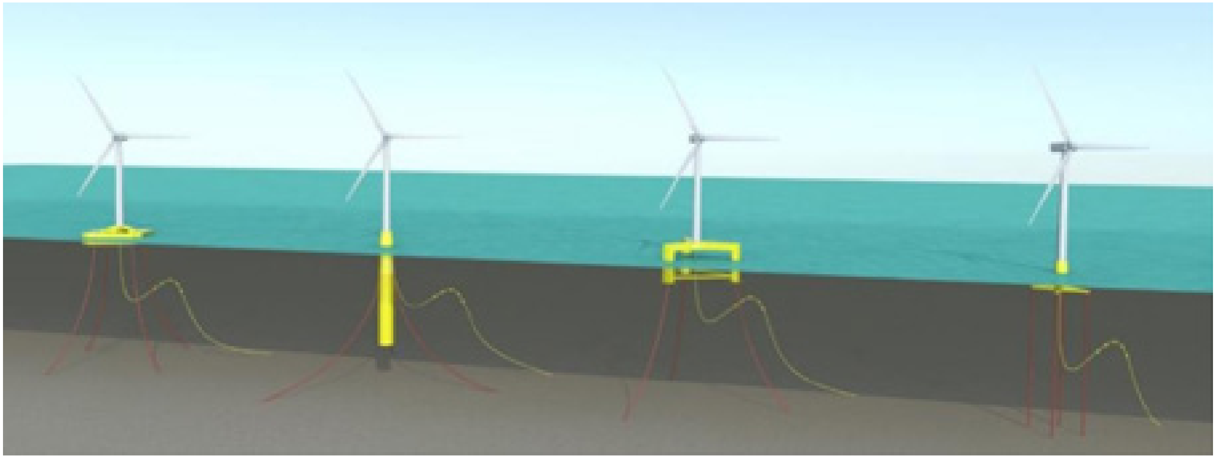

Figure 1-1: Barge, spar, semi-submersible and TLP generic representations (from left to right) [source: Ramboll]

Stationkeeping System: The stationkeeping system keeps the FOWT at its intended location and for some systems (TLP) also provides the primary means of stability. There are two main types of mooring systems: Compliant catenary, semi-taut and taut systems; and tendon systems. Figure 1-2 presents a schematic view of a catenary mooring system with a chain-rope-chain setup and its primary elements. Buoyancy elements and clump weights are optional components that might be applied to improve the restoring characteristic of the mooring system. Depending on the mooring configuration, seabed conditions and the required holding capacity different anchoring solutions are available like drag-embedded, gravity, driven pile and suction pile anchors. Specific rules may apply for each system.

3 The transition piece is usually considered part of the substructure for fixed-bottom offshore wind.

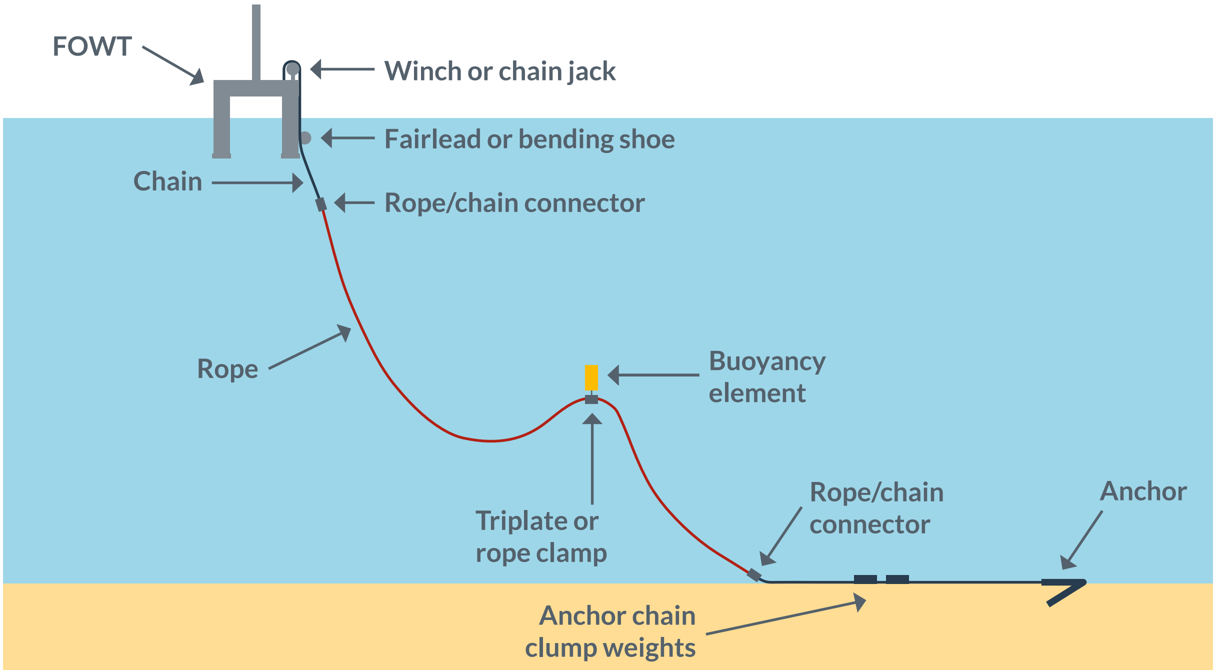

Figure 1-2: Schematic view of a catenary mooring system [source: Ramboll]

Electrical Cable System: The electrical cable system typically comprises three elements, with the dynamic cable being specifically addressed in floating wind standards:

- Inter-array cables operate as a medium-voltage, electrical collection network to connect the individual turbines within an array and consists of a dynamic part from the connection at the floater to the touchdown point on the seafloor and a following static part, see Figure 1 3.
- Export cables are high-voltage, subsea transmission cables delivering power to shore; in larger wind farms they start from an offshore substation (which may be fixed or floating).
- Onshore cables connect to the subsea export cables at the onshore landing point and are used to transmit power to the onshore substation.

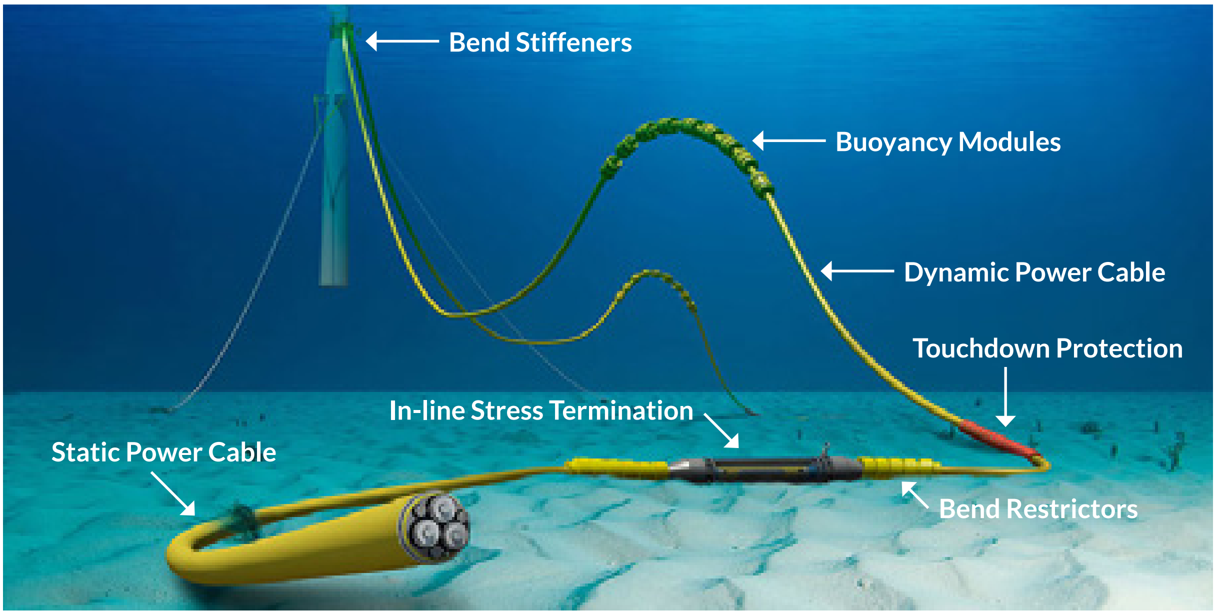

Figure 1-3: Illustration of the general design and layout of inter-array electrical cables for floating wind turbines [source: NREL]

2.7 PROJECT PHASES OF FLOATING OFFSHORE WIND FARMS

Standards not only address different technical components and systems, but also relate to activities in specific project phases. An offshore floating wind farm project is typically broken down into several main project phases: site selection and feasibility; consenting, permitting and EIA; design phase & certification; tendering & contracting; supply, procurement and fabrication; onshore facilities; T&I; O&M; decommissioning or repowering. The tasks commence sequentially but can run in parallel with other project tasks. Figure 1-4 shows a typical timeline of phases within the development of an offshore wind project. While certification can also address the manufacturing through to commissioning phases, the main focus in this report is on the design phase and the associated certification based on design standards. T&I, O&M and decommissioning activities are addressed in this report regarding floating wind specific aspects.

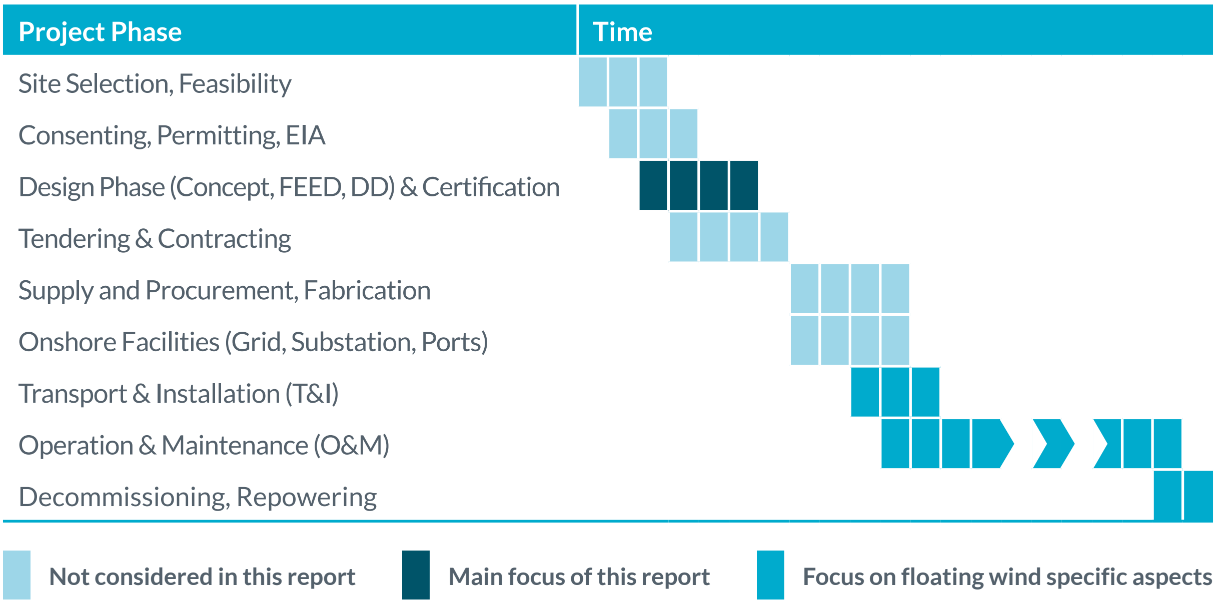

Figure 1-4: Typical project phases of a floating wind farm assuming a contractual strategy

3 OVERVIEW OF TECHNICAL STANDARDS FOR FLOATING WIND TURBINES

3.1 INTRODUCTION

The following subsections provide overview charts showing standards, guidelines and recommended practices referenced within the governing standards listed in Table 1-1. The overviews are not to be understood as a complete set of standards for the classification of a FOWT or the certification of a project. Where not all of the project packages or components are covered, this means that no cross-references to internal or external standards are provided in the respective governing standard, but applicable guidance may exist e.g. in other offshore wind and/or O&G standards (out of scope of this review).

The standards review, including a comparison and gap analysis yielded 18 main technical elements (also called packages in this report) which are typically covered by standards. These provide guidance and regulations on the key components of an offshore floating wind turbine and associated activities and project phases: (1) General, (2) Environmental and Soil Conditions, (3) Materials and Construction, (4) Safety Levels and Safety Concepts, (5) Design Methods and Loads, (6) Fatigue Limit State, (7) Ultimate Limit State, (8) Serviceability and Accidental Limit State, (9) Stability, (10) Corrosion Protection and Control System, (11) Wind Turbine, (12) Mechanical and Electrical Equipment, (13) Power Cable, (14) Stationkeeping System and Anchor, (15) Transport and Installation, (16) Commissioning, Surveys and O&M, (17) Decommissioning and (18) Other. Descriptions of what standards typically cover in each package is provided in Appendix C .

3.2 STANDARDS FRAMEWORK BY IEC TS 61400-3-2

IEC is the internationally recognized main standardization body for wind energy, including offshore floating wind. The IEC Technical Specification 61400-3-2 reference list is rather short compared to the other governing standards. Most references are towards IEC and ISO standards. Related to design methods and stationkeeping systems, API RPs are referred to. Figure 2-1 provides the IEC 61400-3-2 framework to internal and external standards, guidelines and recommended practices related to the packages defined in Section 2.1. TS61400-3-2 is currently in revision to become a full standard.

3.3 STANDARDS FRAMEWORK BY ABS 195

ABS is a US maritime classification society established in 1862. ABS is included in this review because it is the main American classification society for O&G and has a long track record in offshore wind. ABS 195 includes references to various other ABS rules, guides and guidance notes. Additional references also include US standards from API, NACE, ACI and ASTM and international IEC and ISO standards related to environmental conditions and design methods and loads. Figure 2-2 provides the ABS 195 framework related to the packages defined in Section 2.1. Table A-1 in Appendix A provides the abbreviation list of the short names used in Figure 2-2.

IEC TS 61400-3-2				
General	IEC 61400-1 IEC 61400-3-1		Corrosion Protection and Control System	IEC 61400-1 (CS) IEC 61400-3-1 (CS) ISO 19904-1 (CP) ISO 12944-9 (CP)
Environmental and Soil Conditions	IEC 61400-1 IEC 61400-3-1 ISO 19900 ISO 19901-1	ISO 19901-4 ISO 19904-1 ISO 19906 API RP 2FPS	Stability	IMO res. MSC.267(85)
Materials and Construction	ISO 19901-7 ISO 19905-1		Fatugue Limit State	IEC 61400-1 IEC 61400-3-1 ISO 19904-1
Safety Levels and Safety Concepts	IEC 61400-3-1 ISO 19904-1		Ultimate Limit State	IEC 61400-3-1 ISO 19904-1
Design Methods and Loads	IEC 61400-1 IEC 61400-3-1 ISO 2394 ISO 19900	ISO 19901-2 ISO 19901-4 ISO 19901-7 ISO 19904-1 ISO 19906 API RP 2FPS API RP 2T ITTC Guid. 7.5-02-07-3.8	Transport and Installation	IEC 61400-3-1 ISO 19904-6
Stationkeeping System and Anchor	ISO 1901-4 ISO 19901-7 ISO 19904-1 APR RP 2T		Commissioning, Surveys and O&M	IEC 61400-3-1 ISO 19901-6 ISO 19904-1
Mechanical and Electrical Equipment	IEC 61400-1 IEC 61400-3-1		Serviceability and Accidental Limit State	ISO 19904-1
Wind Turbine	IEC 61400-1			

Figure 2-1: IEC 61400-3-2 framework

ABS 195						
General	ABS Class Rules ABS FPI Rules ABS MOU Rules ABS RA Notes				Corrosion Protection and Control System	API PR 2SK (CP) API PR 2T (CP) NACE SP0176 NACE SP0108
Environmental and Soil Conditions	ABS FPI Rules ABS OWT Guide IEC 61400-1	IEC 61400-3-1 ISO 2533 API RP 2MET			Stability	ABS FPI Rules ABS MOU Rules
Materials and Construction	ABS FPI Rules ABS MOU Rules ABS OI Rules ABS Mat Rules ABS OWT Guide	ABS Chain Guide ABS FA Guide ABS Fibre Notes ACI 213R ACI 301	ACI 318 ACI 357 ACI 395 ASTM C31 ASTM C39	ASTM C94 ASTM C172 ASTM C330 AISC St. Const. Manual	Fatugue Limit State	ABS FA Guide ABS PMS Guide ABS Fiber Notes API RP 2T
Design Methods and Loads	ABS FPI Rules ABS MOU Rules ABS Mat Rules ABS MV Rules ABS LRFD Guide ABS PMS Guide	ABS Semi Notes ABS Fiber Notes ABS Anchor Notes ABS Pile Notes ABS FOWT Notes IEC 61400-1	IEC 61400-3-1 IEC 61400-3-2 ISO 19904-1 ISO 19906 ACI 318 ACI 357	AISC St. Const. Manual API RP 2A API RP 2MET API RP 2N API RP 2T API Spec. 9A	Ultimate Limit State	ABS USA Guide ABS Fibre Notes
Stationkeeping System and Anchor	ABS FPI Rules ABS OI Rules ABS Mat Rules ABS OWT Guide	ABS Chain Guide ABS Fiber Notes ABS Anchor Notes ABS Pile Notes	API RP 2A API RP 2SK API RP 2T API RP 9B	API Spec. 9A	Transport and Installation	ABS FPI Rules ABS Anchor Notes ABS Pile Notes
Commissioning, Surveys and O&M	ABS Class Rules ABS FPI Rules ABS MOU Rules	ABS Mat Rules ABS CSurv Rules ABS Chain Guide	ABS NDI Guide ABS RBI Guide ABS MRMT Guide	ABS Fiber Notes ISO 19903	Mechanical and Electrical Equipment	ABS MOU Rules IEC 61400-3-1
Other	ABS MOU Rules[1] IEC 61400-24[2]	1 Helicopter deck, guards and rails, piping, bilge system, ventilation, firefighting 2 Lightning protection			Wind Turbine	IECRE OD-501
					Safety Levels and Safety Concepts	ISO 19904-1

Figure 2-2: ABS 195 framework; for abbreviations see Table A 1

3.4 STANDARDS FRAMEWORK BY BUREAU VERITAS NI572

Bureau Veritas is a French classification society, founded in Antwerp, Belgium in 1828 and moved to Paris, France in 1833. BV NI572 mostly refers to other Bureau Veritas standards. References also include IEC, ISO, EN, IMO, API, AISC, AWS, ASTM and NORSOK standards. Figure 2-3 provides the BV NI572 framework for the packages defined in Section 2.1.

BV NI572					
General	BV NR445 BV NR571 BV NR578	ISO 19902 API RP 2A API RP 2T		**Safety Levels and Safety Concepts**	BV NR493
Environmental and Soil Conditions	BV NR493 BV NI 605 IEC 61400-3 ISO 19901-1 ISO 29400	EN 1997 IMO MODU Code IMO MSC/Circ.884 IMO A765(18)		**Wind Turbine**	BV NI 525 IEC 61400-1 ISO 76 ISO 281 ISO 6336 series
Materials and Construction	BV NR216 BV NR426 BV NR445 BV NR467 BV NR576 BV NI 594	API RP 2T ISO/IEC 17021 ISO 9001 ISO 19903 EN 106 EN 1992	AISC Steel Construction Manual AWS D1.1	**Mechanical and Electrical Equipment**	IEC 60092 series IEC 61892 series IEC 61400 series IEC 60092-401 IEC 61400-24 IEC 61892-6
Corrosion Protection and Control System	BV NI 423 BV NR445 BV NR493 BV NI 605 ISO 9226	ISO 11306 ISO 12944 NORWOK M-501 ASTM G1		**Stationkeeping System and Anchor**	BV NR493 BV NR578 BV NI 604 BV NI 605 API RP 2T
Design Methods and Loads	BV NR426 BV BR445 BV NR467 BV NR493 BV NR571	BV NR578 BV NI 611 IEC 61400-3 API RP 2T ISO 19901-2	ISO 29400 EN 1993-1	**Transport and Installation**	BV NR526 ISO 29400 API RP 2A IMO MSC/Circ.884 IMO A765(18)
Fatugue Limit State	BV NR493 BV NR578 BV NI 604	BV NI 611 API RP 2T		**Commissioning, Surveys and O&M**	BV NR445
Stability	BV NR445 BV NR578 ISO 29400	IMO MSC/Circ.884 IMO A765(18) IMO Res MSC.267(85)		**Ultimate Limit State**	BV NI 615 API RP 2A
Other	BV NR445[1] BV NR467[2]	1 Mooring support, hull attachments, heli deck, bilge system 2 Lifting appliance foundations, bulwarks, guard rails		**Serviceability and Accidental Limit State**	BV NR445

Figure 2-3: BV NI572 framework

3.5 STANDARDS FRAMEWORK BY DNVGL-ST-0119

DNV is a Norwegian classification society, from a merger of DNV (1864, Norway) and GL (1867, Germany). DNVGL-ST-0119 includes mainly references to other standards and RPs from DNV. References are included to IEC, ISO, EN, IMO, IACS, API, PTI, BS, Eurocode, EEMUA and NORSOK standards. Figure 2-4 provides the DNVGL-ST-0119 framework for the packages defined in Section 2.1. Floating-wind-specific rules related to surveys are included in DNVGL-RU-OU-0512, see Section 4.3.2.

DNVGL-ST-0119						
General	DNVGL-ST-0126 DNVGL-ST-0376 DNVGL-RP-A203 IEC 61400-1	Circ.1023– MEPC/Circ.3 92 Guidelines for Formal Safety Assessment		**Corrosion Protection and Control System**	DNVGL-ST-0076 DNVGL-ST-0126 DNVGL-ST-0438 DNVGL-OS-A101 DNVGL-OS-D202	DNVGL-OS-E301 DNVGL-RP-0416 DNVGL-RU-OU-0102 NORSOK M-001
Environmental and Soil Conditions	DNVGL-ST-0126 DNVGL-ST-0437 DNVGL-RP-C205 DNVGL-PR-C207	DNVGL-RP-C212 IEC 61400-1 ISO 19901-2		**Stability**	DNVGL-OS-C301 DNVGL-RP-C205	
Materials and Construction	DNVGL-ST-0126 DNVGL-ST-C501 DNVGL-ST-C502 DNVGL-OS-B101 DNVGL-OS-C103 DNVGL-OS-C105	DNVGL-OS-C106 DNVGL-OS-E301 DNVGL-OS-E302 DNVGL-OS-E303 DNVGL-OS-E304 DNVGL-RP-E304	DNVGL-RP-E305 ISO 13628-5 ISO 898-1 EN 1992-1-1 EN 1992-2 EEMUA pub #194	**Fatugue Limit State**	DNVGL-ST-0126 DNVGL-OS-C401 DNVGL-OS-E301 DNVGL-OS-E303 DNVGL-RP-E305	DNVGL-RP-F401 DNVGL-CG-0129 DNVGL-RP-C203 BS 7910
Safety Levels and Safety Concepts	DNVGL-ST-0126			**Ultimate Limit State**	DNVGL-ST-0126 DNVGL-RP-C202 EN 1993-1-1	EN 1993-1-8 Eurocode NORSOK N-004
Design Methods and Loads	DNVGL-ST-0126 DNVGL-ST-0437 DNVGL-ST-C501 DNVGL-ST-N001 DNVGL-OS-C101 DNVGL-OS-C103 DNVGL-OS-C105 DNVGL-OS-C106	DNVGL-OS-C401 DNVGL-OS-D101 DNVGL-OS-E301 DNVGL-OS-E303 DNVGL-OS-F201 DNVGL-OTG-13 DNVGL-OTG-14 DNVGL-RP-C103	DNVGL-RP-C104 DNVGL-RP-C201 DNVGL-RP-C205 DNVGL-RP-C208 DNVGL-RP-F205 IEC 61400-3	**Transport and Installation**	DNVGL-ST-0437 DNVGL-ST-N001 DNVGL-RP-N101 DNVGL-RP-N103	
Power Cable	DNVGL-ST-0359 DNVGL-ST-N001 DNVGL-OS-F201 DNVGL-RP-0360 DNVGL-RP-C203	DNVGL-RP-C205 DNVGL-RP-F105 DNVGL-RP-F107 DNVGL-RP-F109 DNVGL-RP-203	DNVGL-RP-F204 DNVGL-RP-205 DNVGL-RP-F401 ISO 13628-5 API Spec. 17J	**Commissioning, Surveys and O&M**	DNVGL-ST-0126 DNVGL-OS-E301 DNVGL-OS-E303	
Stationkeeping System and Anchor	DNVGL-ST-0126 DNVGL-ST-C501 DNVGL-OS-C105 DNVGL-OS-E301 DNVGL-OS-E302 DNVGL-OS-E303 DNVGL-OS-E304	DNVGL-RP-C207 DNVGL-RP-C212 DNVGL-RP-E301 DNVGL-RP-E302 DNVGL-RP-E303 DNVGL-RP-E305 DNVGL-RU-OU-0102	EN 1573 EN 1997-1 NORSOK M-001 NORSOK N-006 PTI DC 35.1	**Mechanical and Electrical Equipment**	DNVGL-ST-0076 DNVGL-ST-0359 DNVGL-ST-0378 DNVGL-OS-A101 DNVGL-OS-D101 DNVGL-OS-D201	DNVGL-OS-E301 IEC 61892-6 ISO 13628-5 EEMUA pub #194

Figure 2-4: DNVGL-ST-0119 framework

3.6 GUIDANCE NOTES BY LR

Lloyd's Register (LR) is a UK classification society which follows a slightly different approach as the previously presented class societies and IEC, having one comprehensive offshore standard on "Rules and Regulations for the Classification of Offshore Units", instead of multiple separate documents. LR does not have an explicit floating offshore wind standard, but a Guidance Note for Floating Wind is currently under development. The LR Guidance Notes for Offshore Wind Farm Project Certification, July 2019, which can be applied to both bottom fixed and floating offshore wind farms, mainly includes references to LR's main Standard on "Rules for the Classification of Offshore Units" and "Rules and Regulations for the Classification of Ships", as well as IEC and ISO, API, BS, DNV and IMO. Figure 2-5 provides the LR Guidance Notes standards framework related to the packages defined in Section 2.1.

LR GN for Offshore Wind Farm Project Cerification						
General	IEC 61400 series				**Stability**	IMO MODU Code LR Ship Rules[1]
Environmental and Soil Conditions	IEC 61400-1 IEC 61400-3 IEC 61400-12-1	IEC 61400-12-2 ISO 19900	ISO 19901-2 ISO 19902 ISO 19903	ISO/IEC 17025 API RP 2A-WSD	**Fatigue Limit State**	IEC 61400-1 IEC 61400-3
Materials and Construction	ISO 9001 BS EN 10204				**Transport and Installation**	IEC 61400-22 IECRE OD-502
Safety Levels and Safety Concepts	IEC 61400-3				**Commissioning, Surveys and O&M**	IEC 61400-22 IEC 61400-3 IECRE OD-502
Design Methods and Loads	IEC 61400-1 IEC 61400-3	IEC 61400-22 IECRE OD-502	ISO 19904-1 LR Ships Rules[1]	LR Craft Rules[2] DNVGL-ST-0119	**Wind Turbine**	IEC 61400-1 IEC 61400-3
Stationkeeping System and Anchor	IEC 61400-3 API RP 2SK LR Ship Rules[1] ISO 19901-4	ISO 19902			**Other (Grid Compliance and EIA)**	IEC 61400 series IECRE OD-502 ISO/IEC 17020 ISO/IEC 17025

1 LR Rules and Regulations for the Classification of Ships
2 LR Rules and Regulations for the Classification of Special Service Craft

Figure 2-5: LR Guidance Notes for Offshore Wind Farm Project Certification framework

3.7 ADDITIONAL RELEVANT STANDARDS AND SUITES

The above summarized floating wind specific standard frameworks include many references to national and international standards and rules, including ACI, AISC, API, ASTM, AWS, BS, EEMUA, EN, IACS, IMO, ISO, ITTC, NACE, NORSOK and PTI, see Appendix B. Other maritime class societies also have applicable standards, which have been considered less relevant in a UK context, including:

ClassNK: ClassNK, the Japanese maritime class society, is providing a design guideline for floating offshore wind turbines comprising the chapters *General*, *External Condition*, *Design Load Condition*, *Material and Welding*, *Structural Design*, *Mooring System*, *Stability* and *Survey for the Floating Structures*.

RINA: RINA, the Italian maritime class society is offering certification of fixed offshore wind components and farms, but not explicitly for floating wind technology.

Other major maritime class societies such as the Russian Maritime Register of Shipping, China Classification Society, Korean Register and Indian Register of Shipping do not offer specific classification rules of offshore wind structures. Management systems for occupational health and safety as defined by BS OHSAS 18001 and ISO 45001 are not referenced in the governing standards (level 0) of Table 1-1, but are covered in "The Management of Health and Safety at Work Regulations 1999" in Section 5.2.2. ISO 45001 is optional and HSE regulations state that meeting this standard does not in itself demonstrate compliance with health and safety law.

4 STANDARDS REVIEW

4.1 INTRODUCTION

Floating wind is a developing industry and still in pre-commercial stage. Therefore, only a limited amount of experience exists: The longest operating multi-MW floating wind turbine as of 2021 is a single turbine operating for 12 years (Hywind Demo), less than half of a typical offshore wind farm lifetime. Thus, it is clear that certain design aspects are not covered in standards or are covered to a limited extent only which is considered a gap. A gap does not necessarily represent a weakness of the governing standard because offshore units are generally designed based on a set of standards and items not covered can be covered by other dedicated standards.

4.2 OVERVIEW OF GAPS

Below a summary is provided of the main items which were identified in the gap analysis, arranged in alphabetical order. Full details of the main similarities and differences between key technical standards and regulations, and identified gaps, risks, opportunities and innovations are contained in the full report which is available only to FOW CoE partners.

Category	Gap
Anchor Design and Installation	• There is some lack of alignment regarding standards for geotechnical anchor design, as well as installation of anchors.
Concrete Design	• More consistency and additional guidance regarding concrete design requirements for floating wind would be beneficial to reduce uncertainties.
Commissioning	• The commissioning phase of a FOWT project is not sufficiently covered by most governing technical standards resulting in a lack of guidance.
Decommissioning	• The decommissioning phase of a FOWT project is not sufficiently covered by most governing technical standards resulting in a lack of guidance.
Floating Offshore Substations	• There is a general lack of explicit guidance in the governing standards on floating offshore substations.
Floorings	• The standards lack information on requirements on flooring design including impact of dropped objects, flooring material selection and inspection.
Global Loads and Local Structural Analysis	• Currently no specific guidance and requirements exist regarding a consistent process to apply loads from the coupled global performance analysis of the full design load case set to local structural checks, particularly for fatigue. • Another aspect related to global performance analysis relates to interpretation of the design load case table. • Floating wind specific guidance regarding the consideration of wave run-up on structures is lacking in the governing standards.
HSE	• The floating wind specific aspect of the effect of floater motions on O&M personnel health and safety, as well as workability (e.g. from sea sickness) is not well addressed.

Category	Gap
Innovative Floating Wind Turbine Concepts	• Novel technologies specifically developed for floating wind with no equivalence in the O&G world, such as counterweight concepts, twin-hull weathervaning barge concepts or TLPs with inclined tendons where the restoring principle differs from typical TLPs are not explicitly covered by the standards. • Shared anchor (where one anchor supports multiple mooring lines) and interconnecting mooring system solutions (mooring lines connecting multiple units) are not explicitly covered in standards. • Floating specific requirements on novel turret mooring systems (single point mooring) are not included in standards. • Some FOWT concepts also include innovations in the tower and wind turbine, which are not covered by any of the established wind turbine standards.
Major Component Lifts	• While it is acknowledged that the T&I contractor will develop project and floater specific procedures for major component lifts, generally it is found that further alignment and more consistency across the standards would be beneficial.
Power Cable	• Floating wind specific guidance on the dynamic part of the power cable is not included in any of the other standards, where umbilical standards from O&G would then have to be applied.
Safety Level and Characteristic Loads	• For novel floating wind turbine concepts with significantly non-linear behaviour, the intended safety level may not be fulfilled / or exceeded if following current rules.
Slack Line Regulations	• Guidance on slack line regulation is considered beneficial as there is some difference amongst current standards.
Software Calibration, Performance Validation and Testing	• Overall, there is limited explicit guidance in which cases and how software shall be calibrated and validated. • There is little guidance on validating the performance of FOWTs once installed. • There is limited guidance on application of model scale and prototype testing.
Synthetic Mooring Lines	• Floating wind specific guidance on synthetic mooring lines are not included in all standards and guidance on novel materials for permanent applications are not explicitly covered.
Tower	• Standards do not provide detailed guidance on tower design and relevant specific standards for floating wind.
Tropical Cyclones	• There is some lack of alignment between standards on consideration of tropical cyclones.
Wind Farm Level Effects	• Standards are lacking explicit guidance on floating specific aspects of wind farm level effects.
Wind-Wave Statistics and Simulation Times	• Uncertainties associated with non-physical load case definition from independently gathered wind and wave measurements need to be investigated as standards lack specific guidance on mitigations.
WTG-Floater Interaction & Control	• The interaction of floater or mooring control systems with the wind turbine system is not explicitly addressed in standards and some additional guidance can be beneficial.

Table 3-1: Summary of identified gaps

5 OVERVIEW OF PROJECT CERTIFICATION

5.1 DIFFERENTIATION BETWEEN CLASSIFICATION AND PROJECT CERTIFICATION

Classification has its origin in the 18th century when the condition of a ship's hull and equipment were classified (hull: A, E, I, O or U; equipment: 1 to 3), not to evaluate safety, fitness for purpose or seaworthiness but to evaluate risks associated to a ship that was being insured. Today, a ship (hull, structures, machinery, equipment) either is compliant with relevant rules of a classification society or it is not – i.e. it is in or out of class. Vessels out of class can be uninsurable because of higher risks, and/or not permitted to operate. Classification can also be applied to O&G platforms, submarines, offshore wind installations, other offshore structures, aviation, etc. Classification societies develop and publish technical rules that form the basis for assessing the design and construction of new vessels and the integrity of existing vessels and marine structures. The classification rules are designed to ensure an acceptable degree of stability, safety, environmental impact, etc.

Classification describes:

- the technical review of design documents, construction plans and material specifications to verify compliance with the applicable rules;
- the supervision of the construction or conversion by surveys;
- and the supervision in service by surveys to verify that a condition is maintained according to relevant rule requirements.

The Class assigned to a structure reflects the opinion of the classification society that, for declared conditions of use and within the relevant time frame, compliance with applicable rules is fulfilled. The class certification is a written confirmation and verification of compliance that the design, and/or construction and fabrication and/or installation and/or testing is in conformity with recognized specifications and regulations. For ships, a classification certificate is required for its owner to register the ship and to obtain marine insurance.

Project certification is well established in offshore wind and it describes a third-party conformity assessment of a complete wind farm or individual installations. While a project certificate documents conformity at the time of issue and can be maintained or re-issued (usually not done), a class certification (classification) needs to be maintained with constant inspections, surveys and re-assessments during the operational life of an offshore installation. With respect to the recognition, project certification is very well accepted in offshore wind, while O&G companies are more familiar with classification.

Whilst classification *can* be applied to floating offshore wind sub-structures, it is not clear this is a more appropriate approach than the more typical application of project certification for floating offshore wind projects. Either in terms of effective management of risk, or in terms of supporting appropriate and efficient engineering design, manufacturing, operation and maintenance. However, the classification process does contain a number of key principles relating to the through life monitoring and management of integrity of floating structures. These principles can be applied in the context of project certification to ensure an appropriate risk-based approach to through life monitoring and management of integrity of floating structures.

This report primarily focusses on project certification and applicable technical standards within the framework of a typical offshore wind farm project certification in the UK.

5.2 GENERAL

Project certification is not common in all offshore wind markets. For a UK offshore wind project, project certification is formally not required but is usually performed within projects to fulfil finance, insurance or developer requirements. However, for example project certification is required according to the German Federal Maritime and Hydrographic Agency (BSH) following the standard BSH no. 7005 “Standard Design, Minimum requirements concerning the constructive design of offshore structures within the Exclusive Economic Zone (EEZ)” and according to the Danish Energy Agency’s Executive Order no. 1773 on “Technical certification and servicing of wind turbines” (BEK 1773, released 30 November 2020 as a fundamental revision of BEK no. 73 of 25 January 2013).

A scheme for type, project, component and prototype certification was released in 2010 under IEC 61400-22 “Wind turbines – Part 22: Conformity testing and certification”. The IEC standard was withdrawn on 31 August 2018. It was replaced with the deliverables for the wind sector contained in the IECRE Conformity Assessment System , namely the operational document OD-502 on “Project Certification Scheme”. The operational document OD-501 refers to the applicable “Type and Component Certification Scheme”. In addition, clarification sheets provide clarification for the uniform application of the operational documents.

Besides the IEC, other project certification schemes are outlined by class societies: For example, Lloyd’s Register bases the project certification scheme for offshore wind farm projects in the “Guidance Notes for Offshore Wind Farm Project Certification” on the requirements of IEC 61400-22 and IECRE OD-502. ABS 195 of July 2020 requires that the RNA and tower “have a type certificate in accordance with IECRE OD-501 or other recognized standards” or “the tower and its connection to the RNA are to be included” in the classification if they are “not covered by the wind turbine type certificate”. BV NI572 of January 2019 highlights that the “Guidance Note does not cover top structure, i.e. tower, rotor, blades and nacelle design” and refers to the certification of IEC 61400-22. DNV outlines a scheme in DNVGL-SE-0190 on “Project certification of wind power plants”, which is extended with specific floating wind turbine requirements by DNVGL-SE-0422 on “Certification of floating wind turbines”. DNV is further accredited to certify against IECRE OD-502 in addition to other standards by BSH or BEK.

5.3 PROJECT CERTIFICATION SCHEMES BY DIFFERENT STANDARDS

In general, project certification schemes follow a modular structure to account for individual customer requests. High-level differences between project certification schemes mainly relate to mandatory and optional certification phases/modules, considered assets, available certificate types and used terminology. An overview of a typical project certification process is illustrated below by the example of the IEC and DNV project certification schemes.

5.3.1 IECRE OD-502

The project certification scheme of IECRE OD-502 represents a third-party conformity assessment of a complete onshore or offshore wind farm at a specific location or individual installations associated with a wind farm such as substations and cables. It describes procedures, with respect to specific standards and other technical requirements, relating to the design, manufacturing, transportation, installation, commissioning and operation. The modularity of the operational document accounts for requests for individual conformity statements. Conformity evaluation can result in a project design certificate, project certificate or a site suitability evaluation conformity statement. A project certificate documents conformity at the time of issue, and it can optionally be maintained over the lifetime of a wind farm.

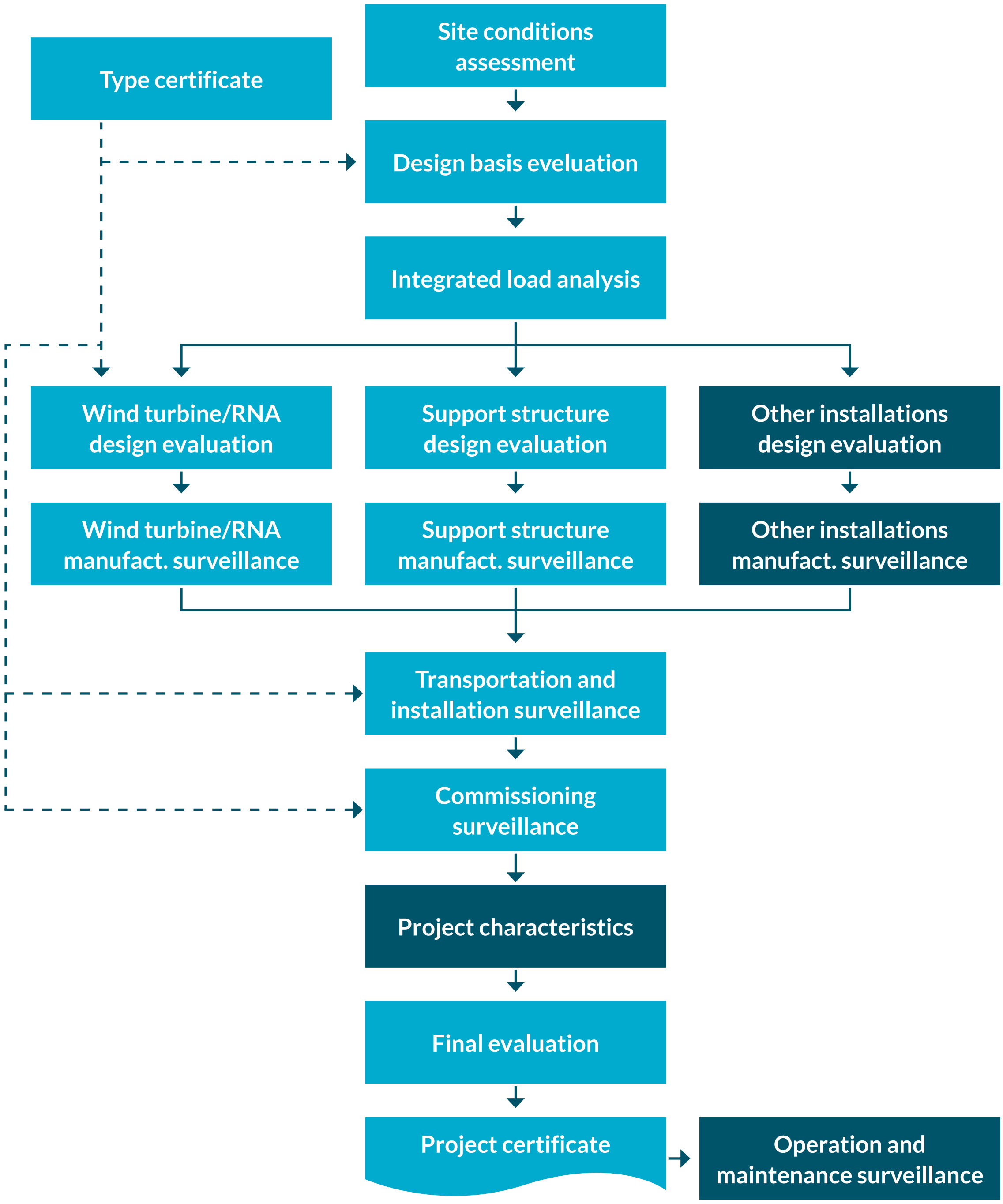

Figure 4-1: Modules of project certification according to IECRE OD-502 (optional modules in dark blue) [modified from source: IEC]

Project certification under IECRE OD-502 is based on a design basis approach and evaluates that a wind farm including wind turbine, support structures, substation, cable, etc. is in conformity with applicable standards for a specific site. A type certificate for the wind turbine according to IECRE OD-501 or the fulfilment of mandatory modules of type certification within project certification is required. Figure 4 1 illustrates mandatory and optional modules of project certification which are concluded with an evaluation report and a conformity statement. Site-specific design evaluation and manufacturing surveillance of the wind turbine RNA and support structure are mandatory, while the same modules are optional for other installations such as cables and substations.

5.3.2 DNVGL-SE-0190, DNVGL-SE-0422 AND DNVGL-RU-OU-0512

DNVGL-SE-0190 covers all lifecycle phases of onshore and offshore wind power plants including development, construction, operation and maintenance, and in addition to IECRE OD-502 also lifetime extension, decommission or repowering of the wind power plant. The following assets are covered and a project certificate can be issued for a single asset or a combination: wind turbine including RNA and (floating or fixed) support structure, substation including topside and support structure, inter-array and export power cables and control station. The project certification scheme consists of five mandatory phases (IECRE OD-502 uses the term modules) and six optional phases, e.g. for concept development or planning and execution of a decommissioning and removal, see Figure 4-2. Similar to IECRE OD-502, each phase is completed by a statement of compliance (IECRE OD-502 uses the term conformity statement) and the project certificate can be maintained over the lifetime. A wind turbine type certificate shall be available during the design basis phase. Besides a project certificate, a certificate on lifetime extension, decommissioning or repowering can be issued.

DNVGL-SE-0422 addresses specific requirements for floating wind turbines and related components such as the mooring system and is an extension to DNVGL-SE-0190. It reflects different development stages of floating wind turbines from the floating concept, prototype installation, serial production to the development and operation of a complete floating wind power plant. The certification scheme covers concept, prototype, site type and project certification based on the Technology Readiness Level (TRL) as well as in-service of floating wind turbines. A risk-based approach is included for novel designs.

DNVGL-RU-OU-0512 supplements DNVGL-SE-0422 certification of floating wind turbines by providing classification services that may be used as part of the design, construction and operation of a floating offshore wind turbine project. Figure 4-3 provide the DNVGL-RU-OU-0512 reference list for the packages defined in Section 2.1, including specific reference to the floating wind design standard DNVGL-ST-0119.

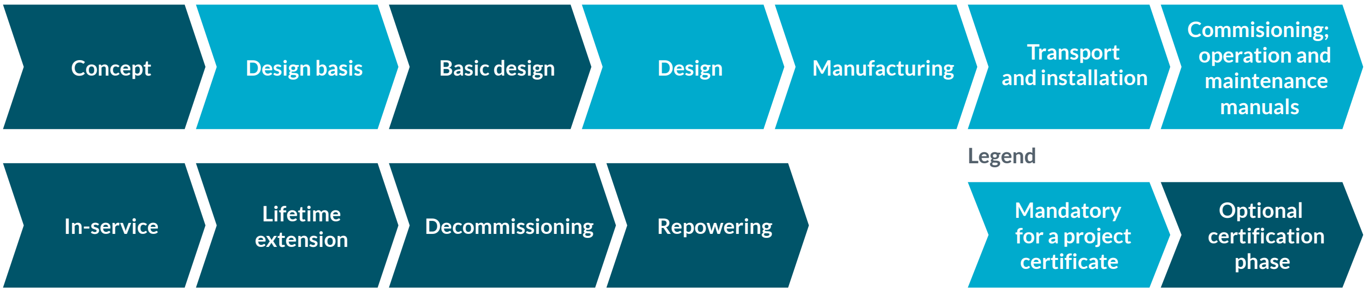

Figure 4-2: Overview of certification phases according to DNVGL-SE-0190 (optional modules in dark blue) [source: DNV]

DNVGL-RU-OU-0512						
Environmental and Soil Conditions	DNVGL-OS-E301			**Wind Turbine**	DNVGL-SE-0190	
Materials and Construction	DNVGL-ST-C502 DNVGL-OS-B101 DNVGL-OS-C102	DNVGL-OS-C401 DNVGL-RU-SHIP		**Mechanical and Electrical Equipmemt**	DNVGL-ST-0119 DNVGL-OS-D101 DNVGL-OS-D201	DNVGL-RU-OU-0300
Safety Levels and Safety Concepts	DNVGL-ST-0119 DNVGL-ST-C502 DNVGL-OS-A101 DNVGL-OS-C101 DNVGL-OS-C102	DNVGL-OS-C103 DNVGL-OS-C105 DNVGL-OS-C106 DNVGL-OS-C301 DNVGL-OS-D101	DNVGL-OS-D201 DNVGL-OS-D202 DNVGL-OS-SHIP	**Stationkeeping System and Anchor**	DNVGL-OS-E301 DNVGL-RP-E308 API RP 2SK	O&G UK, Mooring Integrity Guidelines
Design Methods and Loads	DNVGL-ST-0119 DNVGL-ST-0378 DNVGL-ST-C502 DNVGL-OS-A201 DNVGL-OS-C101	DNVGL-OS-C102 DNVGL-OS-C103 DNVGL-OS-C105 DNVGL-OS-C106 DNVGL-OS-D101	DNVGL-OS-E301 DNVGL-OS-SHIP	**Commissioning, Surveys and O&M**	DNVGL-ST-C502 DNVGL-OS-C401 DNVGL-OS-E301 DNVGL-RP-C301 DNVGL-OTG-08	DNVGL-RU-OU-0101 DNVGL-RU-OU-0300 DNVGL-CP-0484 ISO 12482 IACS UR Z7
Corrosion Protection and Control System	DNVGL-ST-0119 DNVGL-OS-C401 DNVGL-OS-D202	DNVGL-OS-D203 DNVGL-CG-0172 DNVGL-OTG-12	DNVGL-RU-SHIP IACS UR Z87/MSC.1/Circ 1330	**Fatugue Limit State**	DNVGL-OS-C102 DNVGL-OS-C401 DNVGL-OS-E301	DNVGL-RU-OU-0300 API RP 2SK
Other	DNVGL-ST-0358[4] DNVGL-ST-03783[3] DNVGL-OS-C101[3] DNVGL-OS-C201[3] DNVGL-OS-C301[3] DNVGL-OS-D301[1]	DNVGL-OS-E401[2] DNVGL-RP-0496[5] DNVGL-RP-C210[5] DNVGL-RP-C302[5] DNVGL-RP-G108[5] DNVGL-RU-SHIP[2,4,6]	DNVGL-RU-OU-0300[3,4] DNVGL-OTG-17[5] IMO res. MSC.428(98)[6] IMO res. MSC-FAL.1/ Circ. 3[6] ISO 12482[3]	**Stability**	DNVGL-ST-0119 DNVGL-OS-C301	
	1 Firefighting system 2 Helicopter deck	3 Cranes 4 Gangways	5 Risk assessment 6 Cyber security			

Figure 4-3: DNVGL-RU-OU-0512 framework

6 UK SPECIFIC ASPECTS

6.1 GENERAL

The following sections summarize UK regulations and laws, provide a general description of UK regulations that are applicable when considering the development of an offshore floating wind farm in UK waters, and highlight some specific impacts these may have on FOW projects.

6.2 UK SPECIFIC LAWS AND REGULATIONS

6.2.1 OVERVIEW OF UK LAWS AND REGULATIONS

The main sources of UK law are statute law and common law. There is no single series of documents that contains the whole of the law of the UK.

Statute law is made by Parliament and is the primary legislation of the UK. The statutes are written in a formal document and codified into law as Acts. Secondary legislation (such as Rules or Regulations) consists of all other forms of legislation that are not Acts.

Common law is made by judges and developed on the basis of binding precedent from previous decisions of the courts, with the principle that it is unjust to treat similar facts in a different way on varying occasions.

Statutes do not purport to cover all possible circumstances; therefore, common law is important to understanding and applying statute law in the UK. When a judge hears and decides individual cases, they apply both UK statute and common law. However, when common law varies with UK statute, the statute law will overrule.

The withdrawal of the UK from the EU and the end of the transition period means that EU directives are no longer applicable in Great Britain. In particular, the 2019 amendment to the Construction Products Regulation 2011 states that CE-marked construction products will no longer be permitted in Great Britain from 1 Jan 2022, when only UKCA markings will be acceptable. The practical effect of changes in legislation on other aspects of construction or design is yet to be fully clarified.

6.2.2 KEY LEGISLATION RELEVANT TO FLOATING OFFSHORE WIND

The governing primary legislation behind all civil engineering work in the UK is the Health and Safety at Work etc. Act 1974 ("HSWA1974"). This was extended by the Health and Safety at Work etc. Act 1974 (Application outside Great Britain) Order 2013 ("2013 Order") to ensure "that health and safety legislation continues to apply to workers involved in offshore work activities on energy structures (e.g. wind farms) beyond the territorial sea".

The 2013 Order makes distinct definitions for different types of offshore structures, with FOWT structures covered by Article 9 'production of Energy from Water and Wind'. This categorisation determines that the Construction (Design and Management) Regulations 2015 ("CDM2015") is applicable to all FOWT structures, as Article 9 of the 2013 Order is referenced within CDM2015.

CDM2015 effectively instructs the relevant parties within a construction project, such as clients, designers and contractors, how to implement HSWA1974, and its purpose is to ensure that health and safety issues are properly considered during project development so that the risk of harm to those who have to build, use and maintain structures is reduced.

Other UK laws and regulations relevant to FOWT include:

- Electricity Act 1989
- Energy Act 2004
- The Management of Health and Safety at Work Regulations 1999
- Construction Products Regulation 2011 (CPR)
- Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)
- Work at Height Regulations 2005
- The Control of Noise at Work Regulations 2005
- Offshore Chemicals Regulations 2002

Safety, Health and Environment Aspects

The Health and Safety Executive (HSEx) governs the compliance with Regulations, Codes, Standards & Health, Safety and Environment (HSE) requirements for offshore wind projects developed in the UK sector. The HSEx establishes that the parties involved in the development of floating offshore wind projects in UK waters shall be responsible for ensuring its own HSE Management System complies with the scope of works. As such, they shall produce a register of all standards, legislation, regulations and codes that are to be complied with in accordance with the defined scope of work to demonstrate both applicable legal compliance and good industry practice, also to ensure that the asset is fully compliant with legislation.

In the application of these regulations, codes and standards, the HSEx requires that good practice is followed, this means:

1. Compliance with HSEx Approved Codes of Practice (ACoPS) and Guidance publications
2. Construction Design & Management (CDM) 2015 Regulations apply to all aspects of construction and pre-construction works.
3. Where appropriate, apply standards agreed by an industry body such as a trade federation, professional institution, or governing body. Examples of these are the International Marine Contractors Association (IMCA) and the Maritime and Coastguard Agency (MCA).
4. Compliance with G9 Offshore Wind Health & Safety Association guidance documents:
   - Working at height in the offshore wind industry
   - The safe management of small vessels used in the offshore wind industry

The practical impact of the HSEx is that prescriptive regulatory requirements are minimal for a FOWT project in the UK. Specific requirements are generally determined by the industry-wide standards and practices that are discussed in Section 2.

It should be noted however that there is an instructive regulatory approach to risk assessment, which is to ensure risk reduction is ALARP. HSEx state that “Ensuring a risk has been reduced ALARP is about weighing the risk against the sacrifice needed to further reduce it… and to avoid having to make this sacrifice, the project must be able to show that it would be grossly disproportionate to the benefits of risk reduction that would be achieved”. This ALARP requirement may result in different design decisions being made on different projects, and when compared to similar processes in other countries, therefore this should be carefully considered at all stages of a project.

In addition to the HSEx, the MCA and Marine Accident Investigation Branch (MAIB) also have HSE regulatory jurisdiction within offshore wind farms. MCA is responsible for enforcing all merchant shipping regulations in respect of occupational health and safety, the safety of vessels, safe navigation and operation. MAIB is responsible for investigating accidents related to ships and crew in the UK territorial sea. Further details on how these regulatory bodies coordinate offshore can be found in HSEx Operational Working Document no. 2016/447651.

The international requirements MARPOL 73/78 ("Prevention of Pollution from Ships") and SOLAS 1974 ("Safety of Life at Sea") are legally applied to the UK, and are also referenced in the governing standards (level 0) of Table 1-1.

6.3 TECHNICAL ASPECTS IN LAWS AND REGULATIONS

This Section highlights a number of specific technical items found in the UK Laws and Regulations that are considered to be relevant for the development of floating offshore wind farms in UK waters. Note this is not an exhaustive list but is considered to address some of the pertinent issues within the industry.

6.3.1 AIR GAP / BLADE TIP CLEARANCE REQUIREMENTS

The MCA provides information in their Marine Guidance Notes (MGN) about the specific limitations applicable for all offshore wind farms in UK waters. Both MGN 372 Guidance to Mariners Operating in Vicinity of UK OREIs and MGN 543 Offshore Renewable Energy Installations Safety Response state that a minimum clearance of 22 m between blade tip and Mean High Water Spring (MHWS) level should be kept in all UK offshore wind farms. However, this minimum clearance may be increased based on environmental impact assessments and e.g. the cumulative effect of wind farms on bird migration and limiting the risk of bird collisions. This may significantly impact the floater design.

The definition of the term air gap used in the MGN can differ from standards. For example, IEC 61400-3-1 defines the air gap as the "clearance between the highest water surface that occurs during the extreme environmental conditions and the lowest exposed part not designed to withstand wave impingement".

6.3.2 MOORING DESIGN

The HSEx establishes through the Offshore Safety Directive Regulator (OSDR) in one of their guidance documents, HSEx document no. 2019/19168 titled 'Offshore Installation Moorings' and authored by the Offshore Petroleum Regulator for Environment and Decommissioning, that a check of the ALS is to be included on mooring line integrity for a single extreme event (typically a 10 000-year return period, with a safety factor of 1 applied). It is also stated by the HSEx that the standard ISO 19901-7 is the recommended code for offshore moorings in the UK and that the following legal requirements constitute enforced legislation applicable to mooring systems:

1. Offshore Installations (Safety Case) Regulations 2005 (SCR05)
2. Offshore Installations (Offshore Safety Directive) Regulations 2015 (SCR2015)
3. Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996 (DCR)
4. Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations 1995 (PFEER)
5. Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR)
6. Provision and Use of Work Equipment Regulations 1998 (PUWER)

The HSEx document titled 'Regulatory expectations on moorings for floating wind and marine devices' clarifies that guidance in HSEx document no. 2019/19168 titled 'Offshore Installation Moorings' can be used to draw up design specifications for new mooring systems, and that the principles implied are considered essential. However, full compliance is not required. The intention is to use established good practice in O&G as a starting point in developing guidance specific to FOW. The applicable return period for ALS robustness checks of mooring lines needs to be adapted to rules in the governing floating wind standards. OSS often follow more stringent O&G rules so that the design requirements are in general more conservative compared to those for a FOWT based on project specific requirements for safety levels.

6.3.3 RELEASE OF BALLAST WATER INTO THE MARINE ENVIRONMENT

Most floating wind turbine substructures include ballast water. Usually ballast water is added or released during the initial T&I phase. However if a tow-in strategy for major O&M activities is followed, a regular re-adjustment of ballast due to system changes over time (e.g. marine growth, synthetic line creep, etc.) is performed, or non-isolated active ballast systems are implemented, ballast water may be released regularly in the environment by FOWTs.

Currently in the UK, any ballast water discharged from a ship into the marine environment shall be required to meet either the so-called D1 or D2 standard as established by the Ballast Water Management (BWM) Convention internationally on 2017. The BWM convention defines ship as a vessel of any type whatsoever operating in the aquatic environment and includes floating craft or floating platforms for offshore wind turbines.

Relevant to floating wind, there are several alternatives to either D1 or D2 requirements as described in MCA document titled 'Ballast Water Management FAQ' as of January 2021:

- Uptake and discharge of ballast water and sediments in the "same location" only, defined in the proposed UK regulations as within 1 nautical mile. No mixing of ballast water or sediments from another location is allowed.
- Pumping in the dry dock can be permitted, e.g. for maintenance, although disposal must be done on shore and managed appropriately.
- Ballast water reception facilities may be used, however there is no requirement for States or ports to provide these.
- 'Other Methods' may be discussed with MCA, to ultimately gain required approval from the International Maritime Organisation.
- The Convention allows exemption from D1/D2 in specific circumstances and the UK, through the MCA, will consider exemption applications, based on risk assessment and in line with Joint HELCOM/OSPAR Guidelines.

Ballast Water Management Convention

Note that, whilst scheduled for 2020, the UK has not yet ratified the Convention. However, the regulations have been drafted and the UK Government remains committed to acceding to the Convention and implementing it into UK law.

The **D1 – Ballast Water Exchange Standard** set by the BWM Convention states that ships undertaking ballast water exchange shall do so with an efficiency of at least 95% volumetric exchange of ballast water. For ships exchanging the ballast water by the pumping-through method, pumping through three times the volume of each ballast tank will be considered equivalent to meeting the 95% standard.

Ships undertaking ballast water exchange should conduct the operation at least 200 nautical miles from the nearest land and in water at least 200 meters deep; or in cases where the ship is unable to conduct ballast water exchange in accordance with the above, as far from the nearest land as possible, and in all cases at least 50 nautical miles from the nearest land and in water at least 200 meters deep.

In sea areas where the minimum distance and depth criteria cannot be met, the UK have the ability, within their waters, to designate BWE areas. Areas designated should be used in compliance with the terms of use stipulated by the UK government. Vessels may be required to deviate or delay their voyage in order to use the designated BWE area.

The **D2 – Ballast Water Performance Standard** stipulates the acceptable level of organisms that may be found within discharged ballast water. Chemical pollution from vessels is generally regulated by MARPOL, including ballasting. The D2 Standard specifies that treated and discharged ballast water must have:

1. Fewer than ten viable organisms greater than or equal to 50 micrometers in minimum dimension per cubic meter
2. Fewer than ten viable organisms less than 50 micrometers in minimum dimension and greater than or equal to 10 micrometers in minimum dimension per milliliter. In addition, a ballast water discharge of indicator microbes, as a health standard, shall not exceed the following specified concentrations:
   a. Toxicogenic Vibrio cholerae (O1 and O139) with less than one colony-forming unit (cfu) per 100 milliliters or less than 1 cfu per gram (wet weight) zooplankton samples
   b. Escherichia coli less than 250 cfu per 100 milliliters
   c. Intestinal Enterococci less than 100 cfu per 100 milliliters

Any floating platform that meets the D2 standard (usually through the use of a ballast water treatment system), can opt to meet D1, but it is recommended that any fitted equipment is operated. The use of ballast water exchange, which meets the D1 standard, as a management method will be replaced by a requirement for ballast water to meet the D2 discharge performance standard (usually through the use of a ballast water treatment system).

7 SUMMARY

This report provides a review of selected floating offshore wind related standards and guidelines, as well as UK specific laws, rules and regulations affecting the technical design of floating wind turbines. In offshore wind, technical standards are developed privately by classification bodies, by international or national consensus-based groups such as IEC, ISO or API, or as internal standards by larger companies. Standards are continuously updated living documents and their main purpose is to define common criteria for designs to meet defined safety levels. Further, national or international laws, rules and regulations also exist which affect aspects of the technical design.

This review focusses on selected governing floating wind standards with UK relevance, namely IEC TS 61400-3-2, ABS 195, BV NI572, DNVGL-ST-0119, DNVGL-RU-OU-0512 and LR Guidance Notes for Offshore Wind Farm Project Certification, as well as UK specific rules and regulations. Key results are summarized below:

Standards Review: The selected governing floating wind standards listed above are presented by providing overviews of the relevant referenced standards and their related main components (such as wind turbine, hull, mooring, anchor) or operational phase (such as T&I, O&M, decommissioning). The review also identifies general areas where standards differ such as the level of detail of the (dynamic) power cable. Gaps are identified related to explicit coverage of certain novel concept configurations (vertical axis systems, counterweight spars, single point moored weathervaning systems, multi-rotor concepts, etc.), some lack of explicit simulation requirements (e.g. on software calibration, simulation length, model fidelity, processes to apply global loads for local analysis, etc.), guidance on consistent application of wind and concrete construction standards, and guidance for tow-in or large offshore WTG component exchange operations. However, most of these gaps either relate to the current pre-commercial state of the industry and will be addressed as the industry matures, or are not explicitly covered because standards are not able to cover all possible variants or innovations currently under development. Overall, considering the status of the industry, standards are well developed and cover most relevant technical design aspects.

Project Certification and Classification: Project certification of an offshore wind project is formally not required in the UK but is usually performed within projects to fulfil finance, insurance or developer requirements. Project certification schemes are presented by way of example from IEC RE OD-502 and DNVGL-SE-0190.

UK Specific Regulations Affecting the Technical Design: The governing primary legislation behind all civil engineering work in the UK is the Health and Safety at Work etc. Act 1974 which was extended by the Health and Safety at Work etc. Act 1974 (Application outside Great Britain) Order 2013 to ensure “that health and safety legislation continues to apply to workers involved in offshore work activities on energy structures (e.g. wind farms) beyond the territorial sea”. This legislation determines that the Construction (Design and Management) Regulations 2015 (“CDM2015”) is applicable to all FOW structures. The Health and Safety Executive (HSE) governs compliance with CDM2015. Related to technical aspects, there exist UK-specific blade tip clearance (freeboard) requirements for FOW units (related to mast height and bird migration), mooring line ALS calculations for single extreme events shall be considered and ballast water discharge is regulated by the Ballast Water Management Convention.

APPENDIX A ABS ABBREVIATIONS LIST

Short name	Long name
ABS Anchor Notes	ABS Guidance Notes on Design and Installation of Drag Anchor and Plate Anchor
ABS Chain Guide	ABS Guide for Certification of Offshore Mooring Chain
ABS Class Rules	ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)
ABS CSurv Rules	ABS Rules for Survey After Construction (Part 7)
ABS FA Guide	ABS Guide for the Fatigue Assessment of Offshore Structures
ABS Fiber Notes	ABS Guidance Notes on the Application of Fiber Rope for Offshore Mooring
ABS FOWT Notes	ABS Guidance Notes on Global Performance Analysis for Floating Offshore Wind Turbines
ABS FPI Rules	ABS Rules for Building and Classing Floating Production Installations
ABS Inno Notes	ABS Guidance Notes on Review and Approval of Novel Concepts
ABS LRFD Guide	ABS Guide for Load and Resistance Factor Design (LRFD) Criteria for Offshore Structures
ABS Mat Rules	ABS Rules for Materials and Welding – Part 2
ABS MOU Rules	ABS Rules for Building and Classing Mobile Offshore Units
ABS MRMT Guide	ABS Guide for Surveys Based on Machinery Reliability and Maintenance Techniques
ABS MV Rules	ABS Marine Vessel Rules – ABS Rules for Building and Classing Marine Vessels
ABS NDI Guide	ABS Guide for Nondestructive Inspection
ABS OI Rules	ABS Rules for Building and Classing Offshore Installations
ABS OWT Guide	ABS Guide for Building and Classing Bottom-Founded Offshore Wind Turbine
ABS Pile Notes	ABS Guidance Notes on Design and Installation of Dynamically Installed Piles
ABS PMS Guide	ABS Guide for Position Mooring Systems
ABS RA Notes	ABS Guidance Notes on Risk Assessment Application for the Marine and Offshore Industries
ABS RBI Guide	ABS Guide for Risk-Based Inspection for Floating Offshore Installations
ABS Semi Notes	ABS Guidance Notes on Air Gap and Wave Impact Analysis for Semi-Submersibles
ABS USA Guide	ABS Guide for Buckling and Ultimate Strength Assessment for Offshore Structures

Table A-1: Abbreviation list of ABS standards

APPENDIX B RELEVANT NATIONAL AND INTERNATIONAL STANDARDS

Below national and international standards are relevant in floating wind specific standards.

ACI – American Concrete Institute

- ACI 213R – Guide for Structural Lightweight Aggregate Concrete
- ACI 301 – Specifications for Structural Concrete
- ACI 318 – Building Code Requirements for Structural Concrete
- ACI 357 – Guide for the Design and Construction of Fixed Offshore Concrete Structures
- ACI 359 – Code for Concrete Reactor Vessels and Containments

AISC – American Institute of Steel Construction

- Steel Construction Manual

API – American Petroleum Institute

- API RP 2A – Planning, Designing, and Constructing Fixed Offshore Platforms
- API RP 2FPS – Planning, Designing, and Constructing Floating Production Systems
- API RP 2MET – Derivation of metocean design and operating conditions
- API RP 2N – Planning, Designing, and Constructing Structures and Pipelines for Arctic Conditions
- API RP 2SK – Design and Analysis of Stationkeeping Systems for Floating Structures
- API RP 2T – Planning, Designing, and Constructing Tension Leg Platforms
- API RP 9B – Application Care, and use of Wire Rope for Oil Field Service
- API Spec. 9A – Specification for Wire Rope
- API Spec. 17J – Specification for Unbonded Flexible Pipe

ASTM – American Society for Testing and Materials

- ASTM C31 – Standard Practice for Making and Curing Concrete Test Specimens in the Field
- ASTM C39 – Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
- ASTM C94 – Standard Specification for Ready-Mixed Concrete
- ASTM C172 – Standard Practice for Sampling Freshly Mixed Concrete
- ASTM C330 – Standard Specification for Lightweight Aggregates for Structural Concrete
- ASTM G1 – Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens

AWS – American Welding Society

- AWS D1.1 – Structural Welding - Steel

BS – British Standards

- BS 7910 – Guide to methods for assessing the acceptability of flaws in metallic structures
- BS EN 10204 – Metallic materials – Types of inspection documents

EEMUA – The Engineering Equipment and Materials Users Association

- EEMUA Publication 194 – Guide to materials selection and corrosion control for subsea energy equipment

EN – European Standards / Norms

- EN 206 – Concrete – specification, performance, production and conformity
- EN 1537 – Execution of special geotechnical works – Ground anchors
- EN 1992-1-1 (Eurocode 2) – Design of concrete structures – General rules and rules for buildings
- EN 1992-2 (Eurocode 2) – Design of concrete structures – Concrete bridges – Design and detailing rules
- EN 1993-1-1 (Eurocode 3) – Design of steel structures – General rules and rules for buildings
- EN 1993-1-8 (Eurocode 3) – Design of steel structures – Design of joints
- EN 1997-1 (Eurocode 7) – Geotechnical design – General rules
- EN 50308 – Wind Turbines – Protective measures – Requirements for design, operation and maintenance
- EN ISO 14122-1 – Safety of machinery – Permanent means of access to machinery – Part 1: Choice of fixed means and general requirements of access
- EN ISO 14122-2 – Safety of machinery – Permanent means of access to machinery – Part 2: Working platforms and walkways
- EN ISO 14122-3 – Safety of machinery – Permanent means of access to machinery – Part 3: Stairs, stepladders and guard-rails
- EN ISO 14122-4 – Safety of machinery – Permanent means of access to machinery – Part 4: Fixed ladders

IACS – International Association of Classification Societies

- IACS UR Z78/MSC.1/Circ 1330 – Survey and Certification

IMO – International Maritime Organization

- IMO A765(18) – Guidelines on the Safety of Towed Ships and other Floating Objects, including Installations, Structures and Platforms at Sea
- IMO Circ.1023-MEPC/Circ.392 – Guidelines for Formal Safety Assessment
- IMO MODU Code - Code for the construction and equipment of Mobile Offshore Drilling Units
- IMO res. MSC.267(85) – Adoption of the International Code on Intact Stability
- IMO res. MSC 428(98) – Maritime Cyber Risk Management in Safety Management Systems
- IMO res. MSC/Circ. 884 – Guidelines for Safe Ocean Towing
- IMO res. MSC-FAL.1/Circ. 3 – Guidelines on Maritime Cyber Risk Management

ISO – International Organization for Standardization

- ISO 76 – Rolling bearings – Static load ratings
- ISO 281 – Rolling bearings – Dynamic load ratings and rating life
- ISO 898-1 – Mechanical properties of fasteners made of carbon steel and alloy steel – Pt. 1: Bolts, screws and studs with specified property classes – coarse thread and fine pitch thread
- ISO 2394 – General principles on reliability for structures
- ISO 2533 – Standard atmosphere
- ISO 6336 – Calculation of load capacity of spur and helical gears – Basic principles, introduction and general influence factors
- ISO 9001 – Quality management systems - Requirements
- ISO 9226 – Corrosion of metals and alloys – Corrosivity of atmospheres – Determination of corrosion rate of standard specimens for the evaluation of corrosivity
- ISO 11306 – Corrosion of metals and alloys – Guidelines for exposing and evaluating metals and alloys in surface sea water

- ISO 12482 – Cranes – Monitoring for crane working period
- ISO 12944-9 – Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Pt.9: Protective paint systems and laboratory performance test methods for offshore and related structures
- ISO 13628-5 – Petroleum and natural gas industries – Design and operation of subsea production systems – Pt.5: Subsea umbilicals
- ISO 19900 – Petroleum and natural gas industries – General requirements for offshore structures
- ISO 19901-1 – Petroleum and natural gas industries – Specific requirements for offshore structures – Pt. 1: Metocean design and operating considerations
- ISO 19901-2– Petroleum and natural gas industries – Specific requirements for offshore structures – Pt. 2: Seismic design procedures and criteria
- ISO 19901-4– Petroleum and natural gas industries – Specific requirements for offshore structures – Pt.4: Geotechnical and foundation design considerations
- ISO 19901-6– Petroleum and natural gas industries – Specific requirements for offshore structures – Pt. 6: Marine operations
- ISO 19901-7– Petroleum and natural gas industries – Specific requirements for offshore structures – Pt. 7: Stationkeeping systems for floating offshore structures and mobile offshore units
- ISO 19902 - Petroleum and natural gas industries –Fixed steel offshore structures
- ISO 19903 - Petroleum and natural gas industries –Concrete offshore structures
- ISO 19904-1 - Petroleum and natural gas industries –Floating offshore structures - Pt.1: Ship-shaped, semi-submersible, spar and shallow draught cylindrical structures
- ISO 19906 - Petroleum and natural gas industries – Arctic offshore structures
- ISO 29400 – Ships and marine technology – Offshore wind energy – Port and marine operations
- ISO/IEC 17020 – Conformity assessment – Requirements for the operation of various types of bodies performing inspection
- ISO/IEC 17021 – Conformity assessment – Requirements for bodies providing audit and certification of management systems – Pt.1: Requirements
- ISO/IEC 17025 – General requirements for the competence of testing and calibration laboratories

ITTC – International Towing Tank Conference

- ITTC Guideline 7.5-02-07-3.8 – Model tests for offshore wind turbines

NACE – National Association of Corrosion Engineers

- NACE SP0108 – Corrosion Control of Offshore Structures by Protective Coatings
- NACE SP0176 – Corrosion Control of Submerged Areas of Permanently Installed Steel Offshore Structures Associated with Petroleum Production

NORSOK – Norsk Sokkels Konkurranseposisjon

- NORSOK M-001 – Materials selection
- NORSOK N-004 – Design of steel structures
- NORSOK N-006 – Assessment of structural integrity for existing offshore load-bearing structures
- NORSOK M-501 – Surface preparation and protective coating

PTI – Post-Tensioning Institute

- PTI DC 35.1 – Recommendations for Prestressed Rock and Soil Anchors

APPENDIX C MAIN TECHNICAL ELEMENTS IN FOWT STANDARDS

ID	Package name	Clarification
1	General	The *General* package covers the information related to applicability of the standards on FOWTs and their stationkeeping systems as well as general requirements on the coupled wind turbine system mounted on a floating foundation.
2	Environmental and Soil Conditions	The *Environmental and Soil* conditions package includes all relevant requirements regarding environmental data including wind conditions including hurricane data, wave effects including extreme and breaking waves, water level variations, seismicity, current data, ice conditions, marine growth and soil related information as required in the design of floating offshore wind turbines.
3	Materials and Construction	The *Materials and Construction* package comprises all relevant guidances and requirements regarding material selection, material properties, impact of materials on the design of the structure, novel and special materials, quality control and material certificates and fabrication and construction related requirements.
4	Safety Levels and Safety Concepts	The *Safety Levels and Safety Concepts* package includes all information on the safety concept or safety philosophy underlying the standards and the general level of safety achieved by designing in accordance to the standards as well as robustness of the design.
5	Design Methods and Loads	The *Design Methods and Loads* package describes all aspects of the applied methodology used by the standards as a basis for the formulation design requirements. It also covers the definition of design loads and design load cases.
6	Fatigue Limit State	The *Fatigue Limit State* package includes the relevant information collected in the standards towards the required input data for FLS calculations, the requirements on the FLS design load cases and calculations and information on the applicable S-N curves.
7	Ultimate Limit State	The *Ultimate Limit State* package comprises all requirements regarding the required input data for ULS calculations, the requirements on the ULS design load cases and calculations and information on the load and material safety factors.
8	Serviceability and Accidental Limit State	The *Serviceability and Accidental Limit State* package contains all requirements regarding the required input data for SLS and ALS calculations, the requirements on the SLS and ALS design load cases and calculations and information on the load and material safety factors for these calculations.

ID	Package name	Clarification
9	Stability	The *Stability* package includes the information related to hydrostatic and hydrodynamic stability of the foundation during transport, installation and operational states for intact and damage conditions.
10	Corrosion Protection and Control System	The *Corrosion Protection and Control System* package covers two items related to structural integrity of the FOWT. Both the corrosion protection system including its design and functional requirements as well as the control system of the hull and the stationkeeping system including active ballast water systems and SHM are part of it.
11	Wind Turbine	The *Wind Turbine* package contains the information related to floating wind specific requirements on the wind turbine including the tower and the wind turbine control system.
12	Mechanical and Electrical Equipment	The *Mechanical and Electrical Equipment* package comprises the requirements on secondary mechanical and electrical equipment on the floating foundations as e.g. lightning protection, cranes and mooring equipment.
13	Power Cable	The *Power Cable* package includes those guidances and requirements regarding floating wind specific power cable design, impact of the power cable on other parts of the structure, cable technical principles, cable related operational requirements and implications of the power cable on the structural interconnection to the hull and the I-Tube/J-Tube.
14	Stationkeeping System and Anchor	The *Stationkeeping System and Anchor* package covers the requirements on the design of the stationkeeping systems and the anchors.
15	Transport and Installation	The *Transport and Installation* package contains all requirements related to the transport of the assembled structure or components of it and the installation of the units.
16	Commissioning, Surveys and O&M	The *Commissioning, Surveys and O&M* package includes the relevant requirements during the commissioning phase, requirements on surveys and inspections and requirements applying on operational and maintenance activities.
17	Decommissioning	The *Decommissioning* package includes the requirements regarding the decommissioning of the FOWT.
18	Other	The *Other* package includes requirements on specific secondary components of a FOWT as piping systems including bilge and ballast systems, the helicopter deck, fire fighting systems, NavAids, guard and hand rails and floorings.

Table C-1: Overview of technical packages considered in the gap analysis

FLOATING OFFSHORE WIND CENTRE OF EXCELLENCE

Delivered by CATAPULT Offshore Renewable Energy

CONTACT US

ore.catapult.org.uk
info@ore.catapult.org.uk

ENGAGE WITH US

GLASGOW

Inovo
121 George Street
Glasgow
G1 1RD

T +44 (0)333 004 1400

BLYTH

National Renewable Energy Centre Offshore House
Albert Street
Blyth, Northumberland
NE24 1LZ

T +44 (0)1670 359 555

LEVENMOUTH

Fife Renewables Innovation Centre (FRIC)
Ajax Way
Leven
KY8 3RS

T +44 (0)1670 359 555

HULL

O&M Centre of Excellence
Ergo Centre
Bridgehead Business Park
Meadow Road, Hessle
HU13 0GD

ABERDEEN

Subsea UK
30 Abercrombie Court
Prospect Road, Westhill
Aberdeenshire
AB32 6FE

CORNWALL

Hayle Marine Renewables Business Park
North Quay
Hayle, Cornwall
TR27 4DD

PEMBROKESHIRE

MEECE
Pembroke Dock
Pembrokeshire
South West Wales

CHINA

11th Floor, Lan Se Zhi Gu No.5
Ke Ji Avenue, Hit-Tech Zone
Yantai City
Shandong Province
China