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ACP Offshore Compliance Recommended Practices (OCRP) Edition 2: Amendment 1

June 2022 (Am. 20XX)

AMERICAN CLEAN POWER ASSOCIATION

Wind Technical Standards Committee

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The most important part of this U.S. offshore wind standards development effort, the expert technical information that was shared and documented in these RPs, was provided through time and effort from over 300 volunteers and the many dozens of organizations that supported their efforts. However, additional appreciation is extended towards those organizations that provided the resources that enabled the working groups to assemble and these documents to be written independently, following American National Standards (ANS) process, while maintaining a strong and consistent organizational and administrative structure throughout the three-year process.

ACP Offshore Wind Subcommittee Members – We would like to extend our extreme gratitude to the general membership of the ACP Offshore Wind Subcommittee, a subcommittee under the ACP Wind Technical Standards Committee. The subcommittee was responsible for providing technical input and advice on the draft documents and advising on future directions. Each draft was reviewed by the subcommittee members prior to formal reviews that were conducted as part of the ACP/ANSI review process.

Working Group Chairs – We would also like to recognize the chairs of each of the working groups who volunteered their time to ensure each of the documents was published on time and with high quality. The chairs organized and edited their respective recommended practices documents, but also served as members of the ACP Offshore Wind Subcommittee. We are extremely grateful to the following individuals who devoted their time and effort to make these RPs possible:

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FOREWORD

The Foreword section is included with this document for information purposes only and is not part of the American Clean Power Association (ACP) ACP OCRP-1-2022 *Offshore Compliance Edition 2: Amendment 1*.

The regulatory framework for the U.S. offshore wind industry has been under development for well over a decade, but the first commercial projects are just making their way through the process now[1]. In 2005, the United States Department of the Interior (DOI) was given authority, under the Energy Policy Act of 2005 (EPAct 2005), to grant leases on the Outer Continental Shelf (OCS) for offshore renewables and to promulgate any necessary regulations needed to ensure safe and orderly deployments. Under this authority DOI delegated this responsibility to the Minerals Management Service (MMS). The MMS was later reorganized (2010 – 2012) to create the current regulatory agencies, the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE). In 2009, MMS published 30 CFR 585, which are the first federal regulations governing the development of offshore wind facilities. It outlines a process spanning a typical offshore wind project (cradle to grave), from competitive leasing of the OCS and gaining site control, to permitting, commercial operations planning, facility design, fabrication and installation, commissioning, operations and inspection, all the way through decommissioning. In the initial version of the 30 CFR regulation, no specific standards are incorporated by reference. The regulation requires “best practices” be used, with the intent that best practices would eventually evolve from industry experience as it matured.

To that end, from 2009 to 2012, the U.S. offshore wind industry, in collaboration with MMS/BOEM, the National Renewable Energy Laboratory (NREL) the U.S. Department of Energy (DOE), and the American Wind Energy Association (AWEA), developed a roadmap from existing standards to facilitate the definition of “best practices”, which was titled *AWEA Offshore Compliance Recommended Practice (OCRP) 2012*. Over 50 members of the offshore wind industry participated in the development of *AWEA OCRP 2012* which covers all aspects of fixed-bottom offshore wind facility development, starting with the design phase through to decommissioning. It refers to over 100 standards, guidelines, and technical specifications. After its publication in October 2012, it became the *de facto* reference for offshore wind development in the United States and has been used as an informative framework for regulators, developers, and certified verification agents.

However, for several reasons, AWEA OCRP 2012 no longer adequately addresses the regulatory requirements for BOEM/BSEE and the offshore wind development community. In September 2017, the AWEA Wind Standards Committee (later renamed the ACP Wind Technical Standards Committee) voted to approve the formation of the Offshore Wind Subcommittee to oversee the development of this initiative. This subcommittee was formed under the leadership of Walt Musial, Principal Engineer at NREL. At their first meeting on October 23, 2017, five working groups were formed to address the AWEA OCRP 2012 deficiencies. These working groups include:

- Working Group 1 – ACP OCRP-1 *ACP Offshore Compliance Recommended Practices (OCRP) Edition 2* under the leadership of Rain Byars and Graham Cranston.
- Working Group 2 – ACP OCRP-2 *ACP U.S. Floating Wind Systems Recommended Practices* under the leadership of Lars Samuelsson and Leif Delp.
- Working Group 3 – ACP OCRP-3 *ACP U.S. Offshore Wind Metocean Conditions Characterization Recommended Practices* under the leadership of Mike Drunsic and Lorry Wagner.
- Working Group 4 – ACP OCRP-4 *ACP U.S. Recommended Practices for Geotechnical and Geophysical Investigations and Design* under the leadership of Matt Palmer and Mathieu Guinard.

[1] Cape Wind, the first offshore wind project in the United States, received notice of COP approval and notice of no objections to FDR/FIR in September 2014. The project requested a lease suspension in 2015 due to difficulty obtaining project financing. Cape Wind relinquished its lease in 2017.

- Working Group 5 – ACP OCRP-5 *ACP Recommended Practices for Submarine Cables* under the leadership of Georg Engelmann and Bob Hobson.

These dedicated and qualified industry leaders each assembled a diverse group of subject matter experts in their respective working groups. All told, over 300 members of the U.S. offshore wind industry participated in this initiative.

Each Recommended Practice (RP) provides a roadmap for U.S. offshore wind development in its respective area with a view toward adding transparency and consistency to the regulatory approval process, to the benefit of developers, regulators, and the general public.

Although these five RP documents were written independently by their respective working groups, a significant effort was made to coordinate the technical interfaces. As such, they are intended to be used as a set. The governing RP was written by Working Group 1 – ACP OCRP-1-2022 *ACP Offshore Compliance Recommended Practices (OCRP) Edition 2*. This document supersedes original *AWEA OCRP 2012* document and, in several areas, refers directly to the companion RP documents from Working Groups 2 through 5. Similarly, the companion RP documents refer back to the governing ACP OCRP-1 document.

It is the expectation of all who participated in this important standards development process that this comprehensive set of RP documents will clarify the complexities of offshore wind development in the U.S. while providing clarity for all stakeholders and, in doing so, will help lower offshore wind energy costs and increase worker safety for the public good.

Editorial Note

ACP OCRP-1 (Edition 2) represents a major update from AWEA OCRP 2012. In addition to a review and update of referenced standards throughout the document, significant structural changes and content updates were made.

- Organized the chapters by lifecycle of the offshore windfarm:
  - Design of Offshore Wind Farm Assets (corresponding to Structural Reliability in the 2012 edition);
  - Manufacturing and Fabrication;
  - Transport and Installation;
  - Operations and In-Service Inspections;
  - Life Cycle Plan (corresponding to Decommissioning in the 2012 edition)
- and subchapters by asset:
  - Offshore Wind Turbine (including the rotor-nacelle assembly, tower, and sub-structure);
  - Offshore Substation;
  - Subsea Cables (by reference to ACP OCRP-5).
- Removed the chapter *Normative References* because it was deemed inappropriate for a Recommended Practice.
- Removed the chapters *Qualification Testing and Safety Management System*, *Safety Equipment*, and *Navigational Aids* and incorporated relevant content into the other chapters.
- Removed the Annexes, and incorporated relevant content into the body of the text.
- Updated the references to standards, guidelines, and regulations throughout the document, and updated the Chapter *Complete References* to include all documents referred to in the body of the text and remove documents which were not referred to in the body of the text.

Within the chapters, the following updates were made:

- In *Design for Offshore Wind Farm Assets*, guidance on development and application of a Design Basis was added. Electrical system sections were expanded and content was added to address specific aspects of electrical system design for the offshore wind turbine and offshore substation. Content was added on testing and approval of electrical system design as well as interfaces between electrical systems with different code bases. Sections providing guidance on design for occupational health and safety were added. The content on loads and structural design were extensively updated, adding relevant reference standards and clarifying the application of exposure categories to offshore wind farm assets. Guidance was expanded for design of steel and concrete structures.

- In *Transport and Installation*, guidance was added on site specific installation planning, as well as incorporating health, safety, and environmental considerations into installation planning. Content was added to address work at the project port, and development of manuals and documentation. Content on environmental conditions was updated. Guidance on installation of offshore substations was expanded, as was guidance on load-out and sea-fastening.
- In *Operations and In-Service Inspections*, guidance was updated for in-service inspections and post-event inspections, as well as for condition monitoring.
- In *Life Cycle Plan*, content was expanded from decommissioning to address life extension, repowering, and alternate use. Guidance on reporting was added, and guidance on developing the decommissioning plan was updated.

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1 Scope

This document applies to offshore wind farm assets that extract kinetic energy from wind, transmit electricity to the grid, and/or store energy using facilities or devices located offshore or on land. The scope includes wind farm assets that may potentially be installed in state and federal waters in the contiguous U.S., Alaska, and Hawaii, including inland bodies of water such as the Great Lakes. The scope includes wind farm assets installed in salt or fresh water with a rotor swept area greater than 200 m^2. The scope includes the design, manufacturing, installation, commissioning, operation and service, decommissioning, and re-powering within the project life-cycle of a wind farm. The equipment covered in the scope shall include rotor-nacelle assemblies, towers, substructures, foundations, offshore substations, inter-array and export cables (by reference to ACP OCRP-5 Recommended Practices for Submarine Cables), measurement and monitoring equipment, and any other permanently installed auxiliary platforms or equipment.

The initial planning activities for offshore wind facilities, which include site development, ecological issues, socio-economic issues, and other leasing and permitting issues, are not covered by this document. This document is not intended to address land-based wind turbines; or service, installation, or survey vessels. Floating wind farm assets are included by reference to ACP OCRP-2 *U.S. Floating Wind Systems Recommended Practices*. Where the guidance for floating wind farm structures in ACP OCRP-2 conflicts with this document, ACP OCRP-2 shall govern.

This consensus document points to national and international codes and standards that are applicable for use in the U.S. It addresses many unique U.S. issues including hurricanes and safety regulations, but may not provide comprehensive treatment in all areas. In areas where existing codes and standards do not provide adequate guidance, or require adjustment or modifications, the document attempts to provide clarifications or deviations to fill specific gaps. Chapter 10 describes some of these gaps and the effort necessary to fill the gaps.

2 General

This chapter includes general information, background, and other guidance useful to interpret and implement the recommended practices contained in this document.

2.1 Note on State and Federal Waters

This document covers offshore wind farm assets in U.S waters, which includes federal and state waters. Users should be aware that assets installed in state waters may be subject to additional regulations not detailed in this document. Nothing in this document relieves any party from complying with requirements in U.S. state and federal regulations, including occupational health and safety regulations.

2.2 Applicable Version of Reference Standards

Where a reference is given to a document without a specific year or edition, the most recent published edition of that document should be considered the intended reference. In these cases, references to chapters or sections of the referenced document may change with subsequent editions. Where a reference is given to a document with a specific year or edition, only that version of the document should be used.

2.3 Use of Language Giving Direction

In this document and in accordance with the latest edition of the ISO/IEC Directives, Part 2, the following verbal forms are used:

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- 'can' and 'cannot' are used for statements of possibility and capability, whether material, physical, or causal.

Where documents are referenced without use of these terms, it is implied that the reader may use these documents for guidance.

In this document, the term "codes and standards" is used to refer collectively to regulations, codes, standards, specifications, requirements, recommended practices, and guidelines. However, individual documents are referred to by the title given by their authors.

2.4 Discussion of roles of PE, CVA, and MWS

The information in this section is included for context and information only. It is not intended to establish requirements, and should not be a substitute for understanding and complying with applicable regulations.

Professional Engineer

The practice of engineering is regulated through Boards of Professional Engineering which are appointed by individual U.S. states. Engineers must be licensed through a state board in order to perform public or private work which requires engineering training, education, and experience. An individual who has met the licensing requirements of a state board – including successful testing, evidence of experience, professional recommendations, and ongoing education – may maintain their status as a licensed Professional Engineer (P.E.), and may perform and/or direct engineering work in accordance with the regulations of that state. A P.E. must follow strict professional and ethical rules as issued by the Board granting the license, and must not perform work outside of their qualifications. Failure to follow these rules can result in consequences for the P.E. including loss of license, fines, or criminal penalties. Each P.E. is assigned a unique license number, and status of license and good standing may be verified through a public database.

Construction drawings and design calculations submitted to regulators for project construction approval are typically required to be stamped by a P.E. For portions of the offshore wind project located onshore or in state waters, the engineer of record (EOR) is expected to be licensed in the state where the facilities will be used, installed, or operated. For portions of the offshore wind project located in federal waters, it is generally understood that licensing by any state will be accepted by the federal regulator.

Certified Verification Agent

30 CFR ~~585~~ 285 requires the project developer to use a Certified Verification Agent (CVA) to conduct an independent assessment of the design of the facility as well as the fabrication and installation activities. The CVA is nominated by the project developer and is subject to approval by the regulator based on criteria that include technical capabilities, experience, personnel qualifications, global presence, financial stability, and track record, and the specific verification plan for the proposed project.

The CVA reviews design documentation, fabrication drawings and specifications, and installation plans, which are all included in the Facility Design Report (FDR) and the Fabrication and Installation Report (FIR). The CVA certifies in a report that the facility is designed to withstand the environmental and functional load conditions appropriate for the intended service life at the proposed location. This includes evaluation of any aspects of the design that deviate from standard practice and/or requirements. The CVA also monitors the fabrication and installation activities through periodic on-site inspections and certifies in a report that the project is fabricated and installed in accordance with accepted engineering practices, the Construction and Operations Plan (COP), and the FDR/FIR.

The CVA must use good engineering judgement and practices in conducting their independent assessment. Further, 30 CFR ~~585~~285.706(d) requires that work performed by the CVA must be conducted by or under the direct supervision of a registered P.E.

Marine Warranty Surveyor

A Marine Warranty Surveyor (MWS) is normally engaged during the design and execution phases of project development, with their main focus being the transportation and installation phase. The MWS is normally employed by the project developer, and works to manage marine operational risk on behalf of the insurance underwriters, project developers, and financial investors. The risks during offshore construction carry high consequences to safety for the project assets, project personnel, and the public. Therefore, the MWS is required to have specific experience and expertise related to offshore construction activities and marine operations.

The MWS reviews and approves the transportation and installation plans to ensure that they comply with industry recognized engineering standards, and that they employ best practice for safe offshore operations.

Overlap and Interfaces

The CVA and MWS will primarily review and verify the work product issued by the EOR on behalf of the developer. Document transmittal, schedule coordination, and technical clarification calls and emails will be standard methods of interface. The EOR, CVA, and MWS often participate in common meetings related to the execution phase of the project development.

During offshore operations, the CVA and MWS review and inspection will naturally have some overlap. Coordination between the CVA and MWS is encouraged to enable both parties to have a full view of the project activities and risks, and also to avoid duplication of effort. However, the participation of an MWS and CVA does not relieve either party of its duties during any portion of the offshore activities.

2.5 Environmental, Health and Safety

The topics of environment, health, and safety for U.S. wind farms are addressed by the ACP Wind Environmental, Health, and Safety Standards Committee. This document includes recommended practices for design features and activity planning which will support implementation of occupational health and safety processes and environmental protection during construction and operation.

2.6 Hierarchy of Codes and Standards

The design, fabrication, installation, commissioning, operation, and eventual decommissioning of wind farms requires the use of codes and standards from multiple sources. The overarching code hierarchy that should be followed is ranked as follows:

1. Applicable U.S. legislation and regulations and lease requirements
2. Codes and standards identified by this document (ACP OCRP-1) as best practice
3. U.S. codes and standards
4. International codes and standards (e.g. ISO and IEC)
5. Codes and standards and recommended practices from class societies

3 Terms and Definitions

For the purposes of this document, the following terms and definitions apply. Definitions are aligned with IEC 61400-1 and IEC 61400-3-1 wherever possible.

The components of a fixed offshore wind turbine are shown in Figure 1. The components of a floating offshore wind turbine are shown in Figure 2.

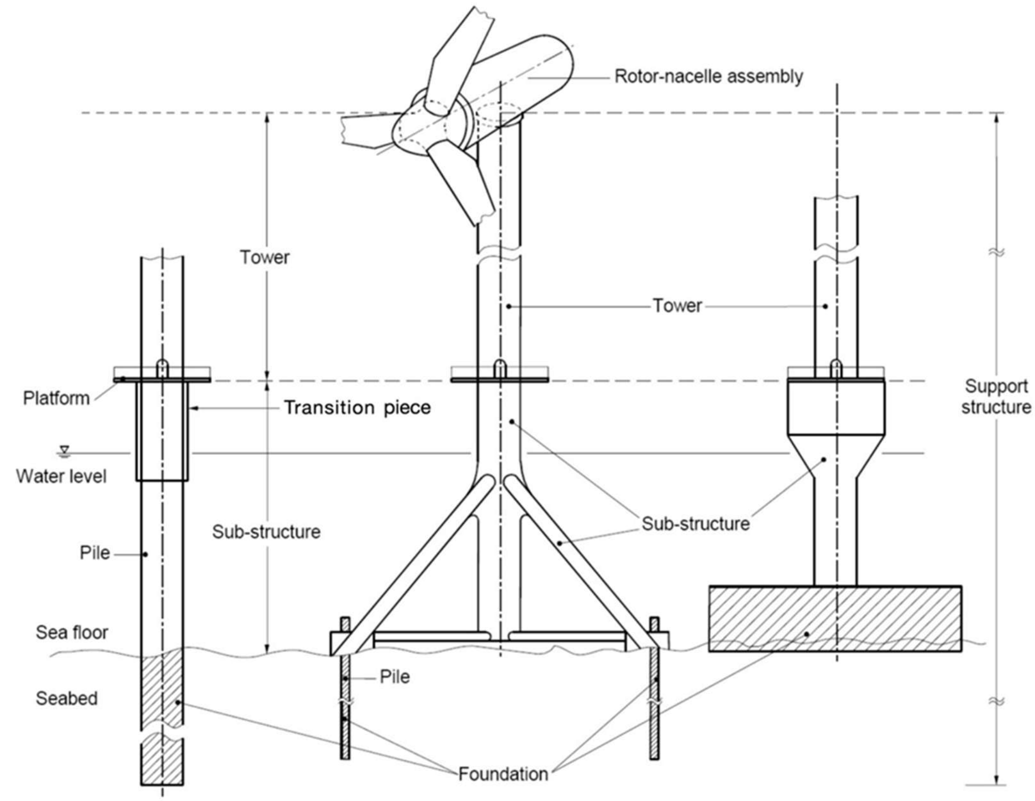
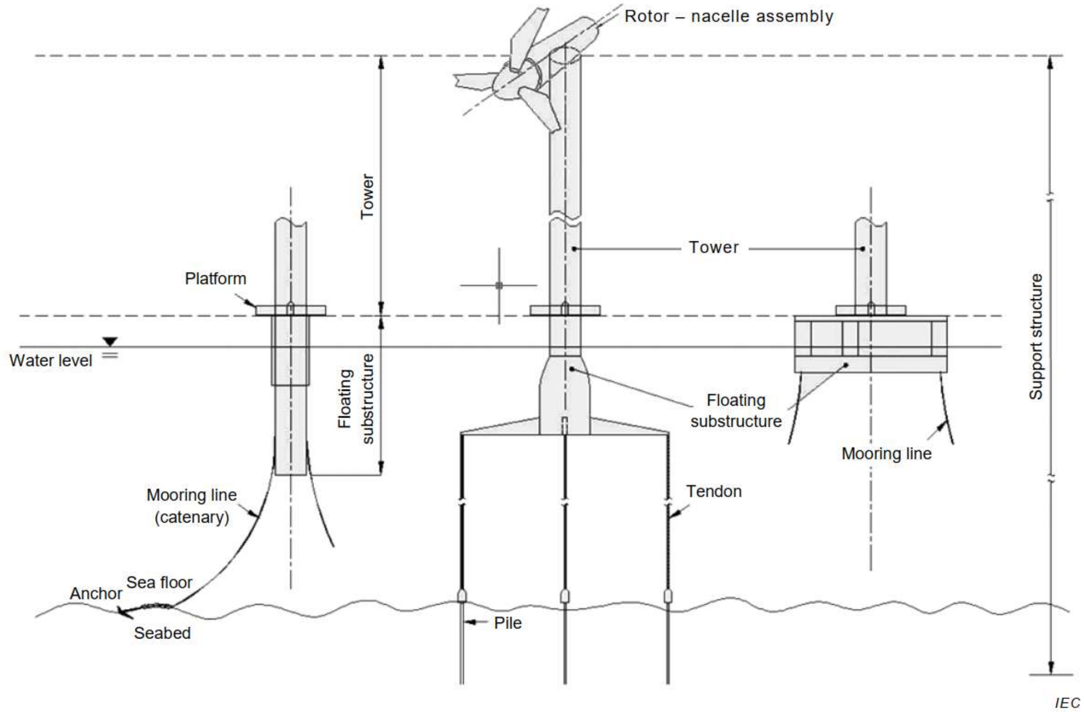


Figure 1 Parts of a fixed offshore wind turbine (Source: Adapted from IEC 61400-3-1)



From left to right: Spar, TLP, and Semi.

~~icing~~

Figure 2 Parts of a floating offshore wind turbine (Source: Adapted from IEC 61400-3-2)

Term	Definition
air gap	Clearance between the highest water surface that occurs during the extreme environmental conditions and the lowest exposed part not designed to withstand wave impingement.
accreditation	Procedure by which an authoritative body gives formal recognition that a body is impartial and technically competent to carry out specific tasks such as certification, tests, specific types of tests, etc.
array cables	Submarine cable conducting power generated by an offshore wind turbine either between turbines or to a substation, as part of the power collection system.
as low as reasonably practicable (ALARP)	The principle that the quantum of residual risk for an activity has been weighed against the sacrifice of money, time, or trouble involved in the measures necessary for averting the risk.
basic insulation levels	The minimum voltage rating of the insulation of electrical equipment.
bulk power system	Facilities and control systems necessary for operating an interconnected electric energy transmission network (or any portion thereof); and electric energy from generation facilities needed to maintain transmission system reliability (see NERC Glossary of Terms).
certification body	Body that performs conformity assessment services, also called conformity assessment body.
certified verification agent (CVA)	An individual or organization, experienced in the design, fabrication, and installation of offshore marine facilities or structures, who will conduct specified third-party reviews, inspections, and verifications in accordance with 30 CFR ~~585~~285.

Term	Definition
corrosion allowance	Extra wall thickness added during design to compensate for any reduction in wall thickness by corrosion (externally and internally) during design life.
critical safety systems and equipment	safety systems and equipment designed to prevent or ameliorate fires, spillages, or other major accidents that could result in harm to health, safety, or the environment in the area of ~~your~~offshore facilities (per 30 CFR 285.112)
design lifetime	The period of time defined in the design basis as the intended minimum useful lifetime of a wind farm component, spanning from the time of installation to the time of decommissioning.
design wave	Deterministic wave with a defined height, period, and direction used for the design of an offshore structure; a design wave may be accompanied by a requirement for the use of a particular periodic wave theory.
designer	Party or parties responsible for the design of an offshore wind turbine or other assets of an offshore wind farm (e.g., offshore substations, cables).
developer	Party or parties responsible for the permitting, planning, design, construction, and commissioning of offshore wind facilities.
dry tow	Transport of objects that are either loaded onto a barge with propulsion provided by tugs or onto self-propelled vessels that may also be semi-submersible during loading and discharge.
environmental conditions	Characteristics of the physical environment (wind, waves, sea currents, water level, sea/lake ice, marine growth, scour and overall seabed movement, etc.) that may affect the offshore wind farm.
export cables	Submarine cable(s) conducting power to shore or to an offshore transmission grid for distribution to the land-based electric grid, as part of the power collection system.
external conditions	External factors affecting the operation of offshore wind farm assets6including the environmental conditions, the electrical network conditions, and other climatic factors (e.g., temperature, snow, ice, etc.).
failure mode and effects analysis (FMEA)	The process of reviewing as many components, assemblies, and subsystems as possible to identify potential failure modes in a system and their causes and effects.
feeder solution	Installation methodology where offshore wind farm assets are transported between a loadout port and an installation vessel at the offshore installation site by secondary vessels.
fetch solution (also referred to as the 'transit solution')	Installation methodology where offshore wind farm assets are loaded directly onto an installation vessel at the loadout port and transported to offshore installation sites, where they are then installed.
foundation	Part of a support structure that transfers the loads acting on the sub-structure into the seabed (see Figure 1).
less-flammable liquid	A liquid used for insulation in a transformer having a fire point above 300 degrees C. This corresponds to a class K liquid according to IEC 61039.
manufacturer	Party or parties responsible for the manufacture and construction of an offshore wind turbine or other assets of an offshore wind farm (e.g., offshore substations, cables).

Term	Definition
marine growth	Surface coating on structural components caused by plants, animals, and bacteria.
marine warranty surveyor (MWS)	An individual or organization who provides independent third-party technical review and approval of high value and/or high-risk marine construction and transportation project operations, from the planning stages through to the physical execution.
mean sea level	Average level of the sea over a period of time long enough to remove variations due to waves, tides, and storm surges.
mean zero crossing period	Average period of the zero-crossing (up or down) waves in a sea state. Relations may exist between mean zero crossing period and peak period.
metocean	Abbreviation of meteorological and oceanographic. Oceanographic is sometimes referred to as “marine” in IEC and other documents.
offshore wind turbine	Rotor-nacelle assembly and support structure, located offshore.
offshore wind turbine site	The location or intended location of an individual offshore wind turbine either alone or within a wind farm.
personal protective equipment	Equipment worn to minimize exposure to a variety of hazards, such as gloves, foot and eye protection, protective hearing devices (earplugs, muffs) hard hats, personal fall protection (harness and lanyard), respirators, or full body suits
pile penetration	Vertical distance from the sea floor to the bottom of the pile.
power collection system	Electric system that collects the power from one or more wind turbines. The power collection system includes all electrical equipment connected between the wind turbine terminals and the network connection point. For offshore wind farms, the power collection system may include the connection to shore.
quay	A structure on the shore of a harbor where vessels dock to load and unload cargo.
rotor-nacelle assembly	Part of an offshore wind turbine carried by the support structure (see Figure 1).
run-up	The rush of water up a structure resulting from incident waves impacting a structure.
sea floor	Interface between the sea and the seabed.
sea state	Condition of the sea in which its statistics remain stationary.
seabed	Materials below the sea floor in which a support structure is founded.
seabed movement	Movement of the seabed due to natural geological and hydrodynamic processes.
scour	Removal of seabed soils by currents and waves or caused by structural elements interrupting the natural flow regime above the sea floor.
significant wave height	Statistical measure of the height of waves in a sea state, defined as either the average height of the highest one third of the zero up-crossing waves or as 4 xσ_η where σ_η is the standard deviation of the sea surface elevation. The former height is called the statistical wave height (usually denoted $H_{1/3}$, while the latter height is called the spectral significant wave height (denoted by H_s or H_{m0}). In deep water, $H_{1/3} \approx 0.956H_s$ regardless of wave spectral form (ISO 21650).

Term	Definition
splash zone	External region of support structure that is frequently wetted due to waves and tidal variations. Refer to the specific reference documents used in the design for the definition of the extent of the splash zone.
still water level	Abstract water level calculated by including the effects of tides and storm surge but excluding variations due to waves; still water level can be above, at, or below mean sea level.
storm surge	Change in water level caused by atmospheric change and/or wind associated with a storm.
sub-structure	Part of an offshore wind turbine or offshore substation support structure that extends upwards from the seabed and connects the foundation to the tower (see Figure 1) or topside.
support structure	Part of an offshore wind turbine consisting of the tower, sub-structure, and foundation (see Figure 1). For the offshore substation the support structure is the sub-structure and the foundation.
tides	Regular and predictable movements of the sea generated by astronomical forces.
tower	Part of an offshore wind turbine support structure which connects the sub-structure to the rotor-nacelle assembly (see Figure 1).
transition piece	Part of an offshore wind turbine sub-structure, particularly a monopile, that may be used to provide a connection between the tower and the sub-structure pile (see Figure 1).
tropical cyclone	Closed atmospheric or oceanic circulation around a zone of low pressure that originates over the tropical oceans. A tropical cyclone is classified as a tropical depression, tropical storm, or hurricane based on wind speed (see API RP 2MET for additional information).
type certification	Procedure by which a certification body gives written assurance that a wind turbine type conforms to specified requirements (see IECRE OD-501).
useful life	The period of time that equipment is economically viable and can be operated safely considering its current condition.
water current	Flow of water past a fixed location, usually described in terms of a current speed and direction.
water depth	Vertical distance between the sea floor and the still water level.
wave crest elevation	Vertical distance between the crest of a wave and the still water level.
wave direction	Mean direction from which the wave is traveling.
wave height	Vertical distance between the highest and lowest points on the water surface of an individual zero up-crossing wave.
wet tow	Transport of floating objects that are supported by their own buoyancy, including floating or submerged pipes or similar, with propulsion provided by secondary vessels such as tugs.
zero up-crossing wave	Portion of a time history of wave elevation between zero up-crossings; a zero up-crossing occurs when the sea surface rises (rather than falls) through the still water level.

4 Symbols and Abbreviated Terms

For the purposes of this document, the following symbols and abbreviated terms apply in addition to those stated in IEC 61400-1:

4.1 Symbols and Units

kV	kilovolt(s)

4.2 Abbreviations and Acronyms

ABS	American Bureau of Shipping
AC	alternating current
ACI	American Concrete Institute
AHC	active heave compensated
AISC	American Institute of Steel Construction
ALARP	as low as reasonably practicable
ALS	accidental limit state
ANSI	American National Standards Institute
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
ASD	allowable stress design
ASME	American Society of Mechanical Engineers
ASSE	American Society of Safety Engineers
ACP	American Clean Power Association
AWS	American Welding Society
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CFR	Code of Federal Regulations
CIGRE	International Council on Large Electric Systems
CMS	condition monitoring system
CMPT	Center for Marine and Petroleum Technology
CoA	Certificate of Approval
COP	Construction and Operations Plan
COV	coefficient of variation
CSSE	critical safety systems and equipment
CVA	certified verification agent
DC	direct current
DNV	Det Norske Veritas
DP	dynamic positioning

EHS	environmental health and safety
EMC	electromagnetic compatibility
EN	European Standards
EOR	engineer of record
FAA	Federal Aviation Administration
FDR	facility design report
FIR	fabrication and installation report
FLS	fatigue limit state
FMEA	failure mode and effects analysis
GBS	gravity based structure
HAZID	hazard identification study
HAZOP	hazard and operability study
HSAC	Helicopter Safety Advisory Conference
HVAC	high-voltage alternating current
HVDC	high-voltage direct current
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICEA	Insulated Cable Engineers Association
ICPC	International Cable Protection Committee
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMCA	International Marine Contractors Association
ISEA	International Safety Equipment Association
ISIP	in-service inspection plan
ISO	International Standards Organization
LRFD	load and resistance factor design
MCC	marine coordination center
MWS	marine warranty surveyor
NDE	non-destructive examination
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NESC	National Electrical Safety Code
NERC	North American Electric Reliability Corporation
NFPA	National Fire Protection Association
NMS	noise mitigation system
NREL	National Renewable Energy Laboratory
OCS	outer continental shelf

OEM	original equipment manufacturer
OSHA	Occupational Safety and Health Administration
OSS	offshore substation
PCI	Precast/Prestressed Concrete Institute
PE	professional engineer
PPE	Personal Protective Equipment
RAMS	risk assessment method statement
RNA	rotor nacelle assembly
ROV	remotely operated underwater vehicle
RP	recommended practice
RUK	Renewable UK
SAP	site assessment plan
SCADA	supervisory control and data acquisition
SIMOPS	simultaneous operations
SLS	service limit state
SMS	safety management system
SSA	site specific assessment
TA&R	technology assessment & research
UL	Underwriters Laboratory
ULS	ultimate limit state
U.S.	United States of America
USCG	United States Coast Guard
UXO	unexploded ordinance
WSD	working stress design
WTG	wind turbine generator

5 Design of Offshore Wind Farm Assets

5.1 General

The present chapter covers design of offshore wind farm assets in U.S. waters. This, in general, includes rotor-nacelle assemblies (RNAs), towers, sub-structures, foundations, offshore substations (OSSs), inter-array and export cables (by reference to ACP OCRP-5 *Recommended Practices for Submarine Cables*), permanent measurement and monitoring equipment, and any other permanently installed auxiliary platforms or equipment. For floating wind farm structures, refer also to ACP OCRP-2 *US Floating Wind Systems Recommended Practices*. Where the guidance for floating wind farm structures in ACP OCRP-2 conflicts with this document, ACP OCRP-2 shall govern.

The designer should be aware that assets installed in state waters may be subject to additional regulations not detailed in this document. Nothing in this chapter relieves the designer from complying with design requirements in U.S. state and federal regulations, including occupational health and safety regulations.

5.2 Hierarchy of Codes and Standards

Designers of offshore wind farm assets should endeavor to determine and select, with a certified verification agent (CVA), certification body, and/or regulatory authority approval, a consistent codes and standards hierarchy that meets their requirements.

The overarching code hierarchy is provided in section 2.6.

5.2.1 Design Basis Approach Toward the Selection of Standards

Where design requirements are not covered by U.S. legislation and regulations or codes and standards recommended by this document, then the use of accepted industry standards shall be applied in the design.

The selection and application of these standards should follow the design basis approach described in Attachment C of the BOEM Information Guidelines for a Renewable Energy Construction and Operations Plan (COP), which consists of the following:

- Establishment of a design basis including a hierarchy of the codes and standards applied in the design of the offshore wind farm assets
- Justification for why the applied codes and standards are appropriate

The design basis does not need to be common for all wind farm assets and can be established separately for the offshore wind turbine, OSS, and cables. Code systems are internally calibrated; code mixing for a specific asset should be avoided as this might lead to an unknown safety level. If standards from different code and standards systems are mixed it should be justified that the intended safety level is achieved.

In general, codes and standards commonly applied to onshore wind farms installed in the U.S., offshore structures installed in the U.S., and offshore wind farms installed globally contribute to the state-of-the art for offshore wind in U.S. waters. If the design basis lists international codes and standards as a substitute for commonly applied U.S. codes and standards, the designer shall justify that the substitution satisfies the objectives of the U.S. codes and standards, especially with respect to environment, health, and safety. This document provides guidance on selecting appropriate codes and standards to form the project design basis.

5.3 Exposure Categories

The exposure category of an offshore structure is derived from the life-safety category and the consequence category according to API RP 2A-LRFD or API RP 2A-WSD.

The exposure category for an offshore wind turbine per API RP 2A-LRFD or API RP 2A-WSD is based on medium consequence of failure C2 and an unattended[2] structure S3 resulting in an exposure category L-2. An offshore wind turbine has a low-level risk of causing damage to the ocean environment, but due to the size and asset value of an offshore wind turbine, it is found reasonable to classify the consequences of failure as C2. This safety level corresponds to a normal safety class inherently given in the IEC 61400-1 and IEC 61400-3-1.

OSS structures should be considered to have high consequence of failure C1 as defined by API RP 2A-LRFD or API RP 2A-WSD, resulting in an exposure category L-1 whether attended (S1 or S2) or unattended (S3). This safety level corresponds to a high safety level in DNV-ST-0145.

[2] “Unattended” structures are referred to as “unmanned” in some standards including API RP 2A-LRFD and API RP 2A-WSD. The terms are equivalent. Similarly, “attended” and “manned” are equivalent.

Other structures in an offshore wind farm (e.g., meteorological towers) may be considered as low consequence of failure (C3) and unattended (S3) as defined by API RP 2A-LRFD or API RP 2A-WSD (i.e., L-3) so long as the loss of the structure would not impact the ability of the wind farm to continue operating. Where the loss of a structure would impair continued operation of the wind farm, that structure should be considered as either medium (C2) or high (C1) consequence of failure, depending on the degree of potential disruption, resulting in a higher exposure category.

Table 1 Offshore wind farm asset exposure categories

Offshore wind farm assets	Applicable exposure category, per API RP 2A-LRFD or API RP 2A-WSD
Offshore wind turbine	(L-2) Medium consequence of failure and unattended
Offshore substation	(L-1) High consequence of failure whether unattended or attended
Other bottom fixed offshore wind farm assets (e.g. meteorological towers)	(L-3) Low consequence of failure and unattended

5.4 Deck Clearance

The deck (or external platform) clearance shall exceed the 1,000-year wave crest elevation, in accordance with API RP 2A-LRFD or API RP 2A-WSD, unless the designer can demonstrate that the global structural integrity and structural robustness are not affected by a lower platform elevation and clearance. When considering a lower platform clearance, global structural integrity shall be assessed under design-level[3] wave loading on the lower platform; structural robustness shall be assessed with wave loading on the lower platform according to sections 5.6.2 and 5.7.2. Loads from wave run-up shall be included in the design of access platforms, and these loads may be determined from 50-year event wave data.

At a minimum, deck or platform clearance shall not be less than the 50-year wave crest plus an air gap not less than 0.2 times the 50-year spectral significant wave height or 1.0 m defined in IEC 61400-3-1. For the OSS, deck or platform clearance should not be less than the 100-year wave crest plus 1.5 m air gap, from API RP 2A-LRFD Section A6.1.3.2. Site-specific considerations may increase the required air gap. This lower limit on deck clearance does not apply to rest or shifting platforms.

When determining the deck elevation, designers should consider the site-specific metocean environment, known or predicted seafloor subsidence, structural rotation, and other effects that may reduce the air gap and/or increase hydrodynamic loading on the platform.

5.5 Environmental Conditions

Measurement and characterization of environmental conditions and selection of values for design input are described in the following documents:

- ACP OCRP-3 *U.S. Offshore Wind Metocean Conditions Characterization Recommended Practices*
- ACP OCRP-4 *U.S. Recommended Practices for Geotechnical and Geophysical Investigations and Design*

Designers shall consider site-specific environmental conditions acting on structures installed in U.S. waters, including for example tropical cyclones/hurricanes, fresh-water and sea ice, and seismic activity, addressed in the recommended practice documents listed above.

[3] Design-level loading includes all factored loads considered in the evaluation of the integrity of the structure for its exposure category as defined in Section 5.3.

5.6 Offshore Wind Turbine Design

5.6.1 General

This section covers the design of the offshore wind turbine, including both the RNA and the support structure.

It is intended that this document be used in conjunction with IEC 61400-3-1 for design of fixed offshore wind turbines and IEC TS 61400-30 for safety principles for design of wind turbines. The information contained in this section provides exceptions, additions, and revisions to IEC 61400-3-1 and does not replicate provisions in IEC 61400-3-1 that are directly applicable to U.S. waters. This document along with IEC 61400-3-1 and other documents referenced herein are to be used together to form a broad guideline for offshore wind turbine design.

5.6.1.1 Use of Type and Component Certification

Where type and/or component certificates are used to support verification of the offshore wind turbine design, the wind class definitions shall be based on those described in IEC 61400-1. For offshore sites affected by the occurrence of tropical cyclones, i.e. hurricanes, the type/component certificate is recommended to take account of this through use of either a wind class S or class T.

For the certificate to be considered valid, the external conditions at the site shall be assessed according to IEC 61400-3-1 and shall be within the load envelope described within the type certificate. Inclusion of 60Hz operation in the type certificate is recommended for wind turbines installed in the US.

It is recommended for a type/component certificate to include not only the design of the RNA but also the tower internal components and damping systems. These can all be included in the wind turbine type certificate.

5.6.2 Loads

Loads considered in the design of the offshore wind turbine should be based on the IEC TC-88 standards, including IEC 61400-3-1 and IEC 61400-1. For floating offshore wind turbines, refer to ACP OCRP-2.

Any conditions that have an impact on loads shall be considered. Additional guidance is found in ACP OCRP-3 and ACP OCRP-4. These conditions should include, but not be limited to, the following:

- Geotechnical conditions
- Metocean conditions
- Seabed level and scour
- Frequency/frequency band
- Damping
- Inclination limit for support structure
- Wake effects
- Tropical cyclones
- Earthquakes
- Breaking waves
- Sea/lake ice
- Vessel impact

The conditions above may not remain constant over the service life the offshore wind turbine; the design should address all conditions during the service life.

Consideration of loads relating to storage, transport, and installation shall be done according to accepted industry standards. API RP 2A-LRFD or API RP 2A-WSD, DNV-ST-N001, and ABS BOWT Guide may be applied for consideration of these loads in addition to load cases described in IEC 61400-3-1.

5.6.2.1 Tropical Cyclone/Hurricane Loading and Structural Robustness

Tropical cyclone/hurricane related loading on the offshore wind turbine shall be considered.

Tropical cyclone/hurricane related loading may be considered as described in IEC 61400-3-1, Annex I. The load cases included in this annex are sufficient to demonstrate fulfilment of the robustness level analysis as described in API RP 2A-LRFD or API RP 2A-WSD. The loading associated with these load cases should be applied toward evaluation of the support structure including the top connection between the RNA and tower. Refer also to section 5.3.

Tropical cyclone/hurricane loading of the support structure including the top connection between the RNA and tower may also be considered as described in the American Bureau of Shipping (ABS) BOWT Guide.

Loading of the remainder of the RNA may exclude these load cases and should be evaluated according to the main body of IEC 61400-3-1.

5.6.3 Structural Design

The design of the offshore wind turbine shall be in conformance with IEC 61400-3-1. System and component resistances shall be determined according to IEC 61400-1 and the ISO 19900 suite of standards, API RP 2A-LRFD and associated standards, or other recognized offshore structural and geotechnical design standards. Guidance specific to offshore wind turbine structural design is also available in DNV-ST-0126 and the ABS BOWT guide. For floating offshore wind turbines, refer to ACP OCRP-2. For foundation design, refer to ACP OCRP-4.

The safety level inherent in the normal safety class for wind turbines defined in IEC 61400-1 can be considered to comply with the API RP 2A-LRFD or API RP 2A-WSD exposure category L-2. This corresponds to a normal safety level in DNV-ST-0126.

It might be necessary to use a combination of standards. In such cases, the designer shall demonstrate that the intended safety level is achieved. The IEC 61400 series of standards define a LRFD approach. Particular care shall be taken when mixing LRFD and WSD/ASD standards, which is generally not recommended. The selected standards shall be included in the design basis and shall not be in conflict with U.S. regulations.

For offshore wind turbine structural design, the following main items should as a minimum be considered:

- Codes and standards
- Loads including normal and abnormal events (earthquake, ship impact, etc.)
- Design cases ULS, FLS, ALS, and SLS
- Geotechnical conditions
- Material requirements
- Structural requirements (For example design fatigue factors)
- Corrosion protection
- Transport and installation
- Connections
- Scour

5.6.3.1 RNA Structural Design

The structural design of the RNA is typically part of the type/component certificate. Refer to Section 5.6.1.1. In that case, the designer shall demonstrate that the site-specific loads and other conditions are within the design envelope described in the certificate.

5.6.3.2 Steel Design

The following standards apply to the design of steel support structures, secondary structures, and other steel elements:

- API -RP 2A--LRFD
- DNV-ST-0126
- DNV-OS-C101
- DNV-RP-C203 (for fatigue design)
- ABS BOWT Guide

Additional ISO, AISC, ASTM, and EN (e.g. EN1993/Eurocode 3) standards may be relevant. It might be necessary to use a combination of standards, and in such cases it should be justified that the intended safety level is achieved. API- RP ~~2A~~ 2A-WSD may be used in lieu of API- RP 2A--LRFD, but particular care shall be taken when mixing LRFD and WSD/ASD standards, which is generally not recommended. The selected standards shall be included in the design basis and not be in conflict with U.S. regulations.

5.6.3.3 Concrete Design

The following standards apply to the design of concrete support structures, secondary structures, and other concrete elements:

- ISO 19903, in conjunction with an applicable concrete design code, such as DNV-ST-C502, or other ISO, ACI, and ASTM standards
- DNV-ST-0126
- ABS BOWT Guide

It might be necessary to use a combination of standards, and in such cases the designer shall demonstrate that the intended safety level is achieved.

All materials shall conform to accepted industry standards, such as ASTM, ACI, or other similar standards. The selected concrete material shall be suitable for the marine environment (see Section 6.4.4).

For concrete support structures special considerations should be given to crack control for the submerged zone and splash zone.

The selected standards shall be included in the design basis and not be in conflict with U.S. regulations.

5.6.3.4 Corrosion Protection

Corrosion protection is achieved through a combination of coatings and cathodic protection, as described in the following sections. Use of a corrosion allowance is permitted in some standards, e.g. where coating maintenance is impractical. The standards chosen for the design shall be included in the design basis.

5.6.3.4.1 Coatings

The following standards may be applied for coating design:

- ISO 12944 *Paints and Varnishes* series, in particular ISO 12944-9 which is specific for offshore structures
- DNV-RP-0416 *Corrosion Protection of Wind Turbines*
- NACE SP0108 *Corrosion Control of Offshore Structures by Protective Coatings*

- NACE SP0178 *Fabrication Details, Surface Finish Requirements, and Proper Design Considerations for Tanks and Vessels to Be Lined for Immersion Service*
- NORSOK M-501 *Surface preparation and protective coating*

In addition to the above, other ISO, ASTM, SSPC/NACE, and VGB/BAW standards may be relevant.

5.6.3.4.2 Cathodic Protection of Steel Structures

The following standards may be applied for steel structure cathodic protection design:

- DNV-RP-B401 *Cathodic Protection Design*
- NACE SP0176 *Corrosion Control of Submerged Areas of Permanently Installed Steel Offshore Structures Associated with Petroleum Production*
- NACE SP0387 *Metallurgical and Inspection Requirements for Cast Galvanic Anodes for Offshore Applications*
- NACE SP0492 *Metallurgical and Inspection Requirements for Offshore Pipeline Bracelet Anodes*
- NORSOK M-503 *Cathodic Protection*

In addition to the above, other ISO, ASTM and other SSPC/NACE standards may be relevant.

For topics not covered by NACE, e.g. coating breakdown and composition requirements of anodes, reference is given to DNV-RP-B401.

5.6.3.4.3 Cathodic Protection of Concrete Structures

The following standards may be applied for concrete structure cathodic protection design:

- ISO 12696 *Cathodic Protection of Steel in Concrete*
- DNV-RP-B401 *Cathodic Protection Design*

5.6.3.5 Ship Collision

A navigational risk assessment for the wind farm is performed as part of the COP; the details of that assessment are not covered in this document. The navigational risk assessment determines among other things the likelihood of impacts from vessels of various sizes and is used as input to the ship collision risk analysis, considering the types of service vessels as well as other ship traffic passing through or nearby.

For impact scenarios found to be likely within the lifetime of the wind farm, the effect of those vessel impacts should be evaluated. For structural design two scenarios should be considered: an operational impact to assure structural design of boat landing and an accidental ship impact on the support structure.

Guidance on collision impact assessments can be found in API RP 2A-LRFD and API RP 2A-WSD

Guidance on service vessel load on boat landing can be found in:

- IEC 61400-3-1
- DNV-ST-0437
- The Wind Partnership OE-RP-02

In the post damage situation the primary structure shall remain intact and without further damage for such time as it takes for repairs to be effected and for the primary structure to be made fit-for-service. An appropriate return period for loads considered in the post damage situation shall be included in the design basis. For reference, API RP 2A-WSD states that the minimum return period is 1 year.

Guidance on risk assessments can be found in:

- ABS Guidance Notes on Accidental Load Analysis and Design for Offshore Structures

- Center for Marine and Petroleum Technology (CMPT) A Guide to Quantitative Risk Assessment for Offshore Installation

5.6.4 Electrical Design

5.6.4.1 General Requirements

The electrical installations on the offshore wind turbine shall be designed to generally accepted industry standards. This may include NFPA 70, *National Electrical Code* (NEC) and IEEE C2 *National Electrical Safety Code* (NESC), which are considered state of the art for electrical and power generation equipment and installations in the U.S., and UL 6141 *Standard for Wind Turbines Permitting Entry of Personnel*, which is specific for U.S. onshore wind. This may also include IEC standards consistent with electrical system requirements from IEC 61400-1 and IEC 61400-3-1 and IEC standards for systems at higher voltages than those covered in the wind turbine standards. These standards are considered state of the art for offshore wind turbine design.

Relevant requirements from 29 CFR 1910.269 *Special Industries – Electric Power Generation, Transmission, and Distribution* and 29 CFR 1910 Subpart S – *Electrical* should, in general, be followed with regards to electrical safety. Reference is made in those sections to U.S. electrical standards. Where IEC or other standards are used as a substitute for these, it should be shown that an equivalent level of safety is achieved, in line with the design basis approach on the selection of standards described in Section 5.2.1.

In some instances specific standards may be required by the interconnect agreement or by other interfacing entities. These standards shall be included in the design basis as long as they are not in conflict with U.S. regulations.

5.6.4.2 Interface of Different Electrical Code-bases

The application of electrical design standards should avoid code-mixing, and any interfaces between electrical systems employing different code-bases shall be identified.

Control measures shall be taken where such code-mixing between electrical systems occurs, to ensure installation and maintenance work can be safely carried out and that proper grounding is applied. These control measures can include wire identification and documentation of interface schematics. A HAZOP may be performed to determine the control measures needed at the interface.

For designs which use an IEC or other non-NEC/NESC code basis, there will ultimately be an interface with the NEC/NESC-designed electrical grid. This interface point may take place at electrical isolation equipment (i.e., switchgear) situated either locally at the offshore wind turbine, at the OSS, or at the onshore substation. The switchgear which comprise this interface shall be designed in accordance with an NEC/NESC code-basis and should be designed according to IEEE standards applicable to the safety requirements and appropriate voltage levels.

5.6.4.3 Testing and Approval of Electrical Design

It is recommended that electrical component testing, evaluation, and listing be performed or witnessed by accredited electrical testing laboratories[4] and that such testing, evaluation, or listing should be in accordance with the applicable electrical codes and standards used in the design.

5.6.4.4 Access Restrictions, Training, Documentation, and Design

Access restrictions, training requirements, and documentation should be linked to the selection of design standards, especially in regard to the use of electrical equipment. Designers should consider that U.S. electrical technicians may not be familiar with European electrical design conventions such as electrical cabinet layout, conductor color convention, labelling, etc. Designers should coordinate with personnel

[4] Accredited electrical testing laboratories perform evaluations, testing, and certification or approval of certain products, and may be based in the U.S. or internationally. If the listing and/or product certification is done by an accredited electrical testing laboratory this listing mark or certificate signifies that the product complies with the requirements of one or more appropriate product safety test standards.

responsible for EHS and training to ensure design, documentation, training, and qualifications of personnel are consistent.

For areas where all technicians and operators will be required to complete model-specific training and are provided with model-specific schematics and documentation, the use of international or non-U.S. design standards can be accepted in accordance with the design basis approach.

For areas where it is foreseeable that operators and technicians will not receive model-specific training, then the use of recognized U.S. design standards should be applied in the design.

5.6.4.5 Electric Shock

Reduction of risk is necessary to ensure:

- Safety of persons and property
- Consistency of control response
- Ease of maintenance

The first opportunity for attaining these safety measures is at the design and development phase. Safeguarding and safe working procedures shall be considered. The extent of safeguarding, which includes means for safeguarding and awareness shall be determined by means of a risk assessment.

Measures shall be taken to protect personnel from electric shock. The following specific areas are critical at the design and development stage to ensure that the risks associated with high-voltage equipment are properly addressed.

- Selection of proper electrical equipment including degrees of protection
- Installation in accordance with equipment manufacturer's instructions, and with considerations for the application
- Supply disconnecting and earthing
- Protection against direct and indirect contact with energized parts
- Equipotential bonding
- Working practices
- Markings and warnings

Selection and installation of cables and conductors should consider the expected operating conditions, grouping and mechanical protection, current carrying capacity, and hazards associated with propagation of fire and emission of corrosive or toxic gases.

Methods of protection of low voltage equipment may be according to the NEC or a combination of IEC 60364-4-41 and IEC 60204-1.

Methods of protection of equipment above 1000V may be according to the NEC, NESC, IEC 60204-11, or IEC 61936-1.

5.6.4.6 Working Space Around Cabinets with Exposed Live Voltages

The required working space in front of and around electrical cabinets containing exposed live parts[5] should be in accordance with generally accepted industry standards. Requirements from NESC, NEC, 29 CFR 1910 Subpart S – *Electrical* and/or IEC 60364-7-729 may be applied.

[5] Electrical cabinets may be considered to have exposed live parts in cases where the level of ingress protection while opened does not fulfill NEC 110.27(A)(2) or IP2X as defined by IEC 60529. Alternative methods of classifying the presence of exposed live parts may be used where suitable.

5.6.4.7 Arc Flash

Electric cabinets, regardless of voltage, shall comply with the electrical hazard identification requirements of 29 CFR 1910.335(b)(1). This shall include information regarding the electric arc flash hazard as specified in 29 CFR 1910.269(i)(8). Further details regarding the hazard analysis are given in 29 CFR 1910 Appendix E. To fulfil this requirement, the designer should perform an arc flash hazard analysis on each cabinet according to the procedures outlined in NFPA 70E, IEEE 1584, or using other methods which may reasonably predict the incident heat energy as specified by 29 CFR 1910.269(i)(8)(ii) Note 1. Additional guidance may be found in G+ *Arc flash labeling and associated signage in the offshore wind industry.*

5.6.4.8 Main Transformer Installation and Protection

This section refers to the main transformer installed at the wind turbine, which increases the voltage from the wind turbine generator or inverter to the collection voltage.

This section does not refer to transformers on circuits exporting the power from multiple wind turbines, for example on the OSS. This section also does not refer to transformers only supplying auxiliary power for equipment on the offshore wind turbine.

Guidance for indoor installations of transformers should be applied where suitable for the transformer technology and level of exposure. When the main transformer is installed inside the wind turbine tower or nacelle, it should meet the requirements for indoor installation according to IEC 61400-1[6] and one or more of the following:

- 29 CFR 1910.305 (j) (5)
- the NEC Sections 450.21 through 450.27 and 450 Part III
- NESC Rule 152 *Location and arrangement of power transformers and regulators* and Rule 124 *Guarding live parts*
- IEC 61936-1 *Power installations exceeding 1 kV a.c. - Part 1: Common rules*

These rules consider the installation of dry-type, oil-insulated, less-flammable liquid insulated[7], and non-flammable liquid insulated transformers. Requirements for transformers for wind turbine applications may be found in IEC/IEEE 60076-16 and relevant parts of UL 6141 and IEC 61400-1.

5.6.4.9 Switchgear

Switchgear shall be designed to generally accepted industry standards. This may include IEEE or IEC[8].

5.6.4.10 Control Systems

Offshore wind turbine control systems, including the use of emergency stops, should be designed in accordance with requirements from relevant sections of IEC 61400-1. The application of design standards for emergency stop systems should include either ISO 13850 or the relevant sections of NFPA 79.

The wind turbines should be designed to feature remote monitoring, control, and shut down capabilities by authorized wind farm operators.

[6] Refer to IEC 61400-1:2019 Chapters 10.19 and 10.21. Please note that requirements from 10.21 (switchgear) pertaining to restricted accessibility and lock-out are also applied to power transformers.

[7] Liquids having a fire point higher than 300 C meet the requirements for “less-flammable” liquid as defined in NEC 450.23. This is equivalent to Class K liquid according to IEC 61039 or IEEE C57.12.00.

[8] Due to space constraints on offshore wind farm assets and harsh environmental conditions, Gas Insulated Switchgear (GIS) are frequently used to provide compact switchgear equipment at voltages 66kV and above. Both integrated and standalone Local Control Cubicles (LCCs) can be used, subject to the space limitation and design of the asset.

5.6.4.11 Lightning Protection, Grounding, and Earthing

Lightning protection systems, grounding, and bonding of electrical equipment and metal structural components shall be designed in accordance with . NEC and NFPA 780 should be applied to portions of the installation not covered by IEC 61400-24.

The designer shall ensure that the effectiveness of the grounding system is maintained across interfaces between electrical equipment designed to different standards.

5.6.4.12 Receptacles

Receptacles (electrical outlets) available for common U.S. equipment and tools should be of an approved NEMA (National Electrical Manufacturers Association) configuration:

- 2 pole-2 wire ungrounded
- 2 pole-3 wire grounding
- 3 pole-4 wire grounding

Examples include but are not limited to 1-15R, 5-15R, 6-15R and 10-20R and include locking type receptacles.

All 2 pole receptacles shall be protected by a Ground Fault Circuit Interrupter (GFCI).

Additional receptacles for special tooling or equipment shall be designed according to generally accepted industry standards. This may include the IEC 60309 series of standards for plugs, socket-outlets and couplers for industrial purposes. These special receptacles shall be listed or certified by an accredited testing laboratory and protected in accordance with their ratings.

5.6.4.13 Electromagnetic and Environmental Compatibility

The requirements for Electromagnetic Compatibility (EMC) emissions and immunity and environmental compatibility shall comply with best industry practice.

EMC Emissions

EMC emissions limits and emissions testing requirements are specified in the following standards and regulations:

- U.S. Standards and Regulations:
  - 47 CFR 15 *Radio Frequency Devices*
  - IEEE/ANSI C63.4: *American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz*
  - IEEE/ANSI C63.10: *American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices*
- International standards:
  - IEC 61000-6-3 *Electromagnetic Compatibility (EMC) – Generic standards - Emission standard for residential, commercial and light-industrial environments*
  - IEC 61000-6-4 *Electromagnetic Compatibility (EMC) – Generic standards - Emission standard for industrial environments*

EMC Immunity

EMC immunity testing is specified in the following standards:

- U.S. Standards and Regulations:
  - IEEE 1613 *Communications Networking Devices Installed in Transmission and Distribution Facilities*

- IEEE C37.90 Series *Relays and Relay Systems Associated with Electric Power Apparatus*

- International Standards:
  - IEC 60255-26 *Measuring relays and protection equipment - Part 26: Electromagnetic compatibility requirements*
  - IEC 61000 Series *Electromagnetic compatibility (EMC): Testing and measurement techniques*
  - IEC 61000-6-1 *Electromagnetic Compatibility (EMC) – Generic standards - Immunity for residential, commercial and light-industrial environments*
  - IEC 61000-6-2 *Electromagnetic Compatibility (EMC) – Generic standards - Immunity for industrial environments*
  - IEC 61000-6-5 *Electromagnetic Compatibility (EMC) – Generic standards - Immunity for equipment used in power station and substation environments*
  - IEC 61000-6-7 - *Electromagnetic Compatibility (EMC) – Generic standards - Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations*

The recommended practice DNV-RP-0440 provides guidelines for applying the IEC standards for emissions and immunity to wind turbines.

Environmental Compatibility

Design and testing for environmental compatibility is specified in the following standards:

- IEEE 693 - *IEEE Recommended Practice for Seismic Design of Substations*
- IEC 60255-1 *Measuring relays and protection equipment - Part 1: Common requirements*
- IEC 60255-21-1:1988: *Electrical relays - Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment - Section One: Vibration tests (sinusoidal)*
- IEC 60255-21-2:1988: *Electrical relays - Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment - Section Two: Shock and bump tests*
- IEC 60255-21-3:1993: *Electrical relays - Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment - Section 3: Seismic tests*

5.6.4.14 Emergency and Standby Power Systems

This section applies to systems used during installation, commissioning, and maintenance typically during extended periods of grid unavailability. This section does not apply to uninterruptable power supplies or standby power systems which are integral to the wind turbine electrical system, nor to standby power systems installed on vessels.

The design of emergency and standby power systems should be according to:

- NFPA 110 *Standard for Emergency and Standby Power Systems*
- ANSI/NETA ATS – *Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*

Diesel generators should also be equipped with protections according to NFPA 30 *Flammable and Combustible Liquids Code*.

5.6.5 Design for Occupational Health and Safety

The design of the offshore asset should be compliant with all local, state, and/or federal legal requirements pertaining to occupational health and safety. This may vary according to the location of the offshore wind farm and the agencies having jurisdiction. The use of generally accepted industry standards is required in the occupational health and safety related design of the offshore wind turbine. The application of these design standards should follow the design basis approach as described in Section 5.2.1. This section is limited to design elements affecting safety; guidance for occupational safety is provided in ACP RP-1002.

It is recommended to use IEC TS 61400-30 as basis for design related to occupational health and safety. In addition to IEC TS 61400-30, standards referenced in subsections below should be considered. Additional Guidance may be found in G+ Good Practice Guide: Safe By Design. The design should avoid code mixing as detailed in Section 5.2.1. In some cases, some of the requirements from the references below may contradict with one another or IEC TS 61400-30. In cases where design builds upon international codes and standards~~,~~ that conflict with the requirements in the following sections, the designer shall perform a gap analysis relative to the requirements below and implement mitigations sufficient to provide the intended level of safety defined in IEC TS 61400-30. Those mitigations should be supported by trainings, site inductions and other relevant measures to ensure sufficient safety is achieved for personnel and the environment.

This section concerns all systems, equipment, and procedures related to design for safety of the offshore wind turbine. Additional requirements for ~~c~~Critical ~~s~~Safety ~~s~~Systems and ~~e~~Equipment (CSSE) are found in Section 5.13.

~~Recommendations for the application of specific design standards and requirements are included in the following sections.~~

5.6.5.1 Requirements from U.S. Code of Federal Regulations

Applicable occupational health and safety requirements from the U.S. Code~~e~~ of Federal Regulations shall be applied in the design of the offshore assets. 30 CFR 285 and 30 CFR 585 regulate the development and operation of offshore wind farms in the US. Furthermore, ~~Depending on the location of the wind farm and the agencies having jurisdiction, this could include the following:~~

- ~~30 CFR 585285, in particular:~~
  - ~~Section 585.810 *What must I include in my Safety Management System?*~~
  - ~~Section 585.620 to .638, *Construction and Operations Plan*~~
  - ~~Section 585285.701 *What must I include in my Facility Design Report?*~~
  - ~~Section 585285.702 *What must I include in my Fabrication and Installation Report?*~~
  - ~~Section 285.810 *What must I include in my Safety Management System?*~~
- ~~30 CFR 585, in particular:~~
  - ~~Section 285.620 to .638, *Construction and Operations Plan*~~
- ~~33 CFR Subchapter N, in particular:~~
  - ~~Section 142.48 *Eyewash equipment*~~
  - ~~Section 142.87 *Guarding of deck openings*~~
  - ~~Section 143.101 *Means of escape*~~
  - ~~Section 143.110 *Guards and rails*~~
  - ~~Section 145.01 *Portable and semi-portable fire extinguishers*~~
  - ~~Section 145.10 *Locations and number of fire extinguishers required*~~
- ~~29 CFR 1910, in particular:~~
  - ~~Subpart D (Sections 21-30) *Walking-Working Surfaces*~~

- ~~Subpart E (Sections 33-39) *Means of Egress*~~
- ~~Subpart G (Sections 94-98) *Occupational Health* and Environmental Control~~
- ~~Subpart I (Sections 132-140) *Personal Protective Equipment*~~
- ~~Subpart J (Sections 141-146) *General Environmental Controls*~~
- ~~Subpart O (Sections 211-219) *Machinery and Machine Guarding*~~
- ~~Section 269 Special Industries – *Electric Power Generation, Transmission, and Distribution*~~

- ~~29 CFR 1926~~
  - ~~Subpart M *Fall Protection*~~

29 CFR 1910 and 29 CFR 1926 ~~is~~are the leading sources of U.S. occupational health and safety requirements and should, in general, be followed. In case of deviations, sufficient justification should be provided that the design standards which are incorporated in the design basis achieve an equivalent level of workplace safety. 33 CFR Subchapter N includes requirements for design of offshore installations for occupational health and safety which are not addressed in 29 CFR 1910 and should be followed for relevant parts of the design. Specific clauses may be referenced in the subsections below, as applicable.

5.6.5.2 Fall Protection Systems

The selection of standards used for fall protection systems and anchor points should comply with all relevant parts of ANSI/ASSE Z359.

An offshore wind farm combines hazards of working over water and working at height. Guardrails and other permanent forms of fall protection should be designed in accordance with generally accepted industry standards and applicable regulations. This may include:

- 33 CFR 142.87 *Guarding of deck openings*, which provides requirements for guarding decks of offshore structures.
- 29 CFR 1910.29 *Fall protection systems and falling object protection—criteria and practices*, which provides requirements for handrails of elevated platforms and walkways.
- ISO 14122 Series *Safety of machinery – Permanent means of access to machinery*, which provides requirements for guardrails and other permanent forms of fall protection.

5.6.5.3 Helicopter Hoisting Areas

Helicopter hoisting areas of the offshore wind turbine designated for use in aerial access to the wind turbine by helicopter shall be designed according to accepted industry standards.

The U.S. Federal Aviation Administration (FAA) and U.S. Coast Guard (USCG) publish regulations for helicopter landing areas, but not helicopter hoisting areas.

CAP 437 is a UK national standard which is commonly applied for wind turbines incorporating helicopter hoisting areas on the offshore wind turbine nacelle. CAP 437 is the recommended standard due to its content specific to wind turbines and wind farms.[9] Other standards can be used where they specifically address offshore wind turbine related hazards and the helicopter access method being used.

5.6.5.4 Service Lifts

Service lifts used for transportation of personnel within the offshore wind turbine tower and/or other parts of the support structure should be designed and certified according to ASME A17.8 *Standard for Wind Turbine Tower Elevators*. The use of other standards, such as EN 81-44 *Lifting appliances for wind turbines* ~~EN 1808 *Safety requirements for suspended access equipment*,~~ may be used in the design of

[9] Note the U.S. Coast Guard accepts CAP 437 as a design standard which is at least as effective as 46 CFR 108, as recorded in CG-ENG Policy Letter No. 03-15 published Sep. 3, 2015.

service lifts where it can be shown that they achieve an equivalent level of safety. Additional guidance may be found in EN 1808 *Safety requirements for suspended access equipment*.

Fall protection systems and anchor points used as part of the elevator system should be compliant with requirements from the ANSI/ASSE Z359 series of standards.

~~A design standard specific to wind turbine applications was under development at the time of publication of this document. Once available, EN 81-44 *Lifting appliances for wind turbines* should be considered among other international standards.~~

5.6.5.5 Cranes and Hoists

General requirements for cranes and hoists may be found in the ASME B30 series and 29 CFR 1910.179, or the EN 13001 series of standards. EN 12999 provides specific requirements toward hydraulic powered cranes and the EN 14492 series provides requirements for winches and hoists. Additional electrical requirements towards hoisting machines may be found in IEC 60204-32.

Cranes used for loading or unloading from vessels shall comply with standards appropriate for the type of crane in use. Commonly used standards include API SPEC 2C, EN 13852-1, DNV-ST-0378, and ABS Guide for Certification of Lifting Appliances.

Cranes and hoists shall be certified by accredited third parties according to the relevant design standards.

5.6.5.6 Lockout/Tagout

Wind farm assets should be designed so that Lockout/Tagout (LOTO) procedures compliant with 29 CFR 1910.147 can be used during operation.

ISO 14118 provides additional guidance on safe design of machinery for isolating and preventing start-up. IEC 60204-1 and ISO 4413 provide specific information on isolation of electrical and hydraulic fluid power systems, respectively.

5.6.5.7 Confined Space

Wind farm assets should be designed so that confined space procedures compliant with 29 CFR 1910.146 can be used during installation and maintenance activity.

5.6.5.8 Boat Landing

33 CFR 143.105 Personnel landings provides requirements for the boat landing. Additional guidance toward boat landings may be found in IMCA SEL 041 *Standardised Boat Landing Research Report* and The Wind Partnership OE-RP-02 *Vessel access aligned interfaces*.

5.6.5.9 First Aid

ANSI Z308 provides guidance on the contents of a first aid kit.

5.6.5.10 Emergency Response and Evacuation

Evacuation measures from the deck are covered by regulation 33 CFR 143.101.

For offshore wind turbines, equipment for evacuation from the nacelle is required in addition to the regulations. This equipment should be designed according to the requirements listed in 5.6.5.2 Fall Protection Systems.

5.6.5.11 Shelter in Place

Procedures for personnel to shelter in place should be included in the emergency response plan for the facility. The shelter in place plan should consider the possibility of personnel sheltering at the offshore work site longer than the planned duration of their work due to adverse weather or other unplanned events. The plan should apply to all structures with personnel access and interior spaces (e.g. offshore wind turbine towers, offshore substations). Equipment should be made available at each structure to address the safety, health, and hygiene of stranded personnel for at least 24 hours and for a period of time determined by the risk assessment. Equipment may include, for example, non-perishable food, water, sanitation, waste management, first-aid, signaling devices, and protection from weather and natural hazards. Additional guidance may be found in *G+ Integrated Offshore Emergency Response*.

5.6.5.12 Storage of Flammable Liquids

Storage of flammable liquids should be according to 29 CFR 1910 and NFPA 30 *Flammable and Combustible Liquids Code*.

5.6.5.13 Oil Spill Risk

An oil spill response plan (OSRP) shall be developed and it should be assured that the largest possible oil spill from a given component can be handled. This volume would take consideration of possible levels prior to spill and also possible volume discharged during firefighting operations.

Responsibility for oil spill risk for offshore facilities falls under the U.S. Oil Pollution Act of 1990 (OPA 90) and is enforced by BSEE. Specific requirements for the development, submission, review and approval of OSRPs are given in 30 CFR 254. BSEE is in the process of reviewing and updating these regulations to account for newer offshore technologies including offshore wind farms, therefore the designer is encouraged to seek the most up to date guidance from BSEE in this area.

5.6.5.14 Fire Safety

The design of offshore wind farm assets for fire safety should take into consideration the operational philosophy and whether the asset classifies as an attended or unattended facility according to 33 CFR 140.10. The offshore wind turbine is generally assumed to be an unattended facility.

Design considerations for fire safety should be taken into account on the basis of a fire hazard analysis and/or fire risk assessment.

For areas of the wind farm asset where fire-fighting systems are necessary as a risk reduction measure, storage locations should be made available for the systems specified by 33 CFR 145.

5.6.5.15 Life Saving Appliances

Lifesaving appliances should comply with International Convention for the Safety of Life at Sea (SOLAS) Chapter III – *Life-Saving Appliances and Arrangements* and 46 CFR 160 as far as practically possible.

5.6.5.16 Walking and working surfaces

The design of walking and working surfaces should comply with generally accepted industry standards. Guidance may be found in ISO 14122, 29 CFR 1910 (OSHA) or DNV-ST-0145.

5.7 Offshore Substation Design

5.7.1 General

This section covers an OSS topside on a steel or concrete support structure. These requirements pertain to an unattended OSS; there are additional requirements for an attended OSS, which are outside the scope of this document.

5.7.2 Loads

Loads considered in the design of the OSS should be based on API RP 2A-LRFD or API RP 2A-WSD, DNV-ST-0145, or ABS Rules for Offshore Installations. The selected codes and standards shall be included in the design basis described in Section 5.2.1.

Any conditions that have an impact on loads shall be considered. Additional guidance is found in ACP OCRP-3 and ACP OCRP-4. These conditions should include, but not be limited to, the following:

- Geotechnical conditions

- Metocean conditions
- Seabed level and scour
- Frequency / frequency band
- Damping
- Inclination limit for support structure
- Tropical cyclones
- Earthquakes
- Breaking waves
- Sea/lake ice
- Vessel impact
- Equipment

The conditions above may not remain constant over the service life the OSS; the design should address all conditions during the service life.

Load cases related to transport, lifting, load-out, sea transportation and installation shall be considered. Criteria shall be defined for acceptable external conditions during these various load cases. These should include, for example, maximum acceptable wind speed and wave height. The vessels used and the duration of the operations in question should also be considered. The main requirements are given in API RP 2A-LRFD or API RP 2A-WSD, API RP 2MOP, and DNV-ST-N001.

5.7.2.1 Tropical Cyclone/Hurricane Loading and Structural Robustness

Tropical cyclone/hurricane related loading on the OSS shall be considered by a robustness level analysis for an L-1 structure as described in API RP 2A-LRFD or API RP 2A-WSD. Refer also to section 5.3.

5.7.3 Structural Design

The exposure category for the OSS structures should be designated as L-1 as defined by API RP 2A-LRFD or API RP 2A-WSD. This is considered to correspond to a high safety level in DNV-ST-0145. Refer to Section 5.3.

It might be necessary to use a combination of standards, and in such cases the designer shall demonstrate that the intended safety level is achieved. Particular care shall be taken when mixing LRFD and WSD/ASD standards, which is generally not recommended. The selected standards shall be included in the design basis and shall not be in conflict with U.S. regulations.

For the support structure the following items shall as a minimum be considered:

- Codes and standards
- Geotechnical conditions
- Loads including normal and abnormal events (earthquake, ship impact etc.).
- Design cases ULS, FLS, ALS, SLS
- Material requirements
- Structural requirements (For example Design Fatigue Factors)
- Corrosion protection
- Transport and installation
- Connections

- Scour

In addition to the above, for OSS topside design the following main items should as a minimum be considered:

- Fire and Safety design, including escape and evacuation
- ~~Critical components~~Key equipment and systems (e.g. crane, helideck, pollution prevention systems as applicable)
- Operational requirements

In addition to the normal load cases, deflections and relative deflections may be critical for some components and should be considered. Furthermore, maximum deflections and accelerations for the electrical components shall be fulfilled or it shall be assured that the topside accelerations and deflections are acceptable for the electrical components.

5.7.3.1 Steel Design

The following standards apply to the design of steel structures:

- API RP 2A LRFD, API RP 2A WSD, DNV-ST-0145, or the ABS Rules for Offshore Installations
- ASTM standards for specific materials where API standards do not cover
- ANSI standards for specific items as stairs, ladders, handrails etc. where API standards do not cover

The selected standards shall be included in the design basis and not be in conflict with U.S. regulations.

5.7.3.2 Concrete Design

For concrete support structures ISO 19903 should be followed, in conjunction with an applicable concrete design code, such as DNV-ST-C502, ABS Rules for Offshore Installations, or other ISO, ACI, and ASTM standards.

All materials shall conform to accepted industry standards, such as ASTM, ACI, or other similar standards. The selected concrete material shall be suitable for the marine environment (see Section 6.4.4).

For concrete support structures special considerations should be given to crack control for the submerged zone and splash zone.

The selected standards shall be included in the design basis and not be in conflict with U.S. regulations.

5.7.3.3 Corrosion Protection

Refer to Section 5.6.3.4.

5.7.3.4 Ship Collision

Refer to Section 5.6.3.5.

5.7.4 Electrical Design for OSS

5.7.4.1 General Requirements

The electrical installations on the OSS shall be designed to generally accepted industry standards following the hierarchy and design basis approach outlined in Section 5.2. This may include NFPA 70, *National Electrical Code* (NEC) and IEEE C2 *National Electrical Safety Code* (NESC), which are considered state of the art for electrical and power generation equipment and installations in the U.S. This may also include IEC standards which are considered state of the art for electrical and power generation equipment and installations internationally.

Relevant requirements from 29 CFR 1910.269 *Special Industries – Electric Power Generation, Transmission, and Distribution* and 29 CFR 1910 Subpart S – *Electrical* should, in general, be followed with regards to electrical safety. Reference is made in those sections to U.S. electrical standards. Where IEC or other standards are used as a substitute for these it should be shown that an equivalent level of safety is achieved, in line with the design basis approach on the selection of standards.

In some instances, specific standards may be required by the interconnect agreement or by other interfacing entities. These standards shall be included in the design basis as long as they are not in conflict with U.S. regulations or best practice. North American Electric Reliability Corporation (NERC) requirements for the design and operation of the Bulk Power System[10] may also apply, but are outside the scope of this document. Refer to Section 10.1.

The design of electrical systems for an OSS may consist of switchgear, reactive power compensation systems, high-voltage transformers and low-voltage systems.

Two documents provide guidelines for design of OSS for offshore wind farms, but other specific U.S. requirements should also be considered:

- CIGRE 483
- DNV-ST-0145

BSEE and BOEM commissioned BSEE TAP 723AA titled *Offshore Substation Design Development of Standards*, dated July 20, 2015. The appendices in that document list industry electrical design standards for the detailed electrical design of an OSS. That document is considered a good reference, but designers should consider new editions of the referenced standards, new standards which did not exist at the time of publication, and changes in industry practice. Additional guidance may be found in IEC 61892-1.

The OSS electrical design elements include the design of various electrical components for the electrical substation, including but not limited to cables, cable trays, panelboards, switchgear, conduits, transformers, and transfer switches, as well as parts of an offshore platform including lighting, backup generators, backup batteries, communication systems, Public Announcement and General Alarm (PAGA) systems, surge arresters, and lightning protections.

By utilizing appropriate design standards, the electrical design shall assure a safe and reliable system both for the high-voltage and low-voltage systems.

5.7.4.2 Interface of Different Electrical Code-bases

Refer to Section 5.6.4.2.

5.7.4.3 Testing and Approval of Electrical Design

Refer to Section 5.6.4.3.

5.7.4.4 Access Restrictions, Training, Documentation and Design

Refer to Section 5.6.4.4.

5.7.4.5 Electric Shock

Refer to Section 5.6.4.5.

5.7.4.6 Working Space Around Cabinets with Exposed Live Voltages

Refer to Section 5.6.4.6.

5.7.4.7 Arc Flash

Refer to Section 5.6.4.7.

[10] Note that the Bulk Power System is distinct from the Bulk Electrical System discussed in Section 5.8.

5.7.4.8 Transformer Protection

Relevant industry standards for indoor and outdoor transformer installations shall be applied according to the transformer technology and installation:

- 29 CFR 1910.305 (j) (5)
- NEC sections 450.21 through 450.27 and 450 Part III
- NESC Rule 152 *Location and arrangement of power transformers and regulators*
- NESC Rule 124 *Guarding live parts*

IEEE 242, Chapter 11, provides recommended practices for the protection of transformers in commercial power systems. IEEE C37.91 is a guide for protective relay applications to power transformers.

Transformers are expected to feature connections from the high-voltage & medium-voltage switchgear with cable, insulated busduct, gas insulated bus, or similar. No live terminals are therefore likely on the OSS.

Neutral connections can be cable or bar type. The latter will require protection against contact if uninsulated bar is used.

The design of the OSS will generally feature large portions of welded steel structures and deck plates, which are bolted or welded to the sub-structure. This provides a low impedance path for any arising fault currents. All of the equipment and metal structures shall be connected to earth to ensure equipotential bonding to prevent touch or step voltages in excess of recognized levels.

Earthing of equipment should follow industry practice for electrical installation and high-voltage equipment based on a study of step and touch potentials (see also section 5.7.4.10). References include IEEE 80, NEC Section 250, and NESC Section 9.

The transformers can be filled with mineral oil (to IEC 60296) or synthetic insulating oils (to IEC 61099). The choice of oil will feature within the fire risk assessment and protection selected for fire probability and fighting. Fire risk analysis studies can be performed to help the design engineer evaluate risks. Other fire abatement considerations could include deluge extinguishing systems and/or rapid depressurization systems for power transformers.

The transformer core and load noise, along with the overall station noise level, should be designed to be below health and safety legislation permitted levels or restricted access with hearing protection.[11] Guidance on transformer noise may be found in NEMA-TR1.

According to national and international standards the unit should be designed to withstand the maximum sustained short circuit current and maximum Basic Insulation Levels. Guidance can be found in IEEE C57.12.00. The likelihood of a catastrophic failure should take into consideration reliability requirements, replacement cost and duration, and if the platform is attended or unattended.

Access to items for maintenance, including fan/motor assemblies sampling and test points, should be from ground level without the need for regular activity at height.

Protection of the transformer will be via electrical protection and mechanical devices. Mechanical devices include oil level monitoring, Buchholz and sudden pressure relays, oil and winding temperature monitoring, pressure relief, and dissolved gas analysis.

Electrical protection of the power transformer and the power system shall be provided using circuit breakers and protection relays as part of an overall power systems protection scheme. A current differential scheme may be used to sense transformer faults along with overcurrent and earth fault protection. Overfluxing should be considered according to IEEE C37.91. The protective relay may also monitor mechanical sensors for pressure and temperature. To ensure transformer protection after an incident, a

[11] Low noise transformer designs are available at an additional cost or noise reduction elements in the environment can be designed.

lock out function shall be used (e.g. electromechanical lockout relay or intelligent electronic device). Depending on the voltage level and criticality, a primary/backup relay redundancy may be employed.

Surge or impulse protection should be provided by a surge arrestor located as near to the transformer as possible based on a surge protection coordination study.

5.7.4.9 Switchgear

Refer to Section 5.6.4.9.

5.7.4.10 Lightning Protection, Grounding and Earthing

Refer to Section 5.6.4.11.

5.7.4.11 Receptacles

Refer to Section 5.6.4.12.

5.7.4.12 Electromagnetic and Environmental Compatibility

Refer to Section 5.6.4.13.

5.7.4.13 Emergency and Standby Power Systems

The design of emergency and standby power systems shall be according to generally accepted industry standards following the design basis approach. Guidance can be found in:

- DNV-ST-0145
- DNV-OS-D201
- NFPA 110 *Standard for Emergency and Standby Power Systems*
- ANSI/NETA ATS – *Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*

Diesel generators should also be equipped with protections according to NFPA 30 *Flammable and Combustible Liquids Code*.

5.7.4.14 Control and Protection Systems

Control and protection systems on wind farm assets shall be designed according to generally accepted industry standards following the design basis approach. Guidance on control and protection systems can be found in:

- UL 508 *Standard for Industrial Control Equipment*
- IEC/UL 61010-1 *Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 1: General requirements*
- IEC/UL 61010-2-201 *Safety requirements for electrical equipment for measurement, control, and laboratory use - Part 2-201: Particular requirements for control equipment*
- IEEE 1613 *IEEE Standard Environmental and Testing Requirements for Communications Networking Devices in Electric Power Substations*
- NEC article 705 *Interconnected Electric Power Production Sources*
- NEMA ANSI/IEC 60529 *Degrees of Protection Provided by Enclosures (IP Code)*
- NEMA 250 *Enclosures for Electrical Equipment (1000 Volts Maximum)*

In addition to application of selected standards, equipment shall be rated for electrical and environmental conditions of use at the installation location.

5.7.5 Design for Occupational Health and Safety

The design of the OSS should be compliant with all local, state, and/or federal legal requirements pertaining to occupational health and safety. This may vary according to the location of the offshore wind farm and the agencies having jurisdiction. The use of generally accepted industry standards is required in the occupational health and safety related design of the OSS. The application of these design standards should follow the design basis approach as described in Section 5.2.1.This section is limited to design elements affecting safety; guidance for occupational safety is provided in ACP RP-1002.

It is recommended to use DNV-ST-0145, as the basis for design related to occupational health and safety. Additional guidance may be found in G+ GPG Safe By Design.

Throughout this section, references are made to the corresponding sections in 5.6.5 for the WTG, ~~many of~~ which includes references to IEC TS 61400-30. While that standard applies only to the WTG and its support structure, the general principles may be considered as guidance for the OSS.

Recommendations for the application of specific design standards and requirements are included in the following sections.

This section concerns all systems, equipment, and procedures related to design for safety of the offshore substation. Additional requirements for Critical Safety Systems and Equipment (CSSE) are found in Section 5.13.

5.7.5.1 Requirements from U.S. Code of Federal Regulations

Refer to section 5.6.5.1.

To ensure that the design of the OSS is in compliance with Safety Management System requirements from 30 CFR 585.810 the following should be accounted for in the OSS design:

- The OSS shall be designed to allow safe execution of emergency response procedures. This should include following 33 CFR 143.101 *Means of escape*.
- The OSS shall be designed to incorporate measures for fire suppression. This can involve providing secure storage locations for portable fire extinguishers as required by 33 CFR ~~.~~145.01 and 33 CFR 145.10 for unattended facilities.

5.7.5.2 Fall Protection Systems

Refer to Section 5.6.5.2.

5.7.5.3 Helidecks

Helidecks shall be designed according to accepted industry standards.

The FAA and USCG publish regulations for helicopter landing areas.

- FAA AC150/5390-2C provides regulations governing the design, marking, and lighting of helicopter landing decks.
- Coast Guard 46 CFR 108.231

Additional information can be found in the below guidelines:

- HSAC RP Nbr 161 *New Build Helideck Design Guidelines*
- HSAC RP Nbr 166 Aviation Support to Offshore Windfarms
- CAP 437 *Standards for Offshore Helicopter Landing Areas*

Other standards can be used where they specifically address offshore wind farm related hazards and the helicopter access method being used.

5.7.5.4 Cranes and Hoists

Refer to Section 5.6.5.5.

5.7.5.5 Lock-Out Tag-Out

Refer to Section 5.6.5.6.

5.7.5.6 Confined Space

Refer to Section 5.6.5.7.

5.7.5.7 Boat Landing

Refer to Section 5.6.5.8.

5.7.5.8 First Aid

Refer to Section 5.6.5.9.

5.7.5.9 Emergency Response and Evacuation

Evacuation measures from the platform are covered by regulation 33 CFR 143.101.

5.7.5.10 Shelter in Place

Refer to Section 5.6.5.11.

5.7.5.11 Storage of Flammable Liquids

Refer to Section 5.6.5.12.

5.7.5.12 Oil Spill Risk

Refer to Section 5.6.5.13.

5.7.5.13 Fire Safety

Refer to Section 5.6.5.14.

The offshore substation is generally assumed to be an unattended facility.

Additional guidance can be found in NFPA 850 *Recommended Practice for Fire Protection for Electrical Generating Plants and High Voltage Direct Current Converter Stations*.

For passive fire protection design guidance can be found in DNV-ST-0145.

5.7.5.14 Life Saving Appliances

Refer to Section 5.6.5.15.

5.8 Cybersecurity

The wind farm electrical control systems risks production discontinuity from potential cybersecurity threats. Control systems on wind farm assets should be designed according to industry and regulatory standards. Cybersecurity best practice utilizing a Defense-in-Depth security architecture allows for cyber threat deterrence, detection and delaying of the bad actor's penetration and potential detrimental action.

Another important distinction for the offshore wind farm control system related to confidentiality, integrity and availability (CIA) typical in information technology security is the operational technology security reprioritization to focus on system availability and data integrity as the cybersecurity objectives.

Guidance on the offshore wind farm control system cybersecurity can be found in:

- ISA/IEC 62443 Series *Industrial communication networks - Network and system security*
- IEEE 1686 *IEEE Standard for Intelligent Electronic Devices Cyber Security Capabilities*

- IEC 62351 Series *Power systems management and associated information exchange - Data and communications security*

Depending on the wind farm generation capacity and export transmission voltage, the relevant offshore wind farm assets shall be assessed to the applicable regulatory standards for the Bulk Electric System. Bulk Electric System (BES) regulatory standards for control systems can be found in the NERC CIP series of Critical Infrastructure Protection Standards. NERC CIP-002-5.1a shall be utilized to determine the offshore substation overall NERC CIP applicability to offshore wind farm assets.

5.9 Navigational Aids

The facility design report of the Construction and Operations Plan outlined in 30 CFR 2~~5~~85.701 requires a marking concept for aids to navigation and aviation obstruction lighting. BSEE and BOEM rely~~ies~~ on the FAA and USCG and subsequently IALA for the basis of their requirements.

Guidelines on marking an offshore wind farm can be found in the following sources.

~~The facility design report of the Construction and Operations Plan outlined in 30 CFR 585.701 requires a marking concept for aids to navigation and aviation obstruction lighting.~~

~~Guidelines on marking an offshore wind farm can be found in the following sources.~~

General

- BOEM Guidelines for Lighting and Marking of Structures Supporting Renewable Energy Development

Aids to Navigation

- USCG COMDTINST M16500.7A *Aids to Navigation Manual - Administration, Chapter 4 section G, Offshore Renewable Energy Installation – 02 March 2005*
- NVIC 01-19 *Guidance on the Coast Guard's roles and responsibilities for offshore renewable energy installations (OREI)*
- Navigation Regulations 33 CFR 67: *Aids to navigation on artificial islands and fixed structures*
- IALA Recommendation 0-139: *The Marking of Man-Made Offshore Structures*

Obstruction Lighting

- FAA Advisory Circular 70/7460 1M *Obstruction Marking and Lighting*
- FAA Advisory Circular 150-5345 43J *Specification for Obstruction Lighting Equipment*

According to the USCG Aids to Navigation Manual, if an electrical transformer station is not considered to be within the wind farm block, it should be marked as an offshore structure in accordance with 33 CFR 67.

5.10 Subsea Cables

Reference is given to ACP OCRP-5.

5.11 Collection of Input to Operations and Maintenance Manuals

It is recommended that design assumptions are compiled into documentation for input to operation and maintenance manuals and instructions. The documentation should list the design assumptions to be sustained throughout the lifetime of the facility and to be ensured through the operation and maintenance of the facility.

5.12 Retention of Design Documentation

It is recommended that a complete design documentation package be retained for later use in structural assessment for life extension, repowering, alternate uses, or decommissioning. See Chapter 9 Life Cycle Plan for further discussion.

5.13 Critical Safety Systems and Equipment

Critical Safety Systems and Equipment (CSSE), as defined in 30 CFR 285.112, are those which require the most scrutiny during the design, commissioning, and operation of offshore wind farms. This section provides guidance on determining what constitutes CSSE, and the necessary activities for design, certification, and commissioning.

To determine what components of a project are CSSE, a risk assessment shall be performed based on established risk criteria. Risk assessments should be performed according to ANSI B11.0, ISO 12100, ~~ANSI B11.0,~~ DNV-ST-0145 Appendix A, or other recognized industry standards. Additional guidance may be found in ISO 13849-1 or IEC 61508-1. The risk assessment shall begin from a hazard identification. At a minimum, the following hazard categories shall be considered:

- Adverse or extreme weather
- Dropped Objects
- Electrical shock
- Fall from heights
- Fires and explosions (including arc flash)
- Oil or other spills
- Release of hazardous energy
- Vessel impact

The preceding list is a minimum only; a project-specific hazard identification shall be performed, and additional hazards may be identified. Systems or equipment intended to mitigate major accidents as identified in the risk assessment constitute CSSE. A major accident is considered to be a single event with the potential to cause multiple fatalities (consistent with ISO 17776) or significant environmental impacts[12], where "significant" environmental impact shall be determined consistent with the definition and use under the National Environmental Policy Act[13]. Only those systems or equipment which provide an automatic protective action (either sensor- or manually-activated), or other systems or equipment that could reasonably fail during the inspection interval shall be considered as potential CSSE.

When CSSE are based on safe control systems, the characteristics of these control systems ~~must~~ shall also be defined on the basis of a specific risk assessment, additional guidance may be found in ISO 13849-1, IEC 62061, IEC 61511 or IEC 61508-1. Examples of potential CSSE are contained in the informative Annex A.

CSSE commissioning may be partially performed onshore, provided that the functionality of the particular system or piece of equipment is independent of other systems or equipment, and is not materially modified during transport or installation, nor through changes to software, firmware, settings, or configurations that could potentially impact functionality or safety. Those CSSE which interface with other systems (e.g.

[12] The emphasis on multiple fatalities and large-scale environmental impact is not intended to diminish the seriousness of a single fatality or small-scale environmental impact. Rather, it is intended to identify the priority subset of safety systems and equipment critical to facility design and operations and in accordance with relevant laws and regulations.

[13] NATIONAL ENVIRONMENTAL POLICY ACT OF 1969, Public Law 91–190, as Amended Through P.L. 118–5, Enacted June 3, 2023.

SCADA connectivity), or are not fully functional prior to final installation (e.g. requiring backfeed from shore) shall be commissioned offshore. The commissioning plan shall describe how piecewise commissioning activities demonstrate the proper functionality of CSSE. Further details on commissioning and completion are found in Section 7.7.7.

The risk assessment establishing the CSSE for the project, details of CSSE designs, and the CSSE commissioning procedures shall be included in the design documentation.

5.13.1 CSSE for Offshore Wind Turbines

Examples of potential CSSE are listed in Annex A.1 and some of these systems are addressed further in the subsections to 5.6.5.

5.13.2 CSSE for Offshore Substations

Examples of potential CSSE are listed in Annex 0 and DNV-ST-0145 Appendix B.2. Some of these systems are addressed further in the subsections to 5.7.5.

6 Manufacturing and Fabrication

Where fabrication requirements are not covered by codes and standards recommended by this document, generally accepted industry standards shall be applied in the design. The selection and application of these standards should follow the design basis approach as described in section 5.2.1.

6.1 Quality Management Systems

The manufacturing of components for offshore wind facilities should be performed by contractors with demonstrated manufacturing experience that employ a Quality Management System compliant with ISO 9001.

Guidance for quality control, welding, inspection, and testing can be found in API RP 2A-LRFD and API RP 2A-WSD.

If other generally accepted industry standards are applied, the design basis approach should be followed according to Section 5.2.1, with relevant justification.

The chosen manufacturing standards do not need to be common for all wind farm assets and components. Code systems are internally calibrated and code mixing for a specific asset should be avoided as this might lead to an unknown safety level.

6.2 Wind Turbines for Offshore Applications

The manufacturing of offshore wind turbines should be in accordance with manufacturing requirements as defined in the type/component certificate and in accordance with the quality management system standard ISO 9001 referenced by the design standard IEC 61400-1. Any requirements in these standards pertaining to support structures subject to fatigue or an offshore environment should apply.

6.3 Offshore Substation Electrical System Manufacturing Requirements

International Council on Large Electric Systems (CIGRE) Study Committee B3 covers design, construction, maintenance, and ongoing management of high-voltage substations and electrical installations in power stations, excluding generators. Guidance is given in the following document:

- CIGRE 483 *Guidelines for the Design and Construction of AC Offshore Substations for Wind Power Plants*

6.4 Offshore Wind Turbine Support Structure and Offshore Substation Structural Fabrication

6.4.1 Welding

Requirements for welding—including weld procedures, welding details, records, and documentation—and qualification of weld procedures, welders, and weld operators are given in API RP 2A-LRFD or API RP 2A-WSD, as well as AWS D1.1. In lieu of those API and AWS standards, welded connections may be fabricated following ISO 9692-1 and ISO 9692-2, or DNV-OS-C401. ISO 10474 should be used for the documentation requirements when fabricated according to ISO 9692.

6.4.2 Corrosion Protection

Fabrication, application, installation, and testing of corrosion protection measures for the atmospheric, splash, and submerged zones of the support structure should be performed in accordance with the standards selected for design; refer to Sections 5.6.3.4 and 5.7.3.3. Equipment installed in the tower or rotor-nacelle assembly should adhere to guidance given in IEC 61400-3-1, Annex G.

In addition to the above, other ISO, ASTM, SSPC/NACE, and VGB/BAW standards may be relevant.

6.4.3 Drawings and Specifications

The drawings and specifications for use in connection with fixed offshore wind turbine support structures and foundations, offshore substations, and related facilities are defined in API RP 2A LRFD or API RP 2A-WSD. Other ISO standards (in particular ISO 128-1: *Technical Drawings – General principles of presentation*, and ISO 1101: *Geometrical Product specifications (GPS)*) may apply.

Additional ASTM standards may apply depending on the material selected. Requirements for the compilation and maintenance of records and documentation concerning materials are given in API RP 2A-LRFD or API RP 2A-WSD. For inspection documentation ISO 10474 is an acceptable alternative.

6.4.4 Materials

Requirements for the selection, supply, and fabrication of structural steel used for fixed offshore wind turbine support structures and foundations and for offshore substations are provided in API RP 2A LRFD, API RP 2A-WSD, DNV-OS-B101, or the ABS Rules for Materials and Welding. Additional requirements are found in ASTM A6 and other applicable ASTM standards, or in EN 10025 / EN 10225 depending on the steel grades selected.

Requirements for the selection, supply, and use of cement grout for fixed offshore wind turbine support structures and foundations and for offshore substations are provided in API RP 2A LRFD or API RP 2A WSD. Guidance on the selection, supply, and use of cement grout used for connections between offshore wind turbine transition pieces and monopiles should follow recognized standards that are specific to offshore wind turbines.

Requirements for mixing of concrete materials for use in offshore wind turbine structures shall follow standards and guidelines which are in compliance with the design standards identified in the design basis described in Section 5.2.1. Special requirements regarding durability and water-tightness of the material will normally apply for the marine environment. This can for example be related to chloride content, total cement content, water-cement ratio, and air content. Normal requirements for concrete material are included in for example the ACI 304 series and in the ISO 22965 series, and additional guidance specific for offshore structures can be found in for example ACI 357.3R, UFGS-03 31 30, DNV-ST-0126, DNV-ST-C502, ABS BOWT Guide, and ABS Rules for Offshore Installations.

Requirements for reinforcing steel for use in offshore wind turbine structures shall follow standards and guidelines which are in compliance with the applied design standards. Normal requirements for reinforcing steel material are included in for example ASTM A615, A706, A955, or other ASTM standards; in the ISO 6934 series; and in the ISO 6935 series. Requirements for prestressing strands, wires, and bars are xincluded in ASTM A416, A421, and A722. Special requirements for the marine environment can be found in ACI 318, DNV-ST-0126, DNV-ST-C502, ABS BOWT Guide, and ABS Rules for Offshore Installations.

Additional requirements and information concerning structural materials supply are provided in API RP 2A-LRFD or API RP 2A-WSD.

Requirements for the compilation and maintenance of records and documentation concerning materials are given in API RP 2A-LRFD or API RP 2A-WSD.

6.4.5 Steel Fabrication

Requirements for fabrication of offshore steel structures for wind turbines shall follow standards and guidelines which are in compliance with the design standards identified in the design basis described in Section 5.2.1 and material standards for the material grades used in the fabrication. Steel fabrication should be in accordance with API RP 2A-LRFD or API RP 2A-WSD and its references to ASTM A6 and ISO codes. Additional guidance may be found in DNV-OS-C401 and the ABS Rules for Materials and Welding. AISC 303 and AISC 360 Chapters M and N contain additional guidance relevant to platforms, boat landings, ladders, railings, and other small or secondary steel components.

Each member of the support structure should be located accurately to the final fabrication tolerances given in the design documentation. Other tolerances not stated herein should be in accordance with the API RP 2A LRFD or API RP 2A WSD, AISC 303, and AISC 360.

Provisions for the fabrication of grouted pile-to-sleeve connections are given in API RP 2A LRFD or API RP 2A WSD. Additional guidance is given in DNV-ST-0126, DNV-ST-C502 and NORSOK N-004. Provisions for fabrication of the grouted connections between offshore wind turbine transition pieces and monopiles should follow recognized standards that are specific to OWT.

Any temporary attachments to the support structure, such as scaffolding, fabrication, and erection aids should be limited as much as practicable. When these attachments are necessary, the requirements stated in the design documentation, and at a minimum API RP 2A-LRFD or API RP 2A-WSD should be met.

6.4.6 Concrete Fabrication

Requirements for fabrication of offshore concrete structures for wind turbines shall follow standards and guidelines which are in compliance with the applied design and material standards. Special requirements regarding fabrication will normally apply for wind turbines in a marine environment. This can for example be related to tolerances, depth of concrete cover, welding on reinforcement, and quality control.

Normal requirements for fabrication of offshore concrete structures are included in for example the ACI 304 series together with ACI 309, in the PCI Design Handbook, and in ISO 22966. Specific requirements for fabrication of offshore wind turbine concrete structures can be found in for example DNV-ST-0126, DNV-ST-C502, and the ABS BOWT Guide.

6.5 Subsea Cables

Reference is given to ACP OCRP-5.

7 Transport and Installation

7.1 General

Guidance provided in this chapter is largely drawn from ISO 29400, *Ships and marine technology – Offshore wind energy – Port and marine operations*. That document is based on ISO 19901-6, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 6: Marine operations*, but has been extensively adapted to meet the specific requirements of the offshore wind industry. ISO 19901-6 has been adopted verbatim in the U.S. under API RP 2MOP.

Additional guidance is also included from DNV-ST-N001, Marine operations and marine warranty, which is a standard that is widely adopted throughout the global maritime industry and is regarded as a benchmark of recognized safety levels and current industry best practice.

The combination of activities required to safely transport and install offshore wind farm components is complex and often carried out by a number of different parties. Due to the interdependence of those activities, it is necessary to ensure that a holistic perspective of the overall process is maintained at all times. This particularly applies when considering the potential consequential impacts of proposed changes in any one area of a plan that has been agreed between multiple parties.

At all times during the transportation and installation of offshore wind farm components, the primary objective should be to ensure that all activities are carried out in such a way that risk of accidents or incidents to personnel, environment and/or property is minimized. The recommended target is to bring these risks to a level that is as low as reasonably practicable (ALARP).

Due to the magnitude, complexity and level of investment that offshore wind projects require, it is generally the case that developers, investors and/or insurance underwriters will require that a Marine Warranty Surveyor (MWS) be appointed to act as marine experts on their behalf. The role of MWS is to ensure that specific project marine operations are performed to recognized codes and standards, and within acceptable risk levels. If an operation proceeds without requisite MWS approval being in place, this may void the insurance policy in the event of an incident.

Guidance on the Marine Warranty Surveyor (MWS) can be found in Section 2.4 of this document, ISO 29400, Section 6.7 and generally throughout DNV-ST-N001.

7.1.1 References

Neither this document, IEC 61400-3-1 nor any other individual documents referenced herein, provide complete guidance for the transport and installation of offshore wind farm components in the U.S. All documents should be supplemented with other guidelines, recommended practices, and/or standards as and where appropriate. Some of these documents and other documents to which they refer may have conflicting information. In many cases, these conflicts occur because not all of the documents treat necessary considerations in the same way or with the same level of detail, and different publication dates result in documents incorporating differing bodies of knowledge.

In addition, transportation and installation of offshore wind farm components will often be carried out across a number of different jurisdictions. Where this is the case, all relevant national, state and/or local regulations should be identified, included in the planning process, and complied with as required.

Those responsible for the transportation and installation of offshore wind farm components should endeavor to determine and select, with a certified verification agent (CVA) and/or regulatory approval authority, which provisions are most appropriate and consistent with the overall transport and installation plan. Reference documents which may be relevant to the planning of transport and installation for offshore wind farm components, without consideration to any order of document priority, are as follows:

IEC References

- IEC 61400-3-1 *Wind turbines - Part 3-1: Design requirements for fixed offshore wind turbines*

ISO References

- ISO 29400 *Ships and marine technology – Offshore wind energy – Port and marine operations*
- ISO 19901-6 *Petroleum and natural gas industries - Specific requirements for offshore structures - Part 6: Marine operations*

- ISO 19905-1 *Petroleum and natural gas industries - Site-specific assessment of mobile offshore units - Part 1: Jack-ups*
- ISO 17776 *Petroleum and natural gas industries, Offshore Production Installations, Guidelines on Tools and Techniques for Hazard Identification and Risk Assessment*

DNV References

- DNV-SE-0080 *Noble Denton marine services - marine warranty survey*
- DNV-ST-0054 *Transport and installation of wind power plants*
- DNV-ST-N001 *Marine operations and marine warranty*
- DNV-ST-N002 *Site specific assessment of mobile offshore units for marine warranty*
- DNV-RP-N101 *Risk management in marine & subsea operations*
- DNV-RP-N103 *Modelling and analysis of marine operations*

API References

- API RP 2MOP *Petroleum and natural gas industries-Specific requirements for offshore structures - Part 6: Marine Operations* (Note that this document is an adoption of ISO 19901-6 in the U.S. without modification)
- API RP 2A-LRFD *Planning, Designing, and Constructing Fixed Offshore Platforms - Load and Resistance Factor Design*
- API RP 2A-WSD *Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design*

Renewable UK References

- RUK13-001-6 *Offshore Wind and Marine Energy Health and Safety Guidelines*
- RUK13-019-3 *Guidelines for the Selection and Operation of Jack-ups in the Marine Renewable Energy Industry*
- RUK15-009-3 *Vessel Safety Guide - Guidance for Offshore Renewable Energy Developers*

European Industry References

- OE-RP-01 *Recommended Practice – Design of Lifting, Transport, Storage and accessory Equipment*
- OE-GL-01 *Recommended Practice & Guideline – Planning and Execution of WTG Lifting Operations*
- IMCA LR 006 *Guidelines for Lifting Operations*

7.2 Risk Management

Vessels employed in the transport and installation of offshore wind farm components will generally have a Safety Management System (SMS). Where personnel from a third-party organization are embarked, such as offshore construction teams, and that organization also has an SMS, it is prudent that a bridging document between the two systems is developed. This will ensure a clear and common understanding of assigned responsibilities and which elements of the respective systems will apply to any given operation.

Hazard identification and risk assessment are essential elements of the planning process for the transportation and installation of offshore wind farm components. A risk matrix should be completed for each step of the transportation and installation process, as part of an overall risk assessment and mitigation plan.

It is good industry practice to develop a Risk Assessment Method Statement (RAMS) for all activities that will be undertaken, particularly where significant safety risks are involved. Each RAMS should be activity-specific and consider unique aspects of the respective activities involved, such as physical location, resources required, environmental constraints and any nearby or simultaneous operations (SIMOPS).

Guidance for assessing risks during marine operations can be found in the following documents:

- ISO 29400 *Ships and marine technology – Offshore wind energy – Port and marine operations*, Section 5.4
- DNV-RP-N101 *Risk management in marine & subsea operations*
- DNV-RP-N103 *Modelling and analysis of marine operations*
- RUK13-001-6 *Offshore Wind and Marine Energy Health and Safety Guidelines*, Section C.13.3
- RUK13-019-3 *Guidelines for the Selection and Operation of Jack-ups in the Marine Renewable Energy Industry*, Section 20

The extent of activities that are required during the transport and installation of offshore wind farm components differs markedly from the traditionally lower numbers of activities required in similar oil and gas operations. This significantly increases the risk of potential interference between concurrent operations, which in turn may give rise to unsafe situations. Any effects on and from any other SIMOPS shall be duly considered and appropriate mitigations applied as needed.

Guidance on SIMOPS can be found RUK13-001-6, Section A.10 and IMCA M 203 – *Guidance on Simultaneous Operations (SIMOPS)*.

7.3 Planning and Documentation

Adequate planning, risk assessment, and documentation should be in place to fully detail the safe transport and installation of offshore wind farm components and all associated activities. Component installers need to be engaged at the earliest opportunity in the offshore wind farm planning process to mitigate risk. As stated above, it is good industry practice to include a RAMS for each activity, as part of an overall documentation process.

Project documentation should at a minimum follow the requirements of 30 CFR 285 and 30 CFR 585 for projects in federal waters, with additional industry-based guidance also available in ISO 29400, Section 6 and DNV-ST-N001, Section 2.

All offshore wind projects located in federal waters are required under 30 CFR 585.620 through 585.~~638~~ 635 to have a Construction and Operations Plan (COP). Any restrictions listed in the COP should be taken into account during the planning stage for transport and installation of offshore wind farm components. In addition, requirements described in the design basis as outlined in Section 5.2.1 of this document should also guide the planning and documentation process.

Requirements for the compilation and retention of data related to inspection that is generated during the fabrication, erection, loadout and installation of offshore wind farm components, can be found in API RP 2A-WSD, Section 16.7.

Documentation may differ on a project-by-project basis, depending on the complexity of activities to be carried out and the level of risk involved. However, it is recommended that project documentation define applicable technical standards to ensure there is agreement and uniformity with bridging documents where necessary. Project documentation should address matters including, but not limited to:

- International and national standards and legislation
- Certifying authority/regulatory body standards
- Marine warranty surveyor guidelines
- Project criteria
- Marine coordination

- Emergency response
- Hazard Identification study (HAZID)
- Risk Assessment Method Statement (RAMS)
- Contingency planning
- Safety Management System (SMS) - including bridging document(s) as appropriate
- Design basis
- Metocean criteria
- Calculation procedures
- Change management
- Interface management

During the planning phase, a full engineering analysis of the installation platform, the installation deployment system, and installation methodology should be completed.

Considerations for developing the installation plan for offshore wind farms can be found in IEC 61400 3-1, Section 12.2, with additional industry-based guidance also available in ISO 29400, Section 18.1.5.

Guidance on documentation for and the planning of marine operations is provided in ISO 29400, Section 6, with additional guidance on hazard identification and risk assessment available in RUK13-019-3, Section 20.

Guidance on documentation for offshore installation of offshore wind farm components can be found in DNV-ST-0054, Section 3.7.1.

When a self-elevating unit is required to elevate at a location, a Site-Specific Assessment (SSA) shall be performed and documented in accordance with ISO 19905-1, *Petroleum and natural gas industries - Site-specific assessment of mobile offshore units - Part 1: Jack-ups*.

7.3.1 Structural Integrity and Allowable Stresses

To ensure the structural integrity of all offshore wind farm components is maintained during each phase of transportation, storage, and installation, allowable stresses and/or loads should be determined during the design phase, as outlined in Section 5 of this document. Respective limit values for each component should be promulgated as part of the project documentation package. These limit values, along with performance characteristics of the vessel(s) and other equipment being used, will form the basis on which operational limits or environmental restrictions are determined.

Guidance on loading and structural strength can be found in DNV-ST-N001, Section 5.

Guidance on structural integrity during transportation can be found in ISO 29400, Section 8.2.

Guidance on grillage and sea fastening can be found in ISO 29400, Section 16.17.5, with additional guidance available in DNV-ST-N001, Section 11.9 and RUK13-019-3, Section 7.

Guidance on structural integrity during storage can be found in ISO 29400, Sections 9.8.

Guidance on structural integrity during installation can be found in ISO 29400, Sections 15.2.2, 16.2.6 and 16.2.7.

7.4 Metocean Requirements

Offshore construction activities and marine operations are generally weather-sensitive, requiring favorable weather and sea-state conditions to ensure they can be carried out in a safe manner. For higher risk activities, operations may be deemed weather-restricted. As such, it is necessary to ensure that weather windows of suitable metocean conditions are specified for each phase of an operation; weather windows must be sufficient in duration and within required limits of both component design and equipment operating parameters.

For metocean considerations reference is given to ACP OCRP-3.

Guidance on metocean conditions, criteria, operational limits, weather restricted and unrestricted operations, weather windows, and metocean forecasts can be found in the following:

- IEC 61400-3-1 *Wind turbines - Design requirements for fixed offshore wind turbines*, Section 12.5
- ISO 19901-1 *Petroleum and natural gas industries - Specific requirements for offshore structures – Part 1: Metocean design and operating considerations*, Section 5.9
- ISO 19901-6 *Petroleum and natural gas industries - Specific requirements for offshore structures – Part 6: Marine operations*, Section 7
- ISO 13628-5 *Petroleum and natural gas industries - Design and operation of subsea production systems - Part 5: Subsea umbilicals*, Section 15.4.3, Weather window for pull-in
- ISO 29400 *Ships and marine technology - Offshore wind energy - Port and marine operations*, Section 7
- DNV-ST-N001 *Marine operations and marine warranty*, Sections 2.6 and 2.7.

Due regard should be given to limitations that apply in each of the respective operating modes of vessels and self-elevating units (e.g. loadout, transit, station keeping, installation, jacking, elevated).

For unrestricted operations, self-elevating units should meet appropriate acceptance criteria for elevated survival and operational conditions as described in ISO 19905-1, with further insight available in DNV-ST-N002.

For weather restricted operations, reference is made to ISO 29400 Sections 7.2 and 7.5, with subsequent reference to DNV-ST-N001 Section 2.6.7 and RUK13-019-3, Section 5.

Weather forecasts should be available from a recognized meteorological agency that has detailed knowledge of the area of operations. The use of an independent weather buoy to monitor prevailing onsite wind and wave conditions is recommended on larger offshore wind facilities.

Guidance on weather forecasts can be found in ISO 29400, Section 7.4 and RUK13-019-3, Section 18.3.

7.5 Transport

When offshore wind farm components are transferred between various locations, a range of factors relating to how they will be transported shall be considered. Transfers may include from their point of manufacture to the site where they are installed to operate, between their offshore operating location and a repair or decommissioning facility, or any other required locations.

Guidance on the transport of offshore wind farm components can be found in ISO 29400, Section 16 and distributed throughout both DNV-ST-0054 and DNV-ST-N001.

7.5.1 Pre-installation Transport

Transport between the point of manufacture and the installation marshalling port may involve modes of transport that include land-based road and/or rail, inland and/or nearshore waterways, and ocean-going voyages. To provide ease of handling and protection of nacelles when they are being transported, a purpose-built and certified transport frame is used as the interface between the nacelle and the vehicle or vessel on which it is being transported.

Guidance on pre-installation transport and transport frames can be found in ISO 29400, Section 8 and DNV-ST-0054, Sections 3.3.1 and 3.3.2.

7.5.2 Intermediate Storage and Load Bearing

To ensure there is a ready supply of offshore wind farm components available for loading onto installation vessels at the marshalling port, adequate storage areas are required to accommodate a sufficient number of components. Due to the size, weight, and load density of offshore wind farm components it is necessary that areas set aside for their storage are engineered with sufficient load bearing capacity. This is particularly the case when components are concentrated in close proximity to each other, such as at the quayside where they will be loaded onto an installation vessel.

Guidance on intermediate storage and load bearing can be found in ISO 29400, Section 9 and DNV-ST-0054, Section 3.2.

7.5.3 Pre-Assembly

In preparation for loadout, some components may require pre-assembly and other pre-installation activities to be carried out. This may include the preparation of turbines to a pre-commissioning stage, by fitting rotor hubs to nacelles and preparing internal electrical components. It may also include assembling tower sections into complete towers, as well as fitting internal electrical switch gear, platforms and/or other equipment to foundation transition pieces before they can be loaded.

Guidance on pre-assembly requirements can be found in ISO 29400, Section 10 and DNV-ST-0054 Section 3.2.

7.5.4 Harbor Infrastructure

Infrastructure in harbors where specialized jack-up installation vessels operate should be able to accommodate their unique operating characteristics. In addition to being able to safely maneuver and having safe clearance from obstacles, either above or below the water, the ability of the seabed adjacent to the quayside to withstand repeated jacking operations is crucial. Prior to a jack-up vessel elevating at a quayside, an SSA as outlined in 7.1.3 above shall be carried out.

Guidance on harbor infrastructure can be found in ISO 29400, Section 11.

7.6 Vessels

All vessels employed in the transport and installation of offshore wind farm components should in general comply with national (e.g.: USCG), international, and class requirements, as applicable to that vessel and its operations.

A range of vessels can be used in the transport and/or installation of offshore wind farm components. Factors that may influence the type of vessel(s) selected include, but are not limited to:

- Amount of space required for storage of components that ensures continuous safe access
- Nature of voyage(s) to be undertaken and other activities to be carried out
- Experience of vessel owner and crew in carrying out the intended voyage(s)
- Sufficient deck strength for point-loads that will be exerted by the components when loaded
- Suitability of the vessel for the intended operating port and anticipated metocean conditions
- Availability of suitable accommodation and facilities for personnel to be deployed onboard
- Appropriate certification and other regulatory approvals for the nature of intended voyage(s)

Methodologies for the installation of an offshore wind farm can generally be categorized as either a “fetch” or “feeder” solution. In the fetch solution, offshore wind farm components are loaded directly onto an installation vessel at the loadout or marshalling port, transported out to the offshore sites and installed. In a feeder solution, the installation vessel remains within the offshore wind farm location and moves between installation sites, while components are provided by secondary vessels. Offshore transfer of components between secondary vessels and an installation vessel may introduce risk to the project, but this may in turn be offset by efficiency gains and other intrinsic benefits.

Guidance on fetch and feeder methodologies can be found in RUK13-001-6, Section B.7.3.

One benefit of the feeder solution for installation of an offshore wind farm in the U.S., is that it is able to address restrictions in Section 27 of the Merchant Marine Act of 1920, more commonly known as the Jones Act. This legislation requires that all cargo shipped between two points within the U.S. is carried on vessels that have been built in the U.S., are owned by U.S. companies, crewed by U.S. citizens, and registered or flagged in the U.S.

In the absence of Jones Act compliant Self-Elevating Heavy-Lift Crane Vessels or where a loadout port has air draft restrictions, feeder solutions may be the most immediately available method to supply offshore wind farm components from U.S. ports to foreign-flagged installation vessels stationed at the offshore wind farm site offshore. It is possible that offshore wind farm components could be supplied from non-U.S. ports, however this would likely also add further complexity and risk to a project.

7.6.1 Vessel Types

The types of vessels that may be used for transport, but not installation of offshore wind farm components include:

- Tug and barge
- General cargo vessel
- Self-elevating vessel (jack-up / lift boat) – self-propelled or towed, no crane fitted
- Semi-submersible heavy lift vessel – no crane fitted

The types of vessels that may be used for transport and/or installation of offshore wind farm components include:

- Self-Elevating Heavy-Lift Crane Vessel (jack-up/lift boat) – self-propelled, crane fitted
- Floating Heavy-Lift Crane Vessel
- Semi-Submersible Heavy-Lift Crane Vessel
- Sheer-Leg Crane Barge – self-propelled or towed

Guidance on vessel types and their selection can be found in RUK13-001-6, RUK13-019-3 and RUK15-~~019~~009-3.

7.6.2 Loadout Operations

The loadout of offshore wind farm components typically involves the transfer of heavy objects from a quayside onto a vessel. However, components may also be transferred directly from one vessel to another. The vessel(s) used may be floating, elevated, or grounded on the seabed. The transfer of offshore wind farm components may be carried out by the use of trailers, skidding arrangements, or cranes.

General guidance on loadout operations and methods employed can be found in ISO 29400, Section 15, DNV-ST-0054, Section 3.6.1, and DNV-ST-N001, Section 10.

Factors that should be considered for loadout operations include, but are not limited to:

- Limiting Conditions – changes in tide level and/or weather restricted operations
  - See ISO 29400, Section 15.2, and DNV-ST-N001, Section 10.2.1
- Deck Strength – adequate to withstand the forces that will be imparted during loadout
  - See ISO 29400, Section 15.2.5
- Stability and Watertight Integrity – calculation and management for vessel safety

  - See ISO 29400, Section 13.10, and DNV-ST-N001, Section 11.10.8
- Ballasting and Anti-Heeling Systems – to ensure vessel remains within permissible limits
  - See ISO 29400, Sections 14 and 15.9, and DNV-ST-N001, Section 4
- Grillage and Sea Fastening – vessel-specific design able to withstand forces/motions
  - See ISO 29400, Section 16.17.3, RUK13-019-3, Section 7, and DNV-ST-N001, Section 10.7.9
- Non-lifted Loads – self-propelled modular transporter (SPMT) or skidding arrangement
  - See ISO 29400, Section 15.10, and DNV-ST-N001, Section 9.3.2 and 10.3.5
- Lifted Loads – use of quayside crane(s), floating crane(s), or installation vessel crane(s)
  - See ISO 29400, Section 15.13, and DNV-ST-N001, Section 9.3.2 and 10.3.5

Irrespective of the approach that is taken, the safety of loadout operations relies on thorough and comprehensive planning that has been effectively communicated to and understood by all parties involved. Guidance on loadout planning can be found in ISO 29400, Section 15.2.3 with additional guidance also available in DNV-ST-N001, Section 15.2.2.

Inspections related to all areas of loadout, sea fastening, and transportation should be carried out in accordance with API RP 2A-WSD, Section 16.5.

As with many other phases in the transportation and installation of offshore wind farm components, a MWS will generally issue a Certificate of Approval (CoA), prior to loadout operations being able to commence.

Guidance on MWS and CoAs can be found in ISO 29400, Section 6.7, and generally throughout DNV-ST-N001.

7.6.3 Voyage Planning

A detailed voyage plan ensures that all relevant parties have appropriate information available as and when it may be needed. This includes the Master of the vessel undertaking the voyage as well as shore-based personnel who may need to provide assistance and/or respond to an incident.

General guidance on voyage planning can be found in ISO 29400, Section 16.2.8, with additional guidance also available in DNV-ST-N001 Section 11.14.

When loaded with offshore wind farm components, a vessel will generally only be permitted to undertake a voyage when the environmental conditions it will be subjected to are forecast to remain within certain pre-determined parameters. This is to ensure the vessel and loaded offshore wind farm components, along with the grillage and sea fastening by which they are interconnected, all remain within their respective design limits at all times. As such, voyages that involve offshore wind farm components may be weather restricted.

For loads on offshore wind farm components, grillage, and sea fastening during transit, refer to Section 7.3.1 above.

Guidance in relation to weather restricted operations can be found in ISO 29400, Sections 7.2.1 and 7.5.2, with additional guidance also available in DNV-ST-N001, Section 11.14.4.

Other factors to be considered in the voyage planning process include, but are not limited to:

- Clearances – maneuvering room, overhead air draft and under keel clearance (UKC)
  - See ISO 29400, Sections 16.9 to 16.12, and DNV-ST-N001, Sections 11.14.2, and 11.14.20 to 11.14.22
- Contingencies – alternate routes, locations of safe haven and ports of refuge
  - See ISO 29400, Sections 16.2.4 and 16.4, and DNV-ST-N001, Section 2.5.4

The MWS will generally also require that a CoA be issued prior to a vessel loaded with offshore wind farm components being able to commence a voyage.

Guidance on MWS and CoAs can be found in ISO 29400, Section 6.7 and more generally throughout DNV-ST-N001.

7.6.4 Towing

Details provided in the above sections relating to loadout operations and voyage planning remain broadly relevant to all forms of seaborne transport. However, when offshore wind farm components are to be towed, either supported by means of inherent buoyancy (wet tow) or when loaded onto a barge (dry tow), additional factors need to be considered.

Guidance on general towing operations can be found in ISO 29400, Sections 16.14 through 16.17, and DNV-ST-N001, Sections 11.11 through 11.13.

Guidance on wet tow operations can be found in DNV-ST-0054, Section 3.6.2.

7.7 Offshore Installation

The approach taken when installing an offshore wind farm will depend on a range of factors including, but not limited to, the unique characteristics of the offshore sites and the type of offshore wind farm components selected for the project. In addition, the type of equipment and experience of personnel will have a bearing on how well offshore installation activities can be optimized, as well as the efficiency with which they can be carried out.

General guidance on offshore installation can be found in ISO 29400, Section 18, with additional guidance also available in DNV-ST-0054, Section 3.7, and DNV-ST-N001, Section 8.7.

Irrespective of the approach that is taken, activities required to complete offshore installation are generally sequenced to allow for interdependencies between the various work scopes. A number of offshore activities such as environmental, geological, and hydrographical surveys are undertaken in the lead up to construction of an offshore wind farm. However, activities executed during the installation phase and the sequence in which they are generally carried out is as follows:

- Wind Turbine Foundations
- Offshore Substation (OSS) – including both the foundation and topside
- Array Cables
- Export Cable
- Wind Turbines

Additional information about the above listed activities is provided later in this chapter.

During the installation of fixed-bottom offshore wind turbine components, any requirements identified under the COP for the protection of marine mammals or threatened and endangered species, such as the embarkation of Protected Species Observers (PSOs) and/or the deployment of Noise Mitigation Systems (NMS), must be fully complied with.

Guidance regarding COP requirements for the protection of marine mammals or threatened and endangered species can be found in 30 CFR 2~~5~~85.801.

Insurers that underwrite risks associated with offshore installation activities will typically require that a MWS be appointed to oversee all relevant marine aspects.

Guidance on MWS can be found in ISO 29400, Section 6.7 and more generally throughout DNV-ST-N001.

Due to the complexity of activities undertaken during the installation of an offshore wind farm, and to reduce the likelihood of potential conflicts, close coordination of all offshore operations is also needed. This function is usually carried out by the Marine Coordinator, who will normally be based in the Marine

Coordination Center (MCC), which is generally located in the project's loadout or marshalling port. The Marine Coordinator is responsible for the exchange of information between all relevant parties involved in offshore installation, coordination of their activities and controlling access to the site.

Guidance on the Marine Coordinator can be found in ISO 29400, Section 21.2, with additional guidance available in DNV-ST-N001, Section H.2.1, and RUK13-001-6, Section C11.

Inspection requirements prior to lifts, launches, and upendings can be found in API RP 2A-WSD, Section 16.6.1.

7.7.1 Lifting Equipment and Lifting Operations

Installing offshore wind farm components generally involves a crane lifting and maneuvering heavy loads into position, within fine tolerances and often at considerable height. To ensure these operations are successfully completed both safely and efficiently a significant level of detail is required in the engineering design and operational planning phases. Design aspects should comply with the relevant engineering standard(s) and include adequate margins of safety, while operational plans should derive from a thorough RAMS process, as outlined in section 7.2.

Lifting equipment shall be certified and compatible with both the component being lifted and the nature of lifting operation being undertaken. Lifting operations should be based on a detailed lifting plan that is consistent with the complexity of the lift being made, taking into account such factors as the load's weight and center of gravity, as well as dynamic amplification, clearances, and load control.

Guidance on the design, manufacture, testing, and certification of lifting equipment can be found in DNV-ST-0378 - *Standard for offshore and platform lifting appliances*.

Guidance on the certification of lifting equipment can also be found in ABS Guide for Certification of Lifting Appliances.

Additional industry-based guidance on lifting equipment is available in OE-RP-01 *Recommended Practice – Design of Lifting, Transport, Storage and accessory Equipment*.

Guidance on lifting equipment and lifting operations can be found in ISO 29400, Section 19, with additional guidance available in DNV-ST-N001, Section 16, and RUK13-019-3, Section 15.

Additional industry-based guidance on lifting operations is available in OE-GL-01 *Recommended Practice & Guideline – Planning and Execution of WTG Lifting Operations*.

When the installation of offshore wind farm components is to be carried out by a Self-Elevating Crane Vessel, operational lifting conditions should be addressed in accordance with ISO 19905-1.

7.7.2 Installation Plan

As part of the planning and documentation process outlined in Section 7.3 above, the installation plan is a key document that provides insight on a wide range of information, with implications for many aspects of an offshore wind farm's development and construction.

Conceptual details such as site characteristics, proposed design standards, tentative schedule, types of installation equipment, and methodology to be used will have a significant bearing on various other aspects of the project and should be defined early in the development phase. More comprehensive information, including but not limited to details of the loadout port, installation vessels, RAMS, and interface management should all be clearly documented, approved, and circulated to all relevant stakeholders well before the commencement of construction.

Guidance on installation planning can be found in IEC 61400-3-1, Section 12.2, ISO 29400, Section 18.1.5 and Annex A.5, DNV-ST-0054, Section 2, and DNV-ST-N001, Sections 2 and 8.2.

Physical characteristics of an offshore wind farm site are key drivers of the installation plan. Activities to establish details about the characteristics of an offshore site may include, but are not limited to:

- Seabed Surveys – bathymetric / side-scan sonar / magnetometer / ground truthing etc.

- See ISO 29400.Section 18.2.1, and RUK13-019-3, Section 9

- Geotechnical / Geophysical Surveys – to determine seabed/subsurface soil conditions
  - See ISO 29400, Section 18.2.2
- Unexploded Ordinance (UXO) Survey – for potential clearance to ensure site safety
  - See ISO 29400, Section 18.2.5, and RUK13-001-6, Section C.19
- Metocean Investigation – for location-specific details of wind, wave, current at the site
  - See ISO 29400, Section 7.3, RUK13-001-6, Section C.12.1.3, and DNV-ST-N001, Section 3

For geotechnical and geophysical considerations, reference is given to ACP OCRP-4.

The installation plan should include information about the types of vessels and equipment to be used, including their respective functions, capabilities, and limitations, along with guidance on any restrictions and/or risks associated with their use. It is good industry practice for a Failure Mode Effects Analysis (FMEA) to be carried out on any vessels, systems, or equipment that are deemed critical to ensuring safe operations.

Guidance relating to vessels, systems and equipment can be found in ISO 29400, Section 6.8.

Guidance relating to FMEA is available in RUK13-019-3, Section 15.6.2.

Due to the complexity of offshore wind farm installation activities, effective management of interfaces between the respective parties involved is crucial to ensuring safe operations. Including a responsibility matrix as part of an installation plan to provide clarity on each party's role is good industry practice.

Guidance on interface management can be found in RUK13-001-6, Section B.2.4, with additional guidance available in DNV-ST-N001, Appendix H.2.1.

Guidance relating to responsibility matrix can be found in DNV-ST-N001, Appendix B.1.3.

To ensure a clear understanding in the case of potential weather restricted operations, details of the limiting criteria, beyond which it has been deemed that operations may become unsafe, should also be included as part of the installation plan.

Guidance on operational limiting criteria can be found in DNV-ST-N001, Section 2.6.8.

7.7.3 Foundation Installation

A range of sub-structure types may be deployed as the foundation for a fixed-bottom offshore wind turbine. Floating deployment of offshore wind turbines is outside the scope of this document and installation of foundation options for floating offshore wind turbine are not addressed here. Reference is given to ACP OCRP-2.

Listed below are the types of fixed-bottom foundations currently in use today, along with references to relevant guidance about the options available for their installation:

- Monopile and transition piece arrangement
  - See DNV-ST-N001, Section 8.7.1, and DNV-ST-0054, Section 4.1.2
- Jacket structure in either a lattice, twisted or hybrid configuration
  - See DNV-ST-N001, Section 13, and DNV-ST-0054, Section 4.1.3
- Gravity based structure (GBS)
  - See DNV-ST-N001, Section 6, and DNV-ST-0054, Section 4.1.1
- Suction bucket or caisson design
  - See DNV-ST-N001, Section 8.7.3, and DNV-ST-0054, Section 4.1.4

Fixed-bottom foundations may be transported from the loadout port to the installation site by a variety of means, as outlined in Section 7.6.1 above. In addition, it is possible that the wet tow method outlined in Section 7.6.4 may be used to bring monopile, jacket, or GBS foundations to the installation site.

Further to the above referenced guidance, additional information regarding installation of fixed-bottom foundations is also available throughout ISO 29400 and DNV-ST-N001.

Guidance on inspections that are required for installation of monopiles and/or pin-piles are defined in API RP 2A-WSD, Section 16.6.2. In addition, blow count records should be maintained, including both the blow count per 1m (3 ft) of penetration and the total blow count at every 1m (3 ft) of penetration, until the design penetration is achieved, the blow count limits are reached, or pile refusal is encountered. For grouted connections relative movement during curing shall be limited to prevent significant early age cyclic loading. Guidance on limiting values can be found in DNV-ST-0126. Sub-structure installation inspection should also confirm that verticality is within the range required to allow the offshore wind turbine tower to be installed within the turbine manufacturer's tolerances.

Guidance on inspections that are required when foundation installation includes underwater operations, can be found in API RP 2A-WSD, Section 16.6.4.

If it has been determined through site investigations that a risk of scour exists, scour protection will typically be installed around the base of a foundation. This will protect against potential movement of seabed sediment as a result of either current and/or wave motion at the site, which may undermine integrity of the foundation itself and/or expose cables in the immediate vicinity, thereby making them susceptible to physical damage. Refer also to ACP OCRP-4.

General guidance on scour protection can be found in DNV-ST-N001, Sections 6.5.7 and 8.4.5, with additional guidance also available in ISO 29400, Section 18.20.4, and DNV-ST-0054, Section 4.2.

7.7.4 Array Cable and Export Cable Installation

Following installation of fixed-bottom foundations, array cables are generally installed between each turbine location and the OSS, prior to the installation of towers, nacelles and blades.

Installation of array and/or export cables is outside the scope of this document. Reference is given to ACP OCRP-5. However, for general information purposes, reference can be made to DNV-ST-N001, Section 7, and Appendices H.3 and H.4, with additional information available in ISO 29400, Section 20, and DNV-ST-0054, Section 4.4.

7.7.5 Wind Turbine Installation

To achieve the precision needed to remain within required tolerance levels, towers, nacelles and blades are generally installed by a Self-Elevating Crane Vessel. However, other innovative solutions are also being explored, such as the use of Active Heave Compensated (AHC) load control systems on floating vessels and the wet tow of fully assembled offshore wind turbines from marshalling ports to offshore installation locations.

The presence of either buried cables and/or scour protection in proximity of an offshore wind turbine location, shall be given due consideration during the installation planning process and appropriate measures taken during installation operations to ensure their continued integrity.

Guidance on turbine installation can be found in IEC 61400-3-1 Chapter 12, ISO 29400, Sections 18.10.8 and 18.10.9, DNV-ST-0054, Section 4, and DNV-ST-N001, Section 8.7.

7.7.6 Offshore Substation (OSS) Installation

The OSS collects power generated by turbines in an offshore wind farm through the array cable system and sends that power to the electrical grid ashore through export cables. Components of the OSS will generally be installed in two phases, with the support structure installed first followed by the topside structure.

The type of support structure to be installed will be determined during the design of the offshore wind farm. For fixed-bottom installations a jacket structure is generally used, although other types of support structure such as monopiles and/or self-installing arrangements are also sometimes employed.

Guidance on the installation of jacket structures can be found in ISO 29400, Sections 18.10.2 through 18.10.4, DNV-ST-N001, Section 13, and DNV-ST-0054, Sections 3.7.2 to 3.7.5.

Once the support structure is installed the topside structure will then be added, usually by means of a Heavy-Lift Crane Vessel. However, large topside structures may also be installed by the float-over method, where the topside is brought to the location on a floating vessel, which is then ballasted down to lower the structure into place.

Guidance on inspection requirements for installation of support structures can be found in API RP 2A-WSD, Section 16.6.3.

Guidance on lifted installation can be found in DNV-ST-N001, Section 16, and ISO 29400 Section 18.10, with guidance in relation to topside structures available in DNV-ST-0054, Section 4.8.

Guidance on float-over operations can be found in DNV-ST-N001, Section 15, with additional guidance also available in DNV-ST-0054, Section 3.7.6.

7.7.7 Commissioning and Completion

Final activities in the installation phase of an offshore wind farm relate to verification inspections that confirm the as-built condition of components and the commissioning of any remaining systems that was not able to be carried out prior to offshore installation. Offshore commissioning tasks will largely be determined during the design phase, with one objective being to minimize as much as possible the extent of work that needs to be carried out offshore.

To ensure the highest possible degree of safety when energizing newly installed electrical systems, all commissioning work should follow a very detailed and incremental plan. Any stage of the commissioning process that fails to meet prescribed acceptance criteria, should be adequately addressed before continuing on to the next stage of the process.

Guidance on completion and commissioning can be found in IEC 61400-3-1, Section 13, ISO 29400, Section 18.20, and RUK13-001-6, Sections B.2.2.4 and B.3.4.2.

Commissioning procedures for an offshore wind turbine and/or OSS will usually be provided by the original equipment manufacturer (OEM). However, for information purposes general guidance can be found in IEC 61400-3-1, Section 13.

8 Operations and In-Service Inspections

The present chapter covers operations and in-service inspections of offshore wind farm assets in U.S. waters. For floating wind farm structures, refer also to ACP OCRP-2. Where the guidance for floating wind farm structures in ACP OCRP-2 conflicts with this document, ACP OCRP-2 shall govern.

8.1 U.S. Regulations

U.S. Regulation 30 CFR 585 and 285 define~~s~~ BOEM and BSEE regulations that directly govern operations and in-service inspections for offshore wind facilities in U.S. OCS waters. Relevant sections of 30 CFR 585 are listed below. Other regulations may also be in effect, particularly in U.S. State waters where the federal regulatory framework may be used as guidance. It is the responsibility of the developer to ensure that all applicable rules and regulations are followed in the development of procedures, manuals, and plans.

- 30 CFR 585.605 through 585.618, *Site Assessment Plan (SAP)*
- 30 CFR 585.620 through 585.~~638~~635, *Construction and Operations Plan (COP)*
- 30 CFR 585.640 through 585.657, *General Activities Plan (GAP)*

- 30 CFR ~~585~~285.701, *What must I include in my Facility Design Report?*
- 30 CFR ~~585~~285.702, *What must I include in my Fabrication and Installation Report?*
- 30 CFR ~~585~~285, Subpart H—*Environmental and safety management, inspections, and facility assessments for activities conducted under SAPs, COPs and GAPs*
  - 30 CFR ~~585~~285.800 through ~~585~~285.803, *General operating requirements*
  - 30 CFR ~~585~~285.810 through ~~585~~285.811, *Safety management systems*
  - 30 CFR ~~585~~285.813, *Maintenance and shutdowns*
  - 30 CFR ~~585~~285.820 through ~~585~~285.825, *Inspections and assessments*. 30 CFR ~~585~~285.825 incorporates API RP 2A-WSD by reference.

BOEM-published guidance includes the following:

- *BOEM Guidelines for Information Requirements for a Renewable Energy Site Assessment Plan (SAP)* provides guidance for preparing a Site Assessment Plan (SAP) for Outer Continental Shelf (OCS) renewable energy activities on a commercial lease to clarify and supplement information requirements for SAP submittals pursuant to 30 CFR 585.605 through 585.618.
- B*OEM Information Guidelines for a Renewable Energy Construction and Operations Plan (COP)* provides guidance for preparing a Construction and Operations Plan (COP) for Outer Continental Shelf (OCS) renewable energy activities on a commercial lease to clarify and supplement information requirements for COP submittals pursuant to 30 CFR 585.620 through 585.~~638~~635.

8.2 Standards and Guidelines

The following documents can be used in the development of operations and in-service inspection plans:

- EN 50308, Section 4.14.1, *Operator's instruction manual and maintenance manual*
- IEC 61400-3-1, Section 13, *Commissioning, operation and maintenance*
- ABS BOWT Guide, Chapter 5, Section 5, *Marine operations*
- ABS BOWT Guide, Chapter 7, Section 2, *Surveys after construction*
- DNV-SE-0190, Section 3.4.3, *Operation Manual*
- DNV-SE-0190, Section 3.4.4, *Maintenance Manual*
- DNV-SE-0190, Section 4, *Operation and Maintenance*
- DNV-ST-0126, *Support structures for wind turbines*, Section 9: In-service inspection, maintenance and monitoring
- ASCE MOP 101 *Underwater investigations standard practice manual*
- API RP 2A-WSD 22nd ed., Section 16, *Inspection*
- API RP 2SIM Section 6, *Surveys*
- BSEE TA&R 627 *Inspection Methodologies for Offshore Wind Turbine Facilities*
- BSEE TAP 650AA *Offshore Wind Turbine Inspection Refinements*
- BSEE TAP 633AC *Template for a Safety Management System for Offshore Wind Farms on the OCS*
- ISO 19902*, Petroleum and natural gas industries, fixed steel offshore structures*, Section 23, *In-service inspection and structural integrity management*
- ISO 19903, *Petroleum and natural gas industries, fixed concrete offshore structures*, Section 14, *Inspection and condition monitoring*

8.3 Operations

8.3.1 Maintenance Manual

The maintenance manual(s) should be developed to track all scheduled and unscheduled maintenance activities for the offshore wind farm, including any manufacturer-specified planned maintenance procedures. Both above- and below-water equipment and systems should be included. The maintenance manual(s) should designate ~~safety critical equipment~~CSSE as noted in the safety management system (SMS) documentation. Additional information on the maintenance manual(s) can be found in BSEE TAP 633AC referenced above.

8.3.2 Condition Monitoring

A condition monitoring system (CMS) captures and records mechanical and/or structural behavior of the offshore wind turbine and its components. The behavior is captured using sensors (e.g., accelerometers) deployed at key locations and recorded using a data acquisition system. Critical component data should be compared with established limiting values. If a limit is exceeded, this should trigger the CMS to send an alarm message to the responsible monitoring body. This allows for evaluation of the behavior exceeding the limit and determination of necessary steps to mitigate, if required.

When CMS is used for an offshore asset, the following considerations should be included in its design:

- Operations under offshore conditions and any extreme conditions likely at the location (e.g., temperatures)
- Data storage and transmission
- Uninterruptible power supply dedicated to the CMS located on board each turbine (e.g., back-up power supply)
- Future expansion of the system
- Redundancy of the system (e.g., additional sensors at critical locations)
- Expected life of the CMS vs. expected life of facility (e.g., will in-service replacement be considered or required)

Use of a CMS should be included in the SMS, especially with respect to responding to anomalous conditions identified by the CMS.

The CMS used for an offshore wind farm or group of facilities may consider design guidance provided by DNV-SE-0439 and ISO 16079-1. ISO 19902 and ISO 19903 contain additional information on condition monitoring.

8.4 In-Service Inspections

8.4.1 General

An in-service inspection plan (ISIP) should be developed for the offshore wind farm that addresses individual wind turbine facilities, the entire offshore wind farm, its infrastructure, and any offshore substation. The ISIP should address the topics in the following sections and should address the entire expected service life of the project. Consideration should be given to:

- Addressing strength or fatigue critical items, to provide guidance during inspections
- Inspection techniques, non-destructive examination (NDE) requirements, and inspector qualifications
- Provisions for expanding the inspection scope when planned inspections identify anomalies
- Updating the ISIP as needed to address changes to the project, anomalous conditions identified, repairs, etc.

- Input from OEMs, which may provide information about recommended inspection procedures and intervals, plus areas prone to failure
- Safety systems and equipment, with emphasis on CSSE.

Structural inspections should focus on identifying damage or degradation such as dents, holes, signs of plastic strain, missing members, loose connections, crack indications, wear, corrosion, and cathodic protection system(s).

When planned inspections identify anomalies, the provisions for expansion may include a more thorough examination of the area around the anomaly, additional inspections for that facility, or additional inspections throughout the offshore wind farm. This expansion may need to be defined based on an engineering review of the data from the planned inspection or could be defined as automatic depending on the anomaly identified. The ISIP may include details of what is considered an anomaly for various common conditions (e.g., crack indications, corrosion, or erosion) to aid in this process. ASCE MOP 101 provides guidance on expanding scope based on inspection findings using the term “special inspection,” and additional information can be found in API RP 2SIM, ISO 19902, and ISO 19903 referenced above.

For offshore wind facilities on the OCS, the requirements in 30 CFR ~~5~~285.824 apply and require the lease holder to develop a comprehensive annual self-inspection plan covering all facilities. These annual self-inspections can be carried out by the lease holder’s personnel, if properly trained and qualified, or by third-party inspectors who are contracted by the lease holder. The regulations require that an annual self-inspection report be submitted to the government no later than November 1st of each year, to document the results of these annual self-inspection activities.

These requirements primarily address structural concerns. Mechanical and electrical system components should be addressed via the operations and maintenance requirements in Section 8.3 of this document, which should also be in accordance with the manufacturers recommendations.

The ISIP should address all points relevant to design assumptions identified in the design phase for input to operation and maintenance manuals and instructions (see Section 5.11).

U.S. Regulations 30 CFR 250 and 282 address BOEM and BSEE requirements for the extraction of minerals from the U.S. OCS, some of which may be useful for offshore wind facilities.

Although not directly applicable to offshore wind facilities, the following regulations could be adopted as a best practice by regulatory bodies to satisfy offshore regulations:

- 30 CFR 250.901 *Industry standards*
- 30 CFR 250.905 *In-service inspection plan submittal*
- 30 CFR 250.919 *In-service inspection plans*

Additional guidance on ISIP development and content can be found in BSEE TA&R 627, BSEE TAP 650AA, ABS BOWT Guide, DNV Guidelines, ISO 19902, ISO 19903, ISO 19901-9, API RP 2A WSD, and API RP 2SIM referenced above.

8.4.2 Frequency of Inspections

For offshore wind facilities on the Outer Continental Shelf, the requirements in 30 CFR §~~585~~285.824 apply and require annual self-inspections and submission of an annual self-inspection report.

Various prescribed inspection frequency intervals for above- and below-water systems have been developed and may be applied to offshore wind turbine structural systems. These include ASCE MOP 101 (Table 2-2, Recommended Maximum Interval Between Underwater Routine Inspections), API RP 2SIM Sections 6.2 through 6.5, BSEE TA&R 627 (Table II.1, Inspection Cycles), DNV-ST-0126 (Section 9, In-Service Inspection, Maintenance and Monitoring), and ABS BOWT Guide—Chapter 7, Section 2, Surveys after construction referenced above.

Alternatively, a risk-based approach may be used to set inspection intervals for above- and below-water systems. A risked-based inspection approach defines the inspection frequency intervals by risk and potential consequence. The U.S. regulatory inspection requirements for the OCS are outlined in 30 CFR ~~585~~285.824 and require an annual self-inspection plan covering all facilities but do not specifically address a risk-based inspection approach. Guidance for development of a risk-based inspection program can be found in API RP 2SIM, API RP 580, EN 16991, DNV-RP-C210, and ABS Guide for Surveys Using Risk-Based Inspection for the Offshore Industry.

Regardless of the approach used, the following should be considered as described in BSEE TA&R 627:

- Condition*:* As facilities age, they may require more or different inspections than newer facilities
- Consequence of Failure*:* More critical systems or components may require more frequent or intensive inspections
- Environmental Conditions*:* The prevailing environmental conditions (e.g., temperature variations, wind and wave loading, seismic exposure) should be considered, especially with respect to their effect on degradation of the facility
- Multi-Unit Offshore Wind Facilities*:* Addressing all inspection needs for a multi-unit offshore wind farm within a given time frame may not be possible; inspections may have to be spread out over several years
- In some instances it may be desirable to perform inspections of personnel safety equipment prior to use in lieu of periodic requirements (e.g., annual inspection of ladders). For these cases, an appropriate procedure for inspection before use should be clearly identified in the ISIP.

8.4.3 Qualifications of Inspection Personnel

It is important that personnel executing inspections have the requisite qualifications applicable to the inspections they will be performing, including the following:

- Training related to the instruments or equipment necessary for the inspections (note that safety-related training should be included in the SMS; see Section 7.2 of this document)
- Understanding of the intent of the inspection and the anomalies that are possible or prevalent
- Knowledge of how to document the inspection results, including anomalies found and positive inspection details. ASCE MOP 101, API RP 2SIM, ISO 19902, and ISO 19903 provide guidance on personnel qualifications.

8.4.4 Subsea Support Structure Inspections

Routine below-water inspections should be performed to detect, measure, and record any defects, deterioration, or anomalies that affect the structural integrity or operation of the offshore wind turbine or OSS. These inspections are typically categorized into structural or equipment components and are performed by divers or a remotely operated underwater vehicle (ROV). The splash zone region may be included in either the below-water inspections or the above-water inspections, but it is important that this region be targeted in the inspection campaign. These topics are further addressed in BSEE TA&R 627, ISO 19902, ISO 19903, API RP 2A-WSD, and API RP 2SIM.

The below-water structural components are the portions of the sub-structure below the waterline. In addition to general inspection of the below-water support structure during inspections, more intensive inspections may be specified for critical areas, as defined during the design process or from existing in-service conditions. These include areas of previous damage or repair and areas known to have higher frequency of degradation.

The below-water equipment are the (non-structural) components related to the operation of the facility below the waterline, including cables, risers, J-tubes, umbilicals, cathodic protection system(s), etc. In addition to general inspection of below-water equipment systems, more intensive inspections should be specified for critical areas, as defined during the design process or from existing in-service conditions. These include areas of previous damage or repair and areas known to have higher frequency of degradation. At a minimum, the following below-water equipment should be included in any general inspection:

- Risers/J-tubes and attachments to the sub-structure
- Electrical and control cables within field with particular attention to cables crossing other infrastructure according to ACP OCRP-5
- Electrical cables to shore with particular attention to cables crossing other infrastructure, according to ACP OCRP-5
- Connectors and junction boxes
- Scour protection system, and any significant changes in the seabed surrounding the facility which could impact its support characteristics for the foundation structure
- Cathodic protection system(s), including anodes, electrical cabling and connections

The cable inspections should periodically confirm that buried cables remain at their installed depth beneath the sea floor as discussed in BSEE TA&R 627.

8.4.5 Above-Water Inspections

Routine above-water inspections should be performed to detect, measure, and record any defects, deterioration, or anomalies that affect the structural integrity or operation of the offshore wind turbine. These inspections are typically divided into three categories: (1) structural and access systems, (2) electrical and mechanical systems, and (3) safety equipment. As indicated in Section 8.4.4, the splash zone region may be included in either the below-water or the above-water inspections, but it is important that this region be targeted in the inspection campaign. These topics are further addressed in BSEE TA&R 627, ISO 19902, ISO 19903, API RP 2A-WSD, and API RP 2SIM, as well as in the ABS Guide, and DNV guidelines referenced above.

The above water structural and access systems include the tower structure, nacelle, blades, sub-structure above the waterline, and various access systems. Inspection of the following should be emphasized during above-water structural inspections:

- Tower to sub-structure attachment
- Transition piece, including grout condition
- Access systems (e.g., ladders, stairs, walkways, boat landing, swing ropes, handrails, helidecks and heli-hoist platforms) and lifting systems
- Appurtenances and attachments (e.g., J-tubes)
- Coating condition
- RNA and tower structural integrity
- Visual inspection of the blades
- Personnel Safety Systems (e.g. fire detection and suppression, fall prevention and arrest, emergency egress equipment)
- Navigational Aids
- Overall facility inclination (i.e., determining if the facility leans due to structural deformation, differential settlement, or other causes)
- Areas of previous damage or repair

The electrical and mechanical systems include the drivetrains, electrical cabling, junction boxes, panels, transformers, generators, rectifiers, hydraulic systems, control systems, etc. Electrical and mechanical systems should be inspected and maintained in accordance with manufacturer recommendations to ensure efficient and safe operations.

8.4.6 Post-Event Inspections

Environmental events that impose loads on the offshore wind turbines and other structures near or above the design level loading (e.g., hurricanes or earthquakes) should trigger an inspection program for the offshore wind farm. For offshore wind facilities on the OCS, the requirements in 30 CFR ~~585~~285.825 apply and require an assessment of the structure, when needed, based on the platform assessment initiators listed in API RP 2A-WSD Sections 17.2.1 through 17.2.5. Guidance on the specific post-event inspections to be performed as part of the assessment can be found in API RP 2SIM Section 6.6.3. NTL No. 2009-G30 provides guidance on post-hurricane inspections for oil and gas platforms in the Gulf of Mexico.

Generally, regulators should consider inspections after load events that can be reasonably estimated to have approached a design limit state, but mandatory inspections may be imposed at lower load levels if sufficient evidence of possible damage is present. These inspections should be planned in the ISIP and should identify specific areas that are likely to have experienced high stresses as shown by design analyses.

The ISIP should contain a post-event inspection plan that includes:

- Threshold(s) for triggering a post-event inspection
- Nominal or default inspection scope of work (subject to modification, based on initial evaluation, when an event occurs)
- Methods for measuring or estimating the magnitude and severity of an environmental event, based on consideration of the required accuracy and speed of provision of the information

Equipment systems and structural appurtenances may experience damage even if there is no significant structural damage. Evaluation of these components should also be part of a post-event inspection plan.

Remote inspection technologies (e.g., drones) may be used to evaluate the condition of the wind turbine as part of the post-event inspection. Use of these technologies may allow for a commencement of operations without the physical boarding by an inspector, if the post-event inspection requirements are adequately satisfied by remote inspection.

This concept is further discussed in BSEE TA&R 627, API RP 2SIM Section 6.6.3, ISO 19902, and ISO 19903. 30 CFR 2~~5~~85.825 contains U.S. regulatory expectations for assessments, including inspections.

8.4.7 Inspection Review

Inspection results should be reviewed by a qualified engineer after each inspection whether it is planned, post-event, or triggered by some other event. This review ensures the following:

- The inspections were performed as planned and have been adequately documented
- Results of the inspection are incorporated into an updated ISIP as needed
- Any anomalous conditions are dealt with in a timely manner, including:
  - Cleared as is with follow-up inspections scheduled as needed;
  - Identified for further investigation either through additional inspections or analysis to determine further action (e.g., repairs); and
  - Addressing similar areas on other facilities in the offshore wind farm, as appropriate

Engineers performing the review should be familiar with inspections, inspection tools, techniques, and their deployment, and the interpretation of inspection results. They should also be familiar with the relevant information about the specific structure's design, past inspection results, operational history, and ISIP (if available).

Additional information on review of inspection data can be found in BSEE TA&R 627, ISO 19902, and ISO 19903 as referenced above. If flaws are identified during in service inspections, their acceptability for fitness for service needs to be demonstrated. Guidance on the assessment of flaws can be found in BS 7910 and API 579.

8.4.8 Data Retention

Data collection allows responsible personnel to be able to evaluate the current condition of the offshore wind facilities and update the ISIP as necessary. Regulators may require various levels of data reporting that is facilitated by establishing a data collection and retention process within the ISIP. The concept of data retention and its use is further discussed in BSEE TA&R 627, API RP 2SIM, ISO 19902, and ISO 19903.

It is recommended that operations and maintenance records, inspection and test reports, SCADA, and CMS data be collected and retained for later use in structural assessment for life extension, repowering, alternate uses, or decommissioning. See Chapter 9 Life Cycle Plan for further discussion of the types of information to be collected and retained.

The ISIP should also indicate data reporting requirements for each inspection activity that should include the following:

- Data collection checklists and expected data to be reported for each activity
- Requirements for anomaly measurements
- Requirements for photographs and videos

9 Life Cycle Plan

9.1 Life Cycle General

As part of planning a project during the development phase, it is prudent to consider the overall life cycle of the project to support ensuring safety, meeting regulatory requirements, and supporting the financial objectives of the project. Life cycle concerns may be reconsidered during the operational phase of the project, especially when approaching later years of the design life, where useful life modification extensions, repowering options, alternate uses, or decommissioning actions may be initiated.

9.2 Life Cycle Planning

9.2.1 Life Cycle Plan

A life cycle plan should be prepared for the project to ensure the high-level technical plan for the project is aligned with the financial goals of the project. Elements of the life cycle plan should include design, construction, maintenance, operations, and decommissioning.

9.2.1.1 Design Expectations

As part of project definition, the project's design life assumptions should be identified and eventually confirmed through the design and fabrication approval process.

A project's design life has commonly been 25 years corresponding to general industry practice, but can be defined as any time interval desired for each asset. Prior to making the decision to operate beyond the original design life, an analysis shall be conducted to determine the remaining useful service life.

BOEM standard leases for the offshore wind site being offered allow an operating period for 25 years from approval of the COP, and then 2 years for decommissioning thereafter. Operators may seek new leases or extensions to their leases after the end of the 25-year period, therefore it would be reasonable to assume that life cycle planning will take on an increasingly important role in project design, maintenance and operations.

Life cycling plans may shift over time due to several factors such as actual loads experienced by the project, rate of structure and equipment deterioration or damage, emerging new technologies (for repowering options), or changes in power market conditions which impact project economics.

Access to the project's original design basis documents, as-built drawings, calculations, and certifications can also be critically helpful if useful life reassessment, useful life extension, or facility reuse may be considered. Such documentation should be systematically collected and stored prior to construction phase closeout.

9.2.1.2 Maintenance

Maintenance activities shall be conducted to prevent deterioration of the project components and to help ensure the design life and useful life objectives of the project are achieved.

As part of maintenance, inspections are particularly important in helping determine remaining useful life as projects approach the end of their design life.

Equipment inspection periods should be planned based on operational loads, age of equipment and equipment design capability.

Refer to Section 8.4 for additional information on inspections.

9.2.1.3 Operations

The projects shall be operated within their specified operational parameters to help ensure the design life and useful life objectives of the project are achieved.

A change to operational parameters to reduce operating loads as projects approach the end of their design life may be used as a strategy to extend useful life of a project.

If operation is desired outside of currently defined operating parameters, a design evaluation is recommended to include an updated certification to ensure equipment and personnel safety.

It must be emphasized the collection and retention of operational and site data during the life of the project, such as SCADA data, Metocean data, and data from inspections may be critical in the later life of a project if useful life reassessment, useful life extension, or facility reuse may be considered.

Refer to Section 8 for additional information on recommended practices for the operational phase.

9.2.2 Decommissioning

Decommissioning will occur at the end of a project's useful life, as stipulated in the site lease, based on applicable regulation, or due to economic situation, whichever comes first.

While other life cycle planning events (such as useful life extension or repowering) may happen prior to decommissioning, a detailed decommissioning plan shall be prepared in the project development phase so that the project's financial model can include a dedicated decommissioning fund that will have sufficient funds to implement the decommissioning plan prior to the reaching the end of the project's design life.

A decommissioning plan shall be developed by the lessee and approved by regulators, as applicable, so that the level of equipment, structure, and cable removal is clearly defined, and the level of site remediation is understood.

9.2.2.1 Decommissioning Plan

U.S. Regulation 30 CFR ~~585~~ 285 Subpart I contains ~~BOEM and~~ BSEE regulations directly related to the decommissioning of offshore wind facilities in U.S. OCS waters. Refer also to Section 9.6. Other regulatory authorities are likely to have requirements for the development for a decommissioning plan.

As part of the project development process, a decommissioning plan shall be created that addresses how the facilities will be decommissioned and removed once the facility is taken out of operation. The decommissioning plan should consider the following:

- Regulatory requirements
- Lease requirements
- Site Environmental Management Plan
- Removal or decommissioning of the rotor-nacelle assembly and above-water support structure and equipment
- Removal or decommissioning of below-water support structure and equipment, usually to 5m below the sea floor
- Removal or decommissioning of offshore and onshore substations
- Removal or decommissioning of array cabling and systems
- Removal or decommissioning of export cable, including submarine cable, shore landing installation and upland cable
- Removal, burial, or abandonment of materials installed for seabed preparation, scour protection, or cable protection
- Removal, restoration, or future use of other project support infrastructure, such as onshore operations & maintenance (O&M) facility
- Removal, restoration, or future use of temporary support infrastructure employed during the decommissioning phase
- Description of vessels, equipment, and methods to be used
- Provisions for waste disposal, recycling, and/or use of materials for approved artificial reefs. Special attention should be given to potentially hazardous or contaminated fluids, such as lubricants or ballast.
- Site clearance verification

The decommissioning plan shall address how the decommissioning process will:

- Comply with applicable laws and regulations
- Be conducted safely
- Not unreasonably interfere with other uses approved uses, such as marine traffic, fishing, and national defense
- Not cause undue harm or damage to natural resources; life (including human and wildlife); property; the marine, coastal, or human environment; or sites, structures, or objects of historical or archaeological significance
- Use best available and safest technology
- Use best management practices
- Use properly trained personal

Financial obligations are often required by regulatory authority for the decommissioning phase. A cost estimate should be prepared and included in the decommissioning plan. The cost estimate should use reasonable assumptions on the value of scrap substantiated by historical data, not current spot market prices. Cost for disassembly, reduction size, and breakdown of components for transport and disposal should not be neglected.

In some instances, it may be economically or otherwise beneficial to consider making artificial reefs from discarded offshore wind project components for habitat enhancement. This approach should first be approved by relevant permitting authorities before being included in the decommissioning plan.

Similarly, it may be economically or otherwise beneficial to consider modifying all or a portion of the offshore wind farm for an alternate use. The alternate use should be approved before being considered in the offshore wind project's decommissioning plan.

9.3 Project Useful Life Extension Considerations

9.3.1 Useful Life Reassessment

Useful life reassessment involves re-evaluating the site conditions and operating conditions to determine site specific load conditions that are less than the original design conditions leading to useful life of the equipment that is greater than the original design life. This can be done in one of two ways using either:

- Actual historical operating loads and design loads for future operation; or
- Actual historical operating loads and normalized site historical loads for future operation (normalized to determine long-term expected site loading)

Useful life reassessment should be informed by the inspections performed during operations as identified in Section 8. There should be special focus on elements that are critical to structural integrity. Additional guidance can be found in DNV-SE-0263 and DNV-ST-0262. Performance of corrosion protection system including cathodic protection data and coating condition should also be considered.

9.3.2 Useful Life Extension by Modification

Useful Life Modification involves modifying the Life Cycle Plan through either Load Management (decreasing operating loads) or Load Capability (increasing equipment rating) adjustment or a combination of both.

9.3.2.1 Load Management

9.3.2.1.1 Operating Limits

Through evaluating and adjusting the unit operating envelope, operating loads can be controlled. Potential operating limit adjustments could include:

- High wind shutdown
- Turbulence intensity limits
- Extreme high or low temperature limits
- Maximum Output

For any of these changes a detailed analysis to understand the impact to loads and ultimately useful life would need to be performed.

9.3.2.1.2 Advanced Controls

Updated control strategies can be incorporated that would lower the unit loads and extend the useful life. Careful evaluation of the new strategy should be performed to ensure new component specific loads are not introduced. Examples of specific advanced control strategies would include:

- Advanced Pitch Control to minimize tower sway and surge
- Yaw control modification to minimize yaw system loading

9.3.2.2 Load Capacity

Increasing load capacity can be viewed as less intrusive version of partial repowering, in that the components are not changed but specific parts may be altered or replaced to provide the increased capacity.

9.3.2.2.1 Special Maintenance

Items to be considered in the area of special maintenance would include intervals of inspection or refurbishment, or upgraded consumable parts (seals, greases, etc.) utilized. Selection of appropriate changes would be based on the site-specific degradation modes observed.

9.3.2.2.2 Modifications: Components or Consumables

Like advanced controls mentioned above, physical modifications can be incorporated to improve the load carrying capability of components. This can include improved parts (e.g., bearings, breakers, etc.) or new components that help manage the turbine loads (e.g., torque limiting devices on the gearbox output shaft). When modifications are performed, the turbine type and/or project certificate should be re-evaluated to ensure it is still valid. The original Certifying Body can assist with evaluation to maintain certification.

9.4 Project Repowering Considerations

Repowering has two distinct variations, Partial Repowering and Full Repowering. The drivers for repowering are typically economic and involve equipment condition, site performance, and various incentives such as tax implications or regulatory requirements. Considerations for the two variants are listed in the sections below.

9.4.1 Partial Repowering

Partial Repowering consists of existing balance of plant systems such as the collection system, substation, or foundations being retained where portions of the tower and/or nacelle are replaced. Typically, existing contracts (Interconnection Agreement, Power Purchase Agreement, Land Leases, etc.) are retained in whole or in part. The repowering work is generally designed, coordinated, and executed by the original wind turbine manufacturer. This is due to the design conditions and loads being easily available for analysis of the repowered combined system. Exceptions to this structure are not uncommon with several of the first land-based partial repowering examples in the U.S. being designed by non-wind turbine OEMs.

9.4.1.1 Above Water Component Replacement: Tower, Nacelle, Hub, Major Components

Most decisions are based on increased Annual Energy Production (AEP). This can be accomplished typically through larger rotor diameter (i.e., replacing blades or adding root extensions) or higher capacity drivetrain. Evaluation of tower base loads and all other drivetrain load capabilities is required. Components that may be replaced based on the results include major components and could result in an entire nacelle replacement.

Alternatively, the replacement decision could be driven by availability improvements. Careful evaluation of the components in need of improved reliability will guide the scope of the repower.

9.4.1.2 Subsurface Component Replacement: Sub-structure, Foundation (if applicable), Collection System, Substation

When repowering decision is based on AEP, the most likely outcome is a reuse of the existing subsurface components. If, however, availability of the subsurface components is the driving factor, replacement of them may be the primary scope. Evaluation of the components in need of improved reliability should be performed to define design changes to gain the desired availability improvements.

9.4.1.3 Recommended Analysis for Partial Repowering

9.4.1.3.1 Re-use of an Existing Sub-structure and Foundation

Where an existing foundation is being re-used for a new turbine, the full design process should be repeated as if the entire installation were new and all new design checks shall be satisfied. Strength checks may be waived if the new turbine system being installed is substantially identical to the previously installed turbine system.

Fatigue checks should be performed to account for the damage accumulation from the previous service life. The safety factor on previously accumulated damage should be the same as that for a new design. The safety factor for future damage should be the same as that for a new design.

A thorough inspection of sub-structure and foundation should be taken with an NDE program. Specific areas and percentage of welds to be inspected shall be informed based on operational data and prior inspections. All welds subject to NDE shall be found to be undamaged or repaired if damage is found.

Additional guidance on re-use can be found in API RP 2A-WSD, Section 18.2.

9.4.1.3.2 Re-use of an Existing Turbine System

Where an existing turbine system (with or without a new tower structure) is being used on a new foundation, the full design process should be repeated as if the entire installation were new and all new design checks should be satisfied. It is recommended that any type certification for the turbine system be renewed or reviewed by the certifying body.

Fatigue checks should be performed to account for the damage accumulation from the previous service life and proposed future service life. The safety factor on previously accumulated damage should be the same as that for a new design.

Depending on the number of years remaining under the original design life assumptions, a thorough inspection of the structural components should be taken with an NDE program. Specific areas to be inspected and criteria for acceptance shall be informed based on operational data, prior inspections, and remaining design life, if any.

9.4.1.3.3 Existing Turbine Modifications or Replacement

Modifications to an existing turbine may also constitute a re-use. For example, replacement of turbine blades with blades of a different design, or upgrades to turbine mechanical and control systems that cause rotational speeds to change from those obtained with the previous turbine for the same wind history, are equivalent to installing a new turbine on an existing sub-structure.

Installation of a replacement turbine does not constitute a re-use provided the replacement is identical to the existing turbine and the service life of the facility is not extended. In order for the turbines to be considered identical, the turbines shall be covered under the same type certificate, or a certification body shall certify that the two turbines are identical.

9.4.2 Full Repowering

Full Repowering entails a complete site re-build. Decommissioning of the current turbines and balance of plant systems would occur. The existing footprint would be reutilized with a newly optimized layout including new turbines and collection systems. The substation may be retained depending on condition and design requirements.

9.4.2.1 Decommissioning

See section 9.2.2 regarding aspects of decommissioning to be considered.

9.4.2.2 Site Rebuild

The scope of a site rebuild is similar to greenfield construction, however, long-term resource data is available for more confident evaluation of site suitability.

9.4.2.3 Current Contracts: Land Lease, Power Purchase Agreement, Interconnect Agreement

A full review is required of all contracts to define where any existing terms or conditions are not able to be met due to the scope of the repower.

9.5 Alternate Use

There is the possibility that a project may not be fully decommissioned but proposed for an alternate use at the end of the useful life of the wind turbine. If this were the case, a new design basis shall be prepared and useful life of components to be retained for the alternate use shall be determined. Elements of the project to be retained or decommissioned and removed shall be identified. Required regulatory approvals shall be pursued.

9.6 Project Decommissioning

9.6.1 Decommission Plan Update

Prior to initiating the decommissioning process, the Decommissioning Plan prepared and approved during the project development phase should be revisited. Proposed deviations from the original plan should be addressed in an amended Decommissioning Plan and submitted to the appropriate regulatory body for review and approval. Changes to the original decommissioning plan may be warranted due to changes such as revisions to regulations, introduction of new technologies, changes in best industry practices, changes to accepted environmental practices, or new science.

9.6.2 Decommission Report

A Decommissioning Report shall be prepared providing a summary of decommissioning activities, including date they were accomplished, identifying deviations from the approved decommissioning plan, if any. The report should identify any significant health, safety, or environmental issues that arose. The report should also identify where the waste and recycled materials were deposited. Confirmation of post-decommissioning site clearance should be included.

9.6.3 U.S. Regulations on Decommissioning

30 CFR 250.902, 30 CFR 250.1725, and 30 CFR 250.1752 address BOEM and BSEE requirements for decommissioning of platforms and pipelines used for extracting oil, gas, and sulfur from U.S. OCS waters, but some of their provisions may also be appropriate for offshore wind facilities.

9.6.4 Transportation and Decommissioning Operations

Decommissioning operations and transportation for decommissioning should follow the same standards, requirements, and considerations discussed in Section 7.

10 Limitations and Addressing Gaps

For offshore wind farm design, installation, and operation, there is no substitute for rigorous engineering at the component and systems level. Due to the complexity of the projects and the desire to facilitate the introduction of new innovations and technology, the industry accepts that standards are incomplete. The designers, developers, certifying bodies, and third-party engineers all play a role in ensuring that the offshore wind farm is deployed in a safe and orderly manner with minimal disruption to the environment.

The following sections address subjects pertaining to offshore wind assets that may not be addressed fully by this edition or by the existing codes and standards of the industry at large. These are organized into limitations and gaps. Furthermore, recommendations for future editions on this document are presented.

10.1 Limitations

The provisions of this document are limited as follows:

- The codes and standards referenced herein are limited to versions published. Draft standards and subsequent revisions were not considered, and may differ from the versions available when developing this document. Projects should consider the most recently published versions of available codes and standards as described in Section 2.2.
- Guidance on deck elevation in the codes is developing. Global consensus on deck elevation and air gap has not yet been achieved. The provisions of IEC differ from those of API, which were developed for the Gulf of Mexico yet represent the best information available at publication regarding tropical storms. The guidance contained in Section 5.4 of this document considers the provisions of IEC and API and endeavors to satisfy the intent of both code systems.
- This document provides guidance only on federal regulations, and those national and international codes and standards that represent industry best practice. Projects or individual assets may be constructed in state waters and may be subject to state and local regulations, which are too numerous to be included in the scope of this document.
- This document does not address certain permitting concerns, including environmental protection and radar interference, which at the time of publication are under review by working groups outside the OCRP process.
- The information given in Section 2.4 regarding the use of Professional Engineers represents typical practice for onshore and offshore infrastructure and energy projects, as well as ~~BOEM's~~ BSEE's expectations given in public presentations and in their review of project documentation to date. However federal regulations do not explicitly require that offshore wind design reports and other engineering and/or construction documents be stamped by a P.E.
- This document does not address certain supply chain considerations, including state and local regulatory requirements for local content or state ORECs.
- The guidance given in this document, while it represents industry best practice, has not yet been tested by U.S. fabrication, installation, and O&M for utility-scale projects.
- This document does not detail the power system studies that must be considered when connecting the offshore substation to an onshore substation and to the interface electric utility. Such studies follow the performance-based methodology defined by the relevant NERC Region. Those facilities identified as elements of the Bulk Power System may be subject to reliability requirements from the NERC Region.
- This document does not address workforce training or occupational safety, which are covered by ACP RP 1001 and ACP RP 1002 (in preparation).
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10.2 Gaps

The provisions of this document have the following gaps:

- The industry has not yet reached a full understanding of the risks of sea ice and fresh water ice, or the associated loading. Some guidance is provided in IEC 61400-3-1, API RP 2N, and the ABS BOWT Guide.
- ~~This document does not address workforce safety or workforce training, which at the time of publication are under review by working groups outside the OCRP process.~~
- Federal regulations concerning the integrity and security of the bulk power system, including country of origin requirements on the supply chain, are not considered.

11 Complete References

11.1 Regulations and Regulatory Guidelines

Title 29: Labor
29 CFR 1910 *Occupational Health and Safety Standards*
Section 29 *Fall protection systems and falling object protection—criteria and practices*
Section 269 *Special Industries – Electric Power Generation, Transmission, and Distribution*
Subpart D *Walking-Working Surfaces*
Subpart E *Means of Egress*
Subpart G *Occupational Health and Environmental Control*
Subpart I *Personal Protective Equipment*
Subpart J *General Environmental Controls*
Subpart L *Fire Protection*
Subpart O *Machinery and machine guarding* (Sections 211-219)
Subpart S *Electrical*
Appendix E *Exit Routes and Emergency Planning*
FR 1926 *Safety and Health Regulations for Construction*
Subpart M *Fall Protection*

Title 30: Mineral Resources
30 CFR 250 *Oil and gas and Sulphur operations in the outer continental shelf*
Section 901 *Industry standards*
Section 902 *What are the requirements for platform removal and location clearance?*
Section 905 *In-service inspection plan submittal*
Section 919 In-service inspection plans
Section 1725 *When do I have to remove platforms and other facilities?*
Section 1752 *How do I remove a pipeline?*
30 CFR 254 *Oil-spill response requirements for facilities located seaward of the coast line*
30 CFR 282 *Approved underground storage tank programs*
30 CFR 5285 Renewable energy alternate uses of existing facilities on the outer continental shelf
Section 701 What must I include in my Facility Design Report?
Section 702 What must I include in my Fabrication and Installation Report?
Section 801 How must I conduct my approved activities to protect marine mammals, threatened and endangered species, and designated critical habitat?
Section 810 What must I include in my Safety Management System?
Section 811 When must I follow my Safety Management System?
Section 813 When do I have to report removing equipment from service?
Sections 820-825 Inspections and Assessment
Subpart H Environmental and safety management, inspections, and facility assessments for activities conducted under SAPs, COPs and GAPs

Subpart I Decommissioning
30 CFR 585 *Renewable energy ~~alternate uses of existing facilities~~ on the outer continental shelf*
Section 605–618 *Site Assessment Plan (SAP*
Section 620–63~~8~~5 *Construction and Operations Plan (COP)*
Section 640–657 *General Activities Plan (GAP)*
~~Section 701 *What must I include in my Facility Design Report?*~~
~~Section 702 *What must I include in my Fabrication and Installation Report?*~~
~~Section 801 *How must I conduct my approved activities to protect marine mammals, threatened and endangered species, and designated critical habitat?*~~
~~Section 810 *What must I include in my Safety Management System?*~~
~~Section 811 *When must I follow my Safety Management System?*~~
~~Section 813 *When do I have to report removing equipment from service?*~~
~~Sections 820-825 *Inspections and Assessment*~~
~~Subpart H *Environmental and safety management, inspections, and facility assessments for activities conducted under SAPs, COPs and GAPs*~~
~~Subpart I *Decommissioning*~~

Title 33: Navigation and Navigable Waters
33 CFR 67 *Aids to navigation on artificial islands and fixed structures*
33 CFR Subchapter N
Part 140 *General* Section 10 *Definitions*
Part 142 *Workplace Safety and Health* ~~Section 48 *Eyewash equipment*~~ Section 87 *Guarding of deck openings*
Part 143 *Design and Equipment* Section 101 *Means of escape* Section 105 *Personnel Landings* ~~Section 110 *Guards and rails*~~
Part 145 *Fire-fighting Equipment* Section 01 *Portable and semi-portable fire extinguishers* Section 10 *Location, number, and installation of fire extinguishers*

Title 46: Shipping
46 CFR 108 *Design and equipment*
Section 231 *Application*
Subpart D *Fire extinguishing systems*
46 CFR 160 *Lifesaving Equipment*

Title 47: Telecommunication

47 CFR 15 *Radio Frequency Devices*

Other
BOEM Information Guidelines for a Renewable Energy Construction and Operations Plan (COP)
BOEM Guidelines for Lighting and Marking of Structures Supporting Renewable Energy Development
Energy Policy Act of 2005 (EPAct 2005)
FAA Advisory Circular, AC150/5390-2C *Heliport design*
FAA Advisory Circular 70/7460- 1M *Obstruction Marking and Lighting*
FAA Advisory Circular 150-5345-43J *Specification for Obstruction Lighting Equipment*
NVIC 01-19 *Guidance on the Coast Guard's roles and responsibilities for offshore renewable energy installations (OREI)*
NTL No. 2009-G30 *Post-Hurricane Inspection and Reporting*
Oil Pollution Act of 1990 (OPA 90)
USCG COMDTINST M16500.7A *Aids to Navigation Manual - Administration*

11.2 Industry Standards and Guidelines

Title
ABS *Guide For Building And Classing Bottom-Founded Offshore Wind Turbines (ABS BOWT Guide)*
ABS *Rules for Building and Classing Offshore Installations*
ABS *Guide for Certification of Lifting Appliances*
ABS *Guidance Notes on Accidental Load Analysis and Design for Offshore Structures*
ABS *Rules for Offshore Installations*
ABS *Guide for Surveys Using Risk-Based Inspection for the Offshore Industry*
ABS *Rules for Materials and Welding*
ABS *Guidance Notes on Cathodic Protection of Offshore Structures*
ACI 304 *Guide for Measuring, Mixing, Transporting, and Placing Concrete*
ACI 309 *Consolidation of Concrete*
ACI 318 *Building Code Requirements for Structural Concrete*
ACI 357.3R *Guide for Design and Construction of Waterfront and Coastal Concrete Marine Structures*
ACP OCRP-2 *U.S. Floating Wind Systems Recommended Practices*[14]
ACP OCRP-3 *U.S. Offshore Wind Metocean Conditions Characterization Recommended Practices*~~[12]~~
ACP OCRP-4 *U.S. Recommended Practices for Geotechnical and Geophysical Investigations and Design*[14]
ACP OCRP-5 *Recommended Practices for Submarine Cables*~~[12]~~
ACP RP 1001 *Recommended Practice for Offshore Safety Training and Medical Requirements*[14]
ACP RP 1002 *Offshore Wind Safety Recommended Practices*[14]
AISC 303 *Code of Standard Practice for Steel Buildings and Bridges*
AISC 360 *Specification for structural steel buildings*
ANSI/ASSE Z359 *Definitions And Nomenclature Used For Fall Protection And Fall Arrest*

[14] Under development

Title
ANSI B11.0 *Safety of Machinery*
ANSI/ISEA Z308 *Minimum Requirements for Workplace First Aid Kits*
ANSI/NETA *ATS Standard For Acceptance Testing Specifications For Electrical Power Equipment And Systems*
API RP 2A-LRFD *Planning, Designing and Constructing Fixed Offshore Platforms—Load and Resistance Factor Design*
API RP 2A-WSD *Planning, Designing and Constructing Fixed Offshore Platforms —Working Stress Design*
API RP 2D *Operation and Maintenance of Offshore Cranes*
API RP 2EQ *Seismic design procedures and criteria for offshore structures*
API RP 2GEO *Geotechnical and foundation design considerations*
API RP 2MET *Derivation of Metocean Design and Operating Conditions*
API RP 2MOP *Petroleum and natural gas industries - Specific requirements for offshore structures, Part 6-Marine operations*
API RP 2N *Planning, Designing and Constructing Structures and Pipelines for Arctic Conditions*
API RP 2SIM *Structural Integrity Management of Fixed Offshore Structures*
API RP 580 *Risk-Based Inspection*
API SPEC 2C *Specification for Offshore Pedestal Mounted Cranes*
ASCE MOP 101 *Underwater Investigations: Standard Practice Manual*
ASME A17.8 *Standard for Wind Turbine Tower Elevators*
ASME B30 *Cranes and Hoists*
ASTM A6 *Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling*
ASTM A416 *Standard Specification for Low-Relaxation, Seven-Wire Steel Strand for Prestressed Concrete*
ASTM A421 *Standard Specification for Stress-Relieved Steel Wire for Prestressed Concrete*
ASTM A615 *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement*
ASTM A706 *Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement*
ASTM A722 *Standard Specification for High-Strength Steel Bars for Prestressed Concrete*
ASTM A955 *Standard Specification for Deformed and Plain Stainless Steel Bars for Concrete Reinforcement*
AWS D1.1 *Structural Welding Code—Steel*
BSEE TA&R 627 *Inspection Methodologies for Offshore Wind Turbine Facilities*
BSEE TAP 633AC *Template for a Safety Management System for Offshore Wind Farms on the OCS*
BSEE TAP 650AA *Offshore Wind Turbine Inspection Refinements*
BSEE TAP 723AA *Offshore Substation Design Development of Standards*
CAP 437 *Standards for offshore helicopter landing areas*
CIGRE 483 *Guidelines for the Design and Construction of AC Offshore Substations for Wind Power Plants*
CMPT *A Guide to Quantitative Risk Assessment for Offshore Installation*
DNV-OS-B101 *Metallic materials*

Title
DNV-OS-C101 *Design of offshore steel structures, general - LRFD method*
DNV-OS-C401 *Fabrication and testing of offshore structures*
DNV-OS-D201 *Electrical Installations*
DNV-RP-0416 *Corrosion Protection of Wind Turbines*
DNV-RP-0440 *Electromagnetic compatibility of wind turbines*
DNV-RP-B401 *Cathodic protection design*
DNV-RP-C203 *Fatigue design of offshore steel structures*
DNV-RP-N101 *Risk management in marine and subsea operations*
DNV-RP-N103 *Modelling and analysis of marine operations*
DNV-SE-0080 *Noble Denton marine services – marine warranty survey*
DNV-SE-0190 *Project certification of wind power plants*
DNV-SE-0263 *Certification of lifetime extension of wind turbines*
DNV-SE-0439 *Certification of condition monitoring*
DNV-ST-0054 *Transport and installation of wind power plants*
DNV-ST-0126 *Support structures for wind turbines*
DNV-ST-0145 *Offshore substations*
DNV-ST-0378 *Standard for offshore and platform lifting appliances*
DNV-ST-0262 *Lifetime extension of wind turbines*
DNV-ST-C502 *Offshore concrete structures*
DNV-ST-N001 *Marine operations and marine warranty*
DNV-ST-N002 *Site specific assessment of mobile offshore units for marine warranty*
EN 10025 Series *Hot rolled products of structural steels*
EN 10225 *Weldable steels for fixed offshore structures; Technical delivery conditions*
EN 12999 *Cranes - Loader cranes*
EN 13001 Series *Cranes – General design*
EN 13852-1 *Cranes - Offshore cranes - Part 1: General-purpose offshore cranes*
EN 14492 Series *Cranes - Power driven winches and hoists*
EN 16991 *Risk-based inspection framework*
EN 1808 *Safety requirements for suspended access equipment - Design calculations, stability criteria, construction - Examinations and tests*
EN 50308 *Wind turbines—Protective measures—Requirements for design, operation and maintenance*
EN 81-44 *Lifting appliances for wind turbines*
G+ *Arc flash labeling and associated signage in the offshore wind industry*
G+ *Good Practice Guide: Safe By Design*
G+ *Integrated Offshore Emergency Response*
HSAC RP Nbr 161 *New Build Helideck Design Guidelines*
HSAC RP Nbr 166 *Aviation Support to Offshore Windfarms*
IALA Recommendation O-139 *The Marking of Man-Made Offshore Structures*
IEC/IEEE 60076-16 *Power transformers - Part 16: Transformers for wind turbine applications*
IEC 60204-1 *Safety of machinery - Electrical equipment of machines - Part 1: General requirements*

Title
IEC 60204-11 *Safety of machinery - Electrical equipment of machines - Part 11: Requirements for equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV*
IEC 60204-32 *Safety of machinery - Electrical equipment of machines - Part 32: Requirements for hoisting machines*
IEC 60255-1 *Measuring relays and protection equipment - Part 1: Common requirements*
IEC 60255-21-1:1988: *Electrical relays - Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment - Section One: Vibration tests (sinusoidal)*
IEC 60255-21-2:1988*: Electrical relays - Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment - Section Two: Shock and bump tests*
IEC 60255-21-3:1993: *Electrical relays - Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment - Section 3: Seismic tests*
IEC 60296 *Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear*
IEC 60309 Series *Plugs, socket-outlets and couplers for industrial purposes*
IEC 60364-4-41 *Low voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock*
IEC 60364-7-729 *Low-voltage electrical installations - Part 7-729: Requirements for special installations or locations - Operating or maintenance gangways*
IEC 60529 *Degrees of Protection Provided by Enclosures (IP Code)*
IEC 61000 Series *Electromagnetic compatibility (EMC): Testing and measurement techniques*
IEC 61000-6-1 *Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity standard for residential, commercial and light-industrial environments*
IEC 61000-6-2 *Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments*
IEC 61000-6-3 *Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for residential, commercial and light-industrial environments*
IEC 61000-6-4 *Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments*
IEC 61000-6-5 *Electromagnetic compatibility (EMC) - Part 6-5: Generic standards - Immunity for equipment used in power station and substation environment*
IEC 61000-6-7 *Electromagnetic compatibility (EMC) - Part 6-7: Generic standards - Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations*
IEC 61039 *Classification of insulating liquids*
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IEC 61400-1 *Wind energy generation systems~~Wind turbines~~—Part 1: Design requirements*
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IEC 61400-24 *Wind energy generation systems~~Wind turbines~~—Part 24: Lightning protection*
IEC 61508-1 *Functional safety of electrical/electronic/programmable electronic safety-related systems—Part 1: General requirements*
IEC 61511 *Functional safety - Safety instrumented systems for the process industry sector*

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IEC 61892-1 *Mobile and fixed offshore units - Electrical installations—~~ -~~Part 1: General requirements and conditions*
IEC/UL 61010-2-201 *Safety requirements for electrical equipment for measurement, control, and laboratory use—~~ -~~Part 2-201: Particular requirements for control equipment*
IEC 61936-1 *Power installations exceeding 1 kV a.c.—~~ -~~Part 1: Common rules*
IEC 62061 *Safety of machinery - Functional safety of safety-related control systems*
IEC 62351 Series *Power systems management and associated information exchange—~~ -~~Data and communications security*
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ISA/IEC 62443 Series *Industrial communication networks - Network and system security*
IECRE OD-501 *Type and Component Certification Scheme*
IECRE OD-502 *Project Certification Scheme*
IEEE 1584 *IEEE Arc-Flash Hazard Calculations*
IEEE 1613 *IEEE Standard Environmental and Testing Requirements for Communications Networking Devices in Electric Power Substations*
IEEE 1686 *IEEE Standard for Intelligent Electronic Devices Cyber Security Capabilities*
IEEE 242 *IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems*
IEEE 693 - *IEEE Recommended Practice for Seismic Design of Substations*
IEEE 80 *IEEE Guide for Safety in AC Substation Grounding*
IEEE 998 *IEEE Guide for Direct Lightning Stroke Shielding of Substations*
IEEE C37.90 *Standard for Relays and Relay Systems Associated with Electric Power Apparatus*
IEEE C37.91 *IEEE Guide for Protecting Power Transformers*
IEEE C57.12.00 *IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*
IEEE C2 *National Electrical Safety Code (NESC)*
IEEE/ANSI C63.4 *American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz*
IEEE/ANSI C63.10 *American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices*
IMCA LR 006 *Guidelines for Lifting Operations*
IMCA SEL 041 *Standardised Boat Landing Research Report*
IMCA M 203 *Guidance on Simultaneous Operations (SIMOPS)*
International Convention for Life Safety at Sea (SOLAS)
ISO 10474 *Steel and steel products — Inspection documents*
ISO 12100 *Risk assessment and risk reduction*
ISO 12696 *Cathodic Protection of Steel in Concrete*
ISO 12944 Series *Paints and varnishes - Corrosion protection of steel structures by protective paint systems*
ISO 12944-9 *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 9: Protective paint systems and laboratory performance test methods for offshore and related structures*

Title
ISO 13628-5 *Petroleum and natural gas industries—Design and operation of subsea production systems—Part 5: Subsea umbilicals*
ISO 13849-1 *Safety of machinery — Safety-related parts of control systems—Part 1: General principles for design*
ISO 13850 *Safety of machinery - Emergency stop function - Principles for design*
ISO 14118 *Safety of machinery — Prevention of unexpected start-up*
ISO 14122 Series *Safety of machinery*
ISO 16079-1 *Condition monitoring and diagnostics of wind turbines - Part 1: General guidelines*
ISO 17776 *Petroleum and natural gas industries - Offshore production installations - Major accident hazard management during the design of new installations*
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 - Part 1: Metocean design and operating considerations*
ISO 19901-6 *Petroleum and natural gas industries - Specific requirements for offshore structures - Part 6: Marine operations*
ISO 19901-9 *Petroleum and natural gas industries - Specific requirements for offshore structures - Part 9: Structural integrity management*
ISO 19902 *Petroleum and natural gas industries—Fixed steel offshore structures*
ISO 19903 *Petroleum and natural gas industries—Fixed concrete offshore structures*
ISO 19905-1 *Petroleum and natural gas industries - Site-specific assessment of mobile offshore units – Part 1: Jack-ups*
ISO 21650 *Actions from waves and currents on coastal structures*
ISO 22965 Series *Concrete*
ISO 22966 *Execution of concrete structures*
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ISO 4413 *Hydraulic Fluid Power - General Rules And Safety Requirements For Systems And Their Components*
ISO 6934 Series *Steel for the prestressing of concrete*
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ISO 9692-2 *Welding and allied processes — Joint preparation — Part 2: Submerged arc welding of steels*
MNL120-10 *PCI Design Handbook*
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*
NACE SP0178 *Design, Fabrication, and Surface Finish Practices for Tanks and Vessels to Be Lined for Immersion Service*
NACE SP0387 *Metallurgical and Inspection Requirements for Cast Galvanic Anodes for Offshore Applications*
NACE SP0492 *Metallurgical and Inspection Requirements for Offshore Pipeline Bracelet Anodes*
NEMA 250 *Enclosures for Electrical Equipment (1000 Volts Maximum)*

Title
NEMA-TR1 *Transformers, Regulators and Reactors*
NERC CIP Critical Infrastructure Protection Standards
NERC Glossary of Terms Used in NERC Reliability Standards
NFPA 101 *Life Safety Code*
NFPA 110 *Emergency & Standby Power*
NFPA 30 *Flammable and Combustible Liquids Code*
NFPA 70 *National Electrical Code (NEC)*
NFPA 70E *Standard for Electrical Safety in the Workplace*
NFPA 780 *Standard for the Installation of Lightning Protection Systems*
NFPA 79 *Electrical Standard for Industrial Machinery*
NFPA 850 *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*
NORSOK M-501 *Surface preparation and protective coating*
NORSOK M-503 *Cathodic Protection*
NORSOK N-004 *Design of steel structures*
OE-GL-01 *Recommended Practice & Guideline - Planning and execution of WTG lifting operations*
OE-RP-01 *Recommended Practice – Design of lifting, transport, storage and accessory equipment*
OE-RP-02 *Vessel access aligned interfaces*
Renewable UK. RUK13-001-6 *Offshore Wind and Marine Energy Health and Safety Guideline*
Renewable UK. RUK13-019-3 *Guidelines for the Selection and Operation of Jack-ups in the Marine Renewable Energy Industry*
Renewable UK. RUK15-009-3 *Vessel Safety Guide - Guidance for Offshore Renewable Energy Developers*
UL 508 *Standard for Industrial Control Equipment*
UL 6141 *Standard for Wind Turbines Permitting Entry of Personnel*

Annex A Critical Safety Systems and Equipment

While each project will develop its own set of critical safety systems and equipment (CSSE) based on a risk analysis specific to that project's design and safety philosophies, it is likely that most projects will include several common elements in their design. Systems and Equipment intended to mitigate major accidents as determined by the risk assessment are considered CSSE. This annex is informative; it does not prescribe what does and does not constitute CSSE but rather it lists systems and equipment that are likely to be classified as CSSE for offshore assets.

A.1 Offshore Wind Turbine Potential CSSE

Systems and equipment described in Table A.1 are likely to be classified as CSSE for the offshore wind turbine, depending on the risk assessment performed for the project as described in Sec. 5.13.

Table A.1 Potential CSSE for Offshore Wind Turbines

Hazard Category	Hazard	Potential CSSE	Description
Adverse or extreme weather	Changing weather conditions could strand technicians on the structure for extended periods, risking personnel safety.	To be assessed	To be assessed
Dropped objects	Dropped objects that could result in multiple technician fatalities, structural damage or collapse, and/or large-scale environmental impact.	To be assessed	To be assessed
Electric shock	Fires and/or electrical hazards due to electrical system failure, friction, or electrical arcing that could result in multiple technician fatalities, structural damage or collapse, and/or large-scale environmental impact.	Emergency Shutdown System	Typically includes sensors to detect critical conditions, control logic to process sensor data, actuators to initiate shutdown actions (like closing circuit breakers), alarms and communication systems to alert operators, and safety interlocks to prevent unintended operations.
	Uncontrolled electrical surges, overheating, or component failure causing fires and/or other hazards (e.g., high voltage) that could result in multiple technician fatalities, structural damage or collapse, and/or large-scale environmental impact.	Electrical Power Protection System	Quickly disconnect faulty components from the grid and protecting the wind farm's electrical power system. Typically includes circuit breakers, lightning arresters, surge protection devices, fault ride-through systems, and communication relays.
	Unexpected energization, startup of the machinery/equipment, or release of stored energy in	Emergency Shutdown System	(as above)

	the equipment that could result in multiple technician fatalities.	Other interlocks	Other interlocks may be used to prevent unexpected energization of equipment, and these could be CSSE.
Fall from heights	Failure of service lifts inside the tower could result in multiple technician fatalities	Service Lifts	Multiple technicians may use a service lift to ascend to the nacelle for inspection or maintenance. Typically includes a car, drive system, escape hatches, brakes, fall arrest system, sensors, and controller.
Fires and Explosions (including arc flash)	Fires and/or electrical hazards due to electrical system failure, friction, or electrical arcing that could result in multiple technician fatalities, structural damage or collapse, and/or large-scale environmental impact.	Fire Detection, Alarm, and Suppression System	Detects fires and automatically deploys extinguishing agents to contain and suppress it within the turbine or other critical areas of a wind farm. Opens the main break and disconnects power from the turbine. Typically includes components like heat detectors, flame detectors, emergency power supply, and a fire suppression agent delivery system.
	Lightning could strike the turbine resulting in a potential fire that could result in multiple technician fatalities and/or large-scale environmental impact	Lightning Protection System (LPS)	Coordinated set of protection measures designed to mitigate the effects of lightning strikes on wind turbines. Typically includes an air termination system, down-conductor system, earthing/grounding system, and surge protection measures.[6]
Oil or other spills	Fluid from the turbine could spill or leak in the ocean and result in large-scale environmental impact.	To be assessed	To be assessed
Release of hazardous energy	Loss of turbine mechanical and/or electrical control, leading to blade and tower damage that could result in large-scale environmental impact (e.g., debris, impacting nearby vessels).	Overspeed Protection System	Systems to monitor turbine speed and to safely shut down in case of overspeed. Typically includes a speed sensor, a control unit with

			trip logic, and a braking mechanism to slow the turbine and prevent damage from excessive speeds.
		Other mechanical protection systems	Protection systems to prevent excessive vibrations, excessive cable twist, and other mechanical conditions or states hazardous to the turbine.
	Loss of turbine mechanical and/or electrical control, unable to set or lock yaw and/or rotor, make safe for personnel access, or shut down the turbine.	Supervisory Control and Data Acquisition (SCADA) Controls and software	Monitor and controls various components of an offshore wind farm, allowing operators to manage the entire system remotely, including turbine performance, power output, and safety parameters, from a central control station. Typically includes a human machine interface (HMI), programmable logic controller (PLC) and remote terminal unit (RTU).
	Uncontrolled rotor mechanical movement during inspection or maintenance could result in multiple fatalities for technicians or vessel crew.	Rotor Lock System	Physically secures the turbine's blades and hub. Typically includes the locking bolt, lock disc, hydraulic actuators to engage the lock, and control system to activate and monitor the locking process.
		Yaw lock and/or yaw brake	Physically secures the RNA from yawing. Typically includes the locking bolt, lock disc, hydraulic actuators to engage the lock, and control system to activate and monitor the locking process.
Vessel impact	Inability to locate and navigate around the turbine could result in a ship/aircraft impact with large-scale environmental impact.	Emergency Lighting/Marking for Navigation and Aviation	Sound signals, lighting, markers, and other aids to help mariners and aviators locate the turbine and avoid ship/aircraft impact.

			Typically includes sound signals, automated identification system (AIS) transponder signals, automatic timers or motion activated shutoffs lights, and beacons.[15]
Other	Inability to quickly evacuate in the case of an emergency that could result in multiple fatalities.	Emergency Lighting/Marking for Escape Routes	Sound signals, lighted pathways, markers, and other aids helping technicians navigate the turbine. Typically includes sound signals, automatic timers or motion activated shutoffs, lights, and beacons.[15]

A.2 Offshore Substation Potential CSSE

Systems and equipment described in Table A.2 are likely to be classified as CSSE for the offshore substation, depending on the risk assessment performed for the project as described in Sec. 5.13.

Table A.2 Potential CSSE for Offshore Substation

Hazard Category	**Hazard**	**Potential CSSE**	**Description**
Adverse of extreme weather	Changing weather conditions could strand technicians on the structure for extended periods, risking personnel safety.	To be assessed	
Dropped objects	Dropped objects that could result in multiple technician fatalities, structural damage or collapse, and/or large-scale environmental impact.	To be assessed	To be assessed
Electric shock	Uncontrolled electrical surges, overheating, or component failure causing fires and/or other hazards (e.g., high voltage) that could result in multiple technician fatalities, structural damage or collapse, and/or large-scale environmental impact.	Electrical Power Protection System	Quickly disconnect faulty components from the grid and protecting the wind farm's electrical power system. Typically includes circuit breakers, lightning arresters, surge protection devices, fault ride-through systems, and communication relays.
	Loss of electrical control, unable to make safe for personnel access, or shut down the substation.	Supervisory Control and Data Acquisition	Monitor and controls various components of an offshore wind farm, allowing operators to

[15] Bureau of Ocean Energy Management (BOEM) 2021 Lighting and Marking Guide, https://www.boem.gov/sites/default/files/documents/renewable-energy/2021-Lighting-and-Marking-Guidelines.pdf

		(SCADA) Controls	manage the entire system remotely, including substation performance, power output, and safety parameters, from a central control station. Typically includes a human machine interface (HMI), programmable logic controller (PLC) and remote terminal unit (RTU).
Fall from heights	Fall from heights that could result in multiple technician fatalities	To be assessed	To be assessed
Fires and explosions (including arc flash)	Fires and/or electrical hazards due to electrical system failure, friction, or electrical arcing that could result in multiple technician fatalities, structural damage or collapse, and/or large-scale environmental impact.	Emergency Shutdown System	Typically includes sensors to detect critical conditions, control logic to process sensor data, actuators to initiate shutdown actions (like closing circuit breakers), alarms and communication systems to alert operators, and safety interlocks to prevent unintended operations.
	Fires and/or electrical hazards due to electrical system failure, friction, or electrical arcing that could result in multiple technician fatalities, structural damage or collapse, and/or large-scale environmental impact.	Fire Detection, Alarm, and Suppression System	Detects fires and automatically deploys extinguishing agents to contain and suppress it within the substation or other critical areas of a wind farm. Opens the main break and disconnects power from the substation. Typically includes components like heat detectors, flame detectors, emergency power supply, and a fire suppression agent delivery system.
	Lightning could strike the substation resulting in a potential fire that could result in multiple technician fatalities and/or large-scale environmental impact	Lightning Protection System (LPS)	Coordinated set of protection measures designed to mitigate the effects of lightning strikes on offshore substations. Typically includes an air termination system, down-conductor system, earthing/grounding

			system, and surge protection measures.
Oil or other spills	Fluid from the substation equipment could spill or leak in the ocean and result in large-scale environmental impact.	To be assessed	To be assessed
Release of hazardous energy	Unexpected energization, startup of the machinery/ equipment, or release of stored energy in the equipment that could result in multiple technician fatalities.	Emergency Shutdown System	(as above)
		Supervisory Control and Data Acquisition (SCADA) Controls	(as above)
		Other interlocks	Other interlocks may be used to prevent unexpected energization of equipment, and these could be CSSE.
Vessel impact	Inability to locate and navigate around the substation could result in a ship/aircraft impact with large-scale environmental impact.	Emergency Lighting/Marking for Navigation	Sound signals, lighting, markers, and other aids to help mariners and aviators locate the substation and avoid ship/aircraft impact. Typically includes sound signals, automated identification system (AIS) transponder signals, automatic timers or motion activated shutoffs, lights, and beacons. [15]
Other	Inability to quickly evacuate in the case of an emergency that could result in multiple fatalities.	Emergency Lighting/Marking for Escape Routes	Sound signals, lighted pathways markers, and other aids helping technicians navigate the substation. Typically includes sound signals, automatic timers or motion activated shutoffs, lights, and beacons.[15]

A.3 Subsea Cable Potential CSSE

Subsea cables are not likely to include CSSE, as equipment for protection, isolation, and control are typically provided on other assets, specifically the offshore wind turbines, and the offshore and onshore substations.

A.4 Other Assets Potential CSSE

Other assets such as meteorological towers, supporting platforms, etc. may include CSSE depending on the equipment installed on those assets. Potential CSSE for access and egress should be considered.