Development of Offshore Wind Recommended Practice for U.S. Waters

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Development of Offshore Wind Recommended Practice for US Waters

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Abstract

The American Wind Energy Association (AWEA), as a standards development organization, sponsored the development of recommended practices (RP) for offshore wind turbine facilities and published its RP report in 2012. The challenges faced by the emerging offshore wind energy industry parallel many of the challenges that were faced by the offshore oil and gas industry in its infancy. These challenges are documented and addressed in the development of the AWEA RP and are described in this paper. The paper discusses how the more mature American Petroleum Institute oil and gas standards were interfaced with International Electrotechnical Commission and other wind turbine and offshore industry standards to provide guidance for reliable engineering design practices of these mechanically dynamic, fatigue-driven offshore wind energy systems. Uncertainties requiring further validation and analysis are also described.

Background

There are a number of offshore wind energy projects at various stages of development for both the federal and state waters of the United States, but none have started construction. The National Renewable Energy Laboratory estimates that U.S. coastal waters have approximately 4,000 GW of gross offshore wind energy resources if all the resources over the waters from the shore out to 50 nautical miles out are included (Musial 2010). However, development of offshore wind resources in U.S. waters is in its nascent stages, and several barriers to deployment must be overcome before offshore wind energy can be successfully integrated into the electric energy generation mix at a large scale. Some of the barriers include immature infrastructure and supply chain, the need for further technology optimization, reliability concerns, and lack of uniform regulatory guidance on the design, installation, and operation of these facilities. The focus of this paper is to describe some of the industry efforts that have been devoted to providing guidance to inform developers, designers, and regulators on the application and applicability of existing standards.

In the early 1990s, the development of standards for the wind energy industry in the United States was governed by international organizations such as the International Electrotechnical Commission (IEC) with the full support of the U.S. wind industry. International standards allowed companies to provide consistent hardware options in any country with reasonable assurance that turbine safety and performance would not vary across national borders. This process of international standardization was accelerated by the formation of the European Union (EU) in 1992 when EU countries sought harmony among their members and saw national standards as a potential barrier to free trade. While the desire to recognize a common international set of wind energy standards generally still prevails, recently in the United States some concerns have arisen that compliance solely with international standards may create some unintended consequences. International standards may contradict some statutory national and local ordinances and may not address some real concerns about operation and safety in the context of the existing U.S. infrastructure or the nation's unique physical environment and climate.

The land-based wind energy industry in the United States has been largely unregulated at a federal level, but projects have had to comply with local building codes. Private third-party due-diligence firms are employed by most projects to provide oversight and credibility to lower project risk sufficiently to obtain financing. Unlike the land-based projects, the regulation and approval of offshore wind projects on the Outer Continental Shelf are regulated at the federal level. Regulatory jurisdiction in federal waters has been assigned to the Bureau of Ocean Energy Management (BOEM) and the Bureau of Safety and Environmental Enforcement (BSEE), which were formed as two independent agencies to replace the now defunct Minerals Management Service. Under BOEM/BSEE rules, the process for establishing and demonstrating structural integrity for offshore wind turbines will be more heavily regulated than for land-based turbines. In April 2009, BOEM/BSEE issued the rule 30 Code of Federal Regulations (CFR) 285 (now called 30 CFR 585), which provides a framework for approval of offshore wind turbines [BOEM 2009]. However, 30 CFR 585 does not specify an approach for the use of offshore industry standards, but rather directs developers to use "accepted industry practices" and is vague on how to establish and evaluate such practices.

In October 2009, the National Renewable Energy Laboratory (NREL), the U.S. Department of Energy (DOE), and the American Wind Energy Association (AWEA) hosted an organizational meeting with the purpose of developing three AWEA guidelines for large turbine compliance in the United States that address critical issues identified by industry that were ambiguous or not adequately covered in the existing national and international standards. Three independent groups were formed to develop guidelines to address: (1) electrical compliance issues, primarily with respect to the National Electric Code; (2) land-based structural compliance for typical turbines; and (3) offshore wind energy compliance. One of the biggest challenges for developing the offshore wind guideline was that offshore wind is new to the United States and there have not yet been any installations. Therefore "best practices" were derived from European experience and existing oil and gas practices that have proven successful over the past 50 years. Another challenge was that the scope of the offshore guideline was much broader than the other AWEA guidelines because it attempts to cover all aspects of offshore wind project development. The broad scope of this effort was not an attempt to create new requirements but to create a set of recommended practices that harmonized with existing national and international standards and that reflected the state of the art for what are to be considered "accepted industry practices" as required for regulatory compliance with the 30 CFR 585 regulations. This is seen as a path to simplify and clarify the offshore wind energy regulatory process through a consensus document that primarily references other existing standards.

As evidence that more robust regulatory guidance was urgently needed, in April 2011, the Transportation Research Board (TRB) of the National Academies published a report titled *Structural Integrity of Offshore Wind Turbines: Oversight of Design, Fabrication, and Installation* (TRB 2011). One of the TRB report's objectives was to provide guidance to the Minerals Management Service (MMS) on the adequacy and applicability of the existing standards to the design, fabrication, and installation of offshore wind turbines for the United States. The report concluded "that many sets of standards and guidance documents for offshore wind turbines are available from standards organizations, classification societies, and … governments internationally and that most, have elements that are relevant to the United States and can be applied to installations in U.S. waters." However, according to the report, no single set of standards exists that completely covers all aspects of offshore wind turbine design, installation, or operation.

Offshore Compliance Recommended Practices (OCRP) Summary

The AWEA Offshore Compliance Recommended Practices Committee (AWEA Committee) concurred with this TRB finding. As a joint industry effort, the objective of the AWEA Committee was to develop a roadmap that could guide developers, regulators, and designers in the development of offshore wind turbines in the United States.

The process used to develop the AWEA offshore wind guideline followed the AWEA Standards Development Procedures that were adopted by AWEA in 2007. AWEA is the accredited standards developer under the authority of the American National Standards Institute (ANSI) for consensus wind energy standards in the United States. The AWEA Standards Development Procedures comply with ANSI Essential Requirements: Due Process Requirements for American National Standards. Therefore, AWEA's document, *Offshore Compliance Recommended Practices; Recommended Practices for Design, Deployment, and Operation of Offshore Wind Turbines in the United States* (AWEA OCRP 2012) was developed in full compliance with the authorized U.S. standards development organizations.

AWEA OCRP 2012 was approved by the AWEA Standards Development Board in October 2012. AWEA OCRP 2012 addresses aspects of the life cycle of a wind turbine facility: project design and design basis; manufacturing; construction, installation, and commissioning; operation, inspection, and safety systems; and decommissioning. It covers most stages of development from cradle to grave, excluding the initial permitting stages required to obtain a lease. These stages, shown in Figure 1, mirror the major regulatory stages framed in 30 CFR 585. It is intended for use with fixed-base offshore wind structures in U.S. federal and state waters and applies only to turbines with a swept area greater than 200 m^2, the minimum size covered by most IEC large wind turbine standards. In its current state, the document does not sufficiently cover the requirements for floating offshore wind structures. Work on floating wind turbine standards is currently underway by the IEC, but a detailed discussion on this topic is beyond the scope of this paper.

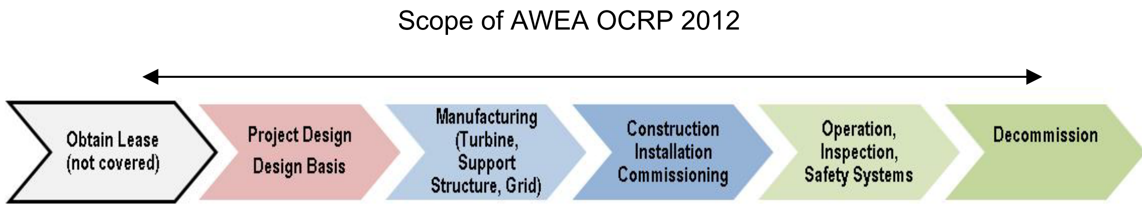

Figure 1 – Figure 1: Offshore wind project development stages and scope of AWEA OCRP 2012

AWEA OCRP 2012 was developed through a consensus process with the efforts of a multidisciplinary volunteer group of more than 50 industry experts. The group was represented by key agencies such as BOEM, responsible for promoting renewable energy development in federal waters, and BSEE, responsible for enforcing regulatory requirements in federal waters. In addition, the members included representatives from DOE, wind energy technology consultants, oil and gas engineers, structural engineering firms, marine class societies, and university professors. AWEA OCRP 2012 contains guidance based on industry best practices learned from installations in other countries as well as approaches that have been successful in U.S. oil and gas offshore installations.

The AWEA Committee used a "wrapper" approach to develop AWEA OCRP 2012. In other words, a few primary guidance documents were referenced, for example IEC 61400-3, and, as necessary, were "wrapped" with modifications or clarifications to suit U.S.-specific requirements. This is similar to how certain countries, such as Canada, adopt International Organization for Standardization (ISO) and IEC guidance documents. This approach proved to be an efficient process and allowed the committee to take existing best practices from a variety of sources, including both the offshore wind industry and the offshore oil and gas industry. In many cases however, the IEC did not address the details of some issues and whole standards or guidelines from other industries were used to fill specific gaps. The resulting document provides a roadmap that describes how to use the existing standards to provide guidance for the design, manufacturing, testing, construction, inspection, and decommissioning of offshore wind turbines in the United States.

The most relevant standards are international, national, and industry specific. IEC and ISO are international standards organizations, and the American Petroleum Institute (API) is a U.S.-based national organization that has significant international acceptance and has standards that are applicable to the offshore wind industry. There are numerous regulations, standards, and guidelines relevant to the offshore wind industry, but the most relevant design standards for offshore wind are:

- IEC 61400-1, Wind turbines - Part 1: Design requirements
- IEC 61400-3, Wind turbines - Part 3: Design requirements for offshore wind turbines
- IEC 61400-22, Wind turbines - Part 22: Conformity testing and certification
- ISO 19900, General requirements for offshore structures
- ISO 19902, Fixed steel offshore structures
- ISO 19903, Fixed concrete offshore structures
- ISO 19904-1, Floating offshore structures – mono-hulls, semisubmersibles and spars
- ISO 19904-2, Floating offshore structures - tension-leg platforms
- API RP 2A-WSD, Recommended practice for planning, designing and constructing fixed offshore steel platforms - working stress design.

Figure 2 shows the applicability of some of these existing standards to the design phase of an offshore wind turbine with a fixed bottom jacket substructure. Note that the IEC standards do a good job addressing the wind turbine design and load cases, but it is necessary to use other standards such as API and ISO when developing a robust design for the entire system. The coupling of these two sets of standards is a complex task and has been addressed in the literature (Dolan 2009, Jha 2013). One of the most critical aspects of the design integration of the substructure and turbine is the need to accurately design the coupled system frequencies to avoid coalescence with the operating frequencies of the wind turbine's primary rotational speed and harmonics that correspond to the blade passing frequency. Unlike oil and gas structures, the coupled offshore wind turbine system must operate inside a band of suitable frequencies for safe operation rather than simply staying above a minimum limit because critical excitation comes from multiple sources.

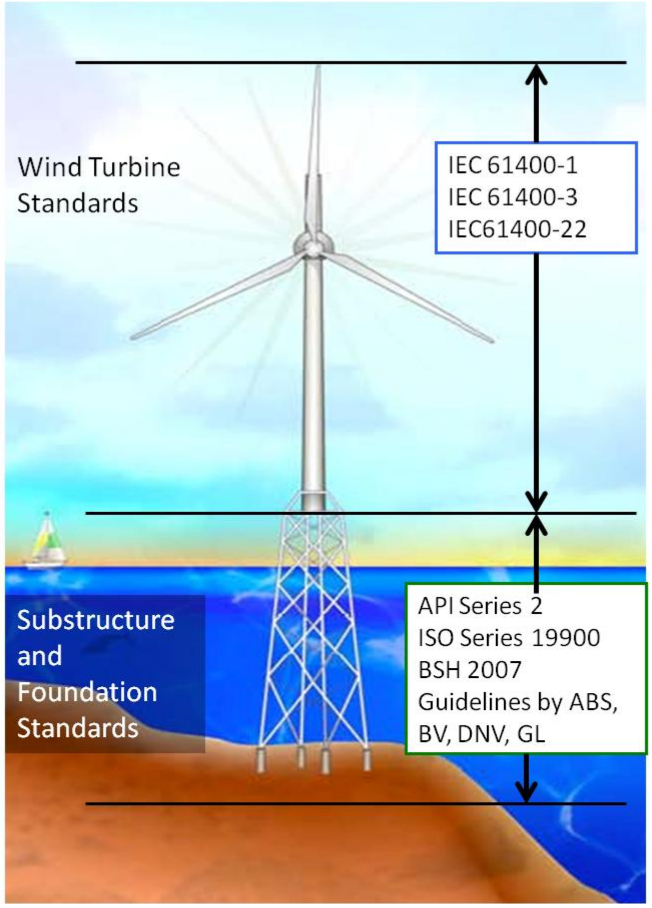

Figure 2 – Applicability of existing design standards for offshore wind turbines

Challenges Facing the Emerging Offshore Wind Industry in the United States

There are a number of challenges that are influencing development efforts of utility-scale offshore wind farms in U.S waters. A number of these are discussed below and how they are addressed by the AWEA OCRP 2012.

Hurricanes

Thus far, the majority of offshore wind turbines installed worldwide do not have significant exposure to tropical storms such as hurricanes. The existing IEC standards do not explicitly identify hurricanes and other tropical events as part of their load cases. But the U.S. Gulf of Mexico and Atlantic coasts, as well as most of the Asia-Pacific regions experience tropical events annually, and therefore, facilities installed offshore must be designed for these conditions.

High winds are nothing new to wind turbine design. For example, an IEC Class IA turbine is the most stringent wind class defined by IEC 61400-01 with sustained winds of 112 mph and peak 3-second gusts defined at 156 mph (about an average category 3 hurricane, according to the Saffir-Simpson Hurricane Scale). Most offshore wind turbines adhere to IEC Class IA, and therefore, theoretically, most offshore wind turbines are already designed to survive category 3 extreme gust conditions. However, for offshore applications, the entire system, including the turbine, substructure and foundation, must be designed for extreme wind events as well as the influence of simultaneous wave loads and, particularly in the southern United States, the impact of much more intense storms must also be considered. The category 4 and 5 hurricanes that have occurred over the past few years (e.g., Andrew, Katrina, Ivan, Wilma) produced powerful storm conditions with peak gusts that exceed the basic 156-mph criteria for an IEC Class IA design and are not adequately addressed by the current IEC standards. In addition, the current method in which the 50-year extreme wind IEC design load case is based solely on a 3-second gust may oversimplify the complex nature of a sustained 12-hour plus hurricane event.

AWEA OCRP 2012 recognizes that hurricanes will present unique challenges for the United States and provides guidance on how to address their impacts on turbine design. References to offshore oil and gas standards, API, ISO, and IEC, as well as studies funded by the BSEE provide useful information to the designer. Generally AWEA OCRP 2012 recommends that all offshore turbines be designed to IEC 61400-01 Class S to account for site-specific turbulence and extreme wind speed criteria that may not correspond to conventional IEC Classes. The AWEA OCRP 2012 guideline also recognizes that IEC does not provide adequate guidance and defers regularly to the estabished API/ISO criteria for offshore structures. For example, AWEA OCRP 2012 recommends that "medium consequence of failure" should be considered in determining the exposure category for an offshore wind turbine support structure. This recommends using the API RP-2A WSD[1] exposure category of L-2, corresponding to an unmanned structure, but recognizes that serial catastrophic failures in an offshore wind facility could have broader impacts to energy production and project perfromance beyond a single unit failure (Efthymiou 2011).

AWEA OCRP 2012 refers specifically to the current versions of the standards and guidelines that it references. This means that as the industry standards evolve to assimilate new experience in oil, gas, and wind, AWEA OCRP 2012 will tend to remain current by automatically adopting these best new practices. For example, IEC 61400-03 and API RP-2A WSD are both currently engaged in revisions to address new hurricane data for their respective industies. As the revisions are adopted by API and IEC, they will become part of AWEA OCRP 2012 as well. Specifically, it may be necessary to satisfy robustness level criteria described in the new API Edition 22 to remain consistent with new oil and gas experience for hurricane survival. Therefore, the wind turbine support structure may be required to have a reserve strength ratio greater than the load ratio of the 500-year and the 50-year tropical cyclone conditions. In some geographic areas exposed to tropical cyclones, higher partial safety factors for environment normal loads will be required to satisfy the robustness level criteria. The API and IEC standards referenced by AWEA OCRP 2012 are still being crafted to accommodate offshore wind, but the vast experience of oil and gas will allow rapid maturation of offshore wind practices by taking advantage of the most recent findings.

Lack of Clear Regulatory Guidance

Clear expectations from a regulator are beneficial to all stakeholders in any industry. Unfortunately, the current 30 CFR 585 regulations are too broad and lack the necessary specificity to be very useful to the designers. This leaves developers and designers without a clear target, so they are not sure if their approach will be accepted. Current language in the 30 CFR 585 directs developers to use "accepted industry practices" for safe and orderly deployment of offshore wind facilities, but it is far short of defining what these accepted practices are. This is more than a regulatory issue because there is no single standard or set of standards that can be used to design an offshore wind turbine facility.

AWEA OCRP 2012 attempts to fill this gap through defining what existing guidance is available and best suited to address the needs of the designer. It considers all phases of the project from design to fabrication to operations. In some cases, references are from other offshore wind guidelines and in other cases guidance has been taken from related industries. As a whole, AWEA OCRP 2012 provides a document that represents the state of the practice for offshore wind with U.S.-specific guidance as needed. It can be used by regulators to judge the suitability of designs submitted by developers and the management of these assets over the life of the wind farm. The authors recommend that AWEA continue to evolve the recommended practices (RP) guideline so that it remains useful as offshore wind development begins in the United States.

Alternative Substructure Systems

Most wind farm installations use a monopile substructure and foundation system. This consists of a steel caisson structure driven in to the soil to provide a stable platform for installation of the wind turbine. There are other structural systems that are used less frequently or are proposed that are not addressed as thoroughly through existing guidance but may be used more frequently in the oil and gas industry. These structures include steel and concrete gravity based structures (GBS), braced frames with multiple piles (e.g., jackets), and floating systems.

For concrete structures, guidance put forth for the offshore oil and gas industry through ISO documents are directly applicable to offshore wind structures. As specified in AWEA OCRP 2012, the ISO design guidance for offshore concrete structures provides a complete set of recommendations for the unique characteristics of gravity base systems. These have been used extensively for offshore oil and gas development, though they support more extensive topsides systems than a wind turbine structure. There are unique aspects of loading from wind turbines that are not specifically addressed in the ISO standard, but they provide a good starting point. As offshore wind development begins in the United States, we expect to see a much greater diversity of substructure types as compared with the first generation of projects installed in Europe. As such, new design challenges will be presented, and the standards will have to be further developed. Figure 3 shows a pie chart of the support structure type used in the current installed offshore wind capacity in Europe as compared to the projected installed offshore wind capacity at the end of 2011. The trends show a clear movement toward jacket and multipile type structures. Note that use of gravity based foundations is declining significantly. This trend may be due in part to the movement toward deeper water in the North and Baltic Seas.

[1] Working Stress Design

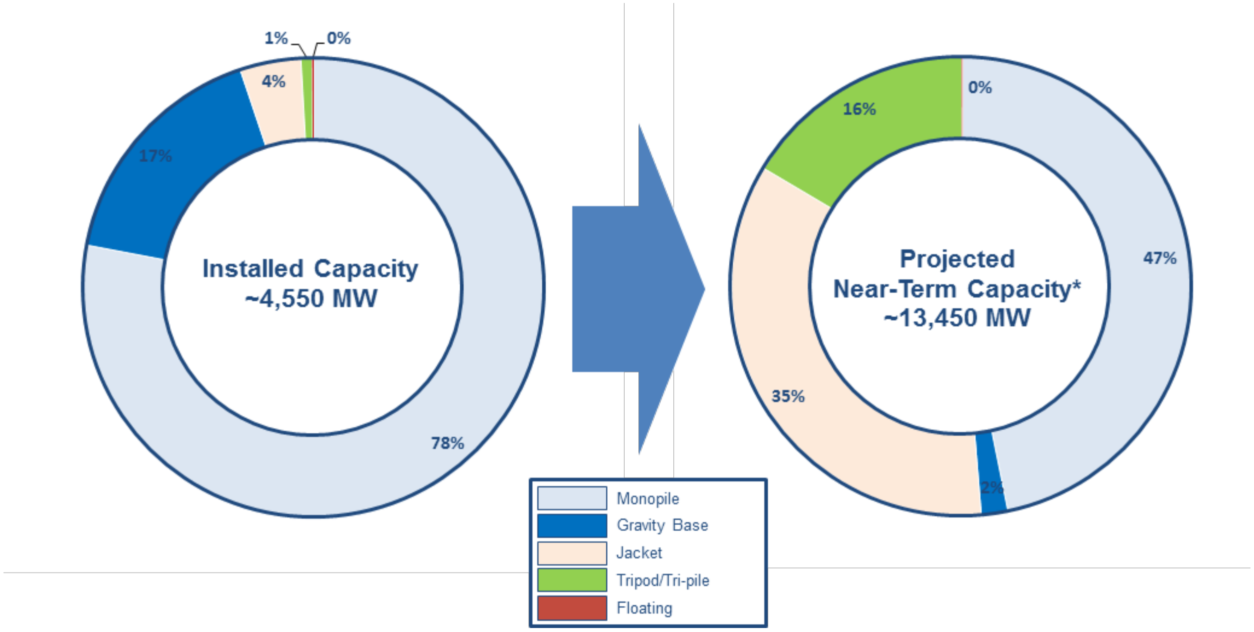

Figure 3 – Offshore wind facilities show trend toward multipile support structures (data source NREL)

For floating systems, AWEA OCRP 2012 does not contain any guidance. The IEC is currently developing a document (IEC 61400-03-2) that specifically addresses these systems.

Integration of IEC and Offshore Oil and Gas Approaches

As mentioned, in addition to the wind-specific guidance available, the offshore oil and gas guidance was a useful resource for many of the areas addressed. With more than 50 years of experience designing, installing, and maintaining offshore structures in U.S. waters, much of what has been learned by that industry is directly applicable to offshore wind development efforts. There are 10 normative references in OCRP 2012 from API and ISO that have been developed for the oil and gas industry that have informed the structural design of the wind turbine and support structure. The design phase proved to be the most challenging task in the integration of offshore standards from different industries. The above examples help illustrate these challenges. From a structural reliability standpoint, most of the guidance in API and ISO standards for the substructure and foundation are directly applicable to offshore wind turbines. In some cases, these documents provide the commonly accepted approaches for design of these systems.

Beyond the design phase, the integration of the standards became more straightforward because in most cases, there were no conflicting wind standards for manufacturing, construction, installation, commissioning, operation, inspection, or decommissioning of offshore wind facilities. The task became a process of discriminating between the relevant sections of each normative or informative reference standard. In many cases, the existing standards, in the absence of no further guidance on the wind side, provided an excellent default to establish a baseline for best practices. In other cases, the relevant material was called out specifically by the industry experts. For example, this was true for many of the fabrication aspects of AWEA OCRP 2012, including material specifications and welding procedures for the substructure. In some cases, a concrete substructure may be desired, and the AWEA OCRP 2012 references the ISO concrete structures document (developed for oil and gas structures) as a guideline.

Operational guidance for inspections and maintenance exists from offshore wind-specific publications; however, certain aspects of these activities are addressed in oil and gas guidance as well, and these have been integrated where useful. This is particularly true for programmatic aspects of inspections, such as how to expand the inspection scope where issues are identified and what to inspect after a storm event occurs at or near the wind farm. AWEA OCRP 2012 specifically did not include any aspects of human safety in the document to avoid conflicts with other ongoing efforts that are already working on similar guidance.

Future Validation and Analysis Needs

Hurricanes

The offshore wind industry recognizes that assessment of the impact of tropical storm events on offshore wind turbines is currently addressed insufficiently in all standards except the oil and gas. The wind industry is making rapid progress to close the gaps. IEC TC-88 has convened a new maintenance team that is addressing hurricanes and other design load cases missing from the current standard. The team's findings will be incorporated into a new edition of the IEC 61400-03 offshore wind design standard. Among the topics being considered are special typhoon design classes and designs for higher peak winds, longer duration high-cycle fatigue load cases, extended power grid failures, extraordinary wind shear events, rapid extreme wind direction changes, unusual wind-wave combinations, and unusual gusts.

Another consideration is the impact of a single storm system on an entire wind facility. Offshore oil and gas facilities are customized designs whereas the design for typical offshore wind facilities is replicated. As each turbine system in an offshore wind facility will have nearly identical designs, a storm system with extreme conditions may induce similar impacts on many turbines. The possibility of multi-turbine failures may increase the consequences of failure and require more stringent design safety than would typically be used for single structure designs. These consequences would be largely viewed from an economic impact rather than a human safety impact because wind turbines are unmanned most of the time.

Breaking Waves

Despite the dynamic nature of waves and the loads they impose on offshore structures, in most cases, from a design standpoint, wave loads can be represented as equivalent static loads using techniques that are standard for the design of offshore and coastal structures. Within certain ranges of wave height, wave period, and water depth, the use of these static approaches is valid to predict the water particle kinematics (velocity and acceleration) acting on submerged members of the size and shape typical for offshore structures and to calculate the loads they impart to the structure. These approaches are not necessarily valid when a wave breaks and linear assumptions about the water particle kinematics no longer provide conservative results. Higher energy associated with the physics of the breaking wave lead to higher loads as the water particles impact a structure. These breaking wave effects can have a controlling influence on structural design, particularly as a local design factor.

A wave used for design of offshore structures is more likely to become a breaking wave in shallow water regions. Because many of the initial offshore wind turbine installations are expected to be in shallow water (compared to offshore oil and gas structures), the breaking wave effects will need to be considered for design of the turbine support structure. Because the diameter of the typical monopile wind turbine design is much larger than the typical member diameter for offshore oil and gas structures, loading assumptions that are valid for oil and gas facilities may not be valid for wind turbines. How these effects should be addressed more thoroughly for offshore wind will be an important area of further study as the industry matures in the U.S. market. This concern will be particularly important in shallow waters where breaking waves may occur under extreme conditions and normal attenuation is minimal. In addition, the mitigating effects of different support structure types, such as jackets, have not been fully quantified (Dolan 2009, Jha 2013) and need better treatment.

Submarine Cable Installation

Cable installations are not novel offshore activities and marine installations of intra-array distribution cables and high voltage array interconnect cables are common. However, there are no common standards for installation of either submarine medium-voltage array cables or submarine high-voltage export cables. Installation procedures, standards, and guidelines rely largely on the cable installers' experience and industry best practices that rely heavily on the past experience of the telecommunications industry. This has proven to be unsatisfactory as wind facility operators and developers in European seas have reported high volumes of cable failures because of poor installation and wind facility service conditions.

As the offshore wind industry develops in the U.S. market, the need for experienced cable installers may slow development efforts. Poorly installed cables are more likely to be damaged or fail to operate properly, which will lead to downtime and costly repairs or reinstallation efforts.

To expand the core group of experienced contractors and ensure that cables are installed safely and reliably, the electric power cable industry should have their best practices and lessons learned organized into a standard. This would provide a common baseline that would benefit developers, contractors, and regulators. We recommend that IEC, AWEA, or some other authorized industry standards development group initiate a new committee to develop standards for the installation and maintenance of offshore submarine cables for the purpose of carrying medium- and high-voltage power.

Structural Condition Monitoring

Given the expected size of wind facilities to be installed offshore (100 to 200 turbines per farm), routine inspections will be logistically and financially challenging, and worker safety is always a concern when transferring crew members to and from turbine facilities.

Boarding an offshore wind turbine is not a simple exercise. For most offshore oil and gas facilities there is a helicopter deck capable of landing a full-sized helicopter and providing a safe, stable access point. Even when access is provided by boat, most oil and gas platforms are large enough to provide a large boat landing platform. Helicopter access to a properly equipped offshore wind turbine is only possible by hovering over the nacelle and lowering workers to the top. The typical boat access is via a much smaller landing platform than those found for oil and gas facilities. Appropriate measures have been taken to ensure safe access but they require limiting the weather windows during which scheduled and unscheduled maintenance operations may occur.

These issues should be mitigated as much as possible through the use of condition-monitoring systems that can provide remote feedback regarding the structural health of the blades, drivetrain, power systems, tower, and substructure. There are robust systems in use today that provide data on power production and the health of mechanical and electrical systems. But structural health monitoring for the substructure is not as advanced. There are issues with false positive indications, failed sensors, how to interpret the data from the sensors, and how to handle and process the volume of data generated from hundreds of wind turbines constantly streaming signals back to shore.

Today, these systems are not robust enough to replace routine inspections to verify structural integrity above and below water. Additional progress in this area would provide significant advantages in managing the integrity of wind farms and limiting the need to send workers out to the facilities to gather basic structural condition data. Over time, advances in condition-monitoring systems can play an important role in the maintenance of an offshore wind facility and will be documented more thoroughly in the evolving standards.

Conclusions

With the goal of providing a guidance document to assist the development of the U.S. offshore wind industry, AWEA sponsored the development of recommended practices recently published in its AWEA OCRP 2012. The recommended practices have a broad scope addressing aspects of the entire life cycle of an offshore wind turbine facility except for the initial phase of permitting, environmental assessment, and leasing. As the first document of its kind focused on U.S. offshore wind development, this document represents an important step in the industry's development that can be used by regulators and developers alike to plan, install, and operate efficient and safe wind turbine facilities. However, it has limitations and gaps that will need to be evaluated by the industry and their experience should be reflected in future editions of the AWEA OCRP 2012. It is the nature of standards to lag behind industry experience, because the documentation of proven experience is the last step in the development of proven practices. Nevertheless, AWEA OCRP 2012 points to the most current versions of the standards and guidelines making it representative of the best practices used by industry today. AWEA OCRP 2012 does not provide new standards. It provides a roadmap for more than 26 normative references that were assembled on a consensus basis by a group of more than 50 industry experts between Oct 2009 and Oct 2012. Recommendations for future improvements include a better treatment of such things as hurricanes, breaking waves, submarine cables, and condition monitoring to keep pace with the most important trends in the U.S. offshore wind industry.

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