

Executive Summary of Research on Offshore Wind Farms on the OCS

Damage and Critical Analysis of Accidents

Safety Management System Template &

Structure, Equipment & Systems (Part 1) Description of Systems (Part 2) Commentary, Standards & Codes

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1. INTRODUCTION

This document summarizes a project sponsored by Minerals Management Service, Dept. of the Interior. The tasks completed were to provide:

1. A report reviewing the accidents and incidents to onshore and offshore wind farms and to document significant issues relevant to offshore wind farms for which appropriate information is available together with analyses of the causes when available. (See separate document entitled Damage and Critical Analysis of Accidents to Assist in Avoiding Accidents on Offshore Wind Farms on the OCS.)
2. Guidance on the content and subject matter for the owner's Safety Management System suitable for offshore wind farms. (See separate document entitled Template for a Safety Management System for Offshore Wind Farms on the OCS.)
3. Guidance for the recommended items to be provided in a Facility Design Report (outlining the basis of the design) for an offshore wind farm which the owner may submit to the regulator. This document invites the owner to state the criteria and standards to be used in the design and provide a justified design basis document to which the project is to be built, which will also provide a basis for regulatory approval. (See separate document entitled Structure, Equipment and Systems for Offshore Wind Farms on the OCS, Part 1 of 2 Parts – Guideline.)
4. A Commentary on the Guidance for the items in a Facility Design Report giving insight into structure and equipment issues, and findings on the appropriate/relevant selection of codes and design standards upon which an approval can be based to ensure structural safety/ reliability/ survivability of offshore wind farms on the US Outer Continental Shelf (OCS). (See separate document entitled Structure, Equipment and Systems for Offshore Wind Farms on the OCS, Part 2 of 2 Parts – Commentary.)

2. DAMAGE AND CRITICAL ANALYSIS OF ACCIDENTS

In order to understand the potential issues for offshore application of wind farm structures on the US OCS, it was appropriate to review the accidents and incidents available in relation to onshore and other countries' offshore wind farm safety, and to use those to draw insights into the potential for offshore wind farm safety and provide "experience" to anticipate likely potential events. From this information it was possible to derive appropriate items for the safety management system procedures and the structure and equipment requirements for safety.

The structures and issues of interest to the establishment of offshore wind farms for this study are:

- Wind Turbine foundations, towers, nacelle, blades and other equipment,
- Subsea cables transmitting power to shore,
- Transformer Stations for modifying the power for transmission to shore,
- Liftboats –observations on site and possibly met towers;
- Jack-up Vessels for coring, installation and maintenance;
- Cranes;
- Access Vessels;
- Secondary structures e.g. access items, emergency escape equipment;

For the wind turbines and towers, particularly, there are the additional issues that the structural integrity may depend on:

- Power, control systems, automated shut-down
- Lightning, damage from
- Fire, suppression of
- Foundations, integrity of
- Codes – which may not have evolved with offshore wind farms structures in mind, and may be applied, with lack of appropriate provisions for structural safety.

By collecting and analyzing the data, insights were gained that will result in understandings and learnings to assist in ensuring that mistakes are not repeated when they involved safety, and destruction of the structures.

Accident data was difficult to locate and lack of transparency in the industry may lead to slowing industry progress since there is no forum for sharing global incidents, accidents and learnings. A database kept by Caithness Windfarm Information Forum provided great value. Various government and research reports supplemented this information. Information was reported on some insurance losses. The results are provided in the form of two Excel spreadsheet “databases” of incidents and accidents. These are accompanied by photographs etc as available, laid out in a format that could be traced back based on the incident identification tag in the format YYMMDD appropriate to the incident as close as could be determined.

Because of the paucity of data it was not possible to run independent statistics but the figures provided by various publications represent an assimilated view that is corroborated by the information the databases provided.

The experience with losses is interesting and is summarized in various references, one of which is noted in Figures 1 and 2:

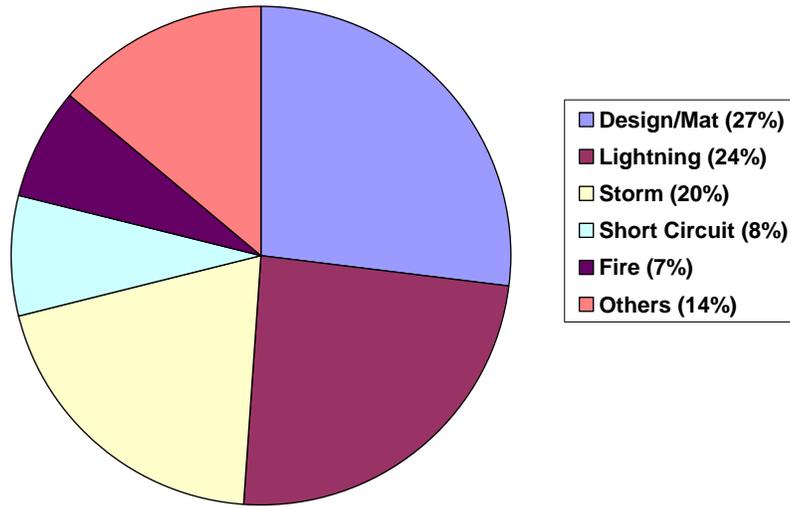


Figure 1: Breakdown of Accident Causes

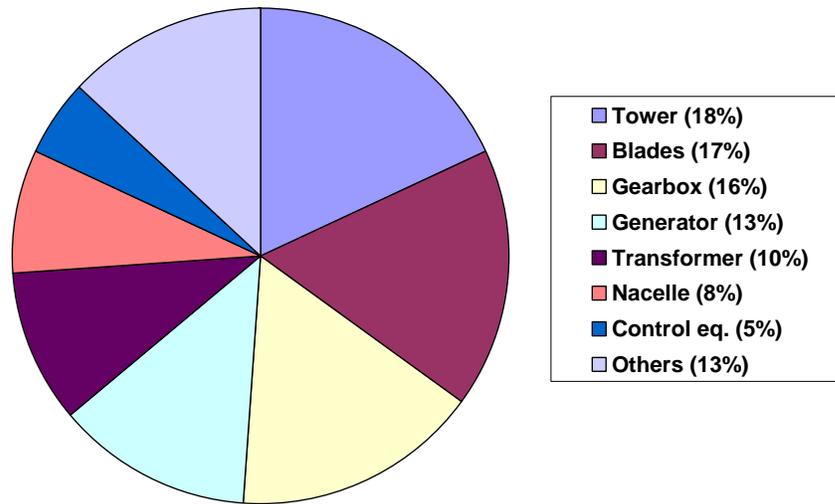


Figure 2: Breakdown of Component Damages (in number of losses)

Wind turbines are like other sophisticated engineering products such as aircraft, helicopters or very very expensive cars: designed to operate to high standards of safety when knowledgably designed and constructed. In that sense they are unlike shallow water fixed oil and gas platforms that are very basic with no requirement for moving parts to ensure safety against overall collapse in extreme weather. For wind farms, there have been a very small number of injuries and fatalities. For operators, accidents have often been caused by failure to observe manufacturer’s instructions,

and standard safety management procedures. Experiences from accidents in India, Japan, and the Philippines which are subject to cyclones and typhoons, and thus have similarity to weather issues in much of the United States, were instructive and further study of these may lead to changes in fundamental design load cases. The offshore experiences being chronicled in Europe at the present time, will also provide some useful lessons to be learned for application offshore on the OCS.

2.1 Tropical Revolving Storm Areas

The reason for looking to India, Japan, Taiwan, and the Philippines for incidents is that they experience cyclones and/or typhoons (tropical revolving storms) much like the hurricanes in the United States.

In 1998 Tropical Cyclone 03/A destroyed 129 or 40% of the 315 wind turbines (approx. 40 MW) at a wind farm in India.



Figure 3: Gujarat, India 1998



Likewise in 2003 in Japan multiple wind turbines were lost due to a typhoon.

The essential issue is that the IEC Code does not take into account hurricane conditions. Structural integrity of wind farms depends on pointing the nacelle into the wind (by one measure + or – 8 degrees) or the maximum design load that can be sustained is a 1-year return period storm. Lack of the ability of the machinery to maintain yaw control has been a significant factor in the failures. As a result the Japanese windfarm industry has responded by studying the issues and resolving to provide new guidance for wind farms in typhoon areas which involves providing battery power to allow the nacelle to orient into the wind for the longer periods required for typhoons. This research, when available, will be valuable guidance for US application in hurricane areas.

Figure 4: Japan after 2003 Typhoon

2.2 European Experience

Horn's Rev, a Danish offshore wind farm, is a good example of the variety of things that can go wrong. These were early adventurers into the offshore market place, and subject to Murphy's Law: "What can go wrong, will go wrong." There are some useful insights in the reports. They had problems in almost all aspects of the wind farm:

- Gears – failed in 2-3 years, earlier than the 20 year expectation
- Generator components failed
- Software and Control systems – overspeed damaged blades
- Hydraulic System failure
- Blades - failed (this is a common "maintenance issue")
- Transformer - insulation on windings was defective
- Lightning arrester system – did not function as planned
- Secondary Appurtenances to the tower – damaged due to waves and boats
- Corrosion Protection – inadequacy led to repairs
- Cables – termination problems and power cable pulled up by a vessel's anchor
- Grout for transition piece without shear connectors – may require some rebuilding of the transition pieces for multiple turbines.

The Danish Industry is to be commended for adventuring into this alternative energy

solution, and in adventuring offshore. There is much we can learn from them.

2.3 Reliability Data

A variety of sources were interrogated for reliability data. An example is shown for annual failure rates for subassemblies. Offshore rates of downtime are likely to be much higher, and availability data, also presented in the report, substantiates that offshore availability is significantly less than onshore. It takes more time to fix problems because of weather delays getting personnel on board and transit times to, from and between turbines.

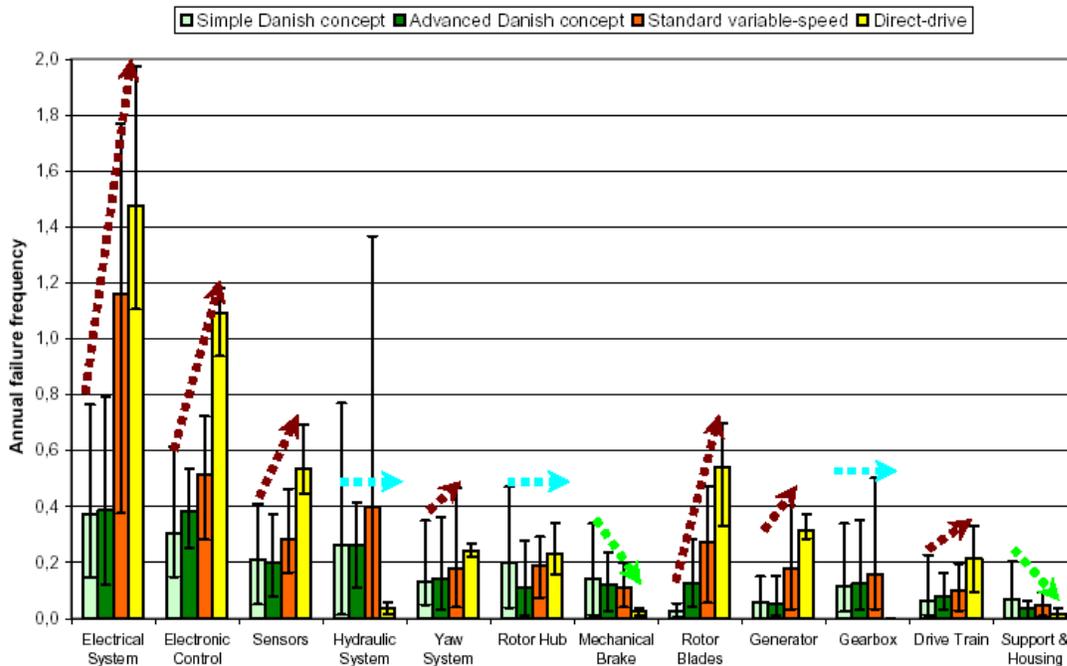


Figure 5: Annual failure rate of WT subassemblies for different technical concepts

2.4 Conclusions

From the information we were able to extract sufficient data to provide for the safety management system information, things we otherwise wouldn't have thought of:

Note: the numbers in brackets refer to case numbers in the database.

- Ensuring that maintenance persons understand the importance of following the instructions (20050827).
- Providing instruction to firefighters NOT to open the door to the turbine to create a chimney effect on a fire (C20041207.1)
- Ensuring that the installation vessel go through a proper procedure on sampling soil data and preloading (20000210).

- Training the personnel to understand that if the power is lost, either through grid loss or battery backup loss the wind tower may fall down in a storm (1990999.1) and (19980609.1)

For the equipment and structure issues much was learned from the databases:

- Multiple tower failures are possible and hurricane areas are particularly prone to that. Several researchers have reported that loss of power, presumably resulting in improper yaw alignment, have been at least partly responsible for the failures (19980609.1), (19990999.1), (20030911.1) and (20070111).
- Burying the subsea cable to the appropriate depth to avoid anchor issues is probably one of the most important factors in preventing major downtime. The resulting grid loss can put the wind turbines at risk during a storm that occurs during the outage. There were a number of issues with the subsea cable which represented some of the highest insurance claims.
- The terminations to the subsea cables need to be of the right material, quality, and installed correctly without damaging the subsea cable with moisture. The quality control of the aspects of the subsea cable is very important.
- Oil does leak from wind turbines (20060303), and (99999999.34).
- Lightning is so frequent that lightning protection becomes mandatory for offshore application of wind turbines.
- Fire is so frequent that fire protection becomes mandatory for offshore application of wind turbines.
- The equipment which is Certified to last 20 years often has to be replaced in 2-3 years and with a guarantee of no longer than a further 5 years (20080630.1), leading to lack of confidence in the existing certification process.
- Foundations need to be reviewed for compliance and a check made to ensure the code is actually applicable to the design. They also need to be inspected carefully (20079999.7) and (20091227).
- Marine issues that plagued the early development in offshore oil are likely to be an issue with offshore wind installations (20091122.1), (20081028.1), (20069999.4), (20070899.8) and (20090130) – these are standard marine procedures that adhering to a reasonable Safety Management System should be able to prevent.
- While no-one had been hurt from blades letting loose it is important to note that one should adhere to the practice of turning the turbine off when it is under maintenance.
- Component integrity is most important (19990301.1) and each component must be well-scrutinized before being put into use.
- There is a lot of understanding and skill needed in maintenance and personnel need to know much more about key structural issues that result in a potential safety threat.

- While we did not chronicle it, we did note one case of a snake bite that was able to be dealt with on land, resulting from a snake having crawled into the nacelle when on the ground, only to attack a maintenance worker some days later. It reminded us of the need to be cautious against the possibility of dangerous situations such as this. A spider bite may have caused a death in a wind turbine onshore, recently.
- Ensuring the integrity of transformers is important (20029999.1), and (20039999).
- There is a great importance to having condition monitoring installed (99999999.6).
- Whenever lifting is going on it is very important to stay out of the way some considerable distance (20061221.1) and (20071107.1) and (20100308.1),
- Blades will from time to time need replacement and repair, and should be considered as more of a maintenance item. It is usually not a safety item since personnel are not expected to be within range of a blade failure (since the custom is to shut the turbines down during maintenance). If it is possible for personnel to be in range of a failed blade they become an important risk to be considered.
-and many other factors were learned from this data.

There is little comfort in the Certification process for structural reliability, assuming that most of the wind farms do have certification of some sort. Perhaps the issues would be worse without certification, but the system can be improved.

The things that were learned from the incidents helped form some of the items included in the Safety Management System Template and the requirements and commentary on the Structure and Equipment guidance documents.

The design requirements for offshore US waters will be significantly different (hurricane issues) from Europe, and safety issues will not be addressed by European codes. Electrical personnel will need to be trained and knowledgeable about any potential differences if foreign standards are used for manufacture, and installation of the electrical equipment.

Monitoring worldwide incidents and informing the US industry with safety alerts is most important. Maintaining a database of issues that are fed by the industry with root cause analysis is safety critical going forward. There needs to be an active body disseminating information to the industry and chronicling the statistics of incidents based on the same measurement techniques used by other industries.

3. SAFETY MANAGEMENT SYSTEM TEMPLATE

3.1 Introduction

As a result of a number of initiatives in the chemical business and the offshore oil & gas business, the 1980s saw an initiative to adopt a set of Safety Management principles looking at safety as a system rather than each component. This led to a sharp decline of incident rates. In that same period quality management systems were introduced in the offshore industry and, following the Piper-A disaster in the North Sea, it was realized that safety should be managed more rigorously and systematically. This has been developed into a format used by many in the offshore oil industry as well as many other onshore industries today.

The tools and concepts developed such as the Bow-Tie diagrams, risk assessment methods, and goals of As Low As Reasonable Practical (ALARP) have become the pillars of a kind of universal language and standards throughout much of the oil and gas industry. The methods assured that hazards were thoroughly identified, analyzed and managed, in an organization with competent people and thorough "checks and balances". While the more sophisticated risk assessment methods are recommended it should be a simple matter to first put in place a rudimentary safety management system which will build to include those more sophisticated techniques as the industry moves forward.

During this study the European standards were examined, but many of them rely on goal-setting requirements and do not delineate specific requirements in sufficient detail. This Template should help the offshore wind farm owner to prepare a suitable safety management system, or advance an existing system, in order to address the key items thought to bring the most critical safety activities to a reasonable level of safety. Each installation is different, with different parameters and personnel cultures and thus the summary report produced using this Template, or the safety management system itself should be adjusted to take care of these unique factors in a project.

Understanding culture and human behavior is important in reducing accidents e.g. payment of bonuses based on speed of activity rather than safety can lead to increased accident rates. Particularly changes to procedures or equipment made without consideration of risk implications and/or without documentation being updated have been important issues. Creating a Template for safety and encouraging enthusiasm for working the issues, together with a rigorous safety system, with personnel at all levels of the organization buying-in, will lead to good results for the offshore wind farm reputation.

The road map to an improved culture starts with making the management expectations crystal clear: verifying whether the person carrying out the task understands the job and has the competence and resources to do the task. Only then can a person be held accountable for the action. The consequences of actions and behaviors, both positive and negative, have to be clear.

3.2 Details of the Safety Management System

The Template provided asks questions about how the owner assures safety in specific targeted areas. In providing answers to those questions it should be clear as to whether there is in place a suitable safety management system. The Template provides questions on the Policies of the company regarding safety; the Senior Management Review confirming that the senior management has safety as a high priority, and that, for example, the Procurement department has adequate knowledge to provide suitable replacement equipment to the appropriate code, particularly for “safety critical” items.

The content of an appropriate safety management system starts with personnel competence and training, both in safety and every day work which might affect overall safety, not just safety to the individual. The standards that the company puts in place such as Permit to Work, Lifting Practices, Emergency Procedures etc. provide a framework for how all jobs are handled. Documentation of the safety requirements provides an audit trail to ensure field personnel are suitably trained, and that safety issues brought forward are listed and closed out in a formal way.

Workforce participation in safety, and safety management is measured to a certain extent by the attendance of appropriate workforce personnel in the safety management meetings and documenting safety findings, creating solutions, and communicating the information to personnel.

Specific procedures to be contained in the Safety Management System include among others:

- Transport Access/ Egress: disembarking and embarking from boat or helicopter to the turbine structure;
- Procedures for site assessment of temporary structures such as jack-ups to ensure they are suitable for the work, have sufficient airgap, and are capable of manned operations in reasonable return period storms;
- Working at heights and climbing (including rope access): use of ladders and man-riding winches;
- Working in confined spaces;
- Material Handling: Lifting operations and equipment/ rigging;
- Electrocution: High Voltage and Medium Voltage electricity;
- Smoke and Fire;
- Moving parts, stored energy;
- Working in appropriate weather conditions;
- Lone working;
- Risk of familiarity and poor communications;

- Diver Safety;
- Competence and training of maintenance personnel to safely operate the equipment;
- Rescue from heights;
- The following of procedures written by the manufacturer when making adjustments and when operating the turbines;

Bridging documents between more than one company in the field working with another company are part of the safety guidance. They ensure that the multiple companies act in an agreed way on matters of safety.

An example is given of the Hierarchy of Documents that might be expected to be used to document the safety management system.

4. STRUCTURE, EQUIPMENT & SYSTEMS (Part 1)

Description of Systems

This Part 1 – Guideline, is for guidance only and is primarily intended as assistance in preparation of the Facility Design Report document on which regulatory approval may be focused. It calls for the designer/owner to provide an explanation on the design of systems upon which safety relies. Appendix B of Part 1 provides a summary table of safety concerns for equipment design, suggested applicable codes and/or guidance, and a reference to anticipated Certification and Regulatory compliance activities. Appendix A to Part 1 provides a generic list of documents to be supplied as a main part of a submission to a regulator or certified verification agent (CVA) as stipulated in 30 CFR § 285.

None of the currently available standards documents, which although “international” are primarily “European”, can be directly applied to the US-OCS as new complete offshore wind standards. Several sources of guidance information should be used in design, construction, installation, operations and demolition of offshore wind farms on the US OCS. Experience from the offshore oil and gas industry should be sought since there is much history and lessons learned which are directly applicable. Several of the standards, while applicable, may, however, also need to be significantly adjusted for the different structures, and industry approaches in the offshore wind turbine industry. API RP2A may be applied to the extreme load cases.

Detailed guidance is available from certification companies such as Det Norske Veritas (DNV) and Germanischer Lloyd (GL).

Germanischer Lloyd in particular offers the most complete set of offshore guidelines. They are an important reference in offshore wind project development. These documents should be consulted when technical details are needed on a specific topic

regarding offshore wind standards for the US OCS. Some tailoring of the standard may be needed to provide confidence that the standard is applicable to the US OCS site specific conditions, e.g. load cases. Procedures for design, testing, transport, installation, operation and maintenance are all specified in the GL standards. DNV and other standards may also be appropriate.

Of the National bodies approving offshore wind farms, the German approach by the Maritime and Hydrographic Agency (BSH) seemed to provide the methods most similar to what has been the US approach to oil and gas structural safety. The following documents reflecting that approach are recommended for further study and potential application as they reflect a similar approach to that outlined in 30 CFR 285.

- Design of Offshore Wind Turbines Bundesamt Fur Seeschiffahrt und Hydrographie (BSH), December 27, 2007.
- Ground Investigations for Offshore Wind Farms, Bundesamt Fur Seeschiffahrt und Hydrographie (BSH), February 25, 2008.

Since the USA does not have its own code for offshore wind farms, nor has it developed a “country addendum” to the IEC code outlining what might be different in the US, the present task of technical review of these falls to rational consideration. The proposed method of technical review is based on not mandating any particular code that must be used, but to have the designer/owner submit as part of the Facility Design Report the philosophy of design and then state the codes they have relied upon and why they believe this is “best practice”. When done in a way that requires justification of the design within certain constraints, (this is the approach used in many parts of the oil and gas sector and in many chemical industries) it allows innovation in the design, which is so necessary as the industry progresses toward a more code-prescriptive environment. Since no specific codes exist for offshore wind farms for the OCS the focus, it is assumed, will be centered on both API RP2A Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms and the IEC 61400-3 Offshore Wind Farms code while noting the modifications of European standards to those that are comparable but more appropriate for the US: steel standards, welding qualifications, concrete standards, etc. Reference to Certification documents developed by private organizations e.g. Germanischer Lloyd and DNV as well as European standards as applicable are relevant for “best practice”.

The process that the “international community” has adopted for wind farms is different than that which has existed for verification of fixed oil and gas facilities in the U.S. The system of Component Certification, Type Certification (design check, manufacture check after which the quality system assures the products are acceptable with annual checks) and Project Certification (ensuring the type certificated equipment is compatible with site conditions) has been a common feature of the “international” (mainly European) regulatory approval process. Co-dependence between the machinery and electrical control equipment for structural safety leads to a realization that basic certification for suitability of these component parts must be part of any approval process.

The Certification can be carried out to a variety of Codes, Standards and Guidelines as stipulated by the owner with the approval of the regulatory authority. The Certification simplifies the process of approval in that it forms the basis of confidence in the facility design basis, and the plans to fabricate and install per existing guidelines while drawing attention to the deviations from those guidelines. Audits can then be carried out on a firm understanding and measure compliance with the approved Facility Design Report and the project plan. Such an approval process can rely upon certification companies, appropriately qualified or accredited by the regulator, to provide assurance in the design in the source country of manufacture, as part of that process.

This Part 1 provides a Guideline for the owner to describe the equipment of the offshore wind farm, its design features and the basis upon which the feature is planned to be approved by Type and Project Certification and/or Certified in an equivalent way by a Professional Engineer qualified by the CVA process with experience in the area being certified. In the case of Professional Engineer certification it is appropriate that the Certification basis be existing certification guidelines of the best practice from the most recent published copy of IEC 61400, GL, DNV, or other independent organization offshore windfarm guidelines. Since both Type and Project Certification have different content in different countries/projects it will be necessary for the owner to provide clear detail of what parts of the system are being covered by the Certification process, to what standard, with what deviations, in what depth and with the quantity of surveillance together with the qualifications of those carrying out the reviews and surveillance. The CVA and Project Certifier may be the same organization, however, because of the potential conflict of interest it has been assumed that these are different organizations in this report as the situation may vary from project to project.

The surveillance is an important ingredient to determine ahead of time to give confidence in the equipment being used. Thus the owner is asked to provide information on the amount of surveillance which will be contracted for with the Certifier(s) and approved CVA related to the specific activities that they will be carrying out.

The CVA process used for oil and gas projects has encompassed few “component parts” and thus 100% surveillance has been practical. Since developing offshore wind farms are assembled at the offshore site with multiple components from different sources the CVA activities may need to be adapted. Identifying the amount of certification and surveillance will establish a basis for the reasonable approval with the CVA filling the identified gaps.

Appendix B contains a list of “Items of Design” and identifies design codes that would be applicable, with adjustments as appropriate depending on the particulars of the design. For example, for “Foundations” depending on the type, codes recommended would be:

- API RP2A for Steel Structures with BSH (German) Ground Investigations for Offshore Wind Farms
- GL Certification 2005 or DNV-OS-J101 or DNV-OS C502 Concrete Structures
- ACI 357R-84 Guide for the Design and Construction of Fixed Offshore Concrete Structures
- API RP 2 N - Recommended Practice for Planning, Designing, and Constructing Structures and Pipelines for Arctic Conditions

The selection of the particular code or combinations would vary depending on the type of foundation but within these documents an appropriate acceptable solution is likely to be found. While the code is not dictated to the owner's design team, and other codes may be acceptable, and even preferred in some cases, it provides a recommended source.

5. STRUCTURE, EQUIPMENT & SYSTEMS (Part 2) Commentary, Standards & Codes

The Part 2 – Commentary, provides a selection of issues that are recommended that the designer/owner provide on the design of systems upon which safety relies. The document is for guidance only and is primarily intended as assistance in preparation of the Facility Design Report on which regulatory approval may be focused. The intent is to provide background and insights into many of the component issues, and references to useful documents for further study for use in developing or reviewing the Facility Design Report.

The establishment of offshore wind farms presents a number of complex issues. Unlike oil and gas structures that are located throughout large areas such as the Gulf of Mexico, multiple wind farm structures are located at one concentrated location over a few square miles. Such concentration of risk may dictate appropriate higher criteria on the principle of "all the eggs in one basket". The most likely location of the larger wind farms, for example, in high population areas up the east coast may be subject to "common cause" events such as hurricanes: a single storm may sweep through multiple wind farms. A good illustration was Tropical Storm Hanna in September 2006.

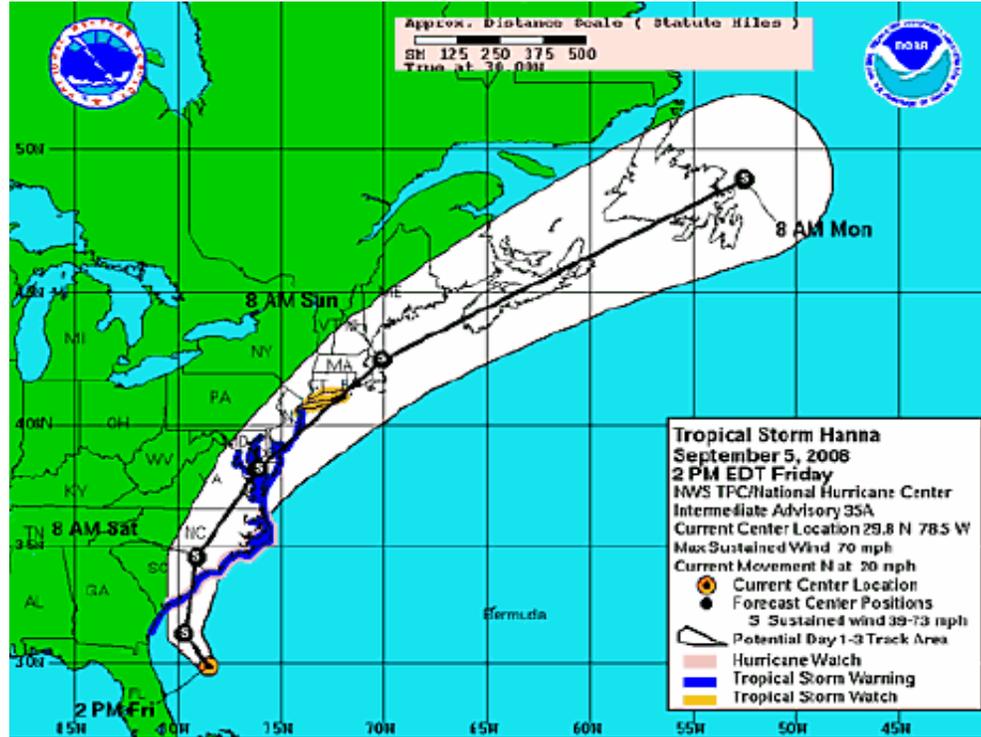


Figure 6: Path of Tropical Storm Hanna September 2006

While codes are available e.g. IEC Codes on wind farms, they are not detailed enough (providing loads but not resistance factors), nor prescriptive enough (e.g. describing lightning protection available but not mandating it; providing information on blade tests but not determining the number of blade tests or information about independent witnessing of blade tests), have not considered hurricanes, and ignore many items of interest such as fire protection. Additionally the requirement for personnel safety is dealt with by statements that do not form the basis for compliance or audit.

In the early days of the industry there will inevitably be failures of one sort or another so prioritizing the failures is important. The appropriate prioritization for the structure might be ensuring no failures in:

- Tower structures, particularly multiple towers (including foundations)
- Subsea Cables
- Blades – particularly serial issues
- Secondary appurtenances to the structure which provide access and protection for the cables.

From the research there appear to be 2 design approaches available for the towers:

- The “omnidirectional” approach where the design is not sensitive to the

year, 50-year and 100-year returns for wind, wave, current and distribution. This will allow some judgments to be made about the risk level based on other factors e.g. number of towers in the field, whether a sheltered location etc. and for the “standard” storm level that will bring the tower down should the yaw system fail.

There has been much discussion on the subject of 100-year storm return design period being used for the design versus a lower design return period customary to the European standards. This “X-year period” storm discussion has been subject of communication gaps since wind is variously quoted at 10 meter height, at hub height, with durations of 3 seconds, 1-minute, and 1-hour thus giving some confusion to the arguments. Section 1.5 of the Commentary attempts to put the issue into perspective for an offshore wind farm and offers some comments on the difference in philosophy between an offshore wind farm and an individual offshore oil and gas platform. The consistency of application of the techniques to develop metocean criteria between the oil and gas industry and the wind industry is recommended for further research.

A further issue with the developed “international” IEC Codes on wind farm structures is that they refer within the documents to provisions in many other European codes. Some of these provisions are unlikely to be understood by the US maintenance personnel, which presents dangers. Electrical standards of European origin would not be readily understood by US qualified electricians. Metric vs. English units may provide opportunities for misunderstandings.

The regulatory regime in Europe has been developed to an acceptance of qualifications of the certifiers in each country. While ANSI is the US equivalent of the accreditation that exists in Europe, ANSI has not developed an accreditation scheme for onshore or offshore windfarms. This accreditation scheme allows interchange between certification agencies such as DNV and GL, without which it becomes more difficult for a project certifier to accept a type certificate from a competitive organization.

The load cases may vary from location to location, and it is important for the owner, designer, and regulatory authority to appreciate the design load case assumptions (as well as document them). A hazard identification session is recommended with appropriate personnel present to review the load cases in a facilitated meeting which is called in technical terms a Hazard Identification (HAZID). The HAZID would clearly identify limits on the systems e.g. a 1 –year return period for sideways loading which if exceeded could bring the tower down; the size and speed of the service vessel which could cause major damage to the tower, etc.. Those load cases would need to be agreed by the owners/designers and be subject to approval by the regulator. It is recommended that the regulator be present at the HAZID.

The Commentary discusses the issue of lightning protection, fire protection, corrosion protection and condition monitoring and recommends they are mandatory for offshore wind turbines on the US OCS. The IEC Code (61400-24) outlines the potential ways of ensuring that the turbine components are protected from lightning, but does not

mandate lightning protection. Certifiers such as Germanischer Lloyd mandate lightning protection and provide guidance on ensuring a path to certification. This is contained in Section 3.6.

The IEC Code provides little guidance on fire protection. German insurance concerns and Germanischer Lloyd have provided a document to guide the requirements for fire protection after much experience with fires in nacelles. This discussion is provided in Section 3.7 with discussion on recommended applicable codes and the adaptation of USCG requirements for oil and gas offshore structures to the offshore wind farm structures.

Corrosion protection is very important. Offshore oil and gas structures typically can deal with corrosion while operating: this is unlikely to be the case for wind turbine structures due to the probable safety requirement to shut down when boarding the platform and maintaining it. The recommended codes to be used are discussed in Section 3.10.

Details of the concern with blade manufacturing, testing and certification are dealt with in Section 3.3 as well as discussion of the icing, and blade throw. Blades have to be purpose built, and are complex structures to manufacture. Some history of the gearbox issues follow with some comments on current state of the art. With blade issues and gearbox issues it is recommended that remote monitoring will be mandatory for offshore wind farms. The control systems will be software dependent and ensuring that the software will control as intended is a difficult item to verify independently. The importance of the control system and, with the early damages to gearboxes and particularly their bearings, the case is made for the regulatory requirement of condition monitoring systems in Section 3.5.

Within the Commentary the explanation for the requirement is liberally accompanied in many instances with examples of what has gone wrong, based on the research of incidents and accidents, and suitably referenced.

The Certification process is discussed in detail, and discussion of the qualifications of the Certifiers is outlined. Because so many parts of the offshore wind turbine are critical to the structural integrity it also requires the certifiers be competent in a number of fields including:

- Structure Analysis – wind turbine structures including dynamics for structure and soil
- Familiarity with standard selected by owner
- Materials & Repair of materials (concrete, composites, grout, steel)
- Joining e.g. welding, bolting, etc.
- Blade Construction – fiberglass, composites
- Manufacturing of Turbine components
- Blade testing
- Gear analysis

- Control system and software
- Subsea cable and Terminations
- Recordkeeping – changes in the type approval

Additionally there needs to be some consideration on the availability of the certifier close to the manufacturer's location and the availability of multiple surveyors in multiple disciplines e.g. bolting, piling, soils, etc. available at site.

From the study, differences between onshore and offshore became apparent most of which have been outlined but three to be emphasized include:

- The marine atmosphere, must be considered for all components for corrosion and salt effects;
- Collision should be considered based on the site-specific location and traffic;
- Because of the remoteness and consequences, meticulous attention to the safety management system is mandatory.

Section 3.2 in the Commentary deals with the probable requirements of floating systems. Although these are not yet determined by a regulatory authority, these have been adapted from the requirements of floating offshore oil and gas structures and initial guidance on the requirements on overall technical hull safety is offered.

Section 4 provides information on the current requirements for soil sampling and recommendations for published guidelines to be used for application on the US OCS for the wind tower and also outlines the recommended requirements for jack-up installation vessels.

The Personal Protection design considerations have not been as yet provided in a comprehensive US document. The European code for offshore wind farms is a very well thought out document and may be used to provide best practice. USCG requirements may also apply and the appropriate paragraphs are explored. Elevators have been considered due to the health issues of multiple daily climbs in tall wind turbine structures. Discussion and advice on code requirements is given in Section 5.

Navigation lights, sounds and marking should be internationally accepted. Currently these requirements appear to be negotiated at each site between the owner, community and the USCG. Suggestions are made as to some of the applicable codes that are required and the certification requirements.

Helicopter platform and landing requirements are discussed in Section 7.

When the offshore wind farm structures are more than about 7 km offshore they will likely have a transformer platform to boost the power before providing it to a subsea cable to take it to shore at a higher voltage. The structural requirements for the transformer platform are recommended to follow the API RP2A code for fixed platforms, with additional requirements as appropriate. These could be manned more often than a traditional oil and gas "unmanned" fixed structure and thus the

requirements need to be considered with that in mind.

There is little guidance on subsea cable code requirements as to date a lot of these have been uniquely designed. Section 9 deals with a discussion of the subsea cables. Based on some recent information from Horns Rev 2, a Danish offshore wind farm, it is clear that attention needs to be paid to this area since the terminations of the subsea cable were unsatisfactory causing the shut down of the field for an extended period to change out the terminations. Anchors have impact if the cable is not appropriately buried. This is an area recommended for further study.

Finally the Transportation Certification and Installation Certification are dealt with in Sections 10 & 11.

The intent of this document Part 2 was to provide some insights into the proposed submission requirements and the importance of ensuring that the Facility Design Report is well thought out, providing where available, examples of incidents may make the issues somewhat clearer.

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