

***MMS TA&R PROJECT 650
OFFSHORE WIND TURBINE INSPECTION
REFINEMENTS
FINAL REPORT***

REVISION 0

Prepared for:
Minerals Management Service
381 Elden Street
Herndon, VA 20170

Prepared by:
Energo Engineering
1300 W. Sam Houston Pkwy S., Suite 100
Houston, Texas 77042

Energo Engineering Project No.: E09261



A KBR Company
A Registered Texas Engineering Firm No. F-10973

This report has been reviewed by the Minerals Management Service and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Service, nor does mention of trade names or commercial products constitute endorsement or recommendation for use



A KBR Company

3 June 2010

Energo Project No.: E09261

Lori Medley
COTR
U.S. Department of the Interior
Mineral Management Service
Engineering and Research Branch
381 Elden Street
Herndon, VA 20170

**Subject: MMS TA&R Project 650 –Offshore Wind Turbine Inspection Refinements
– Final Report**

Dear Lori:

The following is our Final Report documenting the development of the refinements to the Offshore Wind Turbine Inspection Guidelines. The report describes the steps taken, the personnel involved, and the logic behind these refinements to the guidelines with respect to blades and tower inclination.

Comments from the draft version of this report have been incorporated along with findings from the recent WindPower2010 conference. Though this report is designated as final, we can make further modifications if additional comments are generated.

Sincerely,
Energo Engineering

A handwritten signature in blue ink, appearing to read "Robert Sheppard".

Robert Sheppard, P.E.
Principal Investigator

A handwritten signature in black ink, appearing to read "Frank J. Puskar".

Frank Puskar, P.E.

TABLE OF CONTENTS

Executive Summary	3
1.0 Development Approach	4
2.0 Blade Inspections	5
2.1 Blade Degradation Mechanisms	6
2.2 Blade Inspection Techniques	7
2.3 Blade Access	12
3.0 Tower Inclination Inspections	15
3.1 Photographic Inclination Measurements	15
3.2 Other Inclination Measurements	19
3.3 Inclination Tolerance	20
4.0 Recommended Inspection Guideline Refinements	21
4.1 Blade Inspections	21
4.2 Facility Inclination	21

Attachment A – Inspection Guidelines for Offshore Wind Turbine Facilities

EXECUTIVE SUMMARY

With the approval of the Cape Wind project and the expected introduction of wind turbine facilities for the generation of electricity in US Offshore Continental Shelf (OCS) waters, Energo Engineering led the effort to develop guidelines for inspection of offshore wind turbine facilities as part of MMS TA&R No. 627. As a result of this project, a number of technological and practical challenges to assessing the condition of these structures were identified. Specifically, the challenges include performing close visual inspection of wind turbine blades in situ, and identifying the extent and cause of structural inclination.

This report documents the development of recommendations for effective, safe methods using current and novel technology to address both these inspection challenges. The development primarily relied on interaction with industry experts to provide guidance on approaches that are available today and those that are expected to become available in the near future to support blade inspections and evaluation of facility inclination. The most effective and safe approaches are highlighted and implemented in the form of revised inspection guidelines.

Attached to this report is a revised inspection guideline document. The original was developed for TA&R No. 627 and this one has been updated with the findings from this study.

1.0 DEVELOPMENT APPROACH

The development of the inspection guideline refinements was divided into three tasks:

1. Evaluate existing and novel blade inspection practices
2. Evaluate existing and novel inclination determination techniques
3. Recommended inspection procedures

For Tasks 1 and 2, the approach was to develop an understanding of existing practices through a literature search and discussions with industry experts from the manufacturing, service and operational sectors in addition to experts with broad industry experience. The bulk of this expertise comes from land-based experience and some judgment was required to determine its applicability in an offshore implementation.

After reviewing all the information and developing an understanding of existing practice and potential future enhancements, a set of recommended guidelines was developed (Task 3) to be incorporated within the existing guideline document developed as part of TA&R 627.

2.0 BLADE INSPECTIONS

Wind turbine blades are unique structures and typical inspection practices for offshore structures do not necessarily address their unique features and degradation mechanisms. The previous study results identified blades as an area requiring further study beyond what had been developed for the original offshore wind turbine inspection guidelines. This section details how the inspection refinements for blades were developed and revised inspection guidelines were defined.

In order to evaluate the pros and cons of various inspection practices, both established and novel, to determine the best approaches to recommend in the guidelines a set of criteria were established. The following were defined as key factors to use to weigh the various practices against each other:

- Worker Safety – the ability to implement the inspection safely and effectively considering the access requirements for blades in an offshore environment
- Scalability – the ability to implement the inspection across multiple facilities in a field
- Repeatability – the ability to reliably reproduce the inspection activity and obtain results that are consistent on the same blade and across multiple blades in a field
- Cost effectiveness – qualitative assessment of the inspection cost in terms of manpower, downtime, and duration weighed against the potential data gathered

Note that the cost effectiveness factor was assessed in qualitative terms from the standpoint of duration of the test because hard data on costs were not readily available.

The following list shows some of the more helpful organizations that were able to provide useful guidance on this topic. Note that this is not a complete list of the organizations contacted; not all organizations contacted were able or willing to provide information for this project. However, for the focus of this study (safe and effective inspection techniques) the data collected from the participants was useful and in general was consistent among the participants.

- National Renewable Energy Laboratory
- Performance Composites, Inc.
- Safway Services, LLC.
- Wind Access Engineering, Inc.
- Knight & Carver Wind Group

Questions to these participants and the literature search focused on the kind of damage that is most prevalent, what kinds of techniques are used for identifying damage, when those techniques would be used, what access equipment and systems are used, and what technologies are available or will be available that have the potential for widespread use within the next five to ten years.

There are inspection requirements for blade mandated by the manufacturers and related to the warranty provided for the equipment. The manufacturers contacted did not share this information with the study, but based on discussions with other study participants, the types of inspections and the techniques used are not different from those discussed in the following sections.

2.1 Blade Degradation Mechanisms

In order to define the most effective inspection practices for blades it is important to define the degradations that are most prevalent and that have the biggest impact on blade stability and blade performance.

Generally responses from subject matter experts have indicated that lightning and erosion (particularly along the leading edge of the blade) are the most commonly detected in-service degradations (see Figures 2.1 and 2.2). Underlying structural issues such as delamination, cracks at details of the geometry and bond failures are typically manufacture related and generally identified within a short period after installation (e.g., within six months of installation); either through poor blade performance or because of problems with the same or similar blades made by the manufacturer (see Figures 2.3 and 2.4).

Erosion, particularly leading edge, is highly dependent on the local conditions. Some installations see virtually no erosion over many years of service while others can be significantly eroded and require repair within a few years. Airborne particulates, rain, snow, sleet, etc. are drivers of this. Inspection guidelines should emphasize the variable nature of these effects so operators can highlight the evaluation of this effect on their blades.



Figure 2.1 – Lightning Damage to Blades



Figure 2.2 – Leading Edge Erosion

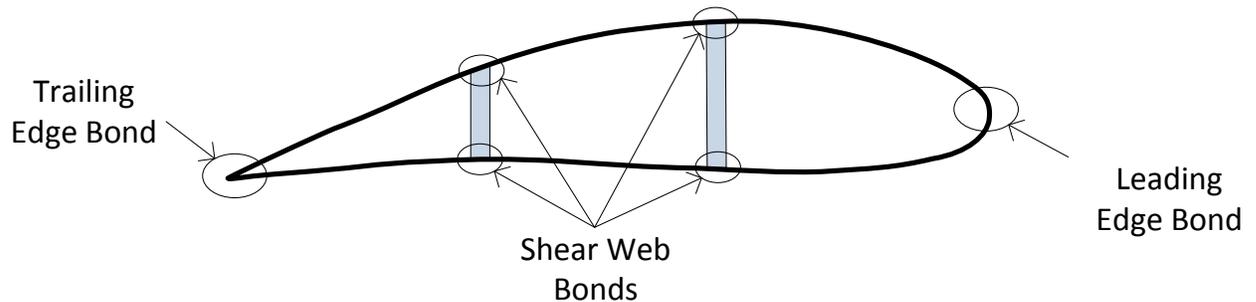


Figure 2.3 – Prevalent Structural Failure Locations

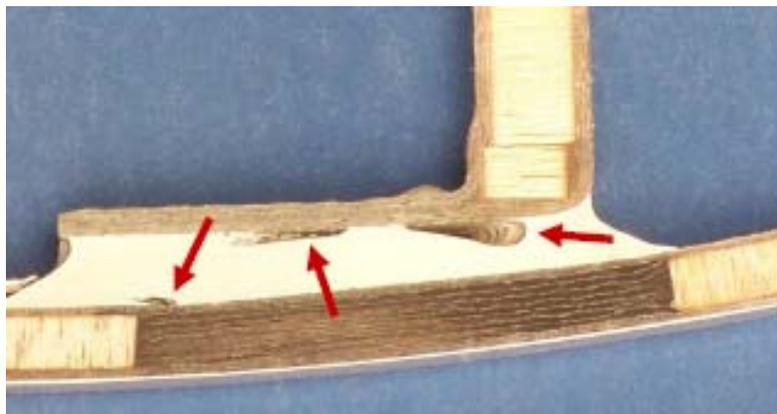


Figure 2.4 – Bond Voids

2.2 Blade Inspection Techniques

The literature search focused on techniques (including visual, non-destructive testing (NDT) and remote monitoring) that can detect damage in composite wind turbine blades. A wide range of techniques capable of detecting potential damage modes have been used for

inspecting blades including: visual inspection, tap tests, ultrasonic testing, acoustic emission testing, thermography, and shearography. As with any collection of inspection techniques, each has its strengths and weakness related to issues such as detection thresholds, portability, accessibility (offshore blades will be inspected at height), safety, and scalability (large number of blades within a wind farm). These also relate to the key factors for assessing the inspection approaches defined in Section 2.0.

Visual inspection is the most common regular inspection technique and is typically performed from a distance (such as the nacelle) though rope and other access systems are not uncommon. Interior blade access is possible (more access is available with bigger blades) though is generally only used when a problem is already suspected. NDT techniques are generally only used if a problem is suspected (e.g., when the manufacturer identifies a systemic problem or a potential problem is identified by another inspection method) and not as a proactive measure.

Power performance data can be used to remotely identify problems with blades though this tends to be useful only with severe damage. Condition monitoring systems using embedded sensors are a developing field for wind turbine blade monitoring though this technology is not widely used either offshore or for land-based units. It is expected that these systems will gain wider use in the five to ten year time frame as a means of reducing manpower requirements for inspections and increasing the ability to proactively address potential blade degradation. Wind turbine facilities are already able to send performance data out remotely, generally related to power production, and this additional data could be sent out using the same or similar systems.

Examples of vendors that provide either equipment or monitoring services include Applied Geomechanics offering hardware and associated data gathering and processing for measuring foundation tilt, strain gauges, crack meters and extensometers and Structural Risk Assessment and Management (STRAAM) who offer structural monitoring through acceleration measurement and structural modeling. These companies have prior experience with monitoring buildings and bridges and it is reasonable to assume their technology is applicable to wind turbines.

The following describes the various techniques considered in more detail with assessments of the pros and cons of each and their applicability to offshore inspections. Note that the inspection techniques described are used worldwide throughout the wind turbine blade industry both offshore and land based.

Visual Inspection

This is by far the most widely used inspection technique and includes any type of visual inspection whether from a remote position using binoculars or from within close reach of the area being inspected. Visual inspection provides the least information regarding the structural condition of the wind turbine blade as it is purely a function of the visible surface condition. As such, the information obtained during a visual inspection will provide the following:

- Indication of gross blade damage such as leading/trailing edge joint failures and severe delamination
- Leading edge erosion
- Lightning strikes
- Bird strikes

Visual inspection cannot provide any information about the subsurface condition of the blade structure. This means that potential fiber or matrix failures, delaminations, voids, and de-bonding may go unnoticed during inspection.

Tap Test

A tap test is a non-destructive test that uses a small metal object (e.g., a coin) to tap on the surface of the composite to produce an audible sound. A clear, sharp sound would be indicative of an intact structure whereas a dull thud may indicate a void or delamination. It is important to ensure that the change in sound associated with the tap test is the result of an internal flaw and not solely a change in internal structure (e.g., proximity to the blade spar or a dropped ply in the skin). This is an extremely useful tool at detecting structural flaws; but it is not practical to survey a large area of the blade simply due to the time it would take to tap along the area required. Also, interpreting the test is subjective and it is not possible to ascertain the extent of damage or archive the measurement for future reference.

Automated implementations of the traditionally manual tap test have been developed and may be useful in an offshore environment with adequate access to the blades.

Ultrasonic Testing

Ultrasonic testing (UT) is a form of NDT where ultrasonic pulses are projected into an object with the reflected signal used to determine the object's thickness, identify potential internal flaws, or characterize the material.

- Advantages
 - The ability to detect both surface and subsurface discontinuities
 - The ability to detect flaws deep within a part
 - The ability to identify small defects
 - Only single-sided access needed for the pulse-echo (reflection) technique
 - Detailed images can be obtained when coupled with automated systems
- Disadvantages
 - A coupling medium to promote the sound energy transfer into the material is usually required (this is not the case with electromagnetic-acoustic transducers [EMAT])
 - Manual operation requires experienced technicians

- Rough, irregular shape, exceptionally thin, or non-homogeneous materials are difficult to inspect

While these are the general characteristics of UT, there are several special features that are applicable to the inspection of wind turbine blade inspection.

- Paint Brush Transducers – A long, narrow transducer comprised of a series of small crystals that are able to scan a larger area for defects more rapidly with a single transducer. However, with the broader sensing area comes a reduction in sensitivity which often requires the use of smaller, more sensitive transducers to provide the fine details of the discontinuity. Also, depending on the curvature of the structure, obtaining the proper contact may be problematic.
- Electromagnetic Acoustic Transducers – EMAT provide a method by which no couplant is required to perform the measurements. However this requires a metallic material in the structure.

Acoustic Emission Testing

Acoustic emission testing (AET) relies on the creation of elastic waves from sources within an object subjected to external loading due to a sudden redistribution of stress within the specimen. The types of events inducing the elastic waves include crack initiation and growth, slip and dislocation, as well as debonding of composites. Observing these acoustic emissions provides feedback related to these damage types. There are two key differences between AET and the majority of other NDT methods: signal source is from the specimen itself, and AET measures dynamic changes in a specimen. These two differences highlight one of the primary strengths of AET, namely the ability to monitor the condition of a specimen while in service.

- Advantages
 - Perform during operations (applied loading is required for an acoustic emission event to occur)
 - Able to identify occurrence of developing defects
 - Fast and complete volumetric inspection using multiple sensors
- Disadvantages
 - Unable to measure stagnant (non-growing) defects
 - Flaws may go undetected if applied loading is not sufficiently high so as to produce an acoustic emission event
 - Provides a qualitative assessment of the damage associated with a structure (other NDT methods would be used to provide size, depth, and acceptability of the specimen)

Thermography

In thermography the surface temperature of a specimen is monitored to identify regions where the heat flow is affected by subsurface anomalies. The conduction of heat through

the specimen is directly affected by the internal structure and by subsurface features. For instance, the presence of an internal void or delamination may cool at a slower rate than adjacent material without the defect. The two types of thermographic NDT techniques are classified based on the manner in which the specimen is heated: active (apply external excitation to the system) or passive (use temperature of specimen under steady-state conditions). For external excitation, a variety of sources can be used including radiative heating (e.g., light, infrared, or microwave) and mechanical stimulation (e.g., sonic or ultrasonic, cyclic stress, or convection).

- Advantages
 - Provides both local and full-field measurements in an image format that can be readily evaluated
 - Able to detect a wide variety of defects including voids, trapped water, delamination, anomalous resin distribution, and validation of patch repairs
 - Alternative stimulation sources provide a variety of opportunities for applying thermography to in-service specimen (though some of these alternatives are still in the research phase)
- Disadvantages
 - Obtaining an acceptable stimulation source may be challenging for an in-service wind turbine blade
 - Challenges with making the unit portable to safely utilize with an in-service wind turbine blade

Shearography

Shearography uses a laser to illuminate a structure with the resulting image captured by a special camera that records an interferometric image of the surface. The specimen is then loaded (mechanisms such as heating, vacuum, vibration, or mechanical stress) and another interferometric image is taken. During this loading, non-uniform properties will result in a non-uniform surface deformation. By subtracting the two images, it is possible to show the surface gradients induced by the loading.

- Advantages
 - Able to detect a wide range of flaws in composite specimens including delaminations, disbonds, wrinkles, and porosity
 - Able to test a large surface area quickly (on the order of 1 m² per minute)
- Disadvantages
 - Mechanism for loading the structure is required
 - Difficulty assessing thicker structures

The qualitative strengths and weaknesses of these methods are summarized in Table 2.1. This is intended to provide broad qualitative comparisons among the techniques with regards to some important criteria. In the table, Close indicates that the inspector must be at

least within arm’s reach of the area inspected; Short, Moderate and Long time durations are simply qualitative distinctions between the various techniques and not indicative of a particular time range; the same is true for the training requirements.

The more equipment-intensive methods are generally more suited to testing in the manufacturing plant rather than in-service though their effectiveness is greatly enhanced if suspended platforms are available. Input from industry experts indicates that UT and thermography are techniques that are used on blades in situ depending on the goal of the inspection and the type of blade being inspected. There are also portable shearography units that are near to being implemented in the field and “up-tower”, notably from Dantec Dynamics (see Figure 2.5).

It can be stated that there are or will soon be reasonably portable NDT options that can be implemented in situ for offshore wind turbine blades that can greatly enhance the ability to detect and document blade damage. These include UT, thermography and shearography.

Table 2.1. Inspection Methods Key Factors (Qualitative)

Factor	Remote Visual	Close Visual	Tap Test	UT	Acoustic Emission**	Thermography	Shearography
Access needs	Remote	Close	Close	Close	N/A	Close	Close
Repeatability	Good	Good	None	Fair	N/A	Good	Good
Duration*	Short	Moderate	Short	Short	N/A	Long	Long
Training required	Minimal	Minimal	Moderate	Moderate	Extensive	Moderate	Moderate

* Duration estimates for tap test and UT assume a local check only. Full blade evaluation using these methods would require a long duration. The long duration for thermography and shearography take into account the more elaborate equipment setup time required.

** Acoustic Emission requires no access once installed and remote monitoring is instantaneous once begun

2.3 Blade Access

The topic of blade access was an important topic with all the industry participants. At the start of the project, it was assumed that remote visual (viewing from a distance with binoculars or other visual aid) and rope access would be the most common means to perform inspections. However based on input from subject matter experts, the use of suspended platforms can provide a robust means to inspect the blades quickly (multiple technicians accessing blade simultaneously), thoroughly (potential for 360-degree access), and in a wider range of wind conditions (increases the weather window for performing the inspection). These are not particularly exotic access systems and are likely to be readily adapted from land-based to offshore use.

The first option is to use rope access since this is the quickest and cheapest of the access options. For areas that cannot be accessed safely using rope access, or to improve inspection efficiency, the next option is to use a suspended platform system (see Figure 2.6 for a typical blade access platform system). These systems are common and can be suspended from existing parts of the nacelle or purpose-built supports can be included in the nacelle design. There are a variety of manufacturers and vendors providing robust access platform solutions for wind turbine inspections including the blades including Safway, Sky Climber, Spider and Kaeufer.

Typical wind speed limitations for access are 20 to 25 mph. Some distinctions have been made by various experts regarding the wind restriction differences between rope-only access and suspended platform access, but the actual differences are relatively minor. It is preferable to plan inspections during times of expected lower wind speeds but this is not always possible.

It is concluded that though access will always be a consideration for inspection of offshore wind turbine facility blades, there are a number of options for rope access or platform access that allow detailed inspections to be carried out in a relatively safe environment. The logistics of these systems is a consideration for inspection planners and implementers, but the capability is present within the industry today.

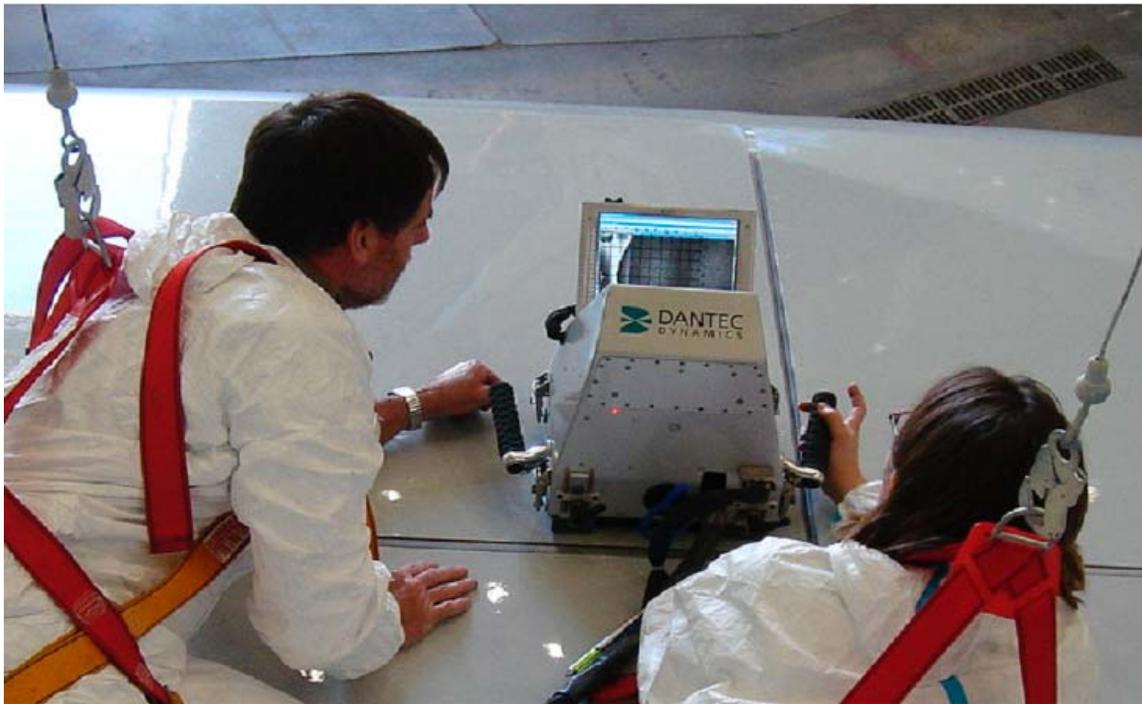


Figure 2.5 – Dantec Q-810[®] Portable Shearography System



Figure 2.6 – Asmus® Suspended Platform

3.0 TOWER INCLINATION INSPECTIONS

Another area identified during the previous study was tower inclination, or lean. An inclination of the tower structure or substructure can be caused due to extreme loading or foundation issues and the ability to detect and measure this inclination is the second area of focus for these inspection refinements.

3.1 Photographic Inclination Measurements

Examples of structural deformation that causes an overall inclination are numerous for offshore oil platforms. One case of an inclined platform following Hurricane Ike is shown in Figure 3.1 with an example from Katrina/Rita in Figure 3.2. These images highlight some of the challenges in determining the inclination angle, namely photographic determination based on local observations of structural members requires a non-trivial effort to properly assess the inclination angle.

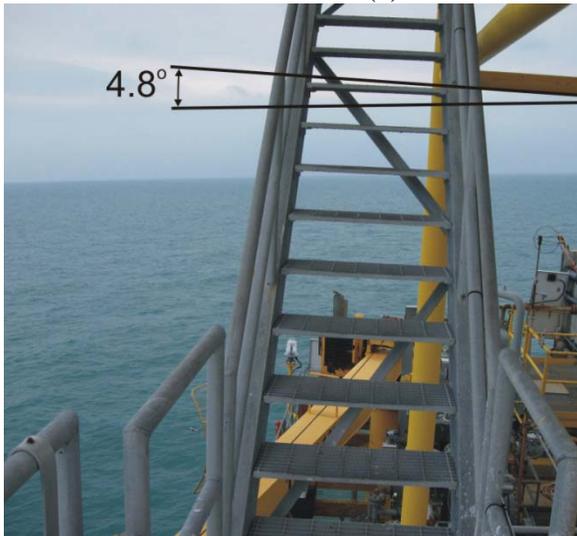
For the example in Figure 3.1, multiple inclination angles ranging from 4.8 to 7.2 degrees could be predicted based on member orientation relative to the horizon. Similar difficulty is present in predicting the inclination of Figure 3.2. In actuality, it is highly likely that the true facility inclinations are not captured by any of the simplified estimates presented. This can be attributed to issues such as the photographs not showing the true orientation of structural members (projecting three-dimensional members in two dimensions) or photographic effects such as keystoning (parallel lines appear to be converging when photographed with a camera not parallel to the plane of the lines) and barreling/pincushion (image magnification varies with distance from optical axis).

Figure 3.3 shows an example of how an offshore wind turbine inclination may appear. In this case, the inclination was varied from as installed (0 degree) to a 3-degree inclination. Note that a rather minor inclination can produce a readily observable variation when considering the height of the turbine. Unlike the jacket structures presented in Figures 3.1 and 3.2, the inclination of a wind turbine facility resting on a caisson could be reasonably predicted provided that a full 360-degree view could be obtained. While this will define the lean, the images may not define the reason for the lean if it is below the waterline. It should be noted that there is often a taper in the tower structure or the caisson substructure that should be considered when evaluating a lean using photographs.

One key inspection quantity to understand is the resolution of the measurement to determine the inclination magnitude. The simplest system is to consider the structure in Figure 3.3 as a rigid body where the facility rotation is governed solely by a rotation of the caisson at the mudline. Given this, the resulting lateral deflection at different elevations can be readily determined as shown in Figure 3.4. In this case, the lateral deflection at the waterline ranges from 1.22 to 3.66 ft for inclinations of 1 to 3 degrees. If attempting to characterize the inclination below water, the measurement technique would be required to resolve a deflection of less than this.



(a) WC 426 following Hurricane Ike



(a) WC 426 structure showing inclination



(b) WC 426 structure showing inclination

Figure 3.1. Inclined Oil Platform (WC 426) following Hurricane Ike



Figure 3.2. Example of Platform Destroyed during Hurricane Katrina/Rita



Figure 3.3. Sample Offshore Wind Turbine Showing Facility Inclination (Turbine taken from Princess Amalia Wind Farm, hub height 59m above waterline)

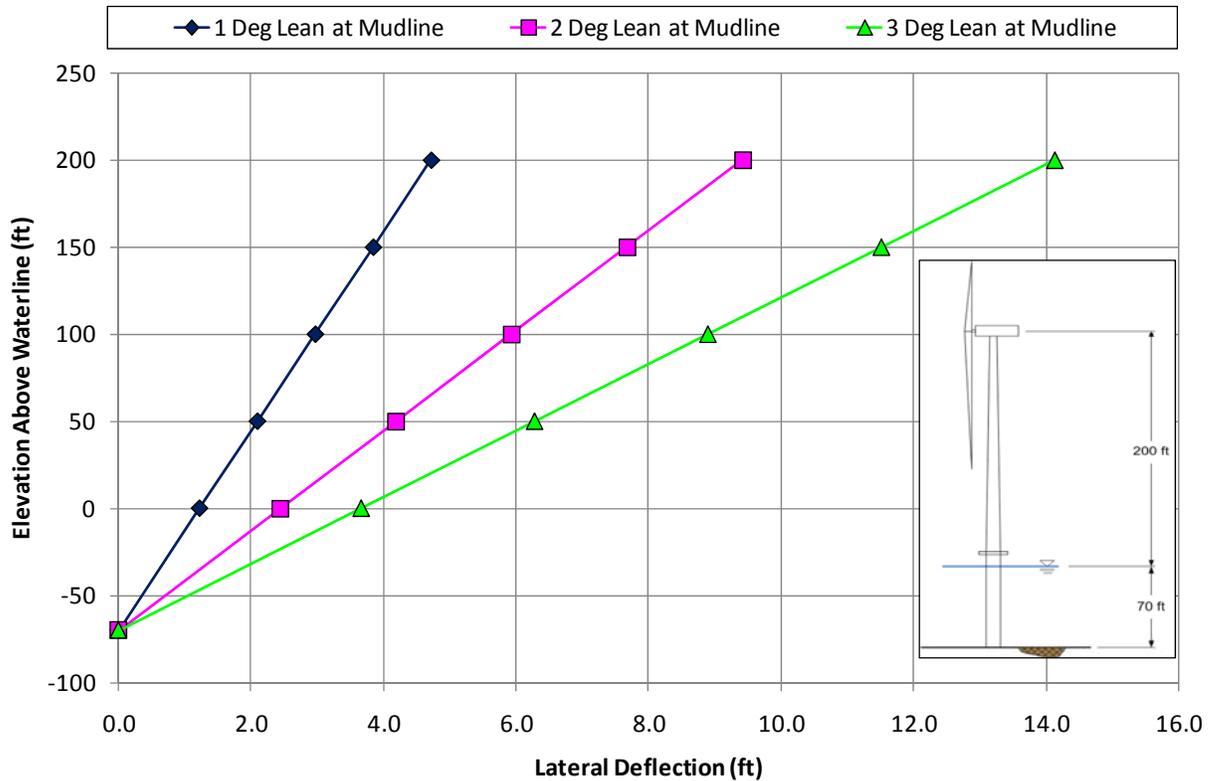


Figure 3.4. Lateral Deflection of Simplified Rigid Wind Turbine Facility Subjected to Rotation at Mudline

3.2 Other Inclination Measurements

There are various survey-type techniques that can be used to accurately measure the inclination of a tower structure such as an offshore wind turbine facility. These include technologies such as Acoustic Positioning Systems. However, given the time and expense of implementing such a system, it is deemed impractical for use in evaluating the inclination of wind turbine facilities post-storm.

Discussions with industry experts indicate that a lower-tech solution can provide reliable and repeatable measurement data. Specifically the use of magnetic level bubbles that could be placed directly on the tower, or substructure if it is steel or has steel elements or the use of “trim cubes” which are electronic devices used extensively on ROVs to measure inclination via electrolytic gravity sensors. They measure pitch and roll and can transmit their readings so it’s possible they could be permanently mounted and read from an inspection vessel or by an inspector on the facility during the inspections.

It is also possible that standard bi-axial inclinometers (such as the tiltmeters from Applied Geomechanics) could be permanently mounted in the nacelle and remotely monitored. These are reliable, and easily obtained devices that can be used across a field of many units. It is likely that oscillations will be apparent when reading these devices due to the

influence of wave action on the facility. In these cases, it is possible to watch the oscillations and select a mid-point as the inclination value.

3.3 Inclination Tolerance

Based on discussions with industry participants, the installation inclination tolerance is roughly 0.25 degrees. In other words, the tower is intended to be installed as close to vertical as possible, but up to a 0.25 degree inclination is tolerable. The amount of inclination a facility could experience and still remain operational is variable and depends on the turbine system, blades and expected environmental loads on the facility. Some industry sources have indicated that this tolerance is as low as 1 degree before the rotor will stop. The exact tolerance is something that must be defined on a facility-by-facility basis, typically by the manufacturer.

To provide some sense of what an acceptance criteria might be, the following data is provided related to oil and gas caisson facilities:

- < 3 deg – acceptable to operate
- 3-5 deg – analysis required to justify continued operation
- > 5 deg – mitigation (e.g., bracing) required

4.0 RECOMMENDED INSPECTION GUIDELINE REFINEMENTS

The goal of these inspection refinements for blades and tower inclination is to provide guidance on safe and reliable methods for implementing these inspections in an offshore environment over the service life of the facilities. Current and emerging technologies have been reviewed and considered against the following criteria to establish a set of best practices:

- Worker Safety
- Scalability
- Repeatability
- Cost effectiveness

The results of this evaluation are contained in the attached inspection guidelines (Attachment A) and briefly summarized below. The original inspection guidelines were developed as part of TA&R 627. They have been edited based on the findings of this study and included as a revised set of guidelines. Only Sections VII and VIII have been modified.

4.1 Blade Inspections

The consensus among the experts contact is that external blade damage is the most prevalent in-service damage expected to be found during the service life of the facility. This includes damage from lightning strikes, edge erosion, etc. which can generally be identified by visual inspection. Internal blade damage (i.e., to the blade structural framing) is expected to be identified based on abnormal blade performance (e.g., as identified from power performance data, condition monitoring, etc.) or through communications with the blade manufacturer, rather than through routine inspections. The guidance reflects this expectation; however, there are requirements for regular close visual or NDT examination of blades to proactively evaluate internal degradation regardless of whether or not other data points to such defects.

4.2 Facility Inclination

There are a variety of inspection options for measuring or estimating the inclination. These range from photographs to sophisticated survey techniques. Some simple, inexpensive tools such as level bubbles and trim cubes are likely to prove the most effective especially considering the need to assess many facilities at once after a storm event or during normal service when adverse inclination is suspected. It is important that a baseline inclination be established at the time of installation and that the operator define inclination tolerance levels both for the operation of the facility and for boarding the facility for inspections and maintenance.

Attachment A

Inspection Guidelines for Offshore Wind Turbine Facilities

Table of Contents

Acronyms, Abbreviations and Definitions	2
I. Overview and Scope	4
II. Frequency of Inspections	4
III. Subsea Structure.....	5
IV. Subsea Equipment.....	8
V. Above Water Structural and Access Systems.....	9
VI. Above Water Electrical and Mechanical Systems	10
VII. Blades.....	11
VIII. Post-Event Inspections.....	13
IX. Engineering Evaluation.....	14
X. Data Requirements.....	15
XI. Regional Variations	15

Appendix A: Sample checklists and data reporting

Acronyms, Abbreviations and Definitions

CP	Cathodic Protection
CVI	Close Visual Inspection
GVI	General Visual Inspection
MMS	Minerals Management Service
MPI	Magnetic Particle Inspection
NDE	Non-destructive Examination
NDT	Non-destructive Testing
OSTS	Office of Structural and Technical Support
ROV	Remotely Operated Vehicle
RVI	Remote Visual Inspection
UT	Ultrasonic Testing

Anomaly: An observed or measured condition which is outside the threshold considered acceptable from the design or most recent fitness-for-purpose assessment.

Condition Assessment: Information that should be gathered on the facility's present condition to perform a fitness-for-purpose assessment.

Corrosion: A component defect categorized as either general or local that manifests itself as either pitting, hole, fretting and/or crevice.

CP measurement: A measurement to determine the effectiveness of the CP system by measuring the cathodic potential at a location typically using a probe held by a diver or ROV system or using a drop cell device from above water.

Defect: An imperfection, fault, flaw or blemish in a component that can include mechanical damage, corrosion and weld defects.

Design Life: The planned time period from initial installation or use until permanent decommissioning.

Deterioration: The reduction in the ability of a component to provide its intended purpose.

Extreme Event: An extreme metocean, seismic and/or ice condition, which a structure may be subjected to during its operational life.

Fitness-For-Purpose: An existing structure is considered fit-for-purpose if it can be demonstrated that it has adequate strength to resist the imposed assessment loads (functional, metocean, seismic and/or ice).

Inspection: The visit to the facility for purposes of collecting data important to its structural integrity and continued operation.

Mechanical damage: A defect type that includes dents, bows, gouges, holes and separated or severed members.

Mitigation: Strengthening, modification or repairs and/or operational procedures that reduce loads or increase capacities.

Mudline: The sea floor.

Nacelle: The structure that houses the generating components, gearbox, drive train, etc. of a wind turbine facility.

OCS: Outer Continental Shelf, a term used primarily in the U.S. for the offshore areas under federal jurisdiction.

Operator: Those employed by the Owners to conduct operations.

Owner: A party who owns physical infrastructure assets and/or a party who owns capacity rights in those physical assets but does not own the asset itself.

Prior Exposure: The historical exposure of a facility to the design metocean, seismic or ice loading.

Repair: The work necessary to restore a facility to a condition deemed fit-for-purpose.

Risk-Based Inspection: The development of inspection strategies based an assessment of the facility's risk.

Splash Zone: The area of the structure that is intermittently wet and dry due to wave and tidal action.

Survey: A specific visual or non-destructive examination of one or more components. Collectively, the surveys make up the complete inspection.

I. Overview and Scope

These guidelines provide a framework for developing and implementing an in-service inspection program for offshore wind turbine facilities either as individual installations or as a group of turbines making up a wind farm facility. Specific inspection plans should be developed based on these guidelines by a qualified engineer, and these plans should be implemented by qualified personnel with adequate training and equipment for the defined inspection tasks.

The scope of these guidelines encompasses the structural integrity of the support structure (above and below water), blades and nacelles (including any helicopter abseil platforms), appurtenances, cables and access structures such as walkways, stairways and platforms. Normal maintenance items such as keeping walkways clear, as well as signage and safety-related items are not part of this scope though inspectors are encouraged to report any issues in these areas to the responsible parties. Also, inspections conducted according to individual manufacturer's specifications are not part of the scope of this document.

This document is divided into sections corresponding to specific areas of the facility containing data on critical inspection areas, inspection frequencies, inspection techniques and other guidance. There is also information on data gathering and retention guidelines as well as regional variations to consider.

II. Frequency of Inspections

Within the following sections reference is made to various inspection cycles: annual, three to five year cycle, etc. When a range is given, it is intended that the engineer responsible for developing the inspection program consider the following when determining where within that cycle the inspection should be scheduled:

Condition: As a facility ages its condition will change as degradation mechanisms affect the various structural systems (e.g., corrosion, marine growth), and modifications are made to the structure (e.g., new walkways, damage repairs). An accurate assessment of the current condition of the facility is necessary to define how often various inspection activities need to occur. If the operation of a facility has shown that corrosion is a problem or scour is a concern, then it is prudent to have a more frequent inspection cycle than a facility with more benign conditions or where historically there have been no issues.

Consequence of failure: Some units may be installed near shipping lanes or near environmentally sensitive locations. It is not anticipated that these units will be manned, so factors such as personnel safety will not typically affect the consequence of structural failure. However, impacts on other activities in the surrounding waters should be considered. Consequence of failure levels should be considered when defining inspection intervals for facilities, with greater

frequency of inspection given to those facilities with higher consequence of failure.

The following table (Table II.1) contains an overview of the suggested inspection cycles for different parts of the offshore wind turbine facilities. These cycles and the inspections are described in more detail in the following sections. Note that Annual Inspections are required even in years when Intermediate or Extended Inspections are completed. It is preferable to schedule Annual Inspections in conjunction with Intermediate or Extended Inspections when they coincide.

Table II.1 Inspection Cycles (years)

Facility Area	Annual	Intermediate	Extended	Additional
Subsea Structure	1	3-5	6-10	As needed
Subsea Equipment	n/a	3-5	n/a	As needed
Above Water Structure	1	3-5	n/a	As needed
Above Water Systems ¹	n/a	n/a	n/a	n/a
Blades	1	3-5	n/a	As needed

¹Above water mechanical and electrical system inspections are driven by maintenance cycles determined by equipment manufacturers.

These recommended cycles are not intended to preclude other rational approaches to defining the inspection program including using risk techniques or other methodologies. However, alternative approaches should be well documented so that reviewing authorities can identify and approve the program.

Multi-Unit Wind Farms

Once a target inspection cycle has been chosen from the suggested range, it should be understood that not all units within a wind farm, if they are all given the same frequency, must be inspected at the same time. For instance, if the Intermediate Underwater Inspections are to be held on a four year cycle, not every unit in the wind farm must be inspected at the same time. In fact, it may be logistically impossible. But all of them must be inspected during that four year cycle. A certain number could be inspected each year so that by the end of the four years, all have been covered. Such a program has the benefit of providing virtually continuous inspections so that if problems do occur, they are identified in a timely manner, rather than waiting years before the next inspection cycle. The implementation of the inspection scope is up to the operator and as long as all the requirements are met, the scheduling is flexible.

III. Subsea Structure

The subsea structure is that portion of the facility that supports the above water components, including the tower, nacelle and blades, and is founded on the sea floor. These structures are likely to be pile founded monopiles or braced frame structures that extend from the mudline to some distance above the water line where the tower structure is attached. These structures are expected to be similar in design and performance to oil

and gas platform structures. Useful references for inspections of subsea structures are the API RP 2A document for steel structures and ISO 19903 for concrete structures.

a. **Critical Inspection Areas**

The following areas should receive primary attention when developing an inspection program due to their importance to maintaining structural integrity:

Steel Substructures

- Circumferential welds on monopiles
- Welded connections on braced structures
- Major vertical members (e.g., legs, braces)
- Splash zone

Concrete Substructures

- Splash zone
- Construction joints
- Penetrations
- Embedded plates

All Substructures

- Cathodic Protection (CP) systems
- Areas of previous repair or damage
- Seabed scour
- Settlement/subsidence

b. **Inspection Cycles**

Annual Inspections:

- CP measurement using drop cells from above water

Intermediate Inspections

This inspection cycle should be performed at a 3 to 5 year interval and documented with a written report including video and photographs.

- General visual underwater inspection (GVI)
This level of inspection includes a visual inspection performed by divers or ROV to detect any of the following:
 1. Corrosion
 2. Damaged or missing members
 3. Scour, seabed instability, exposed seabed cables within visual range of diver or ROV
 4. Cracks or indications at welded joints or circumferential welds
 5. Cracks or spalling of concrete especially at joints, penetrations and around embedded plates
 6. Excessive marine growth
 7. Damaged risers/cables attached to structure

8. Damaged riser/cable clamps or attachment devices
9. Other anomalies

Extended Inspections

This inspection cycle should be performed at a 6 to 10 year interval (at twice the interval chosen for the Intermediate Inspections) and documented with a written report including video and photographs.

- General visual underwater inspection (GVI) as described above for Intermediate Inspections
- Close visual underwater inspections (CVI)

This level of inspection includes a visual inspection from no further than arm's length of an area pre-selected by engineers (e.g., welded joints of the underwater structure determined by analysis to be critical to structural stability). The area to be inspected should be cleaned of any marine growth so clear examination of the underlying material can be made. Close visual inspection is primarily intended to detect:

1. Cracks, indications or pitting at welded joints or circumferential welds
2. Deterioration of concrete surfaces (e.g., cracks, spalling)
3. Structure condition at area of interest
4. Other anomalies

Additional Inspections

When anomalous conditions are identified it may be necessary to expand the inspection scope or implement techniques that are able to provide more information for review of the extent of the anomaly. Of primary importance is the adequate documentation of the anomaly before the inspection team is demobilized. Photos, video, sketches and measurements of the anomalous condition that can be made with the available equipment should be taken so that proper response can be determined.

A qualified engineer should be consulted to determine the scope and technique of the any additional inspections. Typical additional inspections, which may require mobilization of specialized technicians, include:

- Close visual underwater inspections (CVI), as described in the Extended Inspections section, in the area of the anomaly and as directed by a qualified engineer
- Non-destructive testing (NDT) inspections such as magnetic particle inspections (MPI), ultrasonic testing (UT), or other to determine crack depth, material thickness or other data needed to evaluate the anomaly
- These additional inspections should be thoroughly documented in a written report with details gathered including video and photos.

IV. Subsea Equipment

The subsea equipment includes non-structural items related to the operation of the facility. This includes cables, risers and j-tubes to protect the cables, junction boxes, other umbilicals and similar equipment that is located below the waterline. Typically risers and cables are attached to the subsea structure through clamps or other devices. Away from the structure they are buried though in some cases they may be stretched along the sea floor without being buried.

a. Critical Inspection Areas

The following areas should receive primary attention when developing an inspection program due to their importance to maintaining operability:

- Risers/J-tubes and attachments to the substructure
- Electrical and control cables within field
- Electrical cables to shore
- Connectors and junction boxes
- Areas of previous repair or damage

b. Inspection Cycles

Intermediate Inspections

This inspection cycle should be performed at a 3 to 5 year interval and documented with a written report including video and photographs.

- General visual underwater inspection
This level of inspection includes a visual inspection performed by divers, ROV, or other appropriate equipment (e.g., side-scan sonar) to detect any of the following in the area directly adjacent to the facility, and along the cable routes to shore and other facilities:
 1. Exposed cables where cables should be buried
 2. Long unsupported sections of cable (e.g., caused by scour, anchor dragging, displaced J-tubes, etc.)
 3. Damaged cables or other equipment (e.g., from anchor dragging, impact, etc.)
 4. Other anomalies

Note that accurate maps of the “as laid” cable routes should be maintained by the operator in order to facilitate these inspections.

Additional Inspections

When anomalous conditions are identified it may be necessary to expand the inspection scope or implement techniques that are able to provide more information for review of the extent of the anomaly. Of primary importance is the adequate documentation of the anomaly before the inspection team is demobilized. Photos, video, sketches and measurements of the anomalous condition that can be made with the available equipment should be taken so

that proper response can be determined. A qualified engineer should be consulted to determine the scope and technique of the additional inspection.

V. Above Water Structural and Access Systems

The above water structural and access systems include the tower structure mounted on the subsea structure and supporting the nacelle and blades, the nacelle itself and helicopter abseil platforms, lifting devices, walkways, access ladders and stairs, boatlandings, swing ropes, etc. Depending on the design, some of the access systems may be inside the tower structure and shielded from the elements.

a. Critical Inspection Areas

The following areas should receive primary attention when developing an inspection program due to their importance to maintaining structural integrity:

- Tower to substructure attachment (e.g., welds to monopole)
- Access systems (e.g., ladders, walkways, boatlanding, swing ropes, handrails, helipads, helicopter abseil platforms, etc.) and lifting systems
- Nacelle structure integrity
- Overall facility deflection (i.e., does the facility lean due to structural deformation, differential settlement, or other causes)
- Areas of previous repair or damage

b. Inspection Cycles

Annual Inspections:

- General visual inspection (GVI)
This level of inspection includes a visual inspection performed by qualified personnel and documented with a written report including video and photographs. It is permissible, where required by access restrictions, to accomplish these inspections with binoculars or other similar equipment if they can provide sufficient detail to identify the following anomalies:
 1. Corrosion or coating breakdown
 2. Damaged or missing members
 3. Cracks or indications at welded joints
 4. Damaged risers/cables attached to structure
 5. Loose bolts
 6. Evidence of lateral deflection or lean
 7. Other anomalies

Intermediate Inspections

This inspection cycle should be performed at a 3 to 5 year interval and documented with a written report including video and photographs.

- Non-destructive testing (NDT) at the connection between the tower structure and the substructure. The welds or bolts at this connection must be examined to determine their integrity.
 1. Where bolts are used, their proper tensioning shall be determined using a torque wrench or similar device.
 2. Where welds are used, appropriate NDT techniques (e.g., magnetic particle inspection (MPI), eddy current inspection, etc.) shall be used at key areas as determined by a qualified engineer to identify indications.

Additional Inspections

When anomalous conditions are identified it may be necessary to expand the inspection scope or implement techniques that are able to provide more information for review of the extent of the anomaly. Of primary importance is the adequate documentation of the anomaly before the inspection team is demobilized. Photos, video, sketches and measurements of the anomalous condition that can be made with the available equipment should be taken so that proper response can be determined.

A qualified engineer should be consulted to determine the scope and technique of the additional inspection. Typical additional inspections include:

- Close visual inspections (CVI) from at least arms length with cleaning of the area as necessary with measurements of the anomaly and other investigation as directed by a qualified engineer
- NDT inspections such as MPI, UT, or other to determine crack depth, material thickness or other data needed to evaluate the anomaly
- These additional inspections should be thoroughly documented in a written report with details gathered including video and photos.

VI. Above Water Electrical and Mechanical Systems

These systems, including turbines, electrical cabling, junction boxes, panels, transformers and generators, hydraulic systems and control systems should be inspected and maintained in accordance with manufacturer recommendations to ensure efficient and safe operations.

It is recommended that these maintenance activities be coordinated with the inspections defined in this document and, where possible, the same personnel should implement the activities. Where the same personnel are used, qualifications for maintenance and inspection activities must be demonstrated and special training to complete some of the structural tasks may be necessary.

It is also recommended that use of remote monitoring systems be implemented to provide regular feedback on equipment function to identify anomalous conditions without the need to have maintenance crews on the facility.

VII. Blades

External blade damage is the most prevalent in-service damage expected to be found during the service life of the facility. Internal blade damage (i.e., to the blade structural framing) is expected to be identified based on abnormal blade performance or through communications with the blade manufacturer, rather than through routine inspections.

a. Critical Inspection Areas

The following areas should receive primary attention when developing an inspection program due to their importance to maintaining blade integrity:

- Blade attachment bolts
- Blade condition particularly in the following areas
 - Leading and trailing edge condition
 - Condition at bond lines
 - Substructure connection locations
 - Areas identified by blade manufacturer as strength or fatigue critical
- Areas of previous repair or damage

b. Inspection Cycles

Annual Inspections:

- General visual inspection (GVI) documented with a written report including video and photographs
This can be Remote Visual Inspection (RVI) with binoculars or other equipment provided the inspector can identify the following anomalies:
 1. Blade damage (e.g., impact, lightning, etc.)
 2. Erosion particularly at leading edge
 3. Corrosion at attachment points
 4. Significant material degradation (e.g., fiber or matrix failure, de-lamination, stress fracture, stiffness degradation, etc.)
 5. Other anomalies

Inspections should be performed from a safe, stable location or locations allowing full view of the entire blade surface of all blades. Vantage points may include the nacelle, tower base, base of adjacent towers, work boat, etc.

As justified by an approved engineering assessment, and as part of a long-term plan to inspect every blade in the field over a specified time period, annual blade inspections may be performed on a sample of blades in a field in lieu of inspecting the entire blade population annually. This is not meant to supersede manufacturer or insurer inspection and maintenance requirements.

Intermediate Inspections

This inspection cycle should be performed at a 3 to 5 year interval and documented with a written report including video and photographs.

- Non-destructive testing (NDT) of the connection bolts connecting the blades to the turbine system is required.
- Close visual or NDT of the blade surface and substructure to identify degradations identified under Annual Inspections as well as:
 1. Bond defects
 2. Structural frame defects
 3. Delamination or other skin material failure
 4. Other defects known to have occurred with similar blades

Access through the root of blade may be utilized where useful for assessing the blade structure. Rope or other access systems will be necessary for some or all of these examinations.

As justified by engineering assessment, a sample of blades for a group of wind turbine facilities may be inspected in lieu of inspecting the entire blade population. Such assessment shall include long-term plans to sample every blade in a field over a specified time period.

Additional Inspections

When anomalous conditions are identified it may be necessary to expand the inspection scope or implement techniques that are able to provide more information for review of the extent of the anomaly. Of primary importance is the adequate documentation of the anomaly before the inspection team is demobilized. Photos, video, sketches and measurements of the anomalous condition that can be made with the available equipment should be taken so that proper response can be determined. A qualified engineer should be consulted to determine the scope and technique of the additional inspection, keeping in mind the access and safety issues involved in getting personnel and equipment close to the blades. Typical additional inspections include:

- Close visual inspections (CVI) from no more than arm's length of the area as necessary with measurements of the anomaly and other investigation as directed by a qualified engineer
- Non-destructive testing (NDT) inspections suitable for identifying damage to blade material

c. Condition Monitoring

Operators are encouraged to take advantage of data gathered through condition monitoring systems, including evaluation of power performance data, to augment Annual and Intermediate Inspection cycles as described above. Where such data is used, its use should be incorporated into the long-term inspection planning process. If such data is intended to be used to replace Annual or Intermediate Inspection requirements, an approved engineering

justification is required including a description of how the data will ensure that the degradations identified via such physical inspections can be identified using this data. Such justification shall also include details of follow up activities to be conducted when condition monitoring data indicates anomalous conditions. This approach is not meant to supersede manufacturer or insurer inspection and maintenance requirements.

Appropriate NDT techniques should be employed to further evaluate the condition of the blade and the blade material if either of the following is true:

- the anomalous visual or power performance results are not due to anticipated blade wear, material buildup or other mechanism considered in the design of the blades
- the operator cannot demonstrate that the anomalous condition will not result in a loss of structural integrity prior to the next scheduled inspection cycle

VIII. Post-Event Inspections

It is prudent to plan in advance how to inspect a facility if it is subjected to extreme event loads. For instance, in the Gulf of Mexico, the controlling loading on a facility is likely to be a hurricane storm event. If, following a storm, it is determined that the wind and wave levels were close to or above the design values, an inspection should be initiated to proactively look for damage to the system. Such assessments have historically been mandated by the MMS in the Gulf of Mexico after major storm events.

Depending on where the facility is installed, the controlling design event may vary. While hurricanes dominate the gulf coast regions, earthquakes are more likely to control west coast facilities. Whatever the controlling event, the post-event goal is the same, identify damage from high load levels.

It is possible to pre-select the areas of most concern that should be focused on during these post-event inspections. Areas of the structure with the highest loads from design analysis are likely to be the first to experience loading above yield, or other limit state, and will likely be the first to present damage after a high load event. Having these plans laid out in advance will save time and allow for a more efficient inspection process in a sometimes hectic post-event environment.

In addition to structural inspections, cable routes should also be examined after design events, especially in areas where design events may lead to cable damage such as from anchor drags during hurricanes or at fault crossings after earthquakes, in order to identify damage or anomalies that could affect power transmission.

It is also important to consider how to determine remotely whether or not the facility is safe to board and if it is not, how to conduct adequate inspections to determine what can

be done to either make it safe to board or conduct inspections without boarding. Experience in the Gulf of Mexico has shown that access systems such as boat landings and ladders are prone to damage and are not always safe to use following a storm. Alternative access may need to be arranged and planning for this in advance can save time and allow for a safer inspection.

a. **Facility Inclination**

The proper operation of a wind turbine facility depends on the verticality of the support structure. Large loading levels expected from a design level event may lead to an inclination of the substructure or tower or both that can lead to loss of operation or an inability to safely board a facility. Post-Event Inspection Plans shall include plans for measuring the inclination of the tower and substructure. Plans should include the following:

- Installation inclination measurements for comparison
- Inclination tolerances defined for safe operation and safe manning
- Inclination measurement technique or techniques to be used. Potential alternatives include
 - Magnetic level bubbles
 - Trim cubes
 - Other electronic inclination tools
 - Photography (provided a sufficient set of photos are taken around the structure to provide adequate data)
 - Acoustic Positioning Systems
 - Other survey tools
- Follow up inspections to identify the cause and location of inclinations in excess of installed inclination level which may lead to operation or manning disruptions. These may require subsea inspections.

IX. Engineering Evaluation

It is vital that all inspections described in the previous sections should be documented in a written report augmented with sketches, photos and videos. These reports should be reviewed by a qualified engineer familiar with the inspection program and evaluated to determine:

- That the inspections were performed as planned and have been adequately documented
- That results of the inspection are incorporated into integrity management plans and future inspection priorities and plans are updated as necessary with the latest inspection results
- 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)

This ensures that the cycle of integrity management is maintained so that anomalies are adequately addressed and future inspections are planned based on the information gathered from previous inspections.

X. Data Requirements

The collection and use of data generated as a result of the inspection process is as important to the long-term integrity management of a facility as the inspection process itself. The responsible engineer planning and interpreting the inspection data requires current information on the condition of the facility in order to rationally plan the inspections and make decisions regarding adequate response to anomalous conditions found during the inspections.

There are various levels of sophistication in data management approaches. It is not the role of this guideline to define what level is chosen by an operator. But some data management methodology must be defined by the operator in order to track the information on the condition of the facilities they manage. Currently in draft form, the API RP 2-SIM document contains useful guidance (see Section 4.2, Data) on what data should be maintained and what approach should be followed for managing that data. Also, the ISO 19902 document, Section 23.2, contains information on data gathering and evaluation as part of an integrity management program that is applicable here.

As a minimum, checklists (see Appendix A for examples) should be developed to track inspection activities and results. These provide a useful means of both prompting the inspector to gather the required information and a recording mechanism to ensure that the data is reported back to the responsible engineer in a uniform and repeatable manner. Appendix A also contains an example of a reporting chart that should be developed for all units managed by an operator for submittal to the MMS on an annual basis. This is similar to the OSTs report required to be submitted for oil and gas production facilities in the Gulf of Mexico.

It is also important that inspection activities both above and below water be documented with photographs and video. These are often invaluable references for allowing the responsible engineer to evaluate the structure's condition and any anomalies identified.

XI. Regional Variations

Different areas of the country will have different environmental factors affecting the condition and operations of wind turbine facilities. These regional variations should be considered when evaluating where and how to inspect different parts of the structure. These variations go beyond loads that will dominate the design of the facilities (e.g., hurricanes in the Gulf of Mexico or earthquakes offshore California). The following list provides some guidance on factors that could affect facilities in different regions but each operator will need to evaluate how local factors impact condition and review their data to determine dominant degradation mechanisms.

Northeast Region (Atlantic)

- Low Temperatures with potential for icing, especially affecting blade performance
- Loading dominated by hurricane storms

Southeast Region (Atlantic)

- More aggressive corrosion environment at higher temperatures and humidity
- Loading dominated by hurricane storms

Gulf of Mexico Region

- More aggressive corrosion environment at higher temperatures and humidity
- Loading dominated by hurricane storms

Northwest Region (Pacific)

- Potentially higher fatigue damage in more demanding operational wave environment
- Loading dominated by earthquake events
- Effect of tsunamis

Southwest Region (Pacific)

- Potentially higher fatigue damage in more demanding operational wave environment
- Loading dominated by earthquake events
- Effect of tsunamis

Alaska Region

- Low Temperatures with potential for icing, especially affecting blade performance
- Loading dominated by earthquake events
- Effect of tsunamis

Hawaii Region

- More aggressive corrosion environment at higher temperatures and humidity
- Potentially higher fatigue damage in more demanding operational wave environment
- Loading dominated by hurricane storms
- Effect of tsunamis

XII. Startup Inspections

Though these guidelines address in-service inspections it is recommended that an inspection be performed of the facility prior to startup. Guidance for these inspections can be found in ISO 19902, Section 21, covering topics such as inspection scope, inspection methods, and documentation. The goal is to ensure that installation was performed according to the standards set forth in the design documents and installation plan, and that the facility is fit-for-purpose.

Appendix A

Sample Checklists and Data Reporting

**Minerals Management Service
Offshore Wind Turbine Facility Annual Inspections Checklist**

Note: This checklist is not a substitute for an integrity management program and data recording system for offshore wind turbine facilities. It is a data summary requested by the MMS.

Operator: _____ Facility ID: _____

Report Year: _____ Year Installed/Water Depth _____

SAFETY / SIGNAGE / MARKINGS

Indicate Yes or No to each item and whether or not Corrective Action (CA) was taken

No.	Item	Y	N	CA
1.	Are walkways, ladders, handrails, stairs and other access systems in good working condition?			
2.	Are warning/safety/instructional signs visible and legible?			
3.	Are markings showing facility identification, water level markings, etc. visible and legible			
4.	Are there obstructions to egress paths (e.g., equipment stored on stairs)?			
5.	Are fall protection anchorage points in good condition?			
6.	Are navigation and aviation warning lights operational?			
7.	Are fire protection systems operational?			
8.	Are there other anomalies noted?			

SUBSEA CATHODIC PROTECTION

Indicate Yes or No to each item and whether or not Corrective Action (CA) was taken

No.	Item	Y	N	CA
1.	Are CP measurements within acceptable range?			
2.	Are there other anomalies noted?			

TOPSIDES STRUCTURE INSPECTIONS

Indicate Yes or No to each item and whether or not Corrective Action (CA) was taken

No.	Item	Y	N	CA
1.	Are there any signs of coating breakdown and/or corrosion?			
2.	Are there any signs of physical damage including dents, holes or other deformation to structural members or nacelle housing?			
3.	Are there any cracks or visible indications at welded connections?			
4.	At bolted connections are nuts noticeably loose?			
5.	Are cables and risers, and their attachments in good condition?			
6.	Are there other anomalies noted?			

BLADE INSPECTIONS

Indicate Yes or No to each item and whether or not Corrective Action (CA) was taken

No.	Item	Y	N	CA
1.	Is there any sign of blade material degradation (e.g., de-lamination)?			
2.	Are there signs of blade damage or erosion?			
3.	Are there signs of corrosion especially at the blade attachment points?			
4.	Are there other anomalies noted?			