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Offshore Renewable Energy

Jacket Foundation Operation and Maintenance: Early Adopter Experience

Cost-effective maintenance strategies.

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Summary

In 2010, when construction began on the Ormonde offshore wind farm, Vattenfall became the first developer to install jacket foundations on a commercial scale. Jacket foundations are a relatively new technology in the offshore wind sector, but it can be projected that as wind farms continue to move into deeper waters and turbines become larger, their use will become more widespread.

In this case study, Ormonde's owner/operator Vattenfall shares its experience of the operations and maintenance (O&M) activity necessary to sustain these structures, alongside its plans for managing the ongoing integrity of its jacket foundations.

Key findings

Experience gained from O&M professionals in the oil and gas sector has helped inform the inspection and maintenance strategies employed at Ormonde. The wind farm is still in a relatively early phase in its overall O&M lifecycle, but the on-site O&M team are already managing both cost and risk by implementing learning gained during the first O&M phase.

Notable outcomes include:

- Using in-house resources alongside external specialists not only delivers cost savings, but is also a more effective way of managing weather risks.
- Use of remotely operated underwater vehicles (ROVs) eliminates health and safety (H&S) risks for divers.
- Regularly monitoring the condition of jacket foundation pin piles helps assess their longer-term integrity.
- Issues around the accumulation of seabird guano require regular and constant attention.

Recommendations

Wind farm operators considering a jacket foundation solution should note these key success factors:

- Ensure original equipment manufacturer (OEM) guidelines are adhered to in order to retain warranty cover.
- Identifying potential failure modes is crucial.
- The benefits of using ROVs instead of divers could be significant and should be explored.
- Up-skilling in-house team members could reduce exposure to weather risks and should be considered.
- While best practice guidelines from oil and gas installations are informative, specific experience of using jacket foundations at offshore windfarms is still scarce; sharing further knowledge in this area should be encouraged.

Introduction

The Ormonde offshore wind farm was the first – and it remains, to date, the largest – commercial deployment of four-legged steel lattice foundations. The site, which is located off the south coast of Cumbria, is owned and operated by Vattenfall. The Swedish company has considerable experience of developing, owning and operating offshore wind farms, having participated in some of the earliest offshore wind demonstration sites. Having acquired the site from developer Eclipse Energy, construction took place between 2010 and 2012. In December 2015, Vattenfall sold a stake in Ormonde to the Swedish pension company AMF, who took a 49% share in the project. Vattenfall will continue to operate the wind farm as majority shareholder.

Each foundation's four jacket legs are anchored into the seabed using pre-installed pin piles with grouted connections to the main structure. The turbine is connected to each foundation by means of a bolted flange connection. The jacket foundations comprise large structures measuring 20 metres by 20 metres at the seabed and weighing in at over 500 tonnes. The pin piles measure approximately 1.8 metres in diameter and extend 20-45 metres into the seabed, depending on where they are positioned. The jackets are fitted with banks of anodes below the water, which offer cathodic protection from corrosion. In addition, the splash zone and above-water section has a coating aimed at preventing corrosion. For the primary steel, a corrosion allowance of 8mm has been made in the splash zone.

Each jacket foundation has two boat landings positioned diagonally at opposite corners. Access to the turbines is by a sloping ladder which follows the angle of each jacket leg. The ladder is fitted with a fall-arrest inertia reel to mitigate the risks of working at height. The scale and size of the foundation is illustrated in Figure 3, a picture taken during the installation phase of the project.

OWEC Tower AS designed the foundations used at Ormonde using their OWEC Quattropod® design. The steel jackets were manufactured by Burntisland Fabrications, of Fife, Scotland, and are designed to stand in water 17-30 metres deep.

Owner Operator:	Vattenfall
Wind farm:	Ormonde
Capacity:	150 MW
Number of turbines:	30
Wind turbine model:	Senvion 5M
Full commission date:	February 2012
OEM warranty handover date:	2014

Figure 1: Ormonde offshore wind farm – key facts and figures

Figure 2: The OWEC Quattropod® jacket foundation installed at Ormonde

Following the project's construction phase, turbine service and maintenance was provided by the manufacturer, Senvion. Vattenfall retained responsibility for the balance of the plant maintenance and O&M services, which were delivered from a combined O&M base in Barrow-in-Furness.

Figure 3: Jacket foundations being installed at Ormonde

The challenge

Developing a foundation maintenance strategy

The maintenance strategy at Ormonde was developed by Vattenfall's O&M team, who evaluated the design information for the foundations. By looking at potential failure modes and key risks, they implemented proactive inspection and maintenance regimes, allowing the opportunity to address and repair issues as they arose. In order to deliver efficient, cost-effective services, increased flexibility and reduced expenditure, the team developed a multi-contract approach. This involved using in-house resources alongside specialist service providers; for instance, weather risks are now managed by using local contractors where possible.

The predicted failure modes and key technical risks on jacket foundations include:

- Failure of corrosion protection.
- Damage to coatings.
- Increased loads due to marine growth.
- Grout/pile movement.
- Scour around leg structure.
- Fatigue damage.
- Ladder and platform fouling, which impedes safe access.

A design review of the jacket foundations was commissioned during the early operational period of the Ormonde wind farm. It was used to identify maintenance requirements in parallel with feedback and experience from the oil and gas industry. In particular, the design review and certification raised three specific maintenance requirements:

- The need to undertake regular epifaunal surveys[1] of the foundations to establish the level of marine growth, and remove growth should it exceed the project design criteria of 50mm.
- Verification that the electrical potential for the cathodic protection is as per design.
- The need to measure the foundations to verify that the structure satisfies the functional criteria for the wind turbine.

It is vital that, when developing an effective maintenance strategy, both the above water and subsea elements of the foundation are considered separately once it has been installed (as shown in Figure 4).

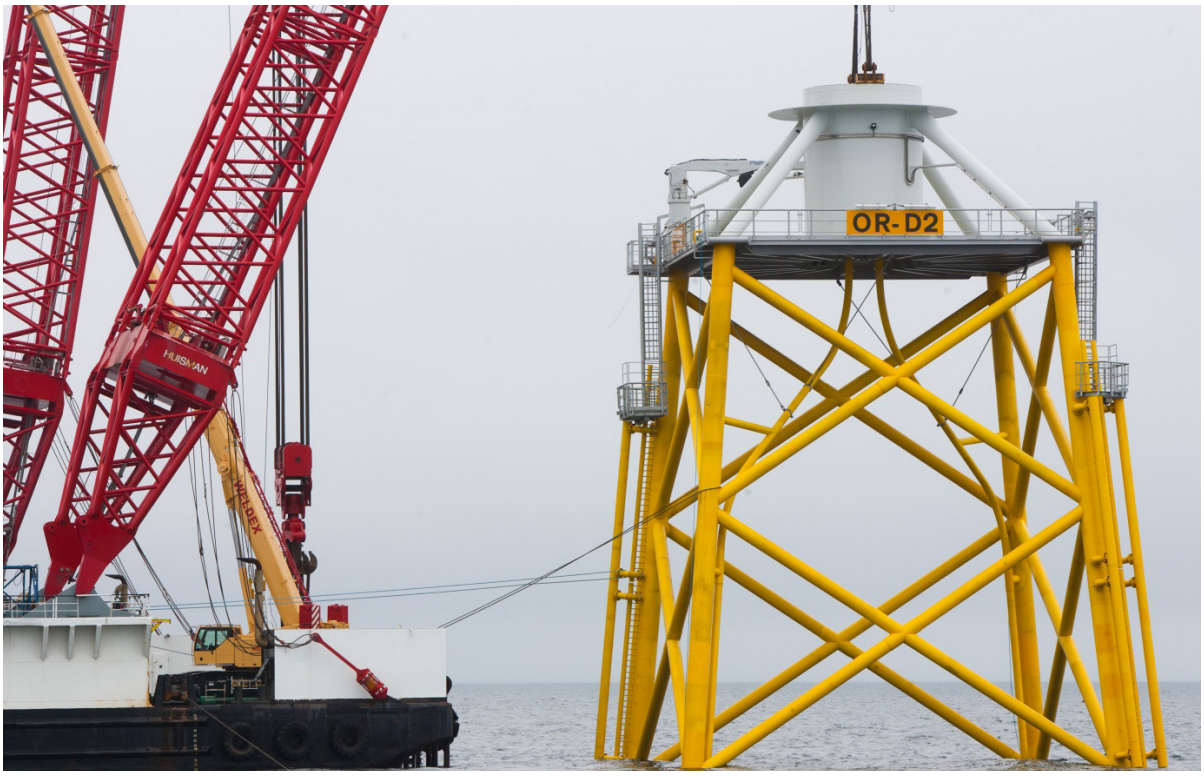

Figure 4: The Ormonde jacket foundation installed at the site

[1] *Epifaunal surveys are used to characterise and count the types of aquatic animals that live on the surface of a submerged object or the sea bed – in this case the underwater portions of the foundation structure*

The approach

The Ormonde O&M team considered a maintenance strategy based on a number of proactive inspection techniques, which are illustrated in Table 1.

Technique	Feature
Visual inspection of the above water structure	Quick and simple inspection technique to identify potential areas for further investigation and to ascertain the general condition.
Detailed inspection of above water structure including non-destructive testing (NDT)	Specialist techniques which may require rope access technicians to access all areas of the above water structure.
Visual inspection of the below water structure	Access using divers or ROV.
Detailed inspection of below water structure including NDT	Access using divers or ROV.
Corrosion protection electrical measurements	Specialist techniques designed to test the effectiveness of the cathodic protection.
Analysis of continuous condition monitoring data	Continuous recording of data from sensors installed on the structure.

Table 1: Inspection techniques used in foundation maintenance strategy

Implementing the foundation maintenance strategy

Key features of Vattenfall's foundation maintenance strategy at Ormonde include:

- The deployment of expert support from in-house paint and civil engineers.
- The use of internal on-site staff to undertake visual inspections of the above water section of the foundations.
- The development of an inspection process, using tablet computers to manage the quality of the inspections.
- All inspection results are uploaded to a computerised maintenance management system.
- Inspections are scheduled every two years and use internal on-site staff.
- The site team uses the results of the visual survey to identify areas for follow-up inspection. Follow-up is carried out by MPM: a local, specialist rope access inspection company based in Cumbria, which has undertaken work at a number of offshore wind farms. As a local company, MPM is able to offer flexible arrangements to better manage weather risks.
- These more detailed inspection works are planned every three years and include paint repairs as well as detailed visual inspection and NDT surveys.

> *"It has been possible to deliver a visual above-water inspection strategy on 100% of the foundations without the need for rope access and solely using in-house resources."*
>
> **John Sharp, Service Leader, Vattenfall**

Implementing improvements to mitigate key issues

Some key issues were identified as a result of general operational experience and the foundation maintenance strategy, including:

- Initial visual inspections identified considerable fouling from seabird guano as a result of birds using the wind farm structures as resting platforms while feeding. Experience at other offshore wind farms has confirmed this as common behaviour, which is difficult to prevent: it allows birds such as cormorants to conserve energy while feeding.
- The size and design of jacket foundation platforms makes it challenging to completely prevent birds from landing on the structure.
- The priority for the O&M team is to ensure safe and effective access around the areas of the two boat landings (as shown in Figure 5). The Vattenfall team developed a successful solution, which entails netting off the sections of the foundation platform around the access and egress areas.
- Regular cleaning with a pressure washer from an access vessel further controls guano levels.
- Minor modifications to Windcat's crew transfer vessel has enabled an ROV to be launched from the stern, facilitating below-water inspections. The ROV and operator is hired in from a specialist company. This innovation enabled Vattenfall to:
    - successfully inspect the pin piles and cable entry points.
    - inspect the cable protection systems and the cable centraliser.
    - assess the level of fouling and condition of the anodes.
    - measure the thickness of marine growth.
    - make cost savings by avoiding the need for a multi-cat charter.
    - exploit favourable weather windows more effectively.
- Side-scan sonar is used to measure the depth of scour holes that have formed around the legs of the structure.
- Condition monitoring equipment has been installed on two of the 25 turbine foundations to measure and monitor any movement of the pin piles.
- A small-scale trial of a self-cleaning mechanism was undertaken. This sits around the jacket legs and rolls up and down with the movement of the tide, preventing the buildup of marine growth.

Figure 5: Vessel access arrangements on the Ormonde jacket foundations

Figure 6: Fitting leg cleaning device to minimise marine growth buildup (photo reproduced with the permission of Found Ocean Ltd.)

The results

Having implemented the maintenance strategy for the jacket foundations at Ormonde, Vattenfall has identified a range of valuable outcomes:

- Vattenfall's in-house O&M team has successfully carried out visual inspections of the above water section of the structure.
- Following on from the initial visual survey results, detailed inspections can be planned and prioritised by the in-house team.
- Detailed inspections by local contractors (such as rope access inspections) provide a flexible approach which helps to mitigate weather risks.
- Scour surveys found a minimal amount of scour, with only small numbers of scour holes of around 1.2m depth identified.
- An ROV deployed from the existing on-site crew transfer vessel avoids the need for additional vessels, thereby reducing costs.
- The ROV is used to inspect the pin piles, cable entry, cable protection and cable centraliser. It also inspects marine growth and anodes, using a variety of specialist attachments on a sample of the foundations.
- The use of an ROV has negated the use of divers and saved considerable time – in one instance, a subsea turbine foundation inspection was undertaken in a single day.
- Condition monitoring equipment has been fitted to two of the foundations, allowing any movement to be monitored and providing a long-term mechanism to check the integrity of the foundations.
- Seabird guano has been a bigger issue than anticipated; this is being managed through a combination of regular cleaning and netting.

> *"The use of an ROV launched from Windcat's crew transfer vessel is an innovation that has allowed us to undertake surveys efficiently and at lower cost."*
>
> **Kevin Jones, Ormonde Site Manager**

The main financial benefit of Vattenfall's novel maintenance strategy has been the ability to internalise the weather risk by adapting an existing site vessel, and making use of in-house resources where possible. The use of local contractors provides greater flexibility when working around bad weather, and the ROV is a more economical option when compared with dive surveys. By avoiding diving work, safety risks have also been reduced. The maintenance strategy developed in-house also has the advantage of third-party certification.

Lessons learned

- Developing a self-led maintenance strategy allows risks to be considered, while at the same time controlling cost and putting the focus on safe and efficient work methods.
- ROVs can be used to replace dive surveys.
- The level of fouling by seabirds was higher than anticipated, resulting in an innovation that controls fouling levels and enables safe access to be maintained.

Recommended reading

A Guide to UK Offshore Wind Operations and Maintenance. The Crown Estate.
http://www.thecrownestate.co.uk/media/5419/ei-km-in-om-om-062013-guide-to-uk-offshore-wind-operations-and-maintenance.pdf

Author profiles

Sally Shenton is the managing director of the offshore wind operations and maintenance consultancy Generating Better. Prior to this, she held the position of operations manager for various offshore wind farms.

Dr Conaill Soraghan is a project engineer with ORE Catapult. He has a background in applied mathematics and completed a PhD in wind turbine design. Conaill's main area of expertise is the management and optimisation of operational assets: he has extensive experience of the design and development of benchmarking systems and data/knowledge-sharing for the offshore wind industry.

Contributors

Kevin Jones is site manager at Ormonde and leads the O&M team for Vattenfall. Kevin has worked in the wind industry since 2005, when he joined Vestas, and supported operational windfarm service activities. At Vattenfall, Kevin has undertaken a number of roles in onshore and offshore wind.

David Blackshaw is O&M manager at Ormonde, and is responsible for servicing, logistics and support. He has worked for Vattenfall for three years, joining as a service leader prior to taking up his current role. David started his career in offshore wind in 2004, working for Vestas at the North Hoyle wind farm as a technician.

This is one in a series of offshore wind O&M-focused case studies, supported by ORE Catapult's O&M Forum and funded by The Crown Estate and the Offshore Wind Programme Board. These studies aim to highlight game-changing O&M projects, and promote the dissemination of knowledge among the offshore wind O&M community.

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