

Offshore Wind Farm Developments and Scouring Effects

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The Marine Renewables Energy Sector is an emerging force in energy provision globally and recent announcements by the UK government have created ambitious targets for the domestic market. In the UK it is driven principally by the Energy White Paper (2003) and, more specifically, by the Renewables Obligation Order. The latter requires electricity suppliers to source 15% of their supply from renewable sources by 2015, increasing to 20% by 2020. The UK is about to overtake Denmark as the world's largest generator of offshore wind power. Eleven sites around the English, Scottish and Welsh coastline have been recently identified by the Crown Estate as suitable to house ranks of giant wind turbines with a capacity for up to 25GW (gigawatts).

Asset Management

From a business viewpoint, the central issue is asset management or, more specifically, asset protection. Substantial amounts of investment have been directed towards development of long-term, safe, offshore power generation, and the maximum return over the full service life on this investment is necessary. Effective asset protection requires an understanding of the probability and any impact(s) of major business risks i.e. application of risk analysis.

One of the chief risks for offshore wind farm developments is that associated with scour around the pile bases and along the length of the cable which carries power between monopiles and to the shore. Although deeper water farms are being discussed, present wind farm technology is limited by the water depth in which foundations can be placed. The cost of grid connection is also a vital consideration. As a result, all the existing Round 1 UK wind farm sites, most of the Round 2 sites and many of the proposed Round 3 sites are in water depths of less than 30m and no further than 12km offshore. The nearshore location of these wind farms means that they are constructed on particularly mobile coastal sediments. It is the movement of these sediments by waves and tides that gives rise to scour.

Addressing Scour Risk

Scour is a serious and ongoing industry-wide issue. It can lead to excessive excavation of the immediate seabed and undercut the foundations with potentially serious consequences for the stability of the turbine. In addition, the structure can suffer increased hydraulic loading on vertical faces and bending stresses on cables, which may exceed design limits. While anti-scour measures are available and the cost of materials is only moderate, the cost of emplacement is high.

So where does this leave developers? How are they most effectively to assess the risk presented by scour? What type of information is required? Consideration of the scour risk early in a project can provide a basis for structural designs to be modified and for the assessment of appropriate preventive (as opposed to remedial) measures. Underpinning and running concurrently with this planning stage is the collection of information and data inputs relevant to scour risk assessment. The range of tools and approaches to collect this information includes field data acquisition, laboratory studies and numerical and physical modelling. An earnest approach to asset protection must evolve in which the best available data is used to undertake the risk assessment and analysis. Acquisition of field data is an attractive option since this involves the collection of data on the natural (often highly specific) sediment and local processes, whereas other approaches (e.g. numerical modelling) inevitably represent these using a range of assumptions.

Understanding Driving Forces

Scour is driven by the motions of the tides, which produce coastal currents, and by waves. Coastal sites highlighted for development can differ significantly due to coastal bathymetry, shoreline geomorphology and orientation and exposure to waves, as well as having a specific sediment composition. These site-specific characteristics give rise to specific oceanographic site conditions. These conditions need to be measured in order to understand the range of conditions driving seabed scour. Is the site wave dominated or tide dominated? Are breaking waves an issue at the proposed wind farm location?

A diverse range of robust instrumentation is now available which can provide long-term unattended acquisition of oceanographic data, and many systems can transmit the data in real time to a shore-based station. 'At a point' flow data (waves, tides) can be

acquired using instrumented bottom-mounted frames, but coastal radar (where the equipment is positioned on the land) is an approach especially suited to offshore wind farm developments because it can instantaneously determine wave and current properties at numerous locations across a proposed site. Regardless of the approach, the key to success is in obtaining long data time series as these permit a thorough description of the site-specific driving forces as well as a statistical (probabilistic) definition of extreme events. Ideally, meteorological and oceanographic (Metoc) data should be collected concurrently with the site assessment meteorological data for e.g. 5 years before site development. In this sense, the risks to development presented by the marine environment are equally as important as the wind resource at the site.

Spatial Mapping of Scour Risk

A holistic approach to scour risk assessment involves collecting field knowledge on the natural sediment transport across the entire site throughout the seasons, together with information on the sub-surface sediment stability. In order to judge whether the flows due to the tides and waves are capable of eroding the bottom sediments, a benthic flume is required. Benthic flumes are marine instruments which can apply a controlled flow across the surface of sediments and measure the ensuing erosion (Figure 1). Flow magnitudes over and above those naturally occurring at the site (as expected to occur around monopile base) can be applied to the sediment, and in this manner the scour rate at the pile location can be derived. A benthic flume survey might involve repeat measurements geospatially across a proposed site, thereby providing engineers with a map of surface sediment transport (Figure 2). This partly reflects the localised scour risk.

Understanding Scour Process

Front-end engineering design (FEED) requires some estimation of the development of scour through time. Although scouring removes sediment from the base area of monopiles, sediment transport during lower energy periods can back-fill the scour pit, repeated throughout the winter and summer. Designing to accommodate or mitigate scour requires a level of information on the temporal variability of scour, and the FEED process can benefit significantly from an understanding of the pattern and magnitude of these changes. Remarkably, such information is not collected by the offshore wind industry on a routine basis, and yet the sonar technology (similar to that used in bridge scour studies) exists to collect this data simply and automatically at offshore sites. Long-term meteorological measurements precede site development and it should be the case (as for the hydrodynamic data) that concurrent long-term measurements, even at only one or two turbine locations, are made to support site development.

Measuring Potential Scour Depth

Scour involves the vertical (downward) excavation of the sediment column and therefore some knowledge is required on the down-core sediment stability. The only means of measuring this is by collecting cores and to sequentially erode down through the sediment layers. This requires a specialised laboratory apparatus (a vertical profiling flume, VPF). Worst-case hydrodynamic events (e.g. major storms, combined wave-currents) can be simulated in the VPF to derive the maximum expected scour depth during the development lifetime. As with the benthic flume work, cores for scour profile assessment should be collected from across the site. Data from the surface sediment transport map and down-core sediment stability measurements can be drawn together in the form of a scour risk map. Collection of data of this type can drive different engineering designs for the piles or underpin the choice of scour protection as well as direct scour protection to where it is most needed.

Acquisition of strategic data on scour can be integrated within the Environmental Impact Assessment (EIA), which is a necessary requirement of the consents route. Long-term hydrodynamic data, and data on in situ scour patterns at one or two localities, can be collected throughout the duration of the EIA in order to provide an appropriate time series. Cores for scour profile assessment can be acquired during the geotechnical site investigation (SI) stage. Since the flume needs only to be positioned on the seabed and left unattended to collect data, deployments of the flume could also be undertaken during the SI phase. The collection of field data for a holistic scour assessment does not therefore require significant additional resources, and is not logistically onerous or exceptional. The cost of acquisition of these data types is a factor that is high on the agenda of developers, but the comparative costs (e.g. in relation to the geotechnical SI to overall EIA costs) are always going to be low, even for projects which are farther offshore. Furthermore, use of state-of-the-art automated data transmission technologies to relay the various data to shore-based (e.g. Web, GIS) systems provides a far lower data loss risk to developers. With over 900 turbine locations due to be developed in European seas in the coming decade, integration of an effective scour risk assessment during the site development EIA forms an essential, and increasingly important, factor in asset protection.