THE ROYAL INSTITUTION OF NAVAL ARCHITECTS

ACCESSING THE FAR SHORE WIND FARM

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SUMMARY

To date, all offshore wind farms constructed have been relatively small and positioned relatively close to a safe haven with personnel transfer times in the order of one hour. Round 2 and, in particular, Round 3 offshore wind farms will result in wind farms firstly being positioned significantly further offshore and secondly consisting of a much larger number of wind turbines. The increase in distance offshore will result in significant operational challenges for the transfer vessels without a fundamental redesign in the wind farm support vessel fleet.

Transporting wind turbine technicians further offshore will require a change in the current regulations applied but, more importantly, it will be vitally important that the vessels are designed to operate comfortably in the rougher sea conditions likely to be encountered and longer transit times in the far shore wind farms, in order to minimise seasickness amongst the personnel, and also provide safe transfer.

This paper assesses the likely availability and operability of wind farm support vessels based on the environmental conditions and the likely requirements for future vessels in order to meet the predetermined servicing requirements, and suggests a forward looking strategy.

1. INTRODUCTION

The European offshore wind industry is undergoing a huge expansion programme. In the UK alone, the expectation is for 25 GW of offshore wind power by 2020, with a maximum planned potential of 32.2GW. Currently the largest offshore wind turbine installed is 5MW, therefore 25GW equates to 5,000 offshore wind turbines.

The installation of large scale wind farms at increasing distance from the shore will result in a significant operational issue when it comes to planned maintenance for wind turbines, let alone unplanned maintenance. Currently, a standard 5MW wind turbine requires a planned maintenance period once a year of 5 days for 3 technicians, a total of 15 man-days.

Whilst significant investment is being made into researching technologies for construction and installation vessels, in the opinion of the authors not enough research is being undertaken in determining the best solutions for supporting and maintaining the offshore wind farms.

The vast majority of the wind farms constructed to date share the common properties of being relatively close inshore (ie. within approximately 10 nautical miles from port) and comprising only a small number of turbines (ie. less than 100). With these vessels operating near to the shore the current fleet are relatively simple craft designed within the existing regulatory regime. These vessels will quickly become inappropriate support vessels as the operational requirements call for transfer further offshore and in increasing wave heights.

It is essential that the industry deals with the issue of technician transfer for the larger wind farms sooner rather than later. The design of these vessels must be suited to the operational requirements and the large numbers of vessels required will need time to be designed and built, and there are only a finite number of shipyards.

2. BACKGROUND

2.1 An Evolution in Vessel Design

Like most vessels, the design of the wind farm support vessel has evolved. The offshore wind industry was able to start life taking advantage of vessels already in service for technician transfer duties; these included small work boats and fishing boats. It has quickly become apparent that the vessel of choice for most operators is a small, relatively fast, aluminium catamaran equipped with custom bow fenders for easy step-across to the turbine access ladder. This type of vessel has now evolved into a dedicated wind farm support vessel with custom bow shapes and tailored power installations to achieve a safe friction level for the step-across procedure.

Due to the specific vessel function, variation in the design is somewhat restricted. The overall length of the vessel has started to creep up from around 15 metres to 20 metres, and likely to arrive at the maximum code length of 24 metres. In the UK, the majority of vessels are coded to the UK MCA Small Commercial Vessels Code [SCV]. The SCV Code limits the vessels to a load line length of 24m and the capacity of the vessels to 12 technicians.

Vessels now are fully customised for wind farm technician transfer, with bespoke arrangements, tailored machinery installations as well as better turbine access platforms and procedures. An example general arrangement of such a vessel is shown in Figure 1.

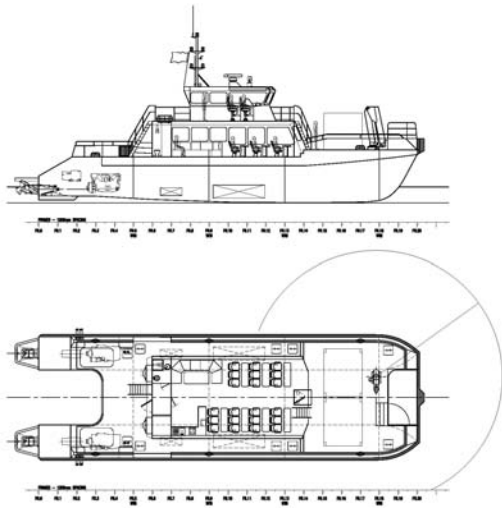

Figure 1 – Typical Turbine Support Vessel Arrangement

However bespoke these vessels are currently, they will not be able to continue to evolve to satisfy the requirements of technician transfer to far-shore sites whilst operating in a more onerous environment.

2.2 An Evolution in Wind Energy Industry

The development of Round 1 wind farms represented the start of what has become a highly progressive policy of wind energy generation offshore in the UK. Round 3 developments are so vast in terms of sheer numbers of turbines that an entire industry will be built over the next ten years. Figure 2 shows the proposed Round 3 sites and Figure 3 shows the relative increase in size and output between the Round 1 & 2 wind farms and those anticipated in Round 3. This magnitude of the growth in offshore wind is summarized in Table 1.

	Total Number of Turbines	Total Power
Round 1	404	1.3 GW
Round 2	2079	7.6 GW
Round 3	6440	32.2 GW

Table 1 - Total Wind Farm Figures

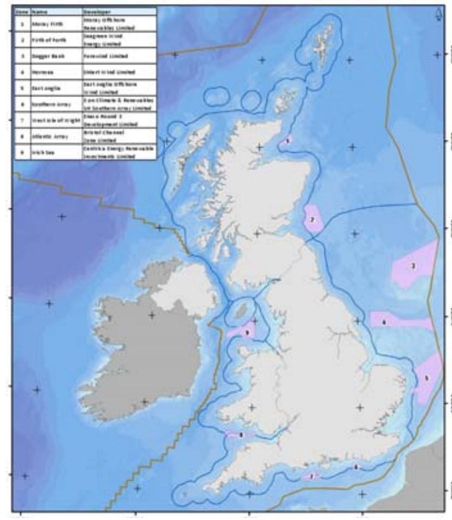

Figure 2 - Proposed UK Round 3 Wind Farms [1]

As an illustration of the proposed size of this industry it is possible to compare the cost of the infrastructure development to other industries. Assuming an estimated installation cost for a single 5MW turbine of approximately £3M, and that all Round 3 turbines are 5MW, the total installation cost when complete will be in the order of £20bn, with a total installed power of 32.2GW. The total manufacturing turnover in the North East of the UK in 2001 was £20bn. Thus, if this industry is to be based in the North East for example, a substantial expansion in manufacturing capacity is required.

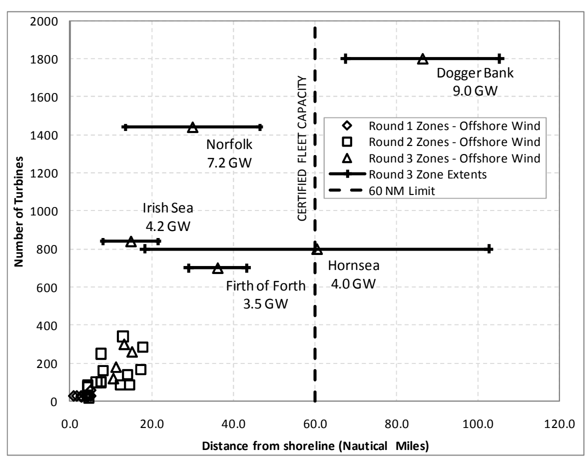

Figure 3 - Relative Size and Distance Offshore of UK Wind Farms

As Figure 3 shows, the majority of offshore wind farms are within 60 nautical miles from shore and therefore could theoretically be serviced by existing vessels operating under the SCV Code.

3. EXISTING FLEET CAPABILITY

3.1 Design Limitations

As mentioned in the UK wind farm support vessels are typically coded using the MCA Small Commercial Vessels Code. Within the code there are limits on the maximum distance from shore which a vessel can operate; anything greater than 60 nautical miles attracts a high level of safety and navigation capability. Given that, up to now, wind farms have been developed relatively close to shore, the application of the SCV Code has normally included the limitation to operate only up to 60 nautical miles from a safe haven. The vast majority, however, have never had to transit anything more than 12 nautical miles from shore given that all but one wind farm to date have been developed within the 12 nautical mile limit, Greater Gabbard lying just outside this. However as already mentioned these existing vessels could theoretically provide support to the majority of the Round 3 wind farms.

It is desirable for a transit from shore to be no longer than around 2 hours given that a normal shift of 12 hours would include 4 hours of travel time. Assuming an average transit speed of 20 knots, this restricts the support vessel to a distance of 40 nautical miles from a safe haven.

3.2 Vessel Capability

As the turbine support vessels have grown, their relative capability in seakeeping has also increased. In order to ascertain how accessible a wind farm is at 40 nautical miles offshore, the vessel motions and its effect on the technicians on board must be measured. In measuring the effect on technicians the most important vessel response is vertical acceleration. The analysis focuses on vessels of three different lengths namely 16, 20 and 24 metres.

A motions assessment on the three catamaran hull forms has been carried out using the strip-theory based VERES seakeeping code developed by Marintek. The three hull forms are geosyms of a single parent form similar to that used in existing turbine support vessels.

The wave statistics used for the vessel motions study were based on hind cast wave data for the North Sea approximately 32 nautical miles from shore in the middle of the proposed site for Norfolk Bank, The wave data was supplied by BMT Argoss and is presented in Table 2.

Significant wave height Hs (metres)	Peak Wave Period (seconds)
0.5	6.1
1.5	6.7
2.5	7.7

Table 2 - North Sea Wave Statistics

The results of the expected RMS vertical accelerations at the centre of gravity of the 24 metre hull form operating in head seas plotted against significant wave height are presented in Figure 4.

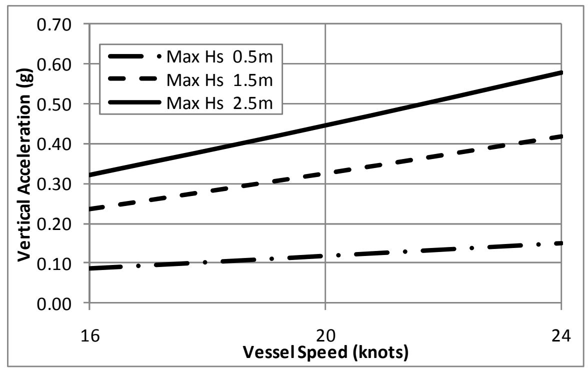

Figure 4 - 24m Hullform Vertical Acceleration

In order to determine limitations for comfort levels for the wind farm support vessels vertical acceleration has been assessed to the vertical acceleration limits of ISO 2631 which provide limiting RMS vertical acceleration against exposure times of 0.5, 1 and 2 hours.

These limits are based on 10% MSI limits for ordinary passengers. In order to ensure a more realistic figure for people more used to travelling at sea, such as the maintenance technicians, a limit twice that of the ISO 2361 has been assumed for this analysis.

The vertical accelerations for all three hullforms, were averaged for head, bow quartering and beam seas and compared to the modified ISO limits, the results are presented in Figures 5 to 7. Using these figures it is possible to approximate the maximum wave height each length of vessel could operate for each speed without exceeding the comfort criteria.

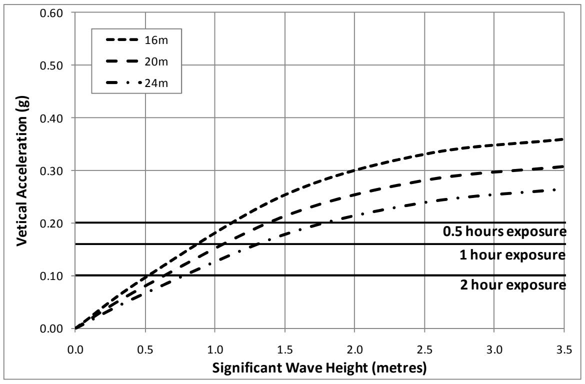

Figure 5 - Vertical Acceleration Response at 16 Knots

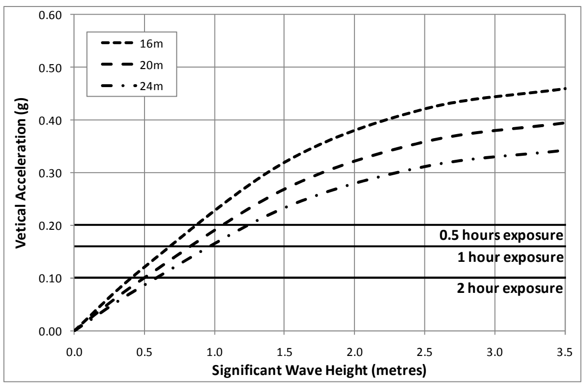

Figure 6 - Vertical Acceleration Response at 20 Knots

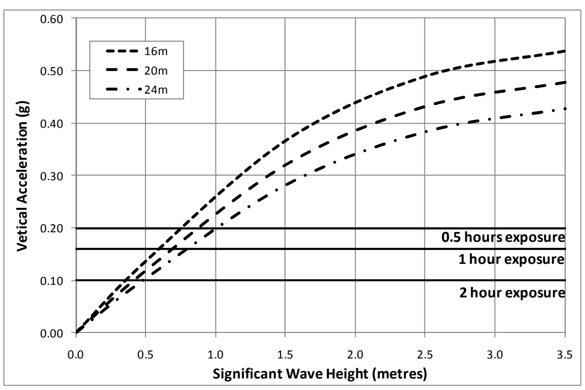

Figure 7 - Vertical Acceleration Response at 24 Knots

4. APPLICATION TO WIND FARMS

4.1 Round 3 Sites

The Round 3 Zone *Norfolk* was used as an example site in this analysis. The site is predicted to have up to 1440 turbines at an average distance to shore of 30 nautical miles. Using this average distance, the maximum wave height at which the vessels could operate at each speed could be approximated; based on the speed, vertical acceleration and exposure data previously presented in this paper. The results of this analysis are presented in Table 3.

Speed	Duration	Max Wave Height		
Kts	hrs	16m	20m	24m
16	1.88	0.59	0.70	0.86
20	1.50	0.55	0.65	0.78
24	1.25	0.54	0.63	0.73

Table 3 - Journey Duration and Maximum Wave Heights

These wave height limits seem low compared to the wave heights in which current wind farm support vessels operate in. However, since the analysis is based on a 30 n.m transit, the exposure time is far greater than that currently required to service existing wind farms. This increased exposure time leads directly to a reduction in the limiting operational wave height for comfort.

4.2 Wave Environment

Wave statistics for the Round 3 *Norfolk* were supplied for coordinates 53° 00'N, 2° 30'E; approximately 32 nautical miles offshore in the middle of the wind farm. The wave statistics in terms of percentage occurrence in wave height bands are shown in Figure 8.

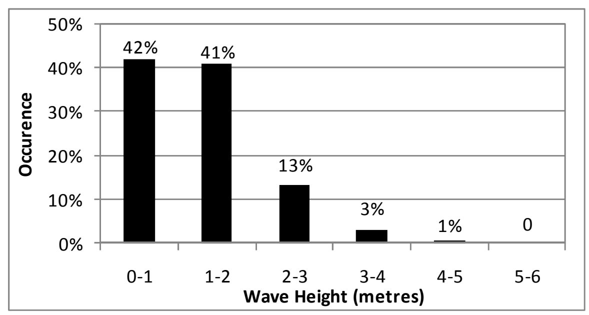

Figure 8 - Norfolk Wave Statistics

For the purpose of this analysis the wave statistics were re-arranged into the percentage of time the significant wave height is exceeded. The exceedance data for the Norfolk wind farm is presented in Figure 9.

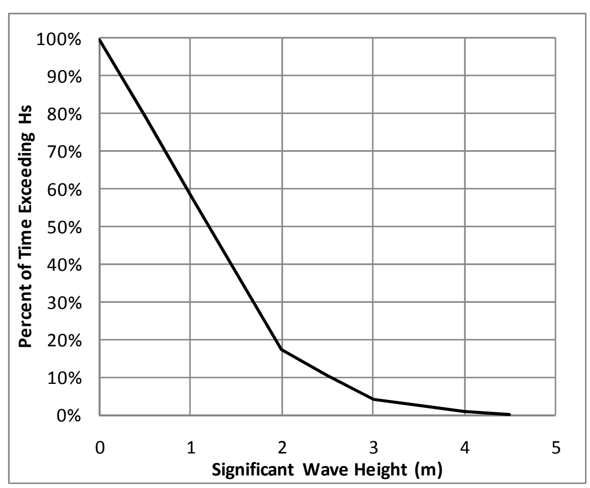

Figure 9 - Vessel Availability vs. Significant Wave Height

4.3 Operability

Using the wave statistics and motions analysis it is possible to estimate the percentage of time the wave height would exceed the limits for each length and speed of vessel and hence determine the estimated availability of the support vessels. The results are presented in Table 4.

Speed	Availability (%)		
Kts	16m	20m	24m
16	25	29	36
20	23	27	32
24	22	26	30

Table 4 - Vessel Availability

The operability does not take into account the wave height limitations affecting the technician transfer 'step-across' process at the wind farm tower. This limitation is also a key driver for the operability and hence availability of the vessels and would need to be investigated fully in the support vessel design. It is however beyond the scope of this paper.

It can be seen from the data presented in Table 4, that in the case of the 16 metre hullform, travelling at 16 knots, the availability is 25%. This equates to the entire fleet of support vessels and their technician only working 91 days of the year, the remaining 274 days of the year would be spent on call, waiting for the sea to calm.

4.4 Turbine Maintenance Regimes

The required number of support vessels per site can be estimated based on the estimated number of days per year that the vessels are available and the maintenance regime of 3 technicians working for 5 days for scheduled maintenance per turbine.

The required number of vessels for the Norfolk Bank farm, which will consist of 1440 turbines, has been identified in Table 5. The number of vessels ahs been calculated assuming 12 technicians per vessel with each vessel accessing 4 turbines in one trip. It is also based on the assumption that each turbine requires 15 man-days of scheduled maintenance per year.

This estimation does not take into account unscheduled maintenance which would of course increase the required number of vessels.

	16 metre Vessel	20 metre vessel	24 metre vessel
16 knots	21	17	14
20 knots	22	19	16
24 knots	22	19	17

Table 5 - Estimated No. of Vessels Required for Norfolk

These results demonstrate that increasing the service speed of the vessels, though reducing the transit time, decreases the availability due to the vertical accelerations increasing above acceptable limits. Thus more vessels are required. The larger vessels are more capable of operating in larger wave heights, increasing their availability and reducing the number of vessels required.

More vessels leads directly to a requirement for more technicians and low availability results in low utilisation of these technicians.

4.5 Improving Operability

By increasing the sea keeping ability of a wind farm support vessel, the operability and subsequently the availability of a vessel can be increased. It follows that the number of boats required for a given site can be reduced.

Fewer vessels would potentially result in lower capital costs and would likely reduce overall operating costs. This is of course dependant on the technology employed to improve the operability.

A reduction in vessels also results directly in a reduction in the number of technicians required. With the vessels in operation more days of the year, the operating company will be paying less for having vessels and technicians on standby.

Take the 24 metre hullform as an example, with a service speed of 20 knots. The number of vessels and technicians required are greatly reduced by increasing the sea keeping ability in terms of the limit of maximum significant wave height. If the wave height capability were to be improved from say 0.78m to 1.5m the number of vessels required would half as would the number of technicians.

Wave Height	Vessels	Technicians	Availability
(metres)	(#)	(#)	(%)
0.78	16	192	32
1	12	144	42
1.5	8	96	62
2	6	72	83

Table 6 - 24 metre hullform, at 20 kts for Norfolk

4.6 Means by Which to Improve Operability

There are numerous methods to increase the sea keeping ability of small marine craft such as the wind farm support vessels, three of which are discussed below.

Active ride control could allow the vessels to operate in wave heights up to 20% higher; however this would result in a small increase in the cost of the vessels. For example considering the 24 metre hull form in Table 6, an increase of 20% in wave height capability would reduce the number of vessels required by 4, saving millions of pounds in vessel costs and hundreds of thousands of pounds in technician costs per year.

Increasing the length above 24 metres would definitely increase the operability of the vessels. However, this option would again increase the construction and operational costs of the vessels. Furthermore, this option would require a change in the regulations governing the operation of wind farm vessels to allow for the increase above 24 metres. An added bonus to the increase in vessel size and amendments to the regulations could be that more technicians may be transported per vessel. This would reduce the number of vessels required per site even further.

A third option would be to employ a small water plane are twin hull (SWATH) type hullform design for the support vessels. SWATH hullforms have the potential for significantly reducing some of the ship motions, over a similar size catamaran hullform. SWATHs however are generally perceived as being much more expensive to build and significantly more expensive to operate with regards to fuel consumption, etc. However, significantly reducing motions would vastly reduce the number of vessels and technicians required. Furthermore, using SWATH hullforms could considerably increase the availability of the vessels, greatly reducing the costs of having the vessels and technician on standby.

5. CONCLUSIONS

It is clear from this investigation that current wind farm support vessels will not be appropriate for accessing far shore wind farms. The increases in wave height will result in low availability due to increased exposure times and high vertical accelerations. The size of fleet required to accommodate the reduction in vessel availability, along with the number of technicians, is not in our opinion economically practical.

More effort is clearly required to increase the operability of the far shore wind farm vessel in order to meet these service requirements. In order to improve the operability different technology from the currently accepted wind farm support vessel will be required.

6. REFERENCES

1. **THE CROWN ESTATE**, 'Offshore Wind - Round 3 Zones', 15th January 2010.

7. AUTHORS BIOGRAPHY

Conrad Cockburn holds the current position of Senior Naval Architect at BMT Nigel Gee. He has experience from a wide background and good academic credentials. He currently focuses on pure Naval Architecture with a bias towards the renewable industry. As a Senior Naval Architect he is responsible for the development of Naval Architecture packages for large design projects. Conrad Cockburn is a Chartered Engineer and Member of the Royal Institution of Naval Architects.

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