Concept Design of an Unmanned Surface Vessel for Offshore Cargo Delivery

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Synopsis

A technological push for the adoption of unmanned surface vessels is afoot in the marine industry, keeping abreast with the developments in the land and aviation transportation sector. The adoption of technology has the potential to improve efficiency and safety of operations, to transfer onshore human activity relating to vessel control and to make working conditions for 'crew' more appealing. Houlder Ltd, with its entrenched vessel and equipment design competencies serving the marine, offshore and defense sectors, has designed the concept of an unmanned surface vessel for offshore operations and maintenance. The project has been undertaken jointly with automation and control and marine logistics experts in the U.K. This paper presents the Houlder unmanned surface vessel concept design, delivering units of cargo to an offshore windfarm monopile platform. The project has been devised as part of the (Windfarm Autonomous Ship) project supported by Innovate UK and other project partners.

Decoupling onboard human intervention from vessel operation has prompted rethinking on the vessel layout and re-examination of the suitability of current regulations. The design considerations have revised the spatial requirements and machinery systems for the unmanned and intended function. Further, the design has incorporated an innovative cargo handling system and its integration to the vessel.

Keywords— Unmanned, Offshore, Windfarm, O&M, Crane

1. Introduction

The word 'autonomy' is gaining attention in the maritime portfolio, particularly for ships involved in liner services, surveys, and coastal security. Besides the end-user benefits, technology advancement such as artificial intelligence and data science are driving the industry to keep the crew onshore. Industry and regulatory bodies like SMI, LR and MCA are developing guidelines for designing ocean-going unmanned vessels including definitions of level of autonomy (Figure 1).

Autonomous vessels are not wholly new to the marine industry. The container vessel named 'Yara Birkland' is planned to move autonomously along the coast line by 2022 [1]. The Rolls Royce led project MUNIN (Maritime Unmanned Navigation through Intelligence Network) has developed an autonomous vessel concept. In 2018, Fin ferries and Rolls Royce successfully trialed autodocking and navigation of the ferry 'Falco'[2].

UK windfarm marine accidents statistics reports that human error is the leading cause of accidents, especially during cargo handling; decoupling human elements could potentially improve safety, accessibility, and efficacy.

The UK has the highest capacity for wind produced electricity globally, and the number of turbines could grow to more than 5500 by 2025 [3]. With many assets commissioned and the number mounting, windfarm O&M now provide increasing technical and commercial opportunities.

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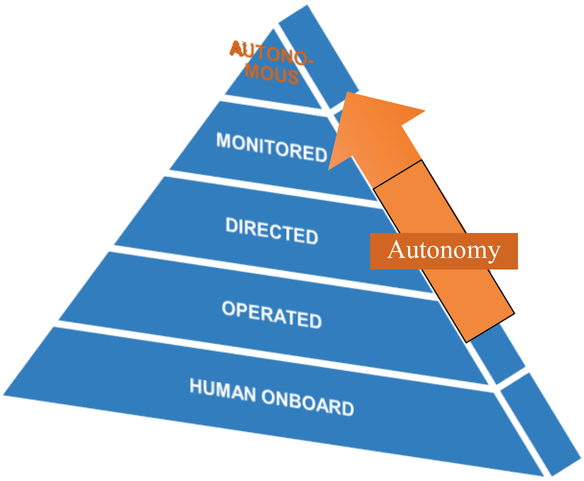

Figure 1 Levels of Autonomy

The key concepts shaping the O&M services are availability, scheduled and unscheduled maintenance, access, and cost-saving. Increasing accessibility seems to increase turbine availability and uptime. Reducing fuel consumption of the vessel enhances the economic efficiency of O&M as fuel approximately accounts for 30% of vessel operating expenditure [4].

This paper discusses the various design elements of the USV (Unmanned Surface Vessel) specifically designed to serve the O&M of the offshore wind turbines.

2. USV Features

The key end user requirement is to reduce the marine related logistics for O&M of wind farm. At present smaller cargoes are transported using Crew Transfer Vessels along with the transfer of maintenance and service technicians. For distant offshore wind farms, the long journey to turbine can be very tiresome and reduce efficiency of technicians. A baseline review of the current and future operational scenarios was carried out and resulted in the following user case scenarios.

- Cargo delivery to SOV
- Cargo delivery to OWF
- Geophysical survey
- Security operation
- In-field crew and cargo transfer

Further, the davit crane on the wind turbine platform requires frequent maintenance. Among the identified operational scenario, the USV design focused on cargo delivery to the OWF. The USV design is primarily focused on the transportation and delivery of medium sized cargo to the turbine platform.

The USV concept (Figure 2) was developed by Houlder working in cooperation with industrial and academic partners such as L3 ASV (vessel control and advanced autonomy), University of Portsmouth (onboard health diagnostics and logistics algorithm), SeaPlanner (logistic management) and Catapult (LCoE model, Cost Performance analysis).

The USV is designed to carry a total of 40 Te of cargo with cargo handling system capable of handling the standardised 1 Te of cargo and reaching 15+ metre height. The vessel's overall length is approximately 25 metres and is designed to perform scheduled O&M tasks. The service speed is therefore low at 9 knots, favouring fuel economy for the selected diesel generator sets.

Figure 2 USV 3D Render

3. Design for autonomy

The traditional ship design spiral was used to design the USV design. The objectives of the design were the operational and economic efficiency of O&M of the wind farm assets.

As no human operate onboard, any breakdown related to the interface between the mechanical system and controls can be challenging. Hence the spatial arrangement and mechanical systems are designed to reduce complexity. Similarly, redundancy and reliability of onboard systems are essential for maintainability. These four key design aspects are focused while conceptualizing the vessel.

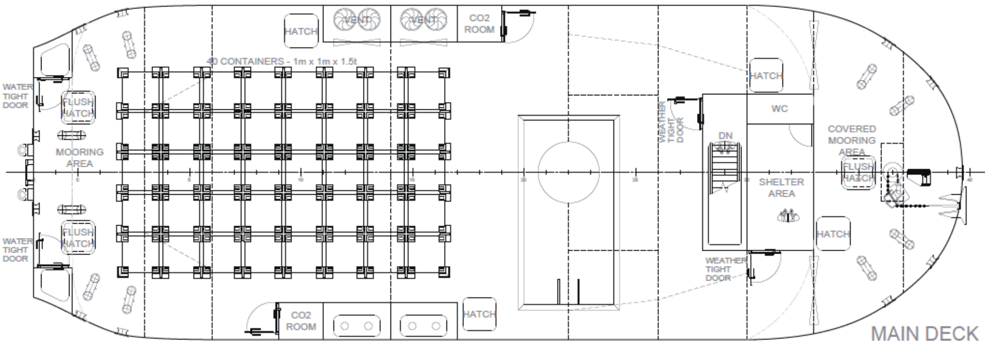

Figure 3 Main deck layout

The USV is 'beamy' (low length to beam ratio) from stability related considerations, and this is expected to affect course keeping. Two skegs are added to improve the performance in the pre-planned routes, in port and other high traffic areas. Course keeping requires further study for the USV to ascertain power required for the azimuth drives.

The USV is equipped with air-conditioned control equipment under the main deck for autonomous navigation and cargo handling. The vessel requires sensors and GPS. The design features include communication with other vessels, both crewed and crewless, and signaling.

The following sections discuss how these design aspects are considered in the USV design.

3.1 Simplicity

As per the main deck layout (Figure 3), the cargo boxes are laid on the main deck with no hatch to simplify operation. The cargo boxes are weather tight of 1m^3 volume and weighing up to 1 Te. The boxes are seafastened using cell guides on the main deck with auto-locking and unlocking mechanism. This layout facilitates picking up the cargo boxes using the crane picking arm.

The bulwarks are raised to reduce the environmental load on the cargo boxes, and enough freeing ports are provided to drain the green water. The crane operation causes concern for vessel stability, and two measures were considered to lower Vertical Centre of Gravity of the vessel, such as bilge keel and dropping down the keel system. The decision to adopt a bilge keel is to avoid the complexity of dropping keel operation. Similarly, a seawater ballasting system is avoided, and an internal ballast system is provided to correct the heel and trim. The cargo box weights can vary and hence symmetrical weight distribution of the cargo cannot be guaranteed about the centerline of the vessel.

The concept of auto docking/mooring is adopted. The vessel propulsion and manoeuvring are achieved through azimuth thrusters and bow thrusters, which also service the dynamic positioning operation.

3.2 Redundancy & Reliability

Redundancy and Reliability are mainly focused on marine systems to ensure the uninterrupted operation and safe return to the port. The vessel is provided with two engine rooms and twin azimuth thrusters, separated by steel bulkhead (Figure 4).

Diesel electric propulsion is selected with multiple and distributed generator sets, electrical distribution equipment and propulsors.

Dynamic Positioning is achieved through two aft thrusters and two bow thrusters. To maintain a safe distance from the wind turbine, dynamic positioning system is provided with redundancy equivalent to DP2 notation.

The selection of the box cooler over a sea water cooling system is based on the system reliability. Battery power is provided in case diesel generator failure or delayed start, to ensure continuous operation.

The Battery power (Energy density) provided for USV is limited but a relatively newer start-up 'Skoon Box' concept could be adapted to swap the battery box with the fully charged one. The spatial

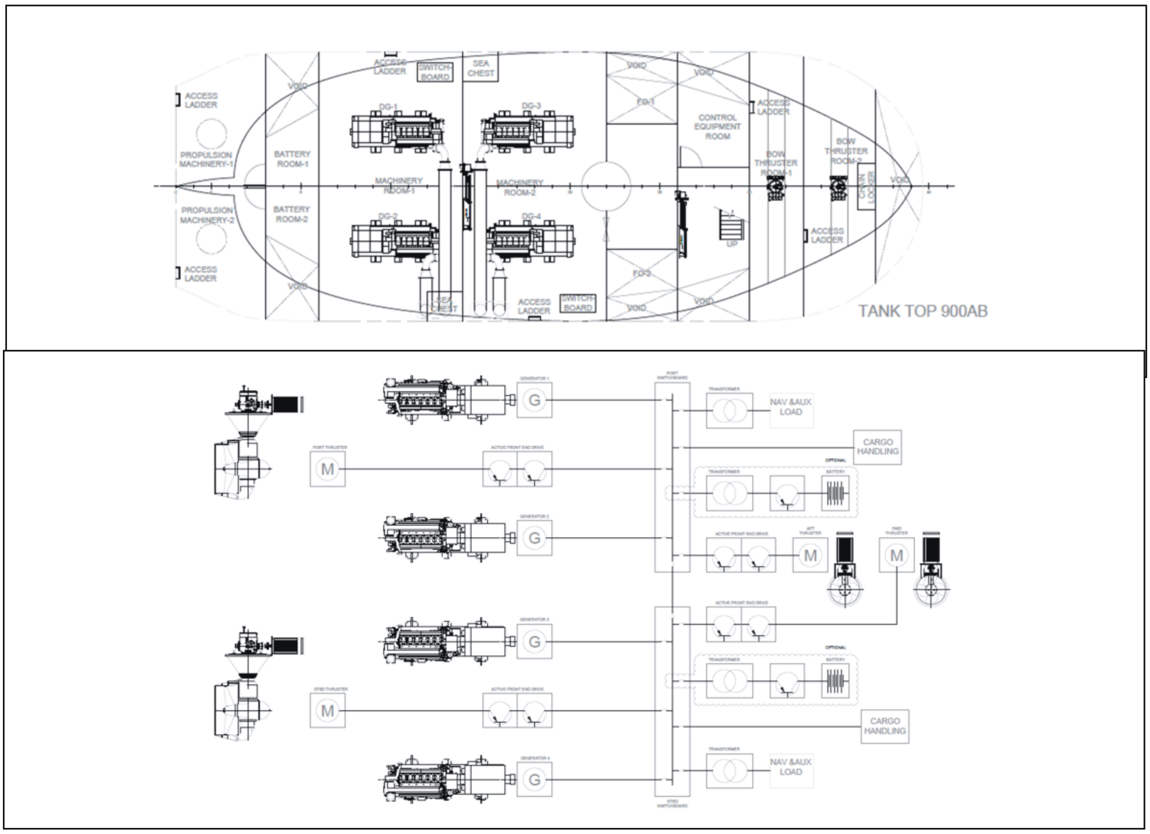

Figure 4 Machinery System Architecture

arrangement to be considered for an easy outreach to the battery room.

3.3 Maintainability

With increased range, it is not always practical to tow the vessel to the nearest port or yard. Access and escape routes are provided for maintenance. Human access for the maintenance is given through the stern boat landing. Marine gas oil is preferred over heavy fuel oil as the latter will call for more frequent maintenance. As the vessel is designed to operate in UK waters, selective catalytic reduction is adopted to reduce NO_x emission. Seamanship systems such as mooring, towing and anchoring are provided in the case of emergency. Inland and coastal transportation with its easier shore communication, network and accessibility for maintenance makes these more attractive to the adoption of USV. The introduction of efficient diagnostics and condition-based maintenance in USV is considered.

4. Automating the cargo handling

An innovative remotely operated crane delivers the cargo boxes to height of 15+ metre over the bow, picking up cargo from the main deck, in environments up to 3 metre significant wave height.
Houlder has developed the crane design providing means of compensating for three degree of freedom using three actuated joints such as slewing, folding and extending functions keeping the crane tip stable while delivering the cargo. Additionally, a luffing cylinder is also provided to pull away the device in case of emergency. The vessel motions, size, equipment weight, cylinder forces and power consumption are benchmarked against similar conventional crane.

The large delivery height above the main deck magnifies even small amplitudes of vessel motion while delivering the cargo to the turbine platform. Therefore, multiple degree of motion compensated crane using hydraulic actuators is provided (Figure 5). The boom tip is fixed in space while the vessel is subjected to pre-calculated motions and the cylinder displacements calculated for full range of motion compensation. The calculated displacement feed to the actuators to estimate the cylinder loads and overall power consumptions. The design assessment in beam sea condition shows that the crane imparts a coupled roll motion to the vessel, and this could negatively affect the transverse stability of vessel. Hence a roll compensating cylinder is also added.

The strength of the crane is checked for accidental case, while the maximum displacements are checked for operating cases. Accidental and operating cases based on wave headings are studied to specify the environmental envelope at which the vessel operates.

Environment with significant wave height up to 3.00 metre are studied for delivery of the cargo to the turbine platform.

Collision risk of the vessel to turbine structures and stability relating to the dropping of the cargo while delivering to the turbine are assessed. Stability assessments are carried out by defining the most onerous loading conditions and applying IS Intact stability code and IMO weather criterion.

The IS code for intact stability is based on the statistics of the damaged or heeled manned vessels. However, this has been retained for autonomous vessel assessments due to dearth of data of unmanned vessel incidents and safe operation. It is considered that the angle of heel after the damage could be reviewed when no humans are onboard.

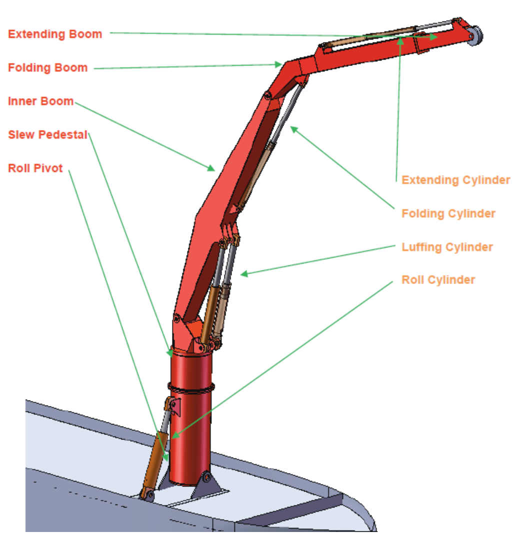

Figure 5 Motion Compensated Crane

5. Challenges and the way forward

Specific challenges to USVs include regulatory, CAPEX, legal and infrastructure challenges.

Intelligent systems onboard, extensive sea trials, expensive digital twin and redundant systems increase CAPEX for USV. Lack of onboard crew, reduction in hotel loads offsets some costs. The satellite cost for communication can be quite high. The reduced steelwork and speed offsets some of these costs.

While cybersecurity plays a vital role in the safety of the USV, hacking the onboard system and taking control can be a threat.

Communicating to a manned vessel or USV nearby, on its position through visual or radio signals as per COLREG, will be required. SOLAS, in its current form, will not apply to USVs with no human onboard. As the vessel operator sits onshore, the international shipping management (ISM) could be better implemented, and the communication can be efficient and fast.

The legal challenges and insurances will be another set of challenge.

Auto mooring suited to USVs requires revamping the port facilities. A system that can automatically drop the anchor in case of a blackout will need development.
The concept design of the USV is being progressed to a basic design stage at Houlder.

Synthetic demonstrations of the Houlder USV simulated in a windfarm environment is scheduled in Q4 2019 in the U.K. The USV function extends to coastal security and hydrographic survey if required.

6. Conclusion

The USV design is primarily driven by simplicity, redundancy, reliability, and maintainability considerations. The vessel motion, stability and crane configurations are the key parameters for the cargo handling vessel function. The course keeping ability of USV needs further study. The USV design shows that accessibility and delivery of the cargo to the offshore wind farm turbine platform in 3.0 metre significant wave height is possible.

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