



Robotics and Autonomous Systems in O&M

Removing the Barriers to BVLOS Operations

Tony Fong | January 2019 | AP-0019

Summary

Robotics and autonomous systems have a key role to play in helping the offshore wind, wave and tidal sectors meet ambitious cost reduction, energy generation, and production targets.

While systems such as unmanned aerial vehicles and remotely-operated vehicles are already in use, performing tasks like turbine blade inspections and subsea surveys, they are currently unable to operate fully autonomously. It is recognised, however, that the introduction of systems that can operate beyond the visual line of sight (BVLOS) could further unlock safety and cost benefits for the industry. For this to happen, a number of challenges must be overcome.

This paper explores the three types of robotic systems currently in use and being developed for use in offshore renewable energy operations and maintenance (O&M), identifies the key barriers to their wider exploitation as autonomous systems, and offers recommendations on how to address and enable their full potential.

Headlines

- Unmanned aerial vehicles are already in use in offshore wind, but the key barriers to their autonomous use include a lack of standardised regulations, quality assurance issues, and their reliance on manual deployment and retrieval.
- Development of unmanned surface vessels with a view to their application in offshore wind, wave and tidal energy is ongoing, but challenges to their introduction include a lack of clarity on cost-benefit analysis and a lack of integration with current marine operations systems and processes.
- Autonomous underwater vehicle technology is already being applied in offshore wind and is being tested commercially for the offshore wind sector. The technology faces challenges around offshore residency in addition to the various issues faced by unmanned aerial vehicles and surface vessels.
- The study carried out by the Catapult indicates that addressing the common issues of appropriate regulation, a lack of industry guidance and standardisation, development of testing and validation facilities, and development of O&M cost models can enable the full potential of BVLOS systems in future offshore O&M strategies.

Introduction

With the UK's growing number of offshore wind turbine assets, the industry is increasing its focus on operations and maintenance (O&M) technology optimisation, cost reduction strategies, and improved health and safety performance.

Autonomous and robotic systems – such as unmanned aerial vehicles (UAVs) and remotely operated underwater vehicles (ROVs) – are already in use within the industry, performing tasks like blade inspections and subsea cable inspections respectively. Currently, many of these technologies are remotely-operated with limited autonomy, and typically require manual deployment, remote operation and manual retrieval of the systems. It is recognised that greater cost savings and increased safety could be unlocked through further automation of these technologies, such that they could operate fully autonomously.

Beyond Visual Line of Site (BVLOS) autonomous systems are capable of operating autonomously without the need for maintained visual line of sight of the operators. These are systems that can operate with varying degrees of autonomy – from being manually deployed and piloted remotely, through to fully autonomous systems that are permanently stationed offshore.

Currently, a number of technology challenges and legislative hurdles present barriers to full exploitation of such systems. ORE Catapult performed a study with three objectives: to investigate key challenges for BVLOS technology exploitation, to identify BVLOS autonomous systems with a high potential for cost reduction, and to produce a technology exploitation roadmap for the offshore wind O&M sector.

Beyond Visual Line of Sight Autonomous Systems

Unmanned aerial vehicles



Figure 1: UAV blade inspection

Manually-piloted unmanned aerial vehicles (UAVs) are currently used in offshore wind O&M for turbine blade visual inspections – an example is shown in Figure 1. UAV inspections reduce the need for specialist rope access, a procedure that can carry high levels of associated risks and costs.

New UAV systems are currently in development by a number of innovators and companies around the world, many with support from industrial partners. However, a lack of standardised regulations, or industry requirements criteria, has been identified as a barrier to their commercialisation.

Challenges around using UAVs in offshore wind

The Catapult consulted with key offshore wind stakeholders across the UK and Europe and identified an appetite for increased automation and a reduction in human offshore operations. The motivation for this is primarily to improve health and safety, and secondly to reduce the cost of O&M activity. UAV systems currently used for offshore blade inspections have a number of associated challenges, including:

Quality assurance

Industry feedback collected by the Catapult indicates that the quality of inspection data gathered by UAVs can vary. This can be associated with a number of factors not limited to: continual technology development, a lack of standards or guidance, and a developing supply chain. The variance in quality in some cases has resulted in organisations preferring to use traditional inspection methods due to the risk of poor inspection data from UAV activities.

Automation

Many systems currently in use are piloted manually. The effect of this is two-fold: it places limits on operating conditions due to human ergonomics and safety factors and adds to the variation in data quality. Manually-piloted systems can be robust, and their adaptability is a strength, but it is anticipated that an autonomous system could carry out repeatable quality inspections with less variance when decoupled from ocean/operator location conditions.

Regulatory

Increasing automation alone unlocks some further potential from UAV systems. However, regulatory requirements within the UK are still evolving around the industrial use of UAV technology. Development of regulation and autonomous technology must be considered together to ensure their full potential can be exploited. An example is the current restrictions on beyond visual line of sight (BVLOS) operations that restrict the use of UAVs to within the line of sight of a human operator. Development of fully autonomous systems to operate BVLOS must take into consideration how this can be achieved with the approval of governing organisations.

Turbine downtime

Under the status quo, UAV inspections require a degree of turbine control. Typically the turbine will be stopped and rotor positioned with blades in a preferred orientation. Depending on the technology in use and the UAV operator's procedures, further turbine manipulation is usually required during the inspection. This enables the UAV to be safely piloted within line of sight conditions, giving enough space for the UAV to be flown while having access to each view of the blade. This can be a limitation as it results in increased turbine downtime and relies on support from the wind farm operator to manipulate the turbine as required.

Deployment and retrieval

Typically, UAV operators deploy and retrieve systems either from the deck of a vessel or by transferring the flight team onto the offshore asset itself. This reliance on vessels and offshore operations can limit the technology operating envelope to that of the vessel and human operating limits such as ocean conditions (wave height). Decoupling the technology from vessel operations could increase the operational envelope of UAV inspection.

Operating location

Typical manually piloted UAV systems require the operator to be within the line of sight of the vehicle such that visual "detect and avoid" flight can be achieved (in accordance to CAA requirements). This means that the operator will typically be located on the offshore wind asset itself, or on a vessel in proximity to it. Again, this means that ocean conditions can limit operations in two ways: by stopping crew transferring from a crew transfer vessel (CTV) to the asset, or by hindering the pilot's health or ability to fly from a non-stationary platform.

Unmanned Surface Vessels



Figure 2: ASV Global's C-Worker 7 autonomous surface vessel.

Research and development is ongoing in the area of unmanned surface vessel (USV) technology for use within the offshore wind industry. There are currently no common commercial uses of USV technology within the sector, however a number of proposed applications for use are currently being developed.

Targeted applications for USVs

Targeted applications for USVs within offshore wind include:

Logistics

USV technology can be used to transport parts and equipment to and from offshore wind farms without the need for a manned vessel. This application would be especially desirable for far offshore sites that use service operating vessels (SOVs) due to long transit times and costs associated with transporting parts and equipment conventionally.

Surveying

Carrying out pre-construction site surveys, e.g. bathymetry mapping, or unexploded ordnance surveys and survey of operational sites, for example to assess cable burial depths.

Monitoring

Carrying out monitoring activities at an operational offshore wind farm, for example to perform sea state assessments, assisting marine operations planning, or security monitoring.

UAV Deployment

Using USVs as operational deployment and retrieval platforms for autonomous UAV inspections, reducing the need for manned vessels such as CTVs to deploy these systems.

Challenges around using USVs in offshore wind

A number of projects are currently being undertaken by technology developers and organisations to develop USV systems for the applications described. The Catapult has carried out stakeholder engagement and is involved with collaborative projects investigating USV technology – for example, the Windfarm Autonomous Ship Project, in partnership with ASV Global, SeaRoc, Houlder and University of Portsmouth. A number of challenges blocking the application of USV technologies to the offshore wind industry have been identified, including:

Regulatory

There is a lack of clear regulatory requirements surrounding the use of USV technology around offshore wind assets. Development of legislation at early stages and acceptance of USV technology by marine operations organisations is required to ensure that the simultaneous operation of USVs and manned vessels can take place on an offshore wind site.

Operations and maintenance requirements

Many concepts for the application of USV technology have been proposed, however a comprehensive evaluation of potential customer requirements is not openly accessible to technology developers.

Quality assurance

A number of technologies using USVs for data gathering and acquisition are under development. Because this data is used for assessment of the site and decision-making, its quality is imperative. Demonstration, validation and qualification at a full-system level – in representative, real-life conditions – is required to assure customers and investors that these new systems meet their requirements.

Cost-benefit

A comprehensive cost-benefit evaluation of applying USV technology to particular O&M applications is currently unclear and not accessible to all technology developers. This information can be used to drive requirements on cost-feasibility of USV systems for particular activities.

Operational logistics and marine co-ordination

A key requirement for the exploitation of USVs in offshore wind is the ability to monitor and communicate with systems in a manner integrated with current marine operations systems and processes. USV operations must have the capability to be managed safely and efficiently in compliance with marine operation rules to ensure that they do not endanger, or interfere with, other operations.

Autonomous Underwater Vehicles



Figure 3: Modus Seabed Intervention's Sabretooth autonomous underwater vehicle undergoes testing at the Catapult's National Renewable Energy Centre.

ROV technology is already commonly applied within the offshore oil and gas sector. Offshore wind has also been employing ROV technology, primarily for inspection purposes (e.g. cable exit/entry inspections). AUV technology is a progression of the ROV, such that they are capable of operating autonomously instead of relying on being remotely piloted.

Targeted applications for AUV technology

AUV technology is already being applied in offshore oil and gas and being tested commercially for the offshore wind sector. Some of the primary targeted applications for such technology include:

Inspection

The primary application for AUV technology foreseeable in offshore wind is carrying out subsea inspections without the need for divers. This includes the inspection of cable entries/exits/burials, corrosion inspection of substructures, and inspection of cathodic protection systems.

Subsea survey

AUVs can be used to provide high-resolution bathymetric surveys of offshore wind farm sites for survey and monitoring of seabed conditions.

Maintenance tasks

Reducing the costs and risks associated with using divers for subsea maintenance and repair is another key application for AUV technology. Proposed maintenance tasks that may be possible using AUVs include cable repair or manipulation, cleaning of biofouling on structures and contact non-destructive testing processes.

Key barriers to exploitation

From the study carried out by the Catapult, a number of key barriers to the exploitation of BVLOS technologies were identified through engagement with the offshore wind industry, supply chain and technology innovators. These challenges are summarised within the high-level barriers described in this report.

Regulatory

The application of BVLOS technology must ensure compliance with relevant legislation and regulations set by the governing bodies. These differ depending on the technology, but can typically be summarised as technologies operating within airspace or marine environments. Airspace technologies, such as UAVs, must comply with Civil Aviation Authority (CAA) regulations when operating within the UK. Regulatory requirements for marine BVLOS technologies are not as clearly defined as the airspace technologies as they are currently in development. The governing body for maritime law is primarily the International Maritime Organisation (IMO), which develops and maintains a framework of global maritime safety regulations. In the UK, the Maritime and Coastguard Agency (MCA) is then responsible for implementing the Government's maritime safety policies.

Any BVLOS technologies operating within the UK are therefore legally bound by the regulations set out by these organisations. Due to the pace of development of autonomous technologies – both in the airspace and marine operating environments – regulations related to BVLOS operations are generally evolving to keep up with the technology as it develops. Unfortunately, due to the time-consuming nature of developing robust legislation, technology tends to develop ahead and suitable legislation follows at a later stage.

This creates a key barrier to the exploitation of such technologies. Developers of innovative autonomous solutions must continue their close engagement with regulatory bodies to ensure the development of future legislation is appropriate for the technology to be exploited and vice versa.

Industry guidance and standardisation

Guidance and standardisation across the industry can be beneficial for customers, service providers and technology developers. Unified understanding of the key requirements for autonomous systems can be of value to each of the stakeholders in a variety of ways.

- Customers would benefit from the validation of O&M service providers to a common fit for purpose criteria by independent organisations, de-risking a wider supply chain with less resource requirement. This could result in more efficient and diverse supply chain as guidance and standards would be more accessible to organisations from other sectors.
- O&M service providers can benefit from the provision of a clear specification of requirements from the customer, allowing for services to be optimised prior to customer engagement and affording the supply chain increased levels of preparation. Additionally, it can enable a more efficient service supply chain where requirements across the industry are unified. This would allow potential service providers from other industries with no background in offshore wind visibility of the requirements for entry into the sector.

- Innovators and technology developers require industry input to drive their developments, but these organisations are often removed from industry. Without access to industry guidance or standards, it can be difficult for developers to target their product development to meet their customer's requirements.

Technology development should be based on customer-defined requirements that are also realistic for the supply chain to develop and provide. Therefore, a key barrier to the full exploitation of BVLOS technology is the current shortage of industry guidance and standardisation on the requirements for such technologies. Robust guidance and standards ensure that developed technologies meet end-user needs, delivering value and benefit to the customer.

The Catapult has engaged with the offshore wind community on the topic of UAV blade inspection quality and received positive feedback from key stakeholders highlighting the value and desire for guidance and standards in this area. It is anticipated that such guidance will assist in the development of suitable technologies and enable technology validation to be performed, de-risking the supply chain for future autonomous O&M solutions.

Technology validation and demonstration

To ensure new autonomous systems technologies meets the requirements of the industry and the standards it has been developed using, a suitable validation must be performed. The validation that ensures BVLOS autonomous systems technologies are “fit for purpose” is a key challenge and a barrier to exploitation for such systems.

To satisfactorily de-risk technology for the industry the importance of representative testing and validation has been highlighted through industry engagement. The offshore wind environment is hazardous and costly for testing and validating of developmental systems and therefore only those technologies with a high level of maturity tend to be tested in the most realistic of environments. This becomes a barrier for early-stage technologies that are low on the technology readiness scale to be tested in a representative manner. As technology and designs mature, fundamental changes to the system configuration will result in larger costs, increased resource and time to implement such changes. This can be a show-stopper for technologies that are only validated in the later stages of development, when costly changes required are unfeasible.

Representative testing facilities with the capability to validate BVLOS autonomous systems for offshore wind O&M are in short supply. This assessment takes into account the limited availability of suitable testing facilities and access to operational assets, as well as the lack of robust test processes for technology validation. Industry engagement has revealed that there is a need for demonstration of integrated systems in operational environments to de-risk technologies and improve investor and customer confidence.

Cost-benefit

Evaluation of technology cost-benefit is complex and often requires knowledge and data, which can be difficult to obtain due to commercial sensitivities. The ability to understand the cost-benefits for a particular application of BVLOS technology is vital to ensuring financial viability for the technology and services it may offer.

Without access to realistic cost models and knowledge, BVLOS technology and service providers face a major challenge to ensure that their products achieve the maximum potential holistic cost reduction. Additionally, the presence of cost models and knowledge can be used to drive innovation in the BVLOS application areas that have the potential to achieve the maximum potential cost reduction.

Recommendations

In order to address and enable the full potential of BVLOS autonomous systems within the offshore renewable energy O&M sector, the key barriers to exploitation highlighted must be addressed.

Based on the findings made through industry engagement and the knowledge gathered by the Catapult, the following actions are recommended to support the adoption of BVLOS systems in future offshore O&M strategies:

- Fostering and continuing industry engagement with regulatory bodies to ensure that future legislation and regulations enable the exploitation of BVLOS technology, and vice versa.
- Development of industry guidance and best practice based on industry requirements for O&M BVLOS operations, to inform the optimal development of new technologies.
- Development of demonstration and validation facilities, assets and processes to enable de-risking of technologies to meet the industry's requirements.
- Development of comprehensive, independent O&M cost models that are capable of assessing the holistic financial impact of the application of specific BVLOS technologies.

Appendices

Author



Tony Fong, Project Engineer

Tony is a Project Engineer focusing on Mechanical Balance of Plant. After graduating from the University of Strathclyde with a Master's Degree in Aeromechanical Engineering, he worked at Airbus and Aquamarine Power before joining the Catapult in 2015. Tony leads a team of mechanical engineers within the Operational Performance directorate and works on projects including supporting the technical development, validation and demonstration of novel technologies within the offshore renewable energy sector. He is also a certified commercial UAV pilot, holding Civil Aviation Authority Permission for Commercial Operation.

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Offshore Renewable Energy Catapult



Inovo

121 George Street
Glasgow
G1 1RD, UK
T: +44 (0)333 004 1400



National Renewable Energy Centre

Albert Street, Blyth
Northumberland
NE24 1LZ, UK
T: +44 (0)1670 359 555



Fife Renewables Innovation Centre

Ajax Way
Leven
KY8 3RS
T: +44 (0)1670 357 649



O&M Centre of Excellence

Ergo Centre
Bridgehead Business Park
Meadow Road, Hessle
HU13 0GD