Predictive maintenance using advanced technology for early damage detection

Words: Stacey Rivers, Chief Innovation Officer at BladeBUG

As wind turbines grow in size and complexity, maintaining them efficiently has become a major challenge. Predictive maintenance and innovative technology, like the BladeBUG robotic platform, are changing wind energy operations for the better by reducing downtime, costs, and risks.

Ensuring the efficiency and condition of turbine blades is key for long-term profitability and sustainability in the wind energy sector. As installations ramp up and turbines increase in size and complexity the challenges of maintaining these massive structures are not scalable using current manual methodologies.

Automated and remote systems, such as the BladeBUG robotic platform, are required to assist and overcome these challenges faced by traditional manual maintenance approaches. The adoption of innovation and new technology is essential to keep pace with the demands and scale of modern wind farms, where costs associated with downtime and repairs can quickly erode profits.

The wind sector industry is turning to innovative, data-driven solutions that use advanced technology and predictive maintenance to reduce the levelised cost of energy (LCoE), minimise risks, optimise performance, and extend the lifespan of these increasingly critical assets.

The growing challenges in wind energy maintenance

Last year saw a record 117 GW of new wind installations, up 50% from the previous year. Whilst this increase should be applauded, collectively 320 GW of annual new installations are required by 2030 to hit COP28 targets and remain on course for the Paris Agreement.

Almost tripling the annual installed capacity is easier said than done, especially when these installations require operations and maintenance (O&M) to operate efficiently with an already stretched workforce struggling with current demand. With larger, more complex wind turbines, sited in remote and further offshore locations, maintaining these critical assets safely and efficiently has become a major challenge for the industry.

Wind turbine blades are a critical element for power generation, and their condition directly impacts the long-term profitability and sustainability of wind farms. Operators face the difficult task of ensuring their assets remain operational while navigating the rising costs of downtime and repairs, creating an urgent demand for advanced and cost-effective maintenance strategies.

Limitations of traditional maintenance approaches

Historically, wind turbine maintenance has relied on periodic manual visual inspections, with aerial drone-based methods being the current state of the art and widely adopted across the industry. Manual analysis of the captured blade images is being automated with machine learning and artificial intelligence to speed up the process.

However, increased costs and extended downtimes are not uncommon from remedial work taking longer due to the damage severity being incorrectly assessed, adding additional time and risk to rope access technicians having to work at height for longer.

Subsurface defects or flaws are not detectable using visual-based systems and appear to be more critical with the new larger generation of blades. There have been some recent high-profile blade failures that have had widespread repercussions throughout the wind industry, from huge losses for manufacturers to sector reputational damage.

These inefficiencies and inaccuracies highlight the urgent need for more proactive, cost-effective strategies. Early damage detection and predictive maintenance offer promising solutions by shifting the focus from reactive repairs to preventive actions.

The synergy between early damage detection and predictive maintenance

With the increasing size and complexity of wind turbines, the importance of early damage detection cannot be overstated. This involves identifying potential issues before they can be detected from visual drone inspections, such as delaminations, disbonds, or fibre wrinkles in key structural elements before they escalate into critical failures.

Cutting-edge technology like condition monitoring sensors, robotics, and non-destructive testing (NDT) methods can reveal subtle and hidden damage or defects often missed by traditional inspections.

Predictive maintenance takes this concept further by analysing a combination of historic and new data gathered from early damage detection technologies and employing advanced analytics to forecast when a wind turbine component might fail, require maintenance and save money through early remedial action.

This predictive capability allows wind farm operators to schedule repairs proactively, preventing sudden breakdowns and costly downtime while extending the operational life of critical components like turbine blades. The correlation between early damage detection and predictive maintenance will be essential for optimising wind farm performance and reducing unplanned downtime.

Key benefits of early damage detection and predictive maintenance include cost efficiency. Timely detection of minor issues allows for low-cost repairs, preventing small problems from escalating into significant failures that are more expensive to fix.

It also leads to reduced downtime, as predictive maintenance minimises unexpected breakdowns, keeping turbines operational and maximising energy output.

Additionally, early damage detection provides crucial data that predictive maintenance algorithms require to deliver accurate forecasts. It extends asset longevity by preventing critical failures, thereby prolonging the lifespan of wind turbine blades and other essential components.

Together, early damage detection and predictive maintenance represent an improved strategy for maintaining wind turbines, ensuring reliability, safety, and operational efficiency. These predictive, high-quality data-driven decisions will be essential as the industry grapples with the increasing blade sizes, complexity, and geographical remoteness of wind farms.

Using robotics and NDT for comprehensive and precise inspections

At the forefront of this technological revolution is BladeBUG, a UK-based deep-tech robotics company that has been developing an innovative platform for inspecting, maintaining, and repairing wind turbine blades. Its robotic platform is designed to walk on turbine blades remotely, offering consistent, repeatable detailed contact inspections performed by generalist technicians, removing any barriers or limitations from using the highly skilled, limited pool of composite NDT experts.

The BladeBUG platform is a compact, easy to use ‘Swiss army knife’ integrated toolbox for the wind energy sector. Its initial offering is in

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remote blade NDT, providing several methods that assess the structural elements of the blades without causing any damage and is essential for identifying and quantifying subsurface defects and damages such as disbonds, delaminations and fibre wrinkles.

If left undetected, these issues can compromise the structural integrity of the blades leading to reduced energy output or worse, catastrophic failure.

A variety of NDT techniques are commonly used during the manufacturing process. However, these are rarely applied to assets in service due to the perceived complexity and specialised skills required. BladeBUG disrupts this norm by facilitating on-site remote NDT inspections with experts able to virtually be on site. This approach provides owners and operators critical insights throughout the entire lifecycle of their assets from production to end of service.

The critical role of NDT for wind turbine blades

NDT is essential for detecting and quantifying critical subsurface damage or defects that remain undetectable using current drone inspection techniques. BladeBUG's agnostic robotic platform enables predefined paths to be followed and areas to be scanned, improving the repeatability, consistency and accuracy compared to technicians working from platforms or ropes.

In addition, its NDT capabilities enable pre-installation inspections, detecting any damage that might have occurred during transportation to the site and be addressed before deployment onto the turbine.

Data-driven precision and remote collaboration

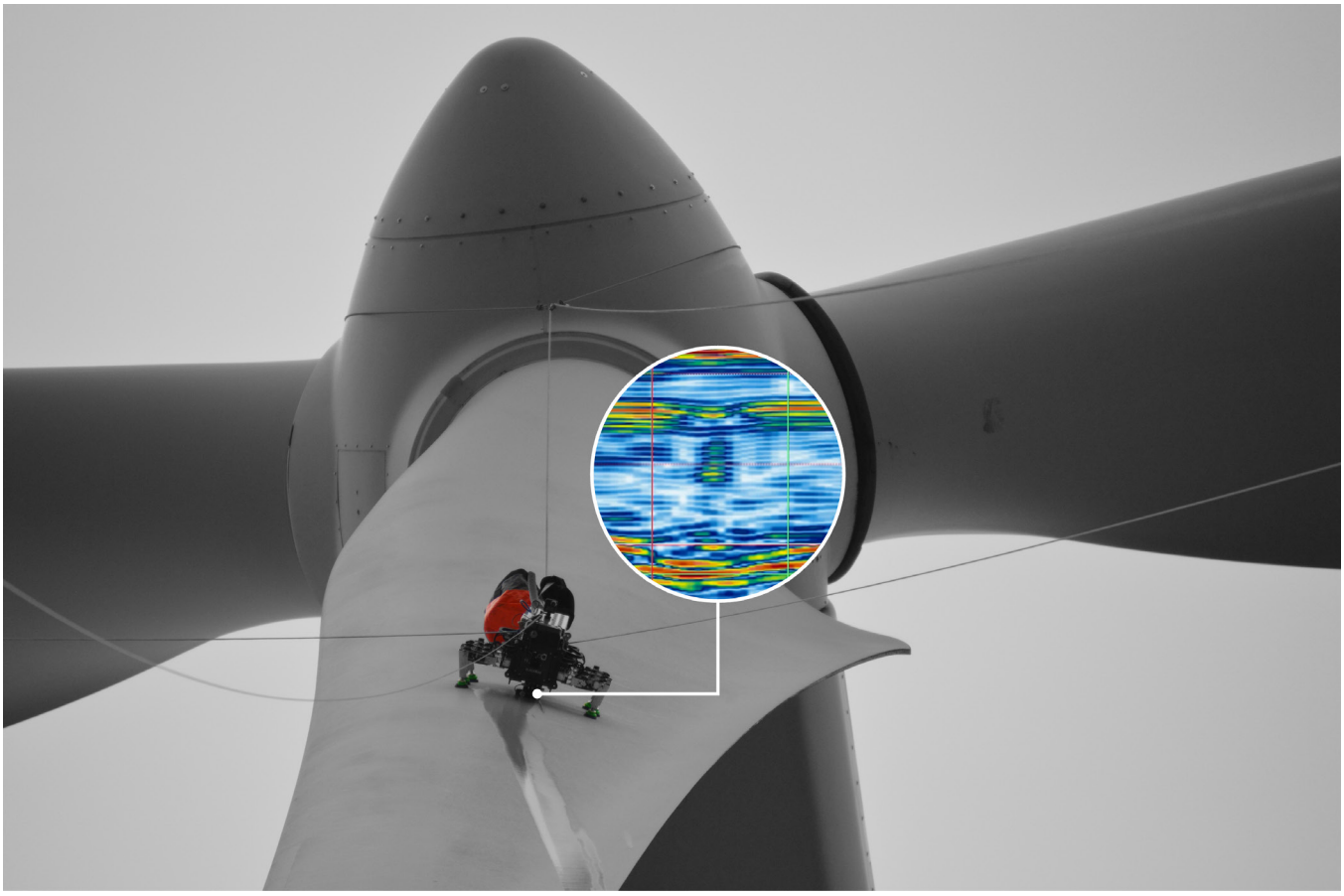
BladeBUG's NDT capabilities enable real-time data collection to be viewed and adjusted by NDT experts remotely, ensuring high-quality data for faster, accurate decisions to be made.

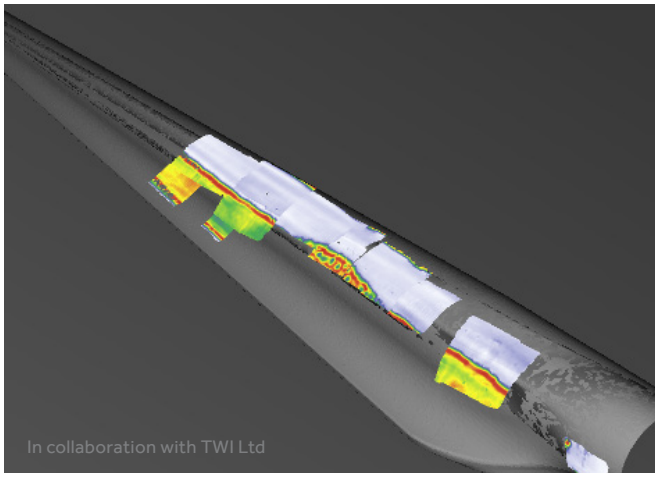
Accurate assessment of subsurface damage enables realistic repair schedules, reducing additional costs from unplanned extended repairs and turbine shutdowns.

Future developments and integrated solutions

BladeBUG has been designed to be agnostic and provide a suite of tools to solve blade inspection and maintenance issues now and in the future. This includes integrating several NDT technologies to ensure that every part of a wind turbine blade can be inspected from root to tip and leading to trailing edge.

The robot has been designed to perform in-situ blade repair to areas it has identified. By equipping the platform with repair tools, it will be able to perform a variety of preventative tasks, improving both the quality and consistency of the repairs.

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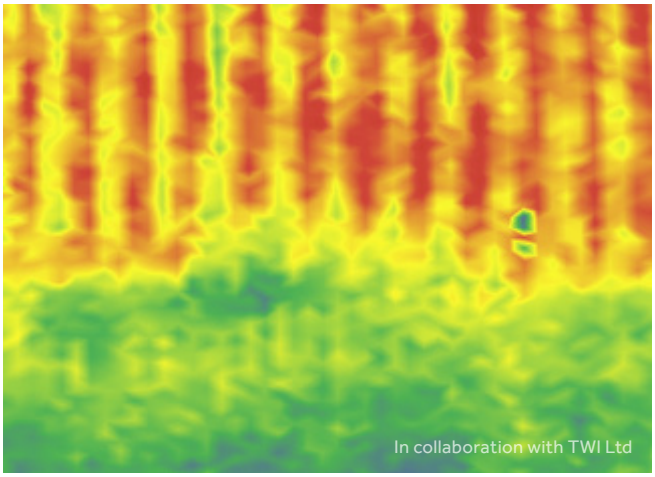
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This all-in-one solution empowers wind farm operators to optimise their O&M strategy to maximise energy generation, minimising costs and maximising the longevity of their turbines.

Collaboration is key: industry partnerships and pilots

New technology cannot deliver products to market without support from the industry. Utilities, owners and operators, OEMs and independent service providers all have a role in bringing new technology to market through collaborating, trialing, and adopting new technologies.

BladeBUG has recently benefited from a pilot with EDP, after being selected to be on the Free Electrons Program, enabling demonstrations of NDT techniques on in-service assets. EDP stated: 'As a leader in renewable energy, EDP is committed to driving the energy transition by seeking innovative solutions that enhance efficiency and future-proof our infrastructure. With wind turbines growing in scale and complexity, traditional maintenance methods are no longer sustainable. Advanced robotic technologies, such as those developed by BladeBUG, offer precise, efficient, and safe inspections in even the most inaccessible locations.

'These innovations reduce human intervention, minimise downtime, and shift maintenance from reactive to predictive, enabling smarter, data-driven decisions.'

Pioneering the next era of wind energy maintenance

The future of wind energy depends on bold thinking, integrated solutions, and strong partnerships. As the industry embraces this advanced technology, the potential for enhanced efficiency and sustainability in wind energy production is limitless.

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