



Understanding blade failure: why surface level inspection is no longer enough

Increasing failure rates across both legacy and new wind turbine fleets are exposing the limitations of optical inspection. Advanced subsurface analysis is enabling operators and OEMs to move from reactive maintenance to accurate repair planning, improved downtime forecasting and proactive asset management.

Across the wind industry, there is a growing trend that is now impossible to ignore. Blade failures are increasing.

This is not limited to one OEM, one geography or one generation of turbine. It is being seen across ageing legacy fleets, midlife assets and newly installed turbines. This is not a future risk; it is happening now.

For legacy fleets, the drivers are relatively well understood. Years of cyclic loading, environmental exposure and repeated repair campaigns are taking their toll. Fatigue is accumulating and repairs have been layered over time, often without full visibility of what sits beneath the surface.

For newer turbines, the challenge is different. Blades are larger, lighter and operating under higher loads than ever before. At the same time, manufacturing has scaled rapidly to meet demand, introducing inconsistency. Across the industry, there is increasing evidence of bonding inconsistencies, insufficient adhesive application, laminate defects and variability in factory and site repair

standards. These issues are now being directly linked to in-service failures.

Despite these different root causes, both legacy and new fleets share the same fundamental problem. The industry cannot see what is happening inside the blade.

Inspection strategies have not kept pace with blade design. The majority of inspections today remain optical, whether via rope access or drone based methods. These approaches identify what is visible, such as cracks, erosion, lightning strike marks and surface repairs. This data has value, but it is fundamentally limited.

Optical inspection does not identify internal bond line defects, insufficient adhesive in spar caps, subsurface delamination, hidden lightning damage or the true quality of previous repairs. These are the defects that drive failure. By the time they become visible, the problem is already advanced.

There is a tendency to describe blade failures as unpredictable. In reality, they are rarely sudden. They are the result of defects that

have existed for months or years, manufacturing defects that were never identified, repairs that did not fully restore structural integrity or fatigue acting on already compromised areas.

These issues are present long before failure occurs. They are simply not being detected.

Minerva Energy, ABJ Renewables and Concept X are global partners delivering WindVue, an advanced blade inspection system designed to address this lack of visibility.

WindVue combines high-resolution optical inspection with thermographic analysis to provide a full understanding of blade condition, both at the surface and within the structure.

Subsurface defects down to 3 to 4 mm in size can be identified, including adhesive inconsistencies, bond line failures, internal cracking, delamination and lightning and LPS damage. The system can also analyse blade structures to depths of up to 15 cm, providing insight not achievable through optical inspection alone.

It has been developed over more than 10 years, with input from and validation by multiple major OEMs, and is supported by ABJ's understanding of applied thermal science in composite structures. This enables optimisation of thermal outputs for thermographic blade analysis.

When combined with optical datasets, this provides a complete picture of blade health and allows direct correlation between visible damage and underlying structural condition.

Optical inspection remains an important part of blade assessment, but on its own it cannot validate what sits beneath the surface. This creates a critical gap.

WindVue closes that gap.

By analysing thermal behaviour across the blade, it becomes possible to identify structural inconsistencies that are not visible externally. This enables operators to detect defects earlier, understand their true severity, and prioritise interventions based on real data rather than assumptions.

One of the most significant risks across both legacy and new fleets is repair quality.

Blades are repaired in the factory, during installation and throughout their operational life. Each repair is recorded and each blade carries a documented history, but in practice, there is often no verification of whether those repairs were completed correctly, if adhesive coverage is sufficient, or whether additional defects exist beyond the repair area.

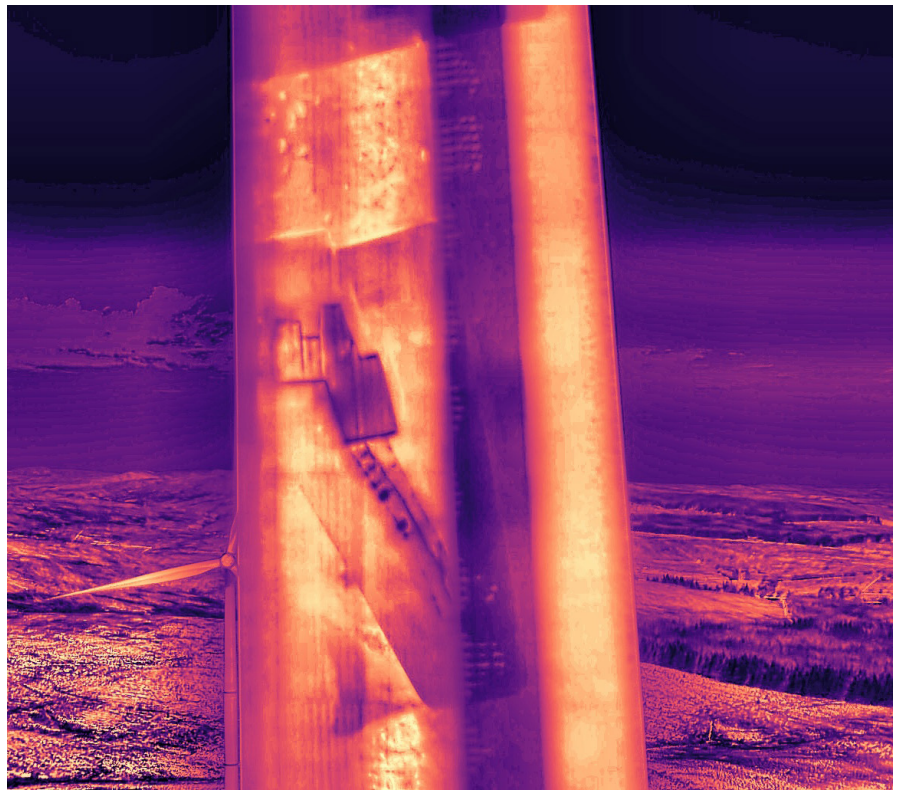


Figure 2²

This creates a disconnect between what is documented and what actually exists on the blade.

WindVue provides that validation. It allows operators to verify factory repairs, audit site repair quality, identify incomplete or ineffective repairs and compare actual blade condition against the blade birth certificate. This introduces a level of transparency and accountability that has historically been missing.

It is not just about identifying defects at a single point in time. The system is designed to track them.

By creating fully stitched 2D and 3D models of both optical and thermographic datasets, WindVue enables complete visualisation of the blade from root to tip, with defect location and sizing accurate down to the millimetre.

Each inspection creates a baseline, and each subsequent inspection allows operators to measure defect growth and track failure propagation over time. This moves blade assessment from a static exercise to a dynamic understanding of how defects are developing under real operating conditions.

The reporting system also provides advanced analytics across multiple levels of the asset portfolio, blade by blade, turbine by turbine and site by site. Operators can score and rank blades based on condition and risk, identify

trends across fleets and prioritise interventions based on data.

The strength of the system is not just in data capture, but in how that data is interpreted.

Concept X's advanced AI-driven analysis and reporting methods, combined with the extensive operational experience of Minerva Energy's blade specialists, ensure that defect identification is not only accurate but directly aligned with real world repair and operational requirements.

This moves the output beyond inspection data and into decision ready intelligence.

This transforms inspection from a reporting exercise into a decision making tool.

One of the biggest gaps in current blade inspection approaches is not just defect detection, it is what happens next.

In many cases today, repair campaigns are still planned with a limited understanding of the true internal condition of the blade. Teams are mobilised based on surface level data, and the reality is only fully understood once technicians are inside the blade. At that point, it is often too late.

We regularly see situations where incorrect core materials have been mobilised, laminate requirements are not fully understood, or the scale of repair is significantly greater than expected. This results in delays, additional mobilisation, extended downtime and increased cost.

WindVue provides the ability to see inside the blade, understand the true condition and act before failure occurs.

WindVue changes this completely.

By providing accurate subsurface visibility, WindVue allows us to map the true repair requirement in advance of mobilisation. We can identify the exact location and extent of internal defects, understand bonding conditions and core integrity and quantify material requirements before work begins.

This ensures repair teams mobilise with the correct core materials, the correct laminates, and the correct consumables. It removes guesswork from the process and significantly improves the efficiency and effectiveness of repair campaigns.

There is also a direct impact on downtime planning.

At present, downtime allocation is often based on assumptions. Once the blade is opened up and the true condition is

understood, repair durations can extend beyond what was originally planned.

With WindVue, operators can understand in advance, with a much higher degree of accuracy, how long each repair will take. This allows for far more accurate planning of maintenance campaigns and turbine downtime.

This has a significant downstream impact. Site operators are able to model downtime more accurately, which in turn allows trading teams to better forecast energy production. That level of confidence in planning has real commercial value.

The combined optical and thermographic approach also removes one of the historical barriers to advanced inspection, scalability.

Traditional NDT methods provide high-quality insight but are slow, localised, and resource intensive. WindVue enables this

level of understanding to be delivered at scale, across entire wind farms, within standard inspection timeframes.

This allows operators to screen entire portfolios, identify high-risk turbines and target intervention where it is needed most.

Blade failure carries a high cost. Not just in repair, but in lost production, extended downtime, vessel and crane mobilisation and increased safety risk. In offshore environments, these costs are amplified.

In many cases, the root cause of failure existed long before the event. It simply was not detected.

The industry is not facing a blade failure problem. It is facing a visibility problem.

Across both legacy and new fleets, critical defects exist that cannot be identified using optical inspection alone. WindVue provides the ability to see inside the blade, understand the true condition and act before failure occurs.

The question is no longer whether these defects exist. The question is whether you can see them.

☐ minervaenergy.org

☐ abjdrones.com

Footnotes:

¹ Thermographic view of a wind turbine providing a different perspective on blade and asset condition

² Thermographic image of an on-site repair showing core patch geometry, bonding variation, and a significant crack tracking toward and along the main spar, highlighting critical defects not identified through conventional inspection

³ Thermographic dataset revealing core distribution, laminate structure, and material thickness, enabling comparison against blade design and identification of unrecorded factory repairs, with this project identifying up to five times more repairs than recorded in blade birth certificates

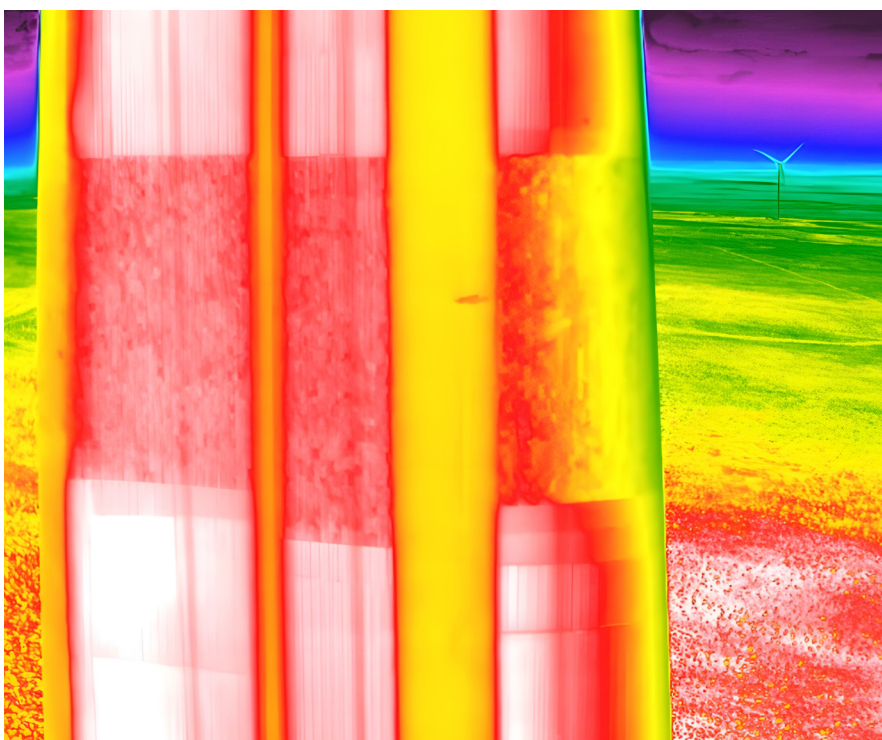


Figure 3³