Leading the way in robotic turbine solutions

The wind industry is expanding rapidly. We are building more and bigger turbines, and with this growth comes new challenges. These high structures are susceptible to various issues: lightning damage, oil leakage, icing, cracks and leading edge erosion. However, the biggest challenge is the lack of people willing to perform the demanding job of manual maintenance while hanging in ropes or baskets. As the turbines increase in size, the areas requiring work also increase, further slowing down the process. Aerones believes that robotization of turbine maintenance is necessary for humans and robots to work together and achieve better results.

Aerones is the first company in the industry to offer robotic repairs, maintenance, and inspections. While we started as a robotics company, we are increasingly becoming a data-driven business.

We offer drone inspections, internal inspections, and lightning protection system (LPS) inspections. We also provide apps for our customer technicians to use during their work, offering insights into what to expect during a job. Our LPS services include drainage hole cleaning, open circuit detection, and a newly launched internal anomaly monitoring system.

Many companies offer drone inspections. Our drone is fully autonomous, requiring only a single click to launch. It performs the entire inspection autonomously, without any human intervention. It is user-friendly and can be operated by our technicians or rented by customers for self inspections. After the drone completes its flight and captures images of the blades, footage is immediately uploaded to the cloud, and a report is generated.

Technologically, our drone stands out due to its 60 megapixel cameras with larger ISO and sensors. These features enable us to capture high-quality images even in less ideal weather conditions. For instance, images taken with our camera on the darker side of a turbine or in poor weather are much clearer and more detailed compared to those taken with lower resolution cameras. You can clearly see details like the blade number on the turbine.

All data is uploaded to our server directly from the field. AI then generates a report, stitching together images of the entire blade. Users can navigate and review the blade from various angles, trailing edge, suction side, pressure side, and leading edge. AI identifies and marks any issues found, noting their size and type, and allowing users to zoom in and out.

Soon we will introduce a feature that allows users to mark erosion spots from previous inspections and track their progression over time. AI will record the progression of the issue and its size, and calculate its potential future progression.

Are drone inspections sufficient? We have occasional discussions with customers about this, and the answer is no. Here are some examples: a blade that appears perfectly fine from the outside may have an 8 meter long category 5 crack inside, which necessitates stopping the turbine.

In other cases, problems seen in drone inspections might not reflect the true extent of the damage. A small pinhole outside could indicate a much larger crack inside.

By conducting both external and internal inspections, customers can make informed decisions about whether a crack extends through the entire blade. Many problems start from the inside and propagate outwards, especially in larger blades. Therefore, internal inspections are crucial and can reveal wrinkles, delaminations, and stress marks earlier than external inspections.

We combine data from both internal and external inspections. In our reports, you can seamlessly switch between drone and internal perspectives to view the same spot. This provides significant value to our customers.

Our internal inspection crawlers are the most advanced in the industry. They feature four electronically driven wheels, and a sophisticated 25 megapixel camera to capture the full blade's interior. A lidar system builds a 3D model of the interior and controls the lighting.

The camera automatically adjusts its angle and takes high-resolution pictures of any issues found, ensuring customers receive data of the highest quality.

The adaptive lighting system, controlled by the lidar, adjusts the light beams based on the crawler's distance from the blade walls. This ensures optimal lighting for the camera to capture the best possible images. Half of the success in image capture comes from the lighting, not just the camera.

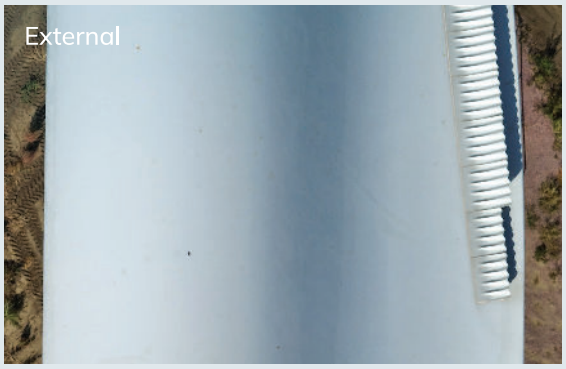
The lidar also measures the size of any issues found, providing precise measurements from a 3D point cloud. The inspection process is streamlined and fast. The crawler is deployed, data is uploaded to the server, the AI identifies problems, and a preliminary report is generated. Our blade specialists then review the data and create the final report.

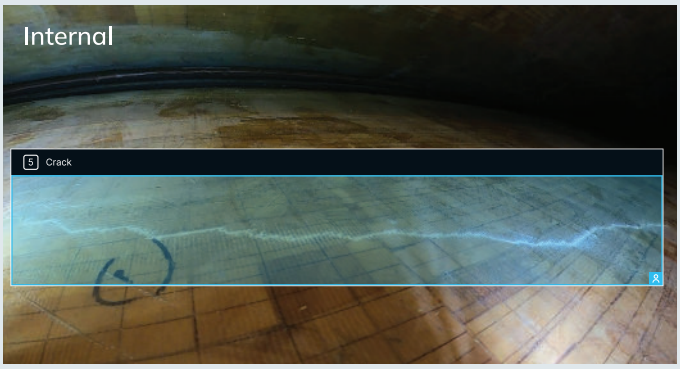
AI is crucial because it examines every pixel, eliminating human error. It consistently finds issues that a human might miss due to fatigue or varying focus. The AI generates a preliminary report, which is then reviewed and refined by humans.

Many customers believe that internal inspections by humans are sufficient, especially since most problems occur in the root area of the blades. However, statistics

Inside out: the full picture of blade health

Combined inspections uncover what the eye can't see, and hidden cracks inside the blade.





Autonomous drone with high-precision imaging

Aerones Blade Crawler GEN 3 with AI-powered fully automated measurements

Combined inspections: no visual damage from outside, crack from the inside

from thousands of turbines show that many category 4 and 5 problems lie deeper inside the blade than a human can reach. Humans can typically access only about 20% to 30% of the blade's length, while our crawlers can inspect almost the entire length.

We conduct factory inspections, after transportation inspections, precommissioning inspections, and regular inspections on spinning turbines both onshore and offshore. Issues are found in all these scenarios. Early inspections and baseline monitoring help prevent blades from failing.

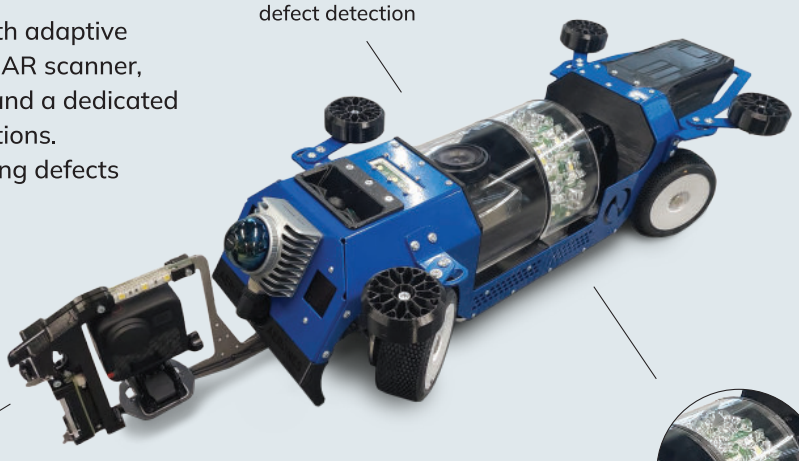
We've observed a rapid increase in category 4 and 5 problems, particularly in the areas where blades are held during transportation. Similar to external visual inspections, we can mark issues found during internal inspections and monitor their growth over time. For instance, we can track the increase in crack size from year to year.

Now we are preparing to launch a feature that gives customers access to raw data from our inspections with the ability to review, measure, categorize and mark up all anomalies themselves. They can also review all anomalies found by our AI and blade experts, and leave comments or request further analysis. Customers will be able to review the data, walk

Next-Gen Blade Inspection

The Aerones crawler is equipped with adaptive LED matrix lights, a powerful 3D LiDAR scanner, a 360-degree front-facing camera, and a dedicated camera module for root zone inspections. The 3D LiDAR is capable of measuring defects with 3 cm accuracy.

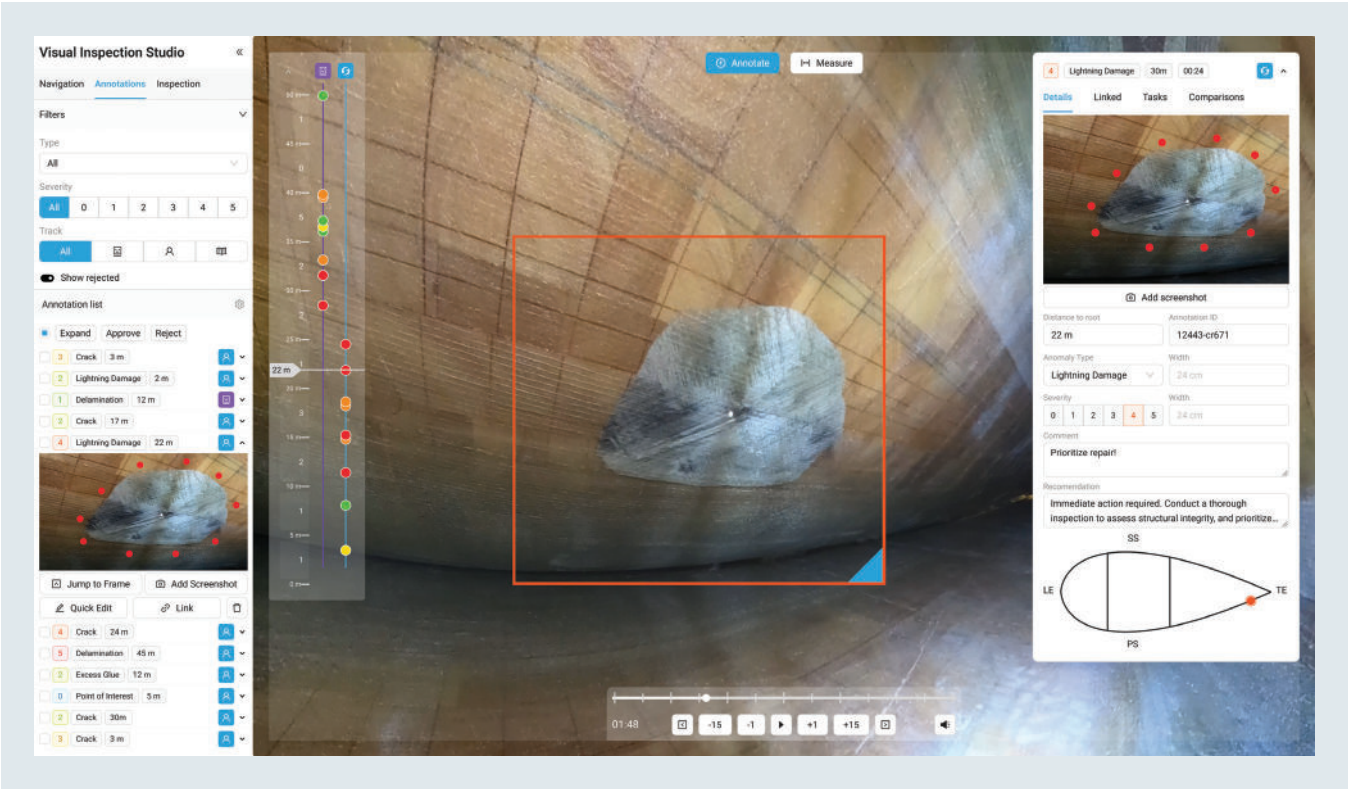
61 MP camera for automated root zone inspection and defect detection



360 degree camera with 5K video resolution to cover 100% of blade surfaces inspected

Lightning modules for bright and even spread to **allow even smallest defect visibility**

Aerones Crawler Gen 3



Aerones Visual Inspection Studio, designed to give customers full access to detailed inspection data

through the virtual blade interior, and mark any issues they find. This provides full transparency and eliminates the need for customers to develop their own data review tools.

We find thousands of issues and conduct thousands of repeated inspections. To understand why and how cracks grow, we developed an anomaly monitoring system. This involves placing small, glued-in cameras inside the blade to continuously monitor identified category 3, 4 or 5 issues. Our technicians are certified and equipped to perform this task during regular internal inspections at no extra mobilization cost.

These cameras capture images at regular intervals, and our AI monitors the growth of the issues. When the growth exceeds a certain threshold, the system automatically sends notifications. We are even considering a system that calls customers if the progression is rapid and the blade is at risk of falling. This system helps prioritize repairs based on issue progression, allowing for dynamic budget allocation.

While we have internal and external inspections and internal monitoring, many issues also require external monitoring. Repeated external inspections can be costly, involving mobilization, travel, turbine stoppage, and restarts. To address this, we developed a system that captures images while the turbine is spinning. This system is unaffected by wind speed, except for rain, and captures high-resolution images.

This system eliminates the need to stop turbines for monitoring. It can be used to monitor potential serial problems or track the growth of existing issues without any downtime or mobilization. We offer zero downtime inspections and monitoring for both internal and external issues.

Are drone and internal inspections, along with monitoring, enough? No. The 'holy grail' of inspections includes internal, external, and lightning protection system testing. More than 50% of turbines are not adequately protected from lightning. We categorize these issues into three main parts: open circuits (broken or damaged cables), broken or poorly connected receptors, and resistance above five ohms.

High resistance in the lightning protection system means that even small lightning strikes will struggle to reach the ground, potentially causing damage to the blades. We find that 20% of turbines have broken cables inside, which can be easily repaired. This highlights the importance of internal inspections in identifying and addressing lightning protection system issues.

Broken cables are often caused by the expansion and contraction of the wires during lightning strikes. Our technicians are equipped to repair these cables on the spot, avoiding the need for extra mobilization. Lightning protection system tests should be conducted based on turbine models, age, and lightning frequency in the area.

In many cases, broken cables are not visible. We use specialized tools to locate open circuits, including a radio signal emitter and scanner, saving our customers time and effort in identifying the problem location. We can calculate the risk of lightning damage and the required inspection frequency based on location, turbine model, and lightning strike data.

Our AI platform gathers data from various sources, internal and external inspections, lightning protection system tests, and operational data, to assess turbine health. This data-driven approach enables us to control risks and plan budgets for optimal maintenance. We also provide tools, such as a technician app, to control our field operations and ensure high-quality work.

Our latest platform updates include a project builder/planner for customers to schedule inspections and track progress. The system also calculates potential idle states based on weather data. We offer a turbine overview dashboard that can be customized to display the desired information.

We believe that transitioning from corrective to preventive maintenance requires comprehensive data about turbines. Technology enables us to gather data and make informed decisions.

Aerones remains at the forefront of innovation, constantly refining its technology and developing new solutions to meet the evolving needs of the wind energy industry. By combining robotics, AI, and data analytics, we are helping to create a more efficient, safe, and sustainable future for wind power.

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