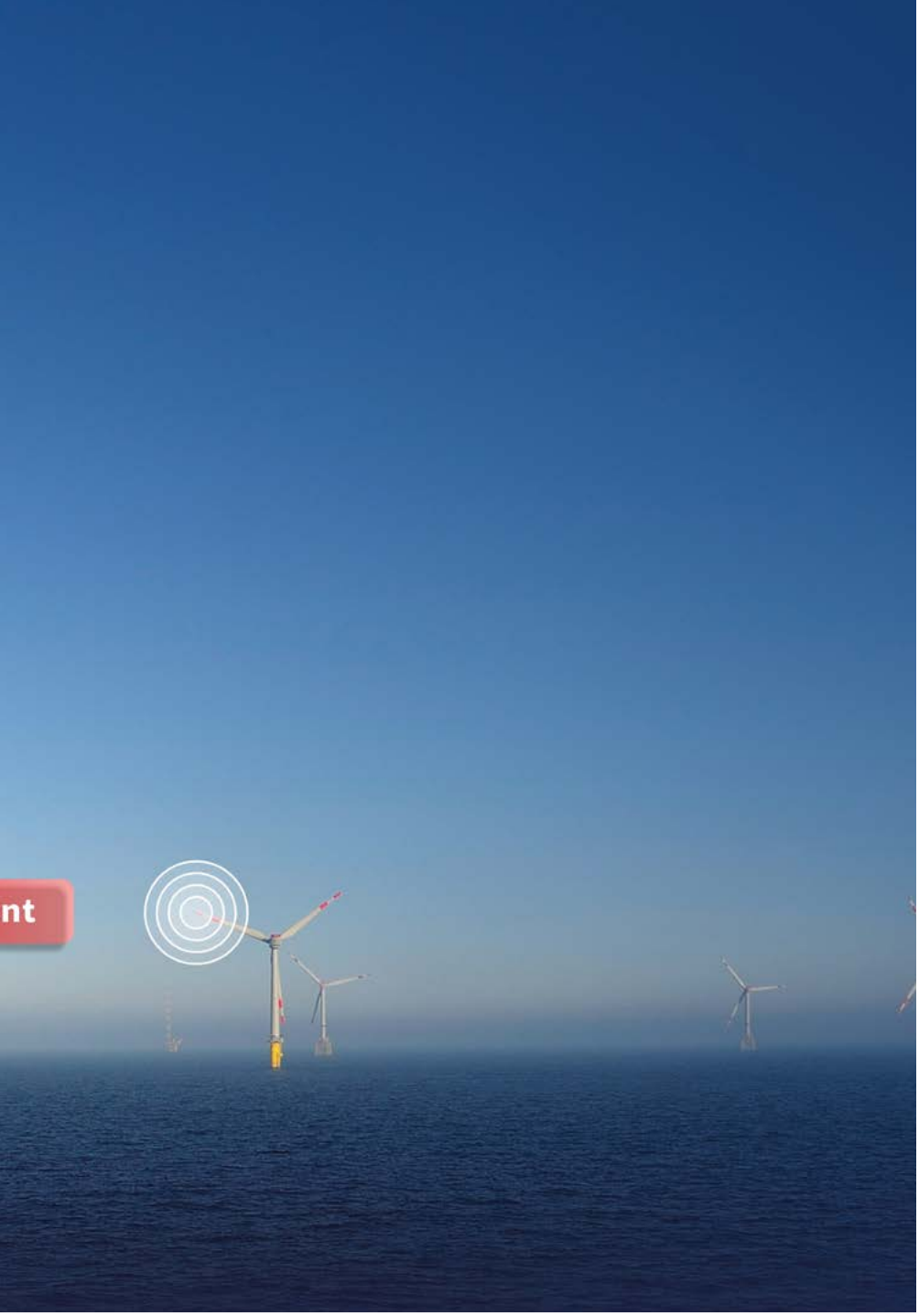

# Driving down LCoE through shape sensing

The wind industry is undergoing an existential challenge in a period where fast growth of wind energy is needed the most. Many factors outside the control of the industry have been increasing the overall levelised cost of electricity (LCoE). However, challenges like unplanned O&M costs, optimisation of lifetime and performance, could be within industry control. More advanced shape sensing solutions can be real enablers in bringing down the LCoE.



### The challenges facing the industry

Contrary to expectations, the LCoE of wind energy is not decreasing as planned. In fact, it is increasing significantly due to a combination of factors, internal and external to the industry. A new geopolitical situation resulted in high inflation rates. Resource scarcity or protectionist movements increased the cost of the supply chain. Furthermore, the push for the fast delivery of larger turbines to drive down LCoE added increased risk and unplanned costs during their manufacture, installation, and operation. These factors are multiplied by the faster and ever-increasing demand to meet the government's renewable targets for 2030 and beyond.

However, if some factors are out of the control of the wind industry, others can, and should be, brought within its control with urgency. We see major OEMs focusing more on standardisation and optimisation of both design and operation of wind turbines in the field. This is a move whereby advanced digitalisation of wind turbines plays a crucial role.

As bigger wind turbines enter service all over the world, the current materials and components are pushed to their limits of performance. Within a wind turbine, the blades are the component that is pushed the most to help reduce the LCoE, as the efficiency of the wind turbines increases to the square of the blade length. Although this push towards bigger blades has supported the reduction of wind energy costs in the past, building them bigger using the same materials and processes is proving to be a big challenge to this industry that is asked to do it faster than ever.

Wind turbine blades have transitioned from a relatively low-maintenance component to the leading problem for some operators. Recent market statements cited quality issues with larger blades as one of the drivers for the current losses being incurred by the OEMs.

The increased power production through the development of bigger blades has been countered by the rising costs due to unplanned maintenance and repair actions hurting the industry. The wind industry needs to better understand the behavior of one of its most critical components: the blades. This new reality calls for advanced condition monitoring solutions to be introduced in these huge composite structures, as the only way to monitor their behavior and health throughout their life.

### How blade shape sensing can help

Longer blades will result in greater tip deflections. This is measured by the Flapwise and Edgewise deflections caused by the aerodynamic and gravitational forces acting on the blade.

Torsional loads at the transition zone also increase with the blade length, up to an exponent of four. This is mainly due to the increased arm created by the tip deflection, causing structural integrity problems at the transition zone.

Wind turbine blade shape sensing technology involves the integration of advanced sensors, such as optic fiber sensors, into the turbine blades. These sensors continuously monitor and measure the real-time shape, deformation, and structural health of the blades during operation. By collecting data on various parameters, including blade curvature, twist, and deflection, the technology provides valuable insights into the aerodynamic performance and mechanical stress experienced by the blades.

### Enhancing efficiency and performance

One of the primary advantages of blade shape sensing technology lies in its ability to enhance the efficiency and performance of wind turbines. By precisely tracking blade shape changes caused by varying wind conditions, turbulence, and loads, operators can optimise the turbine's pitch control and yaw mechanisms in real-time. This optimisation ensures that the turbine operates at its peak efficiency, capturing the maximum amount of wind energy. Manufacturers can move towards mass customisation at scale because a single turbine model can be deployed at various site locations and wind conditions through specific turbine control algorithms.

Moreover, the technology enables early detection of anomalies such as blade misalignment or structural damage. This proactive approach allows for timely adjustments and maintenance interventions, minimising energy losses due to suboptimal blade performance. Ultimately, these efficiency improvements translate into higher energy production and increased revenue, contributing to a reduction in LCoE.

### Reduced maintenance costs

Unscheduled maintenance is a significant cost driver in the wind industry. The blade shape sensing technology plays a pivotal role in reducing maintenance expenditures. By providing continuous monitoring of blade health, the sensors detect even minor issues before they escalate into major problems. This informed and predictive capability enables operators to schedule maintenance activities more efficiently, reducing downtime and the associated financial impact.

Furthermore, the technology assists in optimising maintenance practices. Maintenance crews armed with real-time data on blade condition can perform targeted repairs or replacements, thereby minimising the need for extensive and costly interventions. As a result, operational and maintenance costs are significantly reduced, leading to a direct reduction in LCoE.

### Risk mitigation and safety

Blade failures pose significant safety risks and can lead to costly damage repairs. Blade shape sensing technology contributes to risk mitigation by providing insights into the structural integrity of the blades. Continuous monitoring helps identify stress concentrations, fatigue, and potential defects that could compromise blade performance. By promptly addressing these issues, operators enhance safety for both workers and nearby communities while preventing expensive downtime and repairs.

### Data-driven decision making

The influx of data generated by blade shape sensing technology empowers wind farm operators with a wealth of information. Advanced data analytics and machine learning algorithms can analyse this data to uncover patterns, trends, and performance indicators. These insights enable owners and operators to make informed decisions regarding turbine operation and maintenance strategies. Owners can move from passive asset management into active asset management strategies by choosing to operate their assets between 'Power Mode' and 'Lifetime Mode' and increase their valuation, as well as reduce investment risks and associated insurance costs.

Some of the potential gains and flexibility of using shape sensing solutions are shared below.

### Shape sensing in operation

Fibersail is tackling the industry challenges in a comprehensive manner, from sensor manufacturing and installation to cloud data gathering, processing, and dashboard insights presentation. Fibersail's approach focuses not only on providing new sensing data, but also on ensuring consistent and scalable installation processes, as a way to deliver the data with the required quality.

The focus on data quality brings the need to ensure that the entire data-chain process is properly accounted for. This means that the hardware manufacturing and system setup in the turbine blades are of utmost importance as they are the input of the entire data solution, much like the blades are the input of the entire wind energy generation and turbine condition.

Fibersail's Shape Sensing Condition Monitoring System (CMS) is actively monitoring various wind turbines and delivering transparency on blade operations to all industry segments. From the data gathered locally on the turbines, the data is pre-processed on the edge and then uploaded into the Fibersail Cloud solution where the real data processing and value extraction is done.

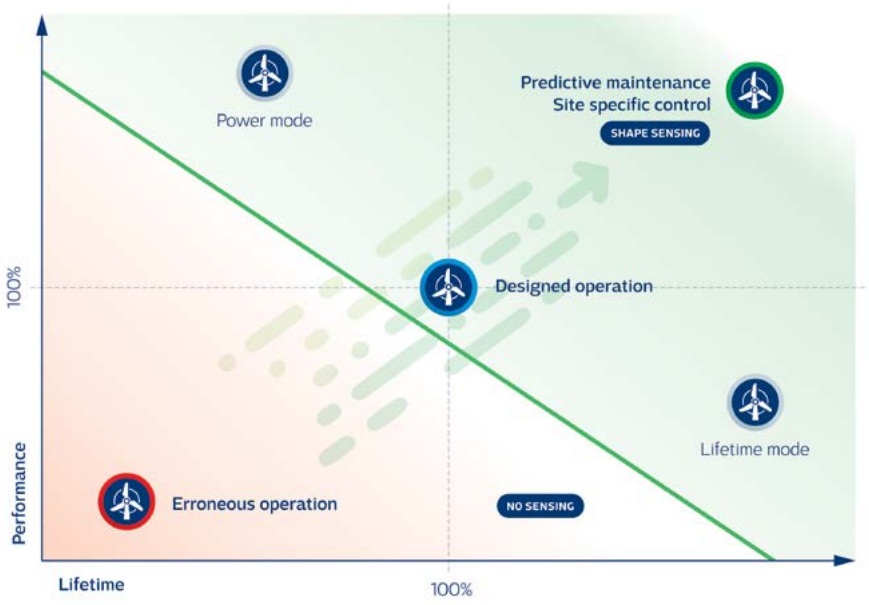
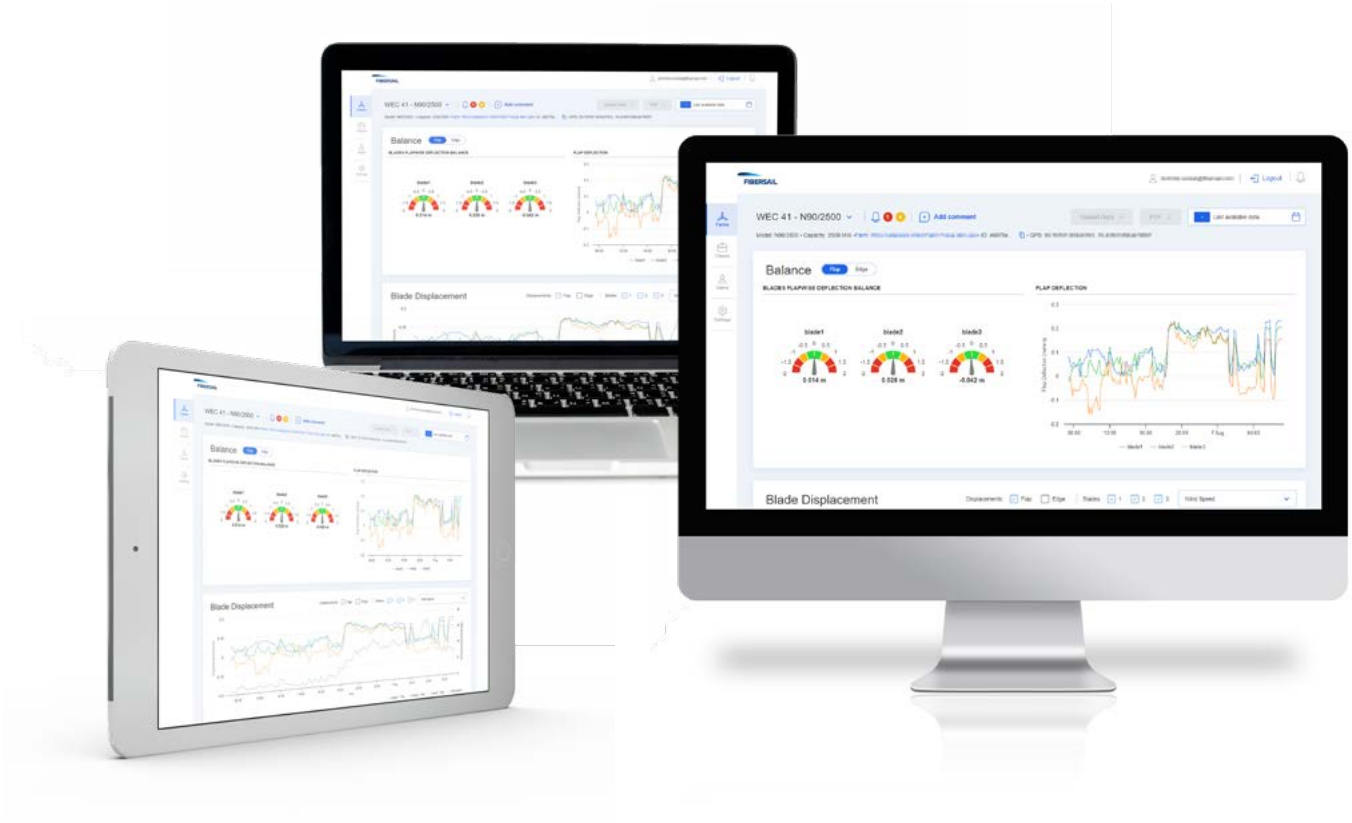



Figure 1 - Shape Sensing potential





The output of the CMS is delivered through the Fibersail Dashboard which allows visibility at different levels. From the wind farms macro level, passing by the wind turbines, all the way into the blade's micro-level detail. The insights provided can go from the basic shape output of the blades into more advanced algorithms that release warnings of erroneous operational conditions and early damage detection as well as insights into overall turbine health. It is worth mentioning that other data can also be uploaded into Fibersail Cloud Solution as an aggregator of your wind turbines data and knowledge platform.

### Future taking shape

Wind turbine blade shape sensing technology marks a pivotal advancement in the wind industry's journey towards lowering the LCoE and increasing overall efficiency. By enhancing turbine performance, reducing maintenance costs, mitigating risks, and enabling data-driven decision-making, this technology is a game-changer in the pursuit of sustainable and affordable wind energy. As the industry continues to embrace innovation, blade shape sensing stands out as a beacon of progress, propelling wind energy toward a more competitive and greener future.

Fibersail believes that the future of the wind industry will have a strong basis on easy-to-use and reliable data, allowing smart and autonomous turbines to be more sustainable and deliver more energy at a lower cost.

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