VAISALA

Wind ramp & gust nowcasting

Solutions for energy trading, asset protection and grid balancing

Quick guide

Why wind detection around wind farms matters

Unexpected wind changes can have major consequences — penalties, equipment damage, and safety risks. Vaisala WindCube® Scan delivers 5-to-20-minute wind forecasts up to 10 km ahead of a wind farm, helping operators optimize trading, improve the wind energy contribution to balancing market, protect assets and ensure safe operations.

Wind farms face significant challenges when wind changes occur without warning. Strong fluctuations create substantial power production variations, causing imbalances between forecasted and actual energy delivery to grid operators.

These gaps result in penalties, increased costs, and direct revenue losses. Sudden wind ramps, gusts, and direction changes also generate mechanical loads on turbines, potentially reducing lifespan or damaging components. It also provides an opportunity to tap into the energy trading market and enhance wind energy's role in balancing the grid.

Construction and maintenance teams need stable wind conditions for safe turbine installation, component servicing, and crane operations. Accurate monitoring helps identify optimal operation windows and maintain safety standards.

How nowcasting benefits wind farms

Wind is complex and highly variable, making it difficult to forecast. Changes in wind regime, wind ramps, and shifts in wind direction can significantly impact wind farm energy production. These sudden variations pose challenges not only to grid stability but also to energy trading and operational planning.

A long-range scanning wind lidar provides detailed wind mapping from 200 m to over 10 km, enabling detection and tracking of strong wind variations around or within targeted areas. Well-located, WindCube Scan can cover an entire wind farm with short-term forecasting capability.

Using this technology, operators can detect and track strong wind variations in all directions around the wind farm or in specific targeted areas — enabling a wide range of applications that result in safer construction, better operational planning, and more predictable energy output.

Applications for lidar-based nowcasting

Optimized energy trading

Strong wind fluctuations can lead to significant variations in power production. When these changes are sudden and unexpected, they can cause serious economic and technical impacts due to the imbalance between forecasted and actual energy supplied to the grid operator.

Better forecasts reduce imbalance costs in electricity markets (where operators are penalized for inaccurate predictions). Improved bidding strategies in intraday markets allows operators to sell power more profitably — enhancing revenue predictability and supporting financing and investment decisions.

Grid resilience and curtailment planning

Accurate wind forecasts help grid operators plan how much electricity will come from wind versus other sources. This can reduce the need for reserve power (backup generators or batteries), while improving grid stability. Improved curtailment planning allows operators to manage power output proactively during grid congestion.

Case study: Experiment in an Australian onshore wind farm

The University of Melbourne has deployed a scanning lidar in the Mount Mercer wind farm with the goal of evaluating lidar-based detection of wind gusts and studying gust propagation speed and impact on wind power ramps. The study showed a good correlation between gusts detected and power generation which are usually not considered in the models.

Read the article on Journal of Wind Engineering and Industrial Aerodynamics: LiDAR-based detection of wind gusts

Micro-grid balancing

In micro-grids with a high dependence on wind energy — such as island or isolated electrical networks — accurate forecasting is essential. Even small variations in wind power production can destabilize the grid and put its balance at risk.

Efficient wind farm asset protection

Strong wind ramps – such as gusts and sudden changes in wind direction – can generate substantial loads on wind turbines, potentially shortening their lifespan or damaging components. Accurate short-term forecasting helps mitigate these risks and protect critical assets.

Although turbines are built to withstand strong winds through robust design, cut-off strategies, and protection controls, rare extreme events can still expose them to conditions beyond their design limits. By anticipating severe wind events and moving turbines to a safe position in advance, operators can reduce mechanical loads and extend the lifetime of the equipment and improves overall operational efficiency.

Safer construction

Turbine erection, heavy component servicing, and craning operations require stable wind conditions to be performed safely. Accurate monitoring of surrounding wind conditions improves safety and optimizes the operational window to:

- Make informed decisions to continue or pause blade installation based on approaching wind conditions
- Optimize the use of high-cost cranes to erect or service more turbines with greater safety
- Conduct maintenance during low-wind periods to minimize production losses

From probabilistic to precise: Lidar improves wind power forecasting

Scientific research has already demonstrated the value of lidar-based forecasting for wind energy applications. In 2020, at the Global Tech I offshore wind farm, the University of Oldenburg showed that WindCube Scan lidar could detect power ramps more accurately than traditional statistical methods. The lidar-based forecasts closely followed actual SCADA measurements, proving their ability to capture rapid changes in wind conditions.

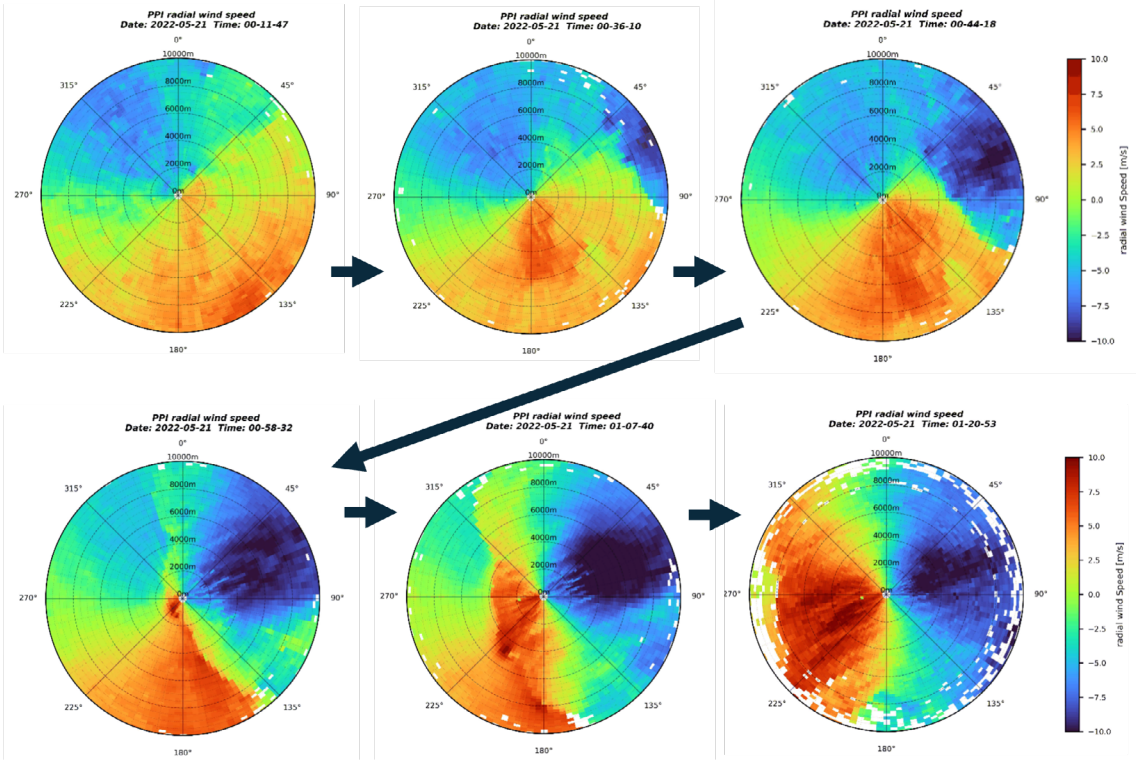
(Source: F. Theuer, M. F. van Dooren, L. von Bremen, and M. Kühn: Minute-scale power forecast of offshore wind turbines using long-range single-Doppler lidar measurements, https://doi.org/10.5194/wes-5-1449-2020).

Scanning strategies

WindCube Scan uses advanced scanning strategies to capture wind conditions in both spatial and temporal coherence. It can measure wind up to 10 km ahead of the site, either on a single horizontal layer using PPI (plan position indicator) scans or across multiple layers in a volume scan composed of several PPIs at different elevation angles.

PPI 360° scan

This strategy scans for wind variations all around.



PPI Sector scan

Used to monitor wind variations in a specific direction, this strategy focuses the lidar's scanning beam on a defined area of interest for targeted detection of approaching wind changes.

Take control of wind variability

Long-range scanning lidars transform how wind farms handle unpredictable conditions by detecting wind changes up to 20 minutes before they reach turbines. This early warning system gives asset owners the critical advantage:

- Asset owners can leverage long-range scanning lidars to optimize energy trading and reduce balancing cost.
- Accurate forecasting is critical for grid balancing micro= enabling higher share of wind energy.
- Long-range scanning lidars help address wind fluctuations by detecting them 15-20 minutes before they reach a wind farm, optimizing maintenance and operation, curtailment and asset protection.
- These use cases have been validated through research projects and are now being deployed in commercial applications.
- For larger wind farms, the potential savings or additional revenue can amount to millions of euros annually.

WindCube Scan delivers the wind intelligence operators need to turn uncertainty into opportunity, making every minute count in an increasingly competitive energy market.

Why Vaisala?

We are innovators, scientists, and discoverers who are helping fundamentally change how the world is powered. Vaisala elevates wind and solar customers around the globe so they can meet the greatest energy challenges of our time. Our pioneering approach reflects our priorities of thoughtful evolution in a time of change and extending our legacy of leadership.

Vaisala is the only company to offer 360° of weather intelligence for smarter renewable energy, nearly anywhere on the planet. Every solution benefits from our over 90 years of experience, deployments in 170+ countries, and unrivaled thought leadership. Our innovation story, like the renewable energy story, continues.

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