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VAISALA

Why are not all turbines equipped with Lidar for feed-forward controls (yet)?

Aurélie JEANNIN[a], Matthieu BOQUET[a], Bastien STEINHAUSSER[a], Samuel DAVOUST[b]
[a]VAISALA, [b] TipSpeed

Bringing Lidar Assisted Control towards industrialization requires anticipation and experience to bridge gaps between theoretical studies and real-world operation

Current state

- Continuously improving the competitiveness of wind energy is vital for the industry and thereby the environment. In that context, control technology advancement is critical to minimize the loads while maximizing the energy production.
- Lidar assisted control (LAC) technology provides benefits in loads reduction and energy capture, which have been extensively demonstrated by researchers through field experiments and simulation studies over the past years [1,2].

Application	Benefit	TRL
Yaw error bias correction	AEP increase	High
Fatigue load reduction	CapEx reduction or Life Time Extension.	High
Extreme load reduction	CapEx reduction	Low

Table 1 : Key LAC applications [3]

- One of the largest manufacturers is providing wind turbines equipped with LAC [4]. The benefits are in turbine design and in the choice of installation site conditions.
- Continuous increase in turbine sizes is constantly improving the business case. Therefore, now is a critical time to characterize and remove the remaining barriers to translate the benefits demonstrated in research to production applications.

References

[1]: Bossanyi, E. Et al. "Wind turbine control applications of turbine-mounted lidar", 2014

[2]: Schlipf, D., et al. "Field testing of feedforward collective pitch control on the CART2 using a nacelle-based lidar scanner." 2014.

[3]: Simley, E. et al. "IEA wind task 32 and task 37: Optimizing wind turbines with lidar-assisted control using systems engineering". 2020

[4]: Goldwind. "Efarm lidar assisted control technology." (2023), [Online]

Barriers and solutions

- Simulation studies are by principle based on simplified physics and assumptions. These are well suited for traditional turbine simulation, but have limited representativity when it assumes a sensor measuring the wind to yield feed-forward controls actions.
- This translate to challenges, discoveries and opportunities when it comes to realizing the benefits, obtained in simulation during research or conceptual design, into the final product field validation

How to bridge the gap from theoretical studies to actual field performances

Simulation models

Risks	Mitigations
- Wind disturbance evolves over time and space - Less predictable turbulence than simulated - More complex wind profiles - Wakes	- Multi-range measurements, - Advanced wind reconstruction - Advanced flow modelling - Increased field testing - Higher benefits in harsher flow conditions

Sensor performance

Risks	Mitigations
- Hardware malfunctions reduce availability -Adverse atmospheric conditions degrade measurement quality- - Long-term drift or wear affects measurement accuracy	- Return on experience on large lidar fleets - Availability characterized in a wide range of location - Decades of ccuracy testing for other application

Sensor integration

Risks	Mitigations
- Beam obstruction by blades or nacelle - Maintenance requirements - Operational requirements (downtime)	- Robust wind reconstruction - A modular & serviceable design and integration

Our complete experience from simulation to large scale field operation

Simulation Business Case → Field testing → Industrialization → Services & Support

Outlook

To support the industry to adopt lidar assisted control, we propose to:

- Draw experience from the use of advanced wind sensors for safety in other industries (airports, maritime).
- Rely on worldwide fleets of various typ of lidars to characterize measurement availability in various conditions.
- Leverage operational feedback from hundreds of nacelle lidar used in the field for controls.
- Embedded robust lidar wind reconstruction module to support both simulation and commercial applications.
- Participate in industry initiatives (IEA) to leverage and develop across organization knowledge and experience.

This, together with clear mitigation of the barriers, puts the industry on track for larger scale of the technology in the coming years.

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