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Assessment and Optimization of Lidar Measurement Availability for Wind Turbine Control

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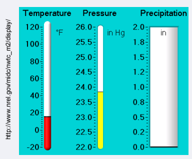
Introduction

Integrating light detection and ranging (lidar) systems to improve wind turbine controls is a potential breakthrough for reducing the cost of wind energy [1]. By providing undisturbed wind measurements up to 400 m in front of the rotor, lidar may provide an accurate update of the turbine inflow with a preview time of several seconds. Focusing on loads, several studies have evaluated potential reductions using integrated lidar either by simulation [2, 3] or full-scale field testing [4].

One of the key aspects from a business standpoint that needs to be validated is the availability of lidar measurements: if the lidar is not delivering measurements, load-reduction benefits cannot be obtained.

Availability is defined as the percentage of valid "wind estimations" obtained over a given period. Figure 1 presents the key parameters governing measurement availability with a turbine-mounted lidar. The sensitivity of availability to these parameters is investigated and modeled using operational feedback from a lidar installed at the National Renewable Energy Laboratory (NREL) test site in Boulder, Colorado, and data collected from more than 20 turbine-mounted lidars deployed in several configurations.

Atmospheric Conditions → **Lidar Configuration** → **Wind Estimation** → **Wind Inflow** → **Turbine Control**



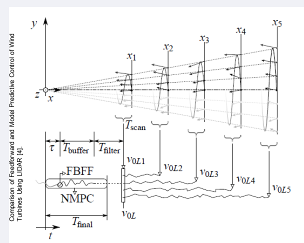
Operating environment
- Offshore, coastal, continental, mountain

Meteorological events
- Rain, snow, fog

Lidar measurement geometry
- Beam angle, mounting position

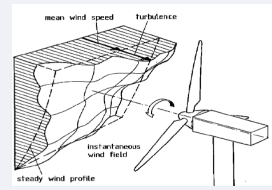
Lidar configuration
- Range, sampling rate

Type of lidar
- Pulsed, continuous wave, direct detection



Wind reconstruction algorithm
- Wind speed, direction, shear

Wind propagation algorithm
- Wind coherency, Taylor hypothesis



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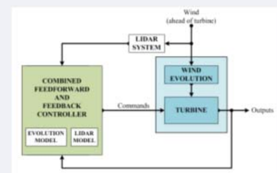

LIDAR Wind Speed Measurements of Evolving Wind Fields. [6]

Figure 1. The key parameters involved in lidar wind estimation

Atmospheric Conditions

NREL researchers performed an analysis of lidar availability under various atmospheric conditions. Over the course of a 6-month campaign, a Wind Iris lidar was installed on the NREL two-bladed Controls Advanced Research Turbine (CART2) located in Boulder, Colorado, at 1,855 m altitude. This pulsed lidar measures 10 ranges at 2 Hz from 50 m up to 225 m. The lidar optics are focused around 100 m to ensure an optimal availability from 50 m up to 150 m. Using a webcam located at 100 m from the turbine and other instrumentation, researchers created weather categories to investigate lidar availability in clear sky, heavy rain, snow, or fog (see Figure 2).

As evidenced under standard conditions, lidar availability is expected to be near 100%. Rain did not lead to a loss of availability. During difficult atmospheric conditions such as fog or snow, it appears that availability can be maintained at least at one lidar range. This feature can be exploited to ensure the availability specification, even in the harshest conditions.

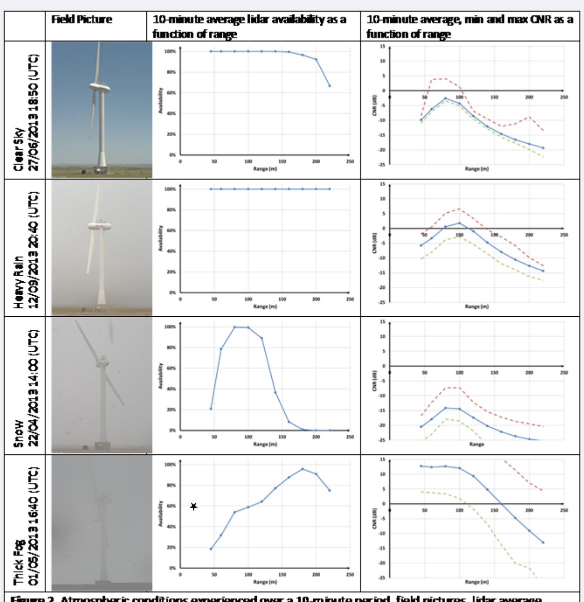

Figure 2. Atmospheric conditions experienced over a 10-minute period, field pictures, lidar average availability and Carrier to Noise Ratio (CNR average, min and max) for one beam.

✶ Close range availability to be improved under thick fog if the upper CNR threshold is relaxed

Lidar Configuration

The lidar can be mounted on either the nacelle or spinner. For a first-generation of turbine control lidar, it seems that nacelle mounting is the most practical solution. In this case, two parameters should be optimized:

1. **Available lidar field of view** (Figure 3). The lidar should be positioned as far back and high on the nacelle as possible. Wider opening angles also tend to favor availability but add constraints to wind-speed estimation at long range.
2. **Ratio of lidar sampling to turbine rpm** (Figure 4). When this ratio is low, availability loss caused by the blades is reduced or can even disappear. The lidar sampling strategy should take this into account.

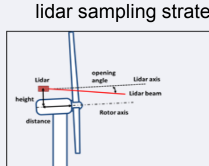

Figure 3 (a). Schematic representation of a lidar at the back of a wind turbine's nacelle

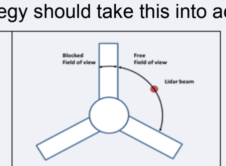

Figure 3 (b). Schematic representation of the position of the lidar beam in the rotor plane

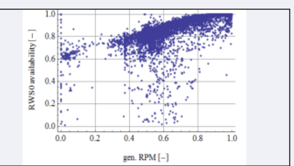

Figure 4. Lidar beam availability as a function of normalized generator rpm [5].

Wind Estimation

The wind estimation step can be made very robust by using measurements available across all lidar measurement ranges. The validity of a wind estimation then depends on a minimum number of ranges and points required during a specific time interval, according to the wind turbine manufacturer control requirements. The lidar system availability performance should be evaluated according to this metric.

Conclusion

Several aspects contributing to the definition and performance of lidar availability for wind turbine control have been established. Promising results were obtained in various operational conditions. Further work and collaboration between research teams and lidar and turbine manufacturers are required to establish measurement availability performance in all weather conditions, which is crucial in order to integrate lidar into the next-generation turbines.

References

1. Byrne, A.; McCoy, K.; Briggs, K.; Rogers, T. "Expected Impacts on Cost of Energy Through Lidar-Based Wind Turbine Control." EWEA conference, 2012.
2. Bossanyi, E. A.; Kumar, A.; Hugues-Salas, O. "Wind Turbine Control Applications of Turbine-Mounted LIDAR." Torque From Wind conference; Oldenburg, Germany; 2012.
3. Bottasso, C. L.; Pietro Pizzinelli, F. P.; Riboldi, C. E. D. "Lidar-Enabled Real-Time Control of Wind Turbines." EWEA conference, 2013.
4. Schlipf, D.; Fleming, P.; Haizmann, F.; Scholbrock, A.; Hofäß, M.; Wright, A.; Cheng, P. W. "Field Testing of Feed Forward Collective Pitch Control on the CART2 Using a Nacelle-Based Lidar Scanner." Torque From Wind conference; Oldenburg, Germany; 2012.
5. Wagner, R. and Davoust, S. Nacelle lidar for power curve measurement: Avedøre campaign. DTU Wind Energy Report, 2013.
6. Simley, E. and Pao, L.Y. LIDAR Wind Speed Measurements of Evolving Wind Fields. NREL Subcontract Report SR-5000-55516. 2012.

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