PO.ID
003

Nacelle-mounted lidar measurement of the axial induction of a wind turbine

John Obrecht, Jennifer Frankland, Justin Creaby
Siemens Wind Power – Boulder, CO

SIEMENS

Abstract

A forward-looking LIDAR unit was installed upon the nacelle of a Siemens wind turbine (SWT-2.3-108) at the National Wind Technology Center in Boulder, CO. The LIDAR unit was used to measure the velocity of the wind 40-200m upstream of the turbine's rotor during operation. Analysis of the LIDAR measurements clearly shows the induction of the wind in front of the rotor plane. The magnitude, length scale, and velocity dependence of the induction field agree well with theoretical models and CFD calculations, confirming our understanding of the influence of an operational wind turbine on the upstream flow field.

Objectives

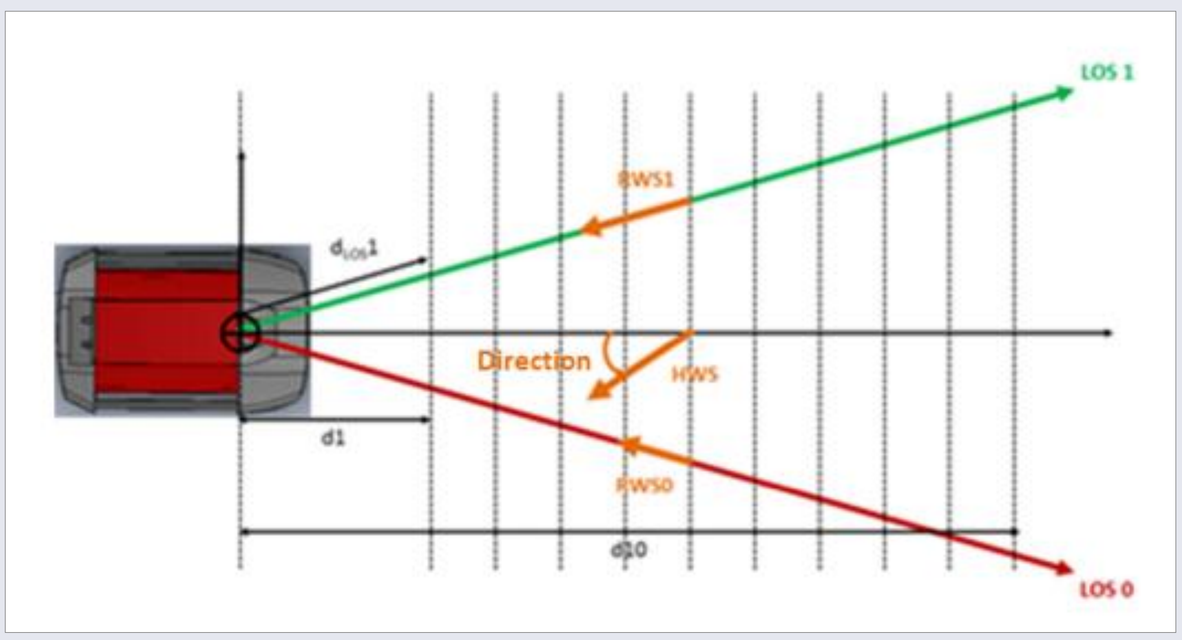
This study was initiated in order to:

- Identify and analyze axial induction measured with a nacelle-mounted lidar unit
- Determine if a nacelle-mounted lidar unit can reliably measure upstream wind speeds and turbine induction
- Compare the lidar-measured induction with inferred induction based on turbine power production.

Methods

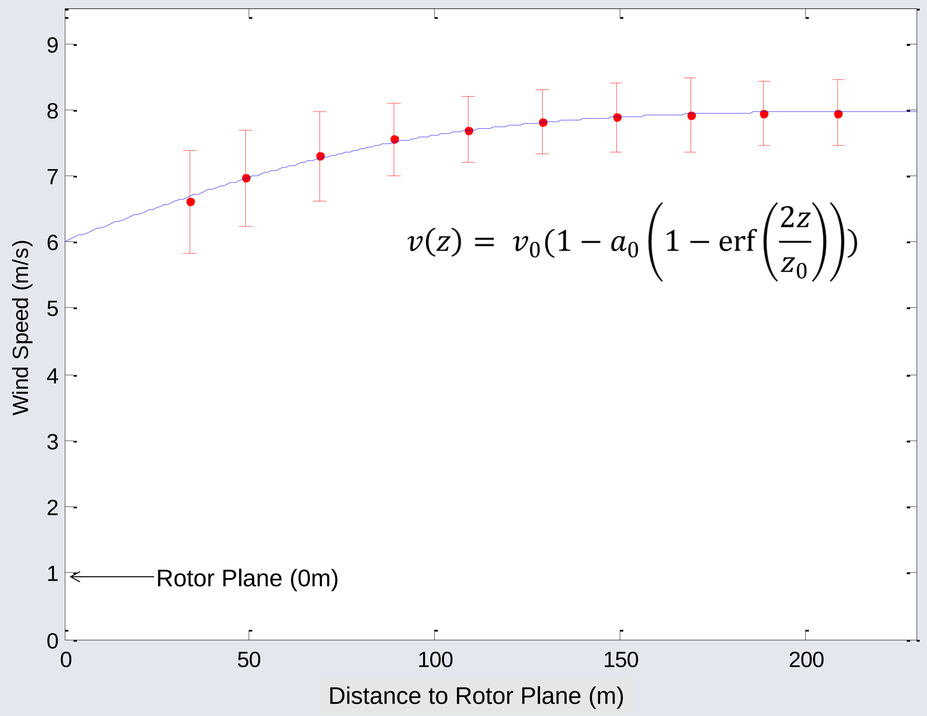
In this study, a nacelle-mounted lidar was used to measure axial induction of wind as it approached a wind turbine rotor. An Avent Lidar Technology nacelle-mounted lidar, the Wind Iris, was placed on a SWT 2.3-108 test turbine located at the National Wind Technology Center in Boulder, Colorado (above). The lidar was forward-facing and positioned approximately 11 meters behind the turbine rotor plane.

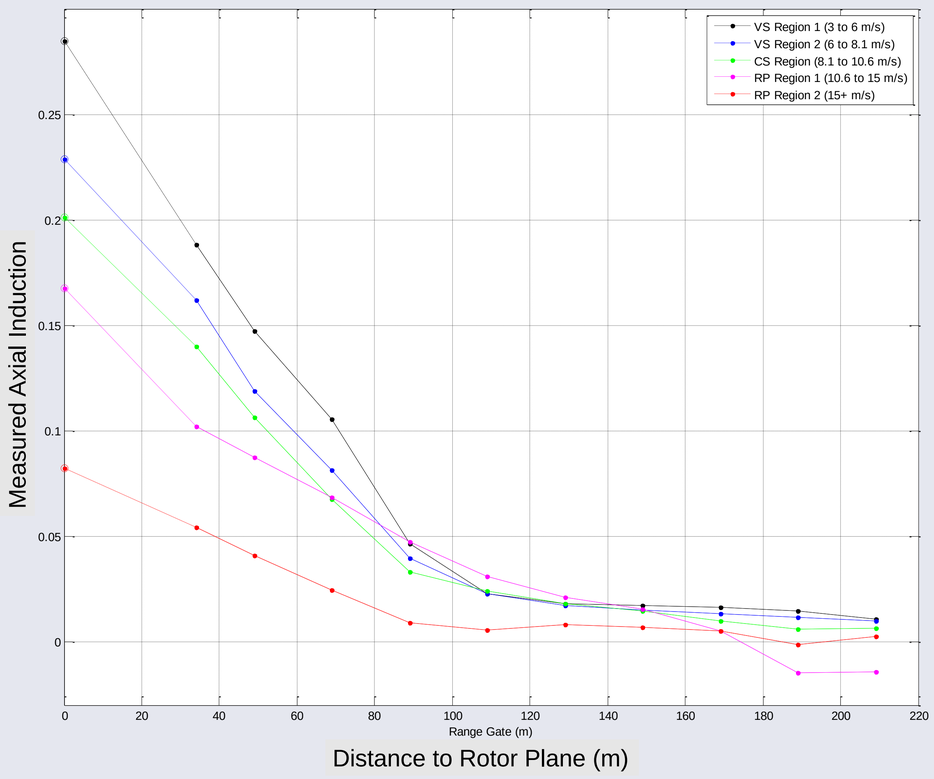
The lidar provided measurements of wind speed and direction at ten different distances in front of the turbine, or range gates. The range gates at which the lidar took measurements were: 45 m, 60 m, 80 m, 100 m, 120 m, 140 m, 160 m, 180 m, 200 m and 220 m. The lidar took these measurements by consecutively measuring radial wind speeds on its two lines of sight, LOS0 and LOS1. It then reconstructed horizontal wind speeds and directions based on each set of two consecutive radial wind speed measurements. Shown below is a diagram of the lidar measurement system.



Results

During this study the lidar was shown to reliably measure induction. The induction measured using the lidar was then compared with the inferred induction based on turbine power production data. Both the lidar and turbine data showed that as free stream wind speed increases, axial induction decreases. A two-variable fit function was used to model induction at the rotor plane, and the modeled data from the fit function correlated well with measured data. The fit function used within this study could provide good estimates of data within modeling scenarios.





Conclusions

The measured behavior of the wind field induction during operation of the turbine is shown to be in fairly good agreement with the induction inferred from turbine power production data (below). The data seem to agree in the variable-speed and constant-speed regions (3-11 m/s), but tends to disagree with the expected induction in the post-rated region (11+ m/s).