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Estimating wind speeds at wind turbines with ARMAX models using Lidar measurements

Ashim Giyanani, Wim Bieerbooms, and Gerard van Bussel
Delft University of Technology, Wind Energy Research Group, Faculty of Aerospace Engineering, Delft, Netherlands (a.giyanani@tudelft.nl)

Wind turbines cannot detect wind speed approaching them, for e.g. gusts. This poses a major risk for fatigue and extreme load failure in the wind turbines. The existing methods using Lidars to estimate wind speeds at the rotor extrapolate the wind speed measured by the Lidar at the last measurement point, (for e.g. 50m). In theory and practise, the blockage effects of the wind turbine, the site conditions, and the atmospheric conditions restrict the validity of Taylor's frozen turbulence, which is conveniently assumed to be true. Thus, the existing methods estimating the rotor effective wind speed are not reliable and need better models to use the Lidar measurements effectively.

This article proposes a real-time wind model to estimate the wind speeds accurately at the rotor by understanding the evolution of wind using Lidars. We use Autoregressive Moving Average Exogenous, ARMAX, models to follow a wind-field or a gust from 200m away to 50m in front of the wind turbine to understand its evolution and dissolution. The ARMAX model for modelling the evolution of a wind field is given by Eqn.(1); where the output wind speed prediction,*y(t)*, is represented by the coefficient *A*, while the deterministic part of the wind speed $u(t-nk)$ based on past measurements is represented by *B*, and the stochastic noise part in the wind is characterized by the coefficient *C*. This understanding can be used to develop a model to incorporate the effects of site and atmospheric conditions on the evolution of wind. It is the intention to also include the blockage effects due to the wind turbine into the model to extrapolate the wind speed estimation through the blind zone of the Lidar to the wind turbine rotor plane.

$$\underbrace{Ay(t)}_{Output} = \overbrace{Bu(t-n_k)}^{DeterministicInput} + \overbrace{Ce(t)}^{StochasticNoise} \quad (1)$$