Wind field data extrapolation based on wind turbine measurement records via compressive sampling

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ABSTRACT

Accurate estimation of operational conditions and their impact on wind turbines is of high importance for both design and maintenance purposes. Indicatively, estimating power output, predicting mechanical failure and modeling long-term structural fatigue, are challenging tasks, particularly when working with real sensor data. Data processing for calibration or validation of a turbine model often requires data reconstruction methods to adress sensor failures or other limitations common in distributed sensor networks, such as limited wireless bandwidth. Further, available measurement records may refer to few only points in the spatial domain, where sensors are placed. Clearly, exploiting these measurements and extrapolating information about the wind field is highly impactful for simulation purposes. In fact, estimating relevant statistics and modeling the wind process as a multi-dimensional (i.e., time and spatial domains) stochastic field is invaluable in considering simulated environmental scenarios within the context of a Monte Carlo analysis (e.g. [1]).

To address the above challenges, a compressive sampling (CS) based approach is developed herein in conjunction with a joint time-frequency harmonic wavelet analysis to account for potentially non-stationary wind time-histories. In this regard, incomplete wind data (in the sense of data points missing in the time-domain and/or of spatially limited sensor positions) are expanded on a harmonic wavelet basis where sufficient sparsity is assumed. Next, to promote a sparse solution of the underdetermined system of equations and determine the expansion coefficients, an Lp - norm minimisation algorithm ($p \leq 1$) is employed [2]. The efficacy of the proposed methodology is demonstrated by processing, reconstructing and extrapolating incomplete wind data measurements from a wind turbine installation.

References

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