![WindSTAR] Wind-Energy Science, Technology, and Research Industry/University Cooperative Research Center

Uncertainty quantification of wind farm performance through high fidelity simulations and wind LiDAR measurements

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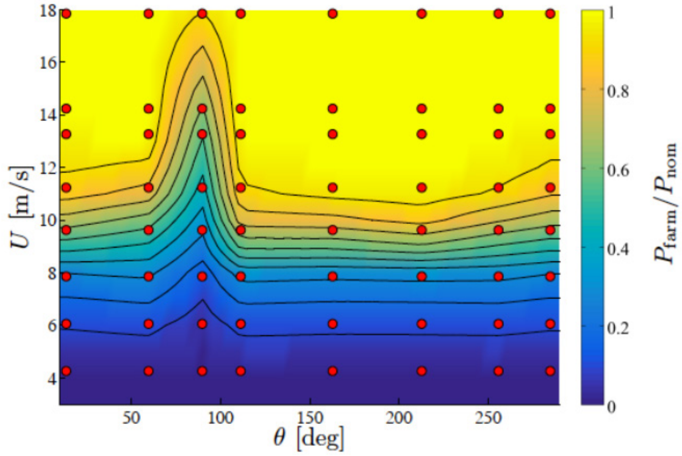
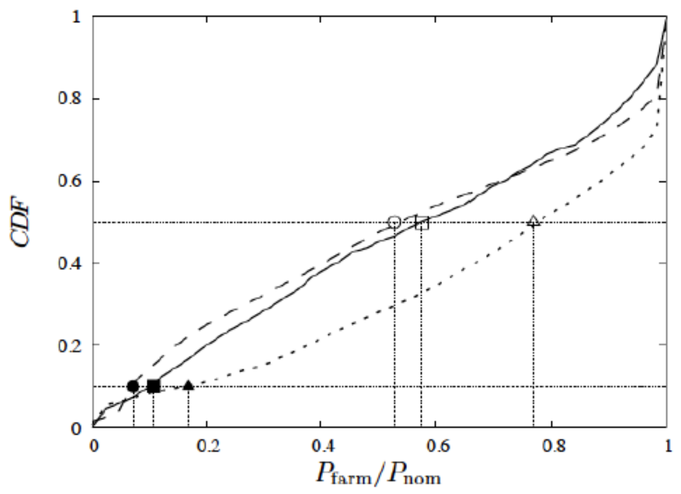
A novel method has been developed to derive a surrogate model for wind farm control. The procedure is based on a stochastic approach using generalized polynomial chaos (PC) and highfidelity simulations. The turbine control law and the incoming wind conditions, such as speed and directions, are treated as uncertain variables. Wind farm power production is then viewed as the random process depending on these uncertain variables. Thus, polynomial chaos expansion can be used to obtain a response function that provides the wind farm power production as a function of the turbine control parameters and the wind speed and direction. The response function is obtained by using a finite set of deterministic realizations, which consist in highfidelity simulations for certain values of wind speed, direction and control parameters,interpolated by polynomials. In PC, the interpolating polynomial basis and the set of realizations are selected according to the probability density function of the uncertain parameters. This allows using a limited number of realizations to obtain an accurate response function and provides uncertainty bounds on the model. Thus, a mapping of the optimal control settings isobtained for any wind speed and direction to be employed for real-time wind farm operations. In this work, the procedure is validated against field measurements in a real wind farm in north Texas. The surrogate model (Fig.1) is obtained by performing 64 simulations with our in-house code interpolated by 7th-order Hermite polynomials. The average power production predicted by the model for six days of operation under stable atmospheric conditions is within 2% accuracy of experimental data. Additionally, other statistical metrics, such as the P50 or P90, are predicted correctly within a 5-10% bound (Fig.2). The results emphasize the importance of the underlying high-fidelity solver used for the development of the model. When the same procedure is applied using an engineering wake model, the error of the surrogate model prediction respect to SCADA data increases of an order of magnitude.



Surrogate model obtained from PC expansion. The red dots indicate the sample points of wind speed and direction.



Cumulative distribution function of the wind farm power production: solid line SCADA data; dashed PC expansion using LES; dotted PC expansion using Jensen model. Symbols indicate the value of P90 (filled symbols) and P50 (empty): square SCADA data; circle PC expansion using LES; triangle PC expansion using Jensen model.

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