Combined stochastic CFD model of offshore wind farms

Abstract

The aim of this project is to take probability density functions (PDFs) of input parameters and convert them into PDFs of output parameters at the turbines within a wind farm. This project proposes a novel use of CFD modelling, in conjunction with stochastic methods, to give a probabilistic assessment of variables, at each turbine within a wind turbine array. This will be accomplished in several stages by combining several smaller CFD analyses with response approximations and stochastic methods. These output PDFs can then be used as a basis for further analysis into power production or fatigue loading throughout the life of the WTA

Introduction

The inputs into turbine aerodynamic models such as wind speed, wind direction and other factors, are not constant values but follow probability distribution functions with only a certain chance that they will be a particular value at any one point in time. A single, steady state, CFD analysis only shows the outcome of one given setting and numerous simple wake models do not provide the same level of accuracy as CFD.

Existing models are either too inaccurate of too computationally expensive [1], [2]. The choice of model is then a compromise between required accuracy and available resources. To achieve the goal of a output PDFs and also use a more accurate CFD analysis, a new stochastic method needed to be developed.

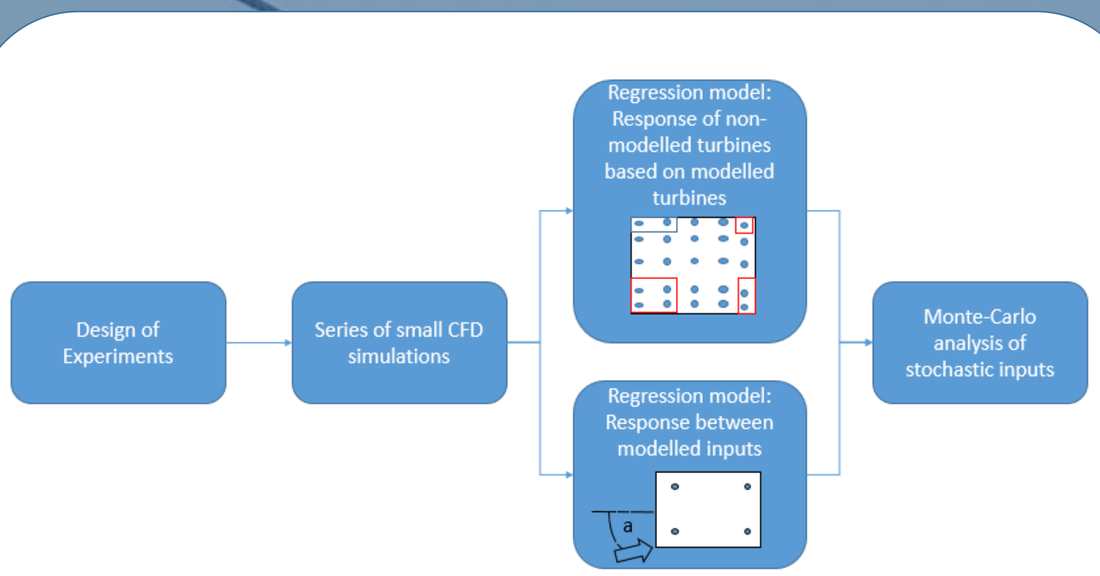


Figure 1. Diagram of method proposed

Method

The method applied is first to conduct a series of small scale CFD analyses which will be used to create a response approximation model. This approximation model will then be used to conduct a Monte-Carlo analysis of the wind farm, providing PDFs of pertinent output parameters at the turbines. This method is shown diagrammatically in figure 1.

The CFD model used is a modified version of E. Svenning's actuator disk model in OpenFOAM [3] which can now be used to implement several NREL 5MW turbines [4].

Results

Some preliminary results have been generated to demonstrate the concept of using regression models to predict the flow field. Four turbines positioned in series and in incident flow field have been modelled using the AD OpenFOAM model. The average velocity magnitude has been taken 100m ahead of each turbine, at each turbine and 100, 200 and 300 meters down-stream of each turbine. The velocity field of these turbines is shown in Figure 3 and a zoomed view is shown in Figure 2.

The velocity at each turbine was predicted in turn after removing the local measurements. The regression models used were Radial Basis Function (RBF), a third order polynomial and Support Vector Regression (SVR). The results from the regression analysis are shown in figure 4.

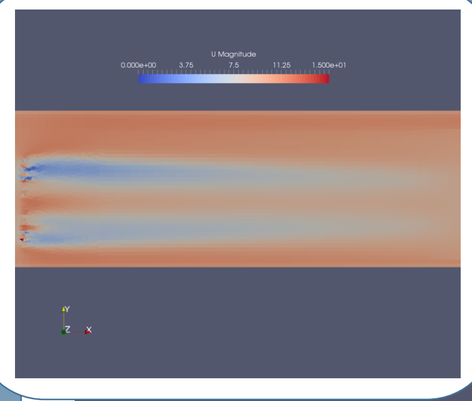
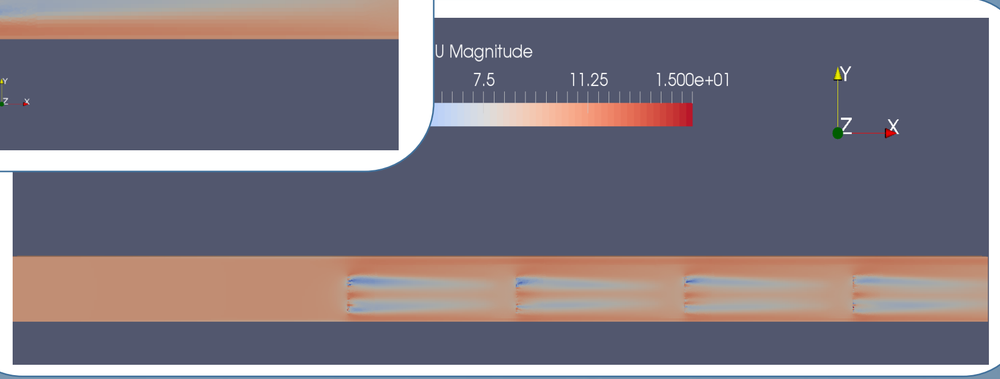


Figure 2. Zoomed view of a single turbine

Figure 3. CFD model of 4 turbines in series



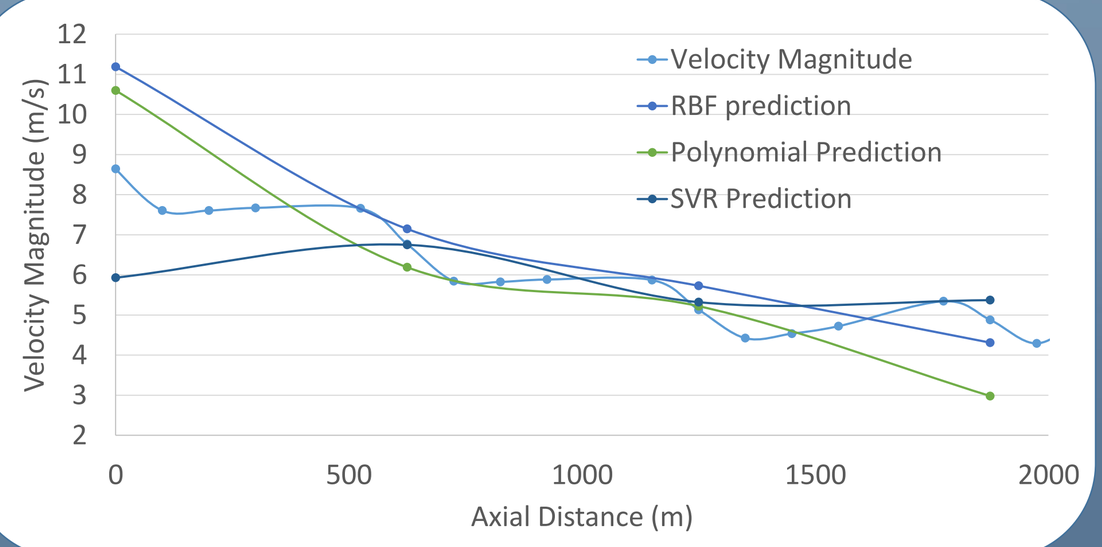


Figure 4. Results from regression analysis

Conclusion and Future Work

A regression method could be used to extrapolate CFD results and conduct a stochastic analysis of wind turbine loading throughout a wind farm. Initial results show promise in the use of this method.

Future work apply this method to a 5 by 5 wind turbine array to produce PDFs of variable at each of the 25 turbines.

References

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