Offshore Wind Farm Siting Optimization (Implementing More Detailed Power Predictions)
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Abstract

Being able to predict the expected power output of a wind turbine and ultimately a windfarm as a whole is essential to the process of trying to find the optimal placement of windfarms inside a region of choice. Throughout our research we use the term wind scenario to denote a combination of wind speed and direction from our set of data. Our research took two approaches on how to produce wind power predictions from a year’s worth of wind scenarios. Using different methods of grouping data points, we are hoping to observe their effect on different aspects of our windfarm siting problem.

Research Objectives

• Improve accuracy of predicted power outputs by using individual wind speed data points rather than means.
• Observe changes in optimized layouts and predicted profits based on changes in power vector calculations.
• Improve optimization computation times by reducing required amount of variables used for optimization

Notation

• $\Omega$ – Denotes set of all wind scenarios.
• $\Omega^*$ – Denotes set of all wind scenarios in a specific direction
• $\Psi^i$ – Denotes set of all wind scenarios in a specific wind speed bin
• $\Psi^i_k$ – Denotes specific wind scenario
• $\star$ – Denotes set of directions $\{ \star \rightarrow \star \}$
• PO – Denotes NREL 5MW Turbine power outputs.

Progress and Results

Using sets we organized our equations as follows:

1st Approach

$\omega^i \subset \Psi^i \subset \Omega^*$

$MP(t) = \frac{[\Psi^i]}{\sum_{j=1}^{n} [\Psi^j]} [\Psi^i] [\text{Hi}]/[\text{Hi}]

DP = \sum_{i=1}^{n} MP(k) \star PO(k)

(Where MP denotes marginal probability of a speed bin and DP denotes predicted power output in kilowatts)

After separating wind scenarios by direction then by 1 m/s speed bins within the direction, the grouping of our two approaches and their power output formats begin to differ. Our first approach sums the power predictions of wind scenarios by three speed level bins (0[6], (6,12] (12<) within a direction, while our second approach simply sums the power predictions of all wind scenarios in a given direction.

Optimized layouts

From Left to Right: Original, 1st Approach, 2nd Approach

Observations Explained

• As hypothesized, the reduction in computational variables produced a drastic cut in computation time in comparison to the 1st and original approach.
• As the profit function is cubically proportional and convex to the wind speed, using our new approaches we are getting lower profit values. In comparison our original approach gave overestimations of actual profit values as a result of producing more sites than our new approaches.
• This is an example of Jensen's inequality whereby using more detailed descriptions of the wind data in the model, we are getting closer to the actual profit function itself.

Example of Jensen Inequality (using $y = x^2$)

Current/Future Work

• Further analysis of the results to check for validity and accuracy of all approaches.
• Implementation of more complex decay modelling to further improve profit and layout accuracy.
• Working database of power predictions to be used by optimization program

Current and Proposed Publications

These research efforts will be apart of:
Ph.D. Dissertation
• A Portfolio Model for Siting Offshore Wind Farms with Economic and Environmental Objectives, Zana Cranmer*, Dr. Erin Baker*

Citations

• NDBC: Kill Devil Hills, NC 2014 data

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