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an industrial power company

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THE CONTINUUM PROJECT

Continuum is our patented wind flow modeling software package used in the development of wind energy projects.

Continuum is an open-source wind resource assessment and site suitability software tool. From met data processing and quality control, to Monte Carlo exceedance modeling, Continuum provides the models and calculations needed to plan any wind project, including *Wind for Industry*.

Background

Continuum was developed by Liz Walls, founder of Cancalia Engineering & Consulting. In 2016, One Energy acquired Cancalia and its Continuum modeling software, with Liz joining One Energy as our Head of Research & Development. One Energy's R&D and Project Planning and Technology teams collaborated to improve and expand the existing software, ultimately leading to the roll-out of Continuum 3.

Already a powerful tool in the development of wind projects, Continuum 3 added beneficial features. The third version of the software notably added time series net energy production output, and One Energy's proprietary Monte Carlo method for estimating the energy losses and uncertainties necessary for project financing.

The main components of Continuum 3 include the wind flow model, energy production estimates, site condition analysis, and site suitability analysis.

Wind Flow Modeling

As described in the **2015 publication of *Wind Engineering***, the Continuum wind flow model uses all available meteorological data and a machine learning algorithm to automatically generate site-calibrated models with a high level of accuracy. The model is derived from a simplified Navier-Stokes equation, that concludes that a change in wind speed is related to the terrain exposure and surface roughness between two points. Continuum predicts the wind speeds at each wind turbine location, including any wake loss from turbine to turbine interaction.

While other wind flow software uses blanket assumptions for "standard" wind project energy losses, Continuum 3 allows the user to input real world data to determine appropriate losses for their project size and location. Continuum 3 includes One Energy's proprietary statistical Monte Carlo method, used to assess project-specific losses and uncertainties. This results in more accurate, transparent 20-year wind resource estimates.

Site Condition Analysis

Continuum's site condition analysis calculates turbine-specific parameters that are important for turbine suitability and turbine model selection. These parameters include turbulence intensity, wind shear, and extreme wind speeds, to name a few.

WHAT'S ON THIS PAGE?

Continuum provides the models and calculations to plan any wind project, including Wind for Industry

Continuum Wind Flow Model: Introduction to Model Theory and Case Study Review

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ABSTRACT

When developing a wind farm, it is very important to accurately define the wind resource distribution across the project area such that an optimized turbine layout can be achieved. To estimate the wind resource distribution, typically, meteorological (met) towers are installed at various strategic locations and the wind speed and direction measured at these sites are used as inputs into wind flow models. Currently, linear and CFD models are most commonly used. Linear models can provide estimates quickly, with little training and at a low cost; however, this type of model is well-known to deliver highly inaccurate estimates particularly in complex terrain. CFD models can provide more accurate estimates however they require significant computational time, an expert knowledge level and a much larger financial investment. Also, all commercially-available linear and CFD models are limited to using a single met site in the model creation.

A new wind flow model, Continuum (patent pending), is introduced which is based on a simplified analysis of Navier-Stokes and utilizes data from all of the met sites simultaneously to develop site-calibrated models. The model coefficients, α_{UP} and α_{DN}, describe the sensitivity of the wind speed to changes in the upwind and downwind terrain exposure and are defined for downhill and uphill flow. The coefficients are a function of terrain complexity and, since terrain complexity can change across an area, the estimates are performed in a stepwise fashion where a path of nodes with a gradual change in complexity are found between each pair of sites. Also, coefficients are defined for each wind direction sector and estimates are performed on a sectorwise basis. The site-calibrated models are created by cross-predicting between each pair of met sites and, through a self-learning technique, the model coefficients that yield the minimum met cross-prediction error are found.

A case study is presented where eleven met masts at a complex terrain site were modeled in Continuum. Using the site-calibrated model, the wind speeds were predicted at the met sites and excellent agreement was found between the estimated and actual wind speeds with a correlation coefficient of 0.96 and a RMSE of 0.90%. The largest wind speed estimate error was 1.8% and five of the eleven sites were modeled to within an error of 0.5%. In Continuum, a Round Robin analysis was performed using met subset sizes of 8, 9 and 10 mets where every possible combination of met sites were used to form a model which were then used to predict at the excluded met sites. The RMS error of the Round Robin predictions was ~1.6% for all three subset sizes which confirmed the very good quality, high level of robustness and validity of the Continuum wind flow model.

1. INTRODUCTION

In wind resource assessment, it is the primary goal to estimate the annual net energy that could be produced from a potential wind farm and this assessment includes several elements such as the wake loss model, the long-term climatic adjustments and, arguably the most important, the wind flow model [10, 15]. The wind flow model is the foundation of the wind resource assessment as it is used to estimate the free-stream (unwaked) wind speed distribution across the project area which is then converted into gross annual energy production. If the wind flow model is flawed or biased then all subsequent calculations will inherit those errors and the assessment will not be representative of the wind farm's true potential. It is therefore very important to have a robust wind flow model upon which to build the resource assessment.

Continuum Wind Flow Model Study
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Site Suitability Analysis

Continuum's site suitability analysis allows the user to determine the feasibility of a site for wind development, apart from the wind resource. The software includes models that calculate shadow flicker, ice throw, and turbine sound propagation for any nearby zone of interest. This allows the user to minimize the impact of the turbine to the surrounding area, while maximizing energy production.

Fast, Simple, Accurate

Continuum was founded around the principles of being fast, simple, and accurate. Unlike cumbersome computational fluid dynamic models that take considerable computing power and time, Continuum provides energy production time series estimates in minutes. It does this without compromising accuracy, using site-calibrated models and machine learning to minimize met cross-prediction errors. Its intuitive user interface streamlines and simplifies model creation for all knowledge levels.

Advancing the Industry; Going Open Source

One Energy has decided to push the wind industry to be better. The only way to advance the industry's technology past its current state is with a more open and sharing culture. It has become our mission to facilitate and expedite the research and development of improved wind resource models and techniques. The best way to do this is to share Continuum with the world.

We will be releasing Continuum as open source software, free and available to anyone to use and improve upon. While other wind flow models are a black box that give no insights into the algorithms behind the results, Continuum 3 will be an open book, encouraging users, customers, and third parties to scrutinize and legitimize the results for themselves.

In the ever-advancing world of R&D, Continuum 3 will provide the customization needed to easily integrate the next big development in wind resource analysis.

Corporate Value #9: Never Settle for the Industry Standard.

Continuum provides energy production time series estimates in minutes, and does so without compromising accuracy.