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Publications:

A framework for medium-fidelity wake dynamics in moderately complex terrain

General information
State: Published
Organisations: Department of Wind Energy, Wind turbine loads & control, Aerodynamic design, Resource Assessment Modelling
Authors: Larsen, G. C. (Intern), van der Laan, P. (Intern), Ott, S. (Intern)
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Loads in wind farms under non-neutral ABL stability conditions: A full-scale validation study of the DWM model.
The purpose of this study is twofold: To validate a generalized version of the DWM approach for load prediction under non-neutral atmospheric stability conditions, and to demonstrate the importance of atmospheric stability for wind turbines operating in wind farm conditions.

General information
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Organisations: Department of Wind Energy, Wind turbine loads & control, Test and Measurements
Authors: Larsen, G. C. (Intern), Larsen, T. J. (Intern), Hansen, K. S. (Intern)
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Loads in wind farms under non-neutral ABL stability conditions: A full-scale validation study of the DWM model.
The purpose of this study is twofold: To validate a generalized version of the DWM approach for load prediction under non-neutral atmospheric stability conditions, and to demonstrate the importance of atmospheric stability for wind turbines operating in wind farm conditions.

General information
State: Published
Organisations: Department of Wind Energy, Wind turbine loads & control, Test and Measurements
Authors: Larsen, G. C. (Intern), Larsen, T. J. (Intern), Hansen, K. S. (Intern)
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Publication: Research › Sound/Visual production (digital) – Annual report year: 2017

Medium fidelity modelling of loads in wind farms under non-neutral ABL stability conditions – a full-scale validation study:

Paper
The aim of the present paper is to demonstrate the capability of medium fidelity modelling of wind turbine component fatigue loading, when the wind turbines are subjected to wake affected non-stationary flow fields under non-neutral atmospheric stability conditions. To accomplish this we combine the classical Dynamic Wake Meandering model with a fundamental conjecture stating: Atmospheric boundary layer stability affects primary wake meandering dynamics driven by large turbulent scales, whereas wake expansion in the meandering frame of reference is hardly affected. Inclusion of stability (i.e. buoyancy) in description of both large- and small scale atmospheric boundary layer turbulence is facilitated by a generalization of the classical Mann spectral tensor, which consistently includes buoyancy effects. With non-stationary wind turbine inflow fields modelled as described above, fatigue loads are obtained using the state-of-the art aeroelastic model HAWC2. The Lillgrund offshore wind farm (WF) constitute an interesting case study for wind farm model validation, because the WT interspacing is small, which in turn means that wake effects are significant. A huge data set, comprising 5 years of blade and tower load recordings, is available for model validation. For a multitude of wake situations this data set displays a considerable scatter, which to a large degree seems to be caused by atmospheric boundary layer stability effects. Notable is also that rotating wind turbine components predominantly experience high fatigue loading for stable stratification with significant shear, whereas high fatigue loading of non-rotating wind turbine components are associated with unstable atmospheric boundary layer stratification.

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State: Published
Organisations: Department of Wind Energy, Wind turbine loads & control, University of Agder
Authors: Larsen, G. C. (Intern), Larsen, T. J. (Intern), Chougule, A. (Ekstern)
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Main Research Area: Technical/natural sciences
Conference: Wake Conference 2017, Visby, Sweden, 30/05/2017 - 30/05/2017
Applied fluid mechanics, Boundary layer and shear turbulence, Wakes, Power and plant engineering (mechanical engineering), Other structures, Fluid mechanics and aerodynamics (mechanical engineering), Elasticity (mechanical engineering), Buckling and instability (mechanical engineering), Fracture mechanics and hardness (mechanical engineering), boundary layer turbulence, elasticity, fatigue, mechanical stability, offshore installations, wakes, wind turbines, medium fidelity loads modelling, nonneutral ABL stability conditions, wind turbine component fatigue loading, wake affected nonstationary flow fields, nonneutral atmospheric stability conditions, dynamic wake meandering model, atmospheric boundary layer stability, primary wake meandering dynamics, large turbulent scales, wake expansion, atmospheric boundary layer turbulence, classical Mann spectral tensor, buoyancy effects, nonstationary wind turbine inflow fields, fatigue loads, aeroelastic model HAWC2, Lillgrund offshore wind farm, WF, wind farm model validation, wake effects, tower load recordings, atmospheric boundary layer stability effects, rotating wind turbine components, unstable atmospheric boundary layer stratification
Electronic versions:
Modeling Atmospheric Turbulence via Rapid Distortion Theory: Spectral Tensor of Velocity and Buoyancy

A spectral tensor model is presented for turbulent fluctuations of wind velocity components and temperature, assuming uniform vertical gradients in mean temperature and mean wind speed. The model is built upon rapid distortion theory (RDT) following studies by Mann and by Hanazaki and Hunt, using the eddy lifetime parameterization of Mann to make the model stationary. The buoyant spectral tensor model is driven via five parameters: the viscous dissipation rate epsilon, length scale of energy-containing eddies L, a turbulence anisotropy parameter Gamma, gradient Richardson number (Ri) representing the local atmospheric stability, and the rate of destruction of temperature variance eta(omega). Model output includes velocity and temperature spectra and associated cospectra, including those of longitudinal and vertical temperature fluxes. The model also produces two-point statistics, such as coherences and phases of velocity components and temperature. The statistics of uniformly sheared and stratified turbulence from the model are compared with atmospheric observations taken from the Horizontal Array Turbulence Study (HATS) field program, and model results fit observed one-dimensional spectra quite well. For highly unstable stratification, however, the model has deficiencies at low wavenumbers that limit its prediction of longitudinal velocity component spectra at scales on the order of 0.6 km. The model predicts coherences well for horizontal separations but overestimates vertical coherence with increasing separation. Finally, it is shown that the RDT output can deviate from Monin-Obukhov similarity theory.
Validation of the dynamic wake meander model with focus on tower loads: Paper

This paper presents a comparison between measured and simulated tower loads for the Danish offshore wind farm Nysted 2. Previously, only limited full scale experimental data containing tower load measurements have been published, and in many cases the measurements include only a limited range of wind speeds. In general, tower loads in wake conditions are very challenging to predict correctly in simulations. The Nysted project offers an improved insight to this field as six wind turbines located in the Nysted II wind farm have been instrumented to measure tower top and tower bottom moments. All recorded structural data have been organized in a database, which in addition contains relevant wind turbine SCADA data as well as relevant meteorological data - e.g. wind speed and wind direction - from an offshore mast located in the immediate vicinity of the wind farm. The database contains data from a period extending over a time span of more than 3 years. Based on the recorded data basic mechanisms driving the increased loading experienced by wind turbines operating in offshore wind farm conditions have been identified, characterized and modeled. The modeling is based on the Dynamic Wake Meandering (DWM) approach in combination with the state-of-the-art aeroelastic model HAWC2, and has previously as well as in this study shown good agreement with the measurements. The conclusions from the study have several parts. In general the tower bending and yaw loads show a good agreement between measurements and simulations. However, there are situations that are still difficult to match. One is tower loads of single-wake operation near rated ambient wind speed for single wake situations for spacing’s around 7-8D. A specific target of the study was to investigate whether the largest tower fatigue loads are associated with a certain downstream distance. This has been identified in both simulations and measurements, though a rather flat optimum is seen in the measurements.

General information
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Organisations: Department of Wind Energy, Wind turbine loads & control, Test and Measurements, Department of Applied Mathematics and Computer Science , Dynamical Systems
Authors: Larsen, T. J. (Intern), Larsen, G. C. (Intern), Pedersen, M. M. (Intern), Enevoldsen, K. (Intern), Madsen, H. A. (Intern)
Number of pages: 10
Publication date: 2017

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Title of host publication: Wake Conference 2017
Volume: 854
Article number: 012027
An experimental and numerical study of the atmospheric stability impact on wind turbine wakes

In this paper, the impact of atmospheric stability on a wind turbine wake is studied experimentally and numerically. The experimental approach is based on full-scale (nacelle based) pulsed lidar measurements of the wake flow field of a stall-regulated 500 kW turbine at the DTU Wind Energy, Risø campus test site. Wake measurements are averaged within a mean wind speed bin of 1 m s\(^{-1}\) and classified according to atmospheric stability using three different metrics: the Obukhov length, the Bulk–Richardson number and the Froude number. Three test cases are subsequently defined covering various atmospheric conditions. Simulations are carried out using large eddy simulation and actuator disk rotor modeling. The turbulence properties of the incoming wind are adapted to the thermal stratification using a newly developed spectral tensor model that includes buoyancy effects. Discrepancies are discussed, as basis for future model development and improvement. Finally, the impact of atmospheric stability on large-scale and small-scale wake flow characteristics is presently investigated. Copyright © 2015 John Wiley & Sons, Ltd.
Demonstration of a Basis for Tall Wind Turbine Design, EUDP Project Final Report

Wind turbine design using calibrated wind models have been proposed to be used in conjunction with load cases which lead to reduced uncertainties in the design of wind turbines with hub heights above 60m. These recommended wind profiles have been made for shear, wind directional change and turbulence. The wind turbulence models used in the loads simulations have been calibrated so that their model parameters reflect the atmospheric stability conditions and the quantile of turbulence intensity considered. Consequently large multi megawatt turbines being designed today can benefit from these more advanced wind inflow models. A revision of the IEC 61400-1 standard is being developed and has incorporated some of the recommendations made from this project. This project demonstrated the impact of wind models by simulating wind turbine loads based on high frequency wind measurements taken between 100m and 200m altitude performed at Havsøre in Denmark. The project also demonstrated the impact of the new wind models on load cases and the certification envelope of turbines. Further the project provided a detailed assessment of safety factors for IEC 61400-1 load cases using reliability-based procedures incorporating the new models and this has been made as an Annex to the new standard that is due to be issued.

General information

State: Published
Number of pages: 101
Publication date: 2016
In search for a canonical design ABL stability class for wind farm turbines

Production as well as loading of wake exposed wind turbines is known to depend significantly on stability of the Atmospheric Boundary Layer (ABL), which adds a new dimension to design of wind farm turbines. Adding this new aspect in wind turbine design makes the number of design cycle computations to blow up with a factor equal to the number of representative stability bin classes. The research question to be answered in this paper is: Can an ABL stability probability distribution in a meaningful way be collapsed into a representative design stability class as based on a (predefined) confidence level.

General information

State: Published
Organisations: Department of Wind Energy, Wind turbine loads & control, Aerodynamic design, Resource Assessment Modelling, University of Agder
Authors: Larsen, G. C. (Intern), Vereis, D. R. (Intern), Bertagnolio, F. (Intern), Ott, S. (Intern), Chougule, A. S. (Ekstern)
Number of pages: 10
Publication date: 2016
Conference: The Science of Making Torque from Wind, Munich, Germany, 05/10/2016 - 05/10/2016
BFI conference series: European Academy of Wind Energy : The Science of Making Torque from Wind (5010078)
Main Research Area: Technical/natural sciences
Investigation of wake interaction using full-scale lidar measurements and large eddy simulation: Investigation of wake interaction using full-scale lidar measurements and LES

In this paper, wake interaction resulting from two stall regulated turbines aligned with the incoming wind is studied experimentally and numerically. The experimental work is based on a full-scale remote sensing campaign involving three nacelle mounted scanning lidars. A thorough analysis and interpretation of the measurements is performed to overcome either the lack of or the poor calibration of relevant turbine operational sensors, as well as other uncertainties inherent in resolving wakes from full-scale experiments. The numerical work is based on the in-house EllipSys3D computational fluid dynamics flow solver, using large eddy simulation and fully turbulent inflow. The rotors are modelled using the actuator disc technique. A mutual validation of the computational fluid dynamics model with the measurements is conducted for a selected dataset, where wake interaction occurs. This validation is based on a comparison between wake deficit, wake generated turbulence, turbine power production and thrust force. An excellent agreement between measurement and simulation is seen in both the fixed and the meandering frame of reference. Copyright © 2015 John Wiley & Sons, Ltd.

General information
State: Published
Organisations: Department of Wind Energy, Wind turbine loads & control, Aerodynamic design, Fluid Mechanics, Test and Measurements, Meteorology & Remote Sensing
Authors: Machefaux, E. (Intern), Larsen, G. C. (Intern), Troldborg, N. (Intern), Hansen, K. S. (Intern), Angelou, N. (Intern), Mikkelsen, T. (Intern), Mann, J. (Intern)
Pages: 1535-1551
Publication date: 2016
Main Research Area: Technical/natural sciences

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Journal: Wind Energy
Volume: 19
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ISSN (Print): 1095-4244
Ratings:
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Scopus rating (2016): CiteScore 3.37 SJR 1.104 SNIP 2.306
We present a homogeneous spectral tensor model for wind velocity and temperature fluctuations, driven by mean vertical shear and mean temperature gradient. Results from the model, including one-dimensional velocity and temperature spectra and the associated co-spectra, are shown in this paper. The model also reproduces two-point statistics, such as coherence and phases, via cross-spectra between two points separated in space. Model results are compared with observations from the Horizontal Array Turbulence Study (HATS) field program (Horst et al. 2004). The spectral velocity tensor in the model is described via five parameters: the dissipation rate ($\varepsilon$), length scale of energy-containing eddies ($L$), a turbulence anisotropy parameter ($\Gamma$), gradient Richardson number ($R_i$) representing the atmospheric stability and the
rate of destruction of temperature variance ($\eta\theta$).

**General information**

State: Published
Organisations: Department of Wind Energy, Meteorology & Remote Sensing, Resource Assessment Modelling, Wind turbine loads & control, University of Agder
Authors: Chougule, A. (Ekstern), Mann, J. (Intern), Kelly, M. C. (Intern), Larsen, G. C. (Intern)
Number of pages: 9
Publication date: 2016
Conference: The Science of Making Torque from Wind, Munich, Germany, 05/10/2016 - 05/10/2016
BFI conference series: European Academy of Wind Energy: The Science of Making Torque from Wind (5010078)
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Issue number: 3
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BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.45 SJR 0.24 SNIP 0.383
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.24 SNIP 0.373 CiteScore 0.35
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.253 SNIP 0.344 CiteScore 0.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.231 SNIP 0.272 CiteScore 0.25
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.28 SNIP 0.354 CiteScore 0.33
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.292 SNIP 0.352 CiteScore 0.43
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.288 SNIP 0.344
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.253 SNIP 0.321
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.265 SNIP 0.294
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.257 SNIP 0.39
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.267 SNIP 0.284
Web of Science (2006): Indexed yes
Original language: English
Electronic versions:
Validation_of_buoyancy.pdf
DOIs:
10.1088/1742-6596/753/3/032038
Wake dynamics in offshore wind farms

Wind turbines within offshore wind farms spend considerable time operating in the wake of neighboring wind turbines. An important contribution to the loads on a wake-affected wind turbine is the slow movement of the wake from the upstream wind turbine across the rotor of the wake-affected wind turbine. A new approach to this so called wake meandering is proposed. Beside the advantage of higher physical realism, the new approach also offers practical advantages compared to the current state-of-the-art method.

An input to the new meandering approach is the time evolution of the so called spectral velocity tensor. An improved such spectral tensor is therefore developed, which, for neutral atmospheric stratification, predicts spatial correlations comparably to the Mann spectral tensor and temporal coherence significantly better than previously existing models, including the Mann model, which is incapable of predicting any temporal correlations beyond those that follows from the application of Taylor’s frozen turbulence hypothesis. As part of the framework a spectral tensor for Lagrangian correlations in space and time is also developed and validated versus measurements of isotropic turbulence. Combined, the models reproduce the cross-over point between Eulerian and Lagrangian temporal covariances. The applications of the Lagrangian spectral tensor, e.g. in the fields of dispersion and mixing, deserve further investigation.

The values of the input parameters of the spectral tensor are shown to be uniquely determined by the friction velocity, the shear and the dissipation of turbulent kinetic energy, all of them physical properties of the flow. If local equilibrium between the turbulent kinetic energy produced by shear and the turbulent kinetic energy dissipated as heat is assumed, then, for neutral atmospheric stratification, the friction velocity and the mixing length determine the spectral tensor.

The developed spectral tensor also depends on a dimensionless quantity, which would be beneficial to determine with higher accuracy. An experiment with this objective, studying the ratio between different components of the cross-spectra at known shear, is proposed. Future work could also include investigating if a Rapid Distortion formulation that also includes a term for buoyancy effects is needed in order to make accurate predictions for non-neutral atmospheric stratification.
validate the modeling setup.

General information
State: Published
Organisations: Department of Wind Energy, Aerodynamic design, Wind turbine loads & control, Fluid Mechanics
Authors: Aagaard Madsen, H. (Intern), Larsen, T. J. (Intern), Larsen, G. C. (Intern), Hansen, K. S. (Intern)
Publication date: 2016

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Conference: 34th Wind Energy Symposium, San Diego, CA, United States, 04/01/2016 - 04/01/2016
DOIs:
10.2514/6.2016-1522
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016

Wind turbine wake measurement in complex terrain
SCADA data from a wind farm and high frequency time series measurements obtained with remote scanning systems have been analysed with focus on identification of wind turbine wake properties in complex terrain. The analysis indicates that within the flow regime characterized by medium to large downstream distances (more than 5 diameters) from the wake generating turbine, the wake changes according to local atmospheric conditions e.g. vertical wind speed. In very complex terrain the wake effects are often "overruled" by distortion effects due to the terrain complexity or topology.

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Main Research Area: Technical/natural sciences

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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.24 SNIP 0.373 CiteScore 0.35
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.253 SNIP 0.344 CiteScore 0.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.231 SNIP 0.272 CiteScore 0.25
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Scopus rating (2012): SJR 0.28 SNIP 0.354 CiteScore 0.33
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Authors: Gögmen, T. (Intern), van der Laan, P. (Intern), Réthoré, P. (Intern), Pena Diaz, A. (Intern), Larsen, G. C. (Intern), Ott, S. (Intern)
Pages: 752–769
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Main Research Area: Technical/natural sciences

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Scopus rating (2016): CiteScore 9.52 SJR 3.051 SNIP 3.454
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.999 SNIP 3.387 CiteScore 8.35
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 3.106 SNIP 3.761 CiteScore 7.79
Web of Science (2014): Indexed yes
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Scopus rating (2013): SJR 3.072 SNIP 3.889 CiteScore 7.88
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Web of Science (2013): Indexed yes
Comparative study of OMA applied to experimental and simulated data from an operating Vestas V27 wind turbine

Today, design of wind turbines is extensively done by the implementation of numerical models. These models simulate the dynamic behaviour of full-scale wind turbines which helps to ensure the structural integrity of prototypes. However, these numerical models need validation from experimental results, and in turn, numerical and analytical modelling help improve and validate new experimental techniques. Wind turbines are complex dynamic systems that consist of mutually moving substructures under high dynamic loads. At a standstill, the system can be modelled as linear time-invariant (LTI), and modal analysis requirements are thus fulfilled for the dynamic characterization. Under operation, the system cannot be considered as LTI and must be modelled as a linear periodic time-variant (LPTV) system, which allows for the application of the related theory for such systems. One of these methods is the Coleman transformation, which transforms the vibrations expressed in the blade rotating coordinates to the fixed-ground frame of reference. The application of this transformation, originally from helicopter theory, allows for the conversion of a LPTV system to a LTI system under certain assumptions, among which is the assumption of isotropic rotors. Since rotors are never completely isotropic in real life, this paper presents the application of operational modal analysis together with the Coleman transformation on both experimental data from a full-scale Vestas wind turbine with instrumented blades and nacelle, and its representative numerical model with a fully isotropic rotor. The results show that the first tower and rotor edgewise modes are well identified, and that the rotor edgewise modes can be identified from the nacelle signals. The results also uncover the challenge the excitation forces imply for the identification of flapwise modes.

**General information**

*State: Published*

*Organisations: Department of Wind Energy, Aeroelastic Design, Brüel & Kjær A/S*

*Authors: Requeson, O. R. (Intern), Tcherniak, D. (Ekstern), Larsen, G. C. (Intern)*

*Number of pages: 10*

*Publication date: 2015*
Empirical modeling of single-wake advection and expansion using full-scale pulsed lidar-based measurements

In the present paper, single-wake dynamics have been studied both experimentally and numerically. The use of pulsed lidar measurements allows for validation of basic dynamic wake meandering modeling assumptions. Wake center tracking is used to estimate the wake advection velocity experimentally and to obtain an estimate of the wake expansion in a fixed frame of reference. A comparison shows good agreement between the measured average expansion and the Computational Fluid Dynamics (CFD) large eddy simulation–actuator line computations. Frandsen's expansion model seems to predict the wake expansion fairly well in the far wake but lacks accuracy in the outer region of the near wake. An empirical relationship, relating maximum wake induction and wake advection velocity, is derived and linked to the characteristics of a spherical vortex structure. Furthermore, a new empirical model for single-wake expansion is proposed based on an initial wake expansion in the pressure-driven flow regime and a spatial gradient computed from the large-scale lateral velocities, and thus inspired by the basic assumption behind the dynamic wake meandering model. Copyright © 2014 John Wiley & Sons, Ltd.
Engineering models for merging wakes in wind farm optimization applications

The present paper deals with validation of 4 different engineering wake superposition approaches against detailed CFD simulations and covering different turbine interspacing, ambient turbulence intensities and mean wind speeds. The first engineering model is a simple linear superposition of wake deficits as applied in e.g. Fuga. The second approach is the square root of sums of squares approach, which is applied in the widely used PARK program. The third approach, which is presently used with the Dynamic Wake Meandering (DWM) model, assumes that the wake affected downstream flow field to be determined by a superposition of the ambient flow field and the dominating wake among contributions from all upstream turbines at any spatial position and at any time. The last approach developed by G.C. Larsen is a newly developed model based on a parabolic type of approach, which combines wake deficits successively. The study indicates that wake interaction depends strongly on the relative wake deficit magnitude, i.e. the deficit magnitude normalized with respect to the ambient mean wind speed, and that the dominant wake assumption within the DWM framework is the most accurate.

General information
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Organisations: Department of Wind Energy, Aeroelastic Design
Authors: Machefaux, E. (Intern), Larsen, G. C. (Intern), Murcia Leon, J. P. (Intern)
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.24 SNIP 0.373 CiteScore 0.35
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.253 SNIP 0.344 CiteScore 0.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.231 SNIP 0.272 CiteScore 0.25
ISI indexed (2013): ISI indexed no
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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.28 SNIP 0.354 CiteScore 0.33
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.292 SNIP 0.352 CiteScore 0.43
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.288 SNIP 0.344
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.253 SNIP 0.321
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.265 SNIP 0.294
Web of Science (2008): Indexed yes
Multiple Turbine Wakes

The central goal of the present research was to study single and multiple interacting wind turbine wakes using both full-scale lidar experiments and high fidelity CFD numerical approaches. Firstly, single wake dynamics have been studied experimentally using full-scale (nacelle based) pulsed lidar measurements conducted on a stall regulated 500 kW turbine at the DTU Wind Energy, Riso campus test site. As part of the experimental analysis, basic Dynamic Wake Meandering modeling assumptions were validated. A wake center tracking algorithm was used to estimate the measured wake advection velocity and to obtain an estimate of the wake expansion in a fixed frame of reference. A comparison of selected datasets from the campaign showed good far wake agreements of mean wake expansion with Actuator Line CFD computations and simpler engineering models. An empirical relationship, relating maximum wake induction and wake advection velocity, is derived and linked to the characteristics of a spherical vortex structure. Additionally, a new empirical model for single wake expansion is proposed based on an initial wake expansion in the pressure driven flow regime and a spatial gradient computed from the large scale lateral velocities, and thus inspired by the basic assumption behind the Dynamic Wake Meandering model.

Secondly, the impact of the atmospheric stability on wind turbine wake deficit is studied experimentally and numerically. The measurements collected from the previous pulsed lidar campaign was reused as part of the experimental analysis. An inflow wind sector of 30° is selected based on both a wind resource and a lidar data assessment. Wake measurements are averaged within a mean wind speed bin of 1 m/s and classified according to atmospheric stability using 3 different approaches: the Obukhov length, the Bulk-Richardson and the Froude number approach. Three test cases are subsequently defined covering various atmospheric conditions. Simulations based on the EllipSys3D ABL flow solver are carried out using Large Eddy Simulation and Actuator disc rotor modeling. The turbulence properties of the incoming wind are adapted to the thermal stratification using a newly developed spectral tensor, which includes buoyancy effects. Discrepancies are discussed as basis for future model development and improvement.

Moreover, the impact of atmospheric stability and terrain on large/small scale wake flow characteristics was investigated. Later, wake interaction resulting from two stall regulated turbines aligned with the incoming wind were studied experimentally and numerically. The experimental work was based on a new dedicated full-scale measurement campaign involving 3 nacelle mounted Continuous Wave scanning lidars. A thorough analysis and interpretation of the measurements was performed to overcome either the lack or the poor calibration of relevant turbine operational sensors, as well as other uncertainties inherent to wake resolving from full-scale experiments. The numerical work was based on the in-house EllipSys3D CFD flow solver, using Large Eddy Simulation and fully turbulent inflow, where the rotors are modeled using the Actuator Disc technique. A mutual validation of the CFD model with the measurements is proposed for a selected dataset where wake interactions occur. An excellent agreement between measurement and simulation is seen in both the fixed and the meandering frame of reference. A benchmark of several wake accumulation models is performed as a basis for the subsequent development of an engineering model for wake interaction. Finally, the validated numerical CFD model is used as part of a parametric study where wake interaction is studied in a generic way, under several turbine spacings, mean wind speeds and turbulence intensities and in the fixed and the moving frame of reference of the wake. The analysis revealed that the industry widely used quadratic summation of single wake deficits for modeling the resulting double wake deficit is only relevant at high turbine thrust coefficients. For high wind speed and low thrust coefficient, linear summation should be primarily used. The first iteration of a new engineering model capable of modeling the overlapped wake deficit is formulated and its performance is tested again double, triple and quadruple wake deficits. Good performance in the prediction of both the maximum merged wake deficit and wake width is observed.

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Offshore Wind Farms
The technology behind constructing wind farms offshore began to develop in 1991 when the Vindeby wind farm was installed off the Danish coast (11 Bonus 450 kW turbines). Resource assessment, grid connection, and wind farm operation are significant challenges for offshore wind power just as it is for the more traditional onshore wind power, which has been under development since the 1970s. However, offshore projects face extra technical challenges some of which requires in-depth scientific investigations. This article deals with some of the most outstanding challenges concerning the turbine structure: the rotor, the nacelle, the tower, and the foundation. Further the determinations of the essential environmental conditions are treated: the wind field, the wave field, the sea current, and the soil conditions. The various options for grid connections, advantages, and disadvantages are discussed. Of special concern are the problems associated with locating the turbines close together in a wind farm and the problems of placing several large wind farms in a confined area. The environmental impacts of offshore wind farms are also treated, but not the supply chain, that is, the harbors, the installation vessels, the O&M ships, and the communication and maintenance challenges.

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Turbulent wind field characterization and re-generation based on pitot tube measurements mounted on a wind turbine
This paper describes a new method to estimate the undisturbed inflow field of a wind turbine based on measurements obtained from one or more five-hole pitot tubes mounted directly on the blades. Based on the measurements, the disturbance caused by the wind turbine is estimated using aerodynamic models that compensate for axial and tangential induction, approximated by blade element momentum theory, radial expansion of the inflow, rotor tilt, dynamic and skew inflow, tip loss, as well as braking and circulation of the flow local to the airfoil. The wind speeds measured on the rotating blades give a better estimate of the turbulence intensity over the rotor plane than can be measured at a single point, e.g. using a cup anemometer, and in addition the wind shear profile can be derived. In addition the measurements can be used to constrain a synthetic turbulence model to exactly produce the measured wind speeds at the recording position. In the theoretical part of this study a quite good agreement is seen between load sensors on a turbine model exposed to the reference and the re-generated turbulence field. Finally the method is applied to full scale measurements and reasonable wind shear profiles are derived. It is expected that this method will lead to a new and effective experimental method to characterize the incoming flow field to a wind turbine and thus contribute to the understanding of wind turbine loads.

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Organisations: Department of Wind Energy, Aeroelastic Design
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Two improvements to the dynamic wake meandering model: including the effects of atmospheric shear on wake turbulence and incorporating turbulence build-up in a row of wind turbines

The dynamic wake meandering (DWM) model is an engineering wake model designed to physically model the wake deficit evolution and the unsteady meandering that occurs in wind turbine wakes. The present study aims at improving two features of the model:

The effect of the atmospheric boundary layer shear on the wake deficit evolution by including a strain-rate contribution in the wake turbulence calculation.

The method to account for the increased turbulence at a wake-affected turbine by basing the wake-added turbulence directly on the Reynolds stresses of the oncoming wake. This also allows the model to simulate the build-up of turbulence over a row of turbines in a physically consistent manner.

The performance of the modified model is validated against actuator line (AL) model results and field data from the Lillgrund offshore wind farm. Qualitatively, the modified DWM model is in fair agreement with the reference data. A quantitative comparison between the mean flow field of the DWM model with and without the suggested improvements, to that of the AL model, shows that the root-mean-square difference in terms of wind speed and turbulence intensity is reduced on the order of 30% and 40%, respectively, by including the proposed corrections for a row of eight turbines. Furthermore, it is found that the root-mean-square difference between the AL model and the modified DWM model in terms of wind speed and turbulence intensity does not increase over a row of turbines compared with the root-mean-square difference of a single turbine. Copyright © 2013 John Wiley & Sons, Ltd.
Dynamic wake meandering, DWM, Wake modelling, Actuator line model, Wind turbine wake, Wake-added turbulence, Wake turbulence, Wind farm modelling

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Wake effects above rated wind speed. - An overlooked contributor to high loads in wind farms

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Authors: Larsen, T. J. (Intern), Larsen, G. C. (Intern), Aagaard Madsen, H. (Intern), Markilde Pedersen, S. (Ekstern)
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Wake effects above rated wind speed. An overlooked contributor to high loads in wind farms

In this paper a new validation of the Dynamic Wake Meandering method for calculating wake effects on power and load levels on a turbine is presented based on load and power measurements on a turbine located in the Lillgrund wind farm. What is unique is the large set of measurements available, where the wake effects from multiple neighboring turbines in high wind speed conditions could be included. It appears that the DWM method gives accurate results in single wake situations as well as for multiwake situations below rated wind speed. However, the so far used method for superposition of multiple wakes above rated wind speed has led to non-conservative load predictions for high wind speeds. Therefore a new approach is presented and compared to both measurements and present practice in the IEC61400-1 standard.

Wake meandering under non-neutral atmospheric stability conditions – theory and facts

This paper deals with modelling of wake dynamics under influence of atmospheric stability conditions different from neutral. In particular, it is investigated how the basic split in turbulent scales, on which the Dynamic Wake Meandering model is based, can be utilized to include atmospheric stability effects in this model. This is done partly by analyzing a large number of turbulence spectra obtained from sonic measurements, partly by analyzing dedicated full-scale LiDAR measurements from which wake dynamics can be directly resolved. The theory behind generalizing the Dynamic Wake Meandering model to non-neutral conditions are summarized and linked to the results of the full-scale experimental results. It is concluded that there is a qualitative match between the conjecture behind the Dynamic Wake Meandering model and the dependence of turbulence structure on atmospheric stability conditions, and consequently that there is a potential for generalizing the Dynamic Wake Meandering model to include effects of atmospheric stability.
A Review of Methodological Approaches for the Design and Optimization of Wind Farms

This article presents a review of the state of the art of the Wind Farm Design and Optimization (WFDO) problem. The WFDO problem refers to a set of advanced planning actions needed to extremize the performance of wind farms, which may be composed of a few individual Wind Turbines (WTs) up to thousands of WTs. The WFDO problem has been investigated in different scenarios, with substantial differences in main objectives, modelling assumptions, constraints, and numerical solution methods. The aim of this paper is: (1) to present an exhaustive survey of the literature covering the full span of the subject, an analysis of the state-of-the-art models describing the performance of wind farms as well as its extensions, and the numerical approaches used to solve the problem; (2) to provide an overview of the available knowledge and recent progress in the application of such strategies to real onshore and offshore wind farms; and (3) to propose a comprehensive agenda for future research.

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Dependence of offshore wind turbine fatigue loads on atmospheric stratification
The stratification of the atmospheric boundary layer (ABL) is classified in terms of the M-O length and subsequently used to determine the relationship between ABL stability and the fatigue loads of a wind turbine located inside an offshore wind farm. Recorded equivalent fatigue loads, representing blade-bending and tower bottom bending, are combined with the operational statistics from the instrumented wind turbine as well as with meteorological statistics defining the inflow conditions. Only a part of all possible inflow conditions are covered through the approximately 8200 hours of combined measurements. The fatigue polar has been determined for an (almost) complete 360° inflow sector for both load sensors, representing mean wind speeds below and above rated wind speed, respectively, with the inflow conditions classified into three different stratification regimes: unstable, neutral and stable conditions. In general, impact of ABL stratification is clearly seen on wake affected inflow cases for both blade and tower fatigue loads. However, the character of this dependence varies significantly with the type of inflow conditions – e.g. single wake inflow or multiple wake inflow.

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De-trending of wind speed variance based on first-order and second-order statistical moments only

The lack of efficient methods for de-trending of wind speed resource data may lead to erroneous wind turbine fatigue and ultimate load predictions. The present paper presents two models, which quantify the effect of an assumed linear trend on wind speed standard deviations as based on available statistical data only.

The first model is a pure time series analysis approach, which quantifies the effect of non-stationary characteristics of...
ensemble mean wind speeds on the estimated wind speed standard deviations as based on mean wind speed statistics only. This model is applicable to statistics of arbitrary types of time series.

The second model uses the full set of information and includes thus additionally observed wind speed standard deviations to estimate the effect of ensemble mean non-stationarities on wind speed standard deviations. This model takes advantage of a simple physical relationship between first-order and second-order statistical moments of wind speeds in the atmospheric boundary layer and is therefore dedicated to wind speed time series but is not applicable to time series in general.

The capabilities of the proposed models are discussed by comparing model predictions with conventionally de-trended characteristics of measured wind speeds using data where high sampled time series are available, and a traditional de-trending procedure therefore can be applied. This analysis shows that the second model performs significantly better than the first model, and thus in turn that the model constraint, introduced by the physical link between the first and second statistical moments, proves very efficient in the present context. Copyright © 2013 John Wiley & Sons, Ltd.
Effect of a Damage to Modal Parameters of a Wind Turbine Blade

This study reports structural dynamic characteristics obtained experimentally from an extensive testing campaign on a 34m long wind turbine blade mounted on a test-rig under laboratory conditions. Further, these experimental results have been compared with analog numerical results obtained from a very detailed FE model of the same blade using 3D solid elements. Both an undamaged and a damaged blade are investigated, and it is observed that the natural frequencies of the first few modes of the blade change very little due to a significant artificial damage imposed in trailing edge, whereas the mode shapes - especially if decomposed into the flapwise, edgewise and torsional components - contain information which might be helpful for detecting and localizing wind turbine blade damages.

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Organisations: Department of Wind Energy, Aeroelastic Design, Wind Turbines, Brüel & Kjær A/S
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Full-scale measurements of aerodynamic induction in a rotor plane

Reliable modelling of aerodynamic induction is imperative for successful prediction of wind turbine loads and wind turbine dynamics when based on state-of-the-art aeroelastic tools. Full-scale LiDAR based wind speed measurements, with high temporal and spatial resolution, have been conducted in the rotor plane of an operating 2MW/80m wind turbine to perform detailed analysis the aerodynamic induction. The experimental setup, analyses of the spatial structure of the aerodynamic induction and subsequent comparisons with numerical predictions, using the HAWC2 aerelastic code, are presented.

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On atmospheric stability in the dynamic wake meandering model

The present study investigates a new approach for capturing the effects of atmospheric stability on wind turbine wake evolution and wake meandering by using the dynamic wake meandering model. The most notable impact of atmospheric
stability on the wind is the changes in length and velocity scales of the atmospheric turbulence. The length and velocity scales in the turbulence are largely responsible for the way in which wind turbine wakes meander as they convect downstream. The hypothesis of the present work is that appropriate turbulence scales can be extracted from the oncoming atmospheric turbulence spectra and applied to the dynamic wake meandering model to capture the correct wake meandering behaviour. The ambient turbulence in all stability classes is generated using the Mann turbulence model, where the effects of non-neutral atmospheric stability are approximated by the selection of input parameters.

In order to isolate the effect of atmospheric stability, simulations of neutral and unstable atmospheric boundary layers using large-eddy simulation are performed at the same streamwise turbulence intensity level. The turbulence intensity is kept constant by calibrating the surface roughness in the computational domain. The changes in the turbulent length scales due to the various atmospheric stability states impact the wake meandering characteristics and thus the power generation by the individual turbines.

The proposed method is compared with results from both large-eddy simulation coupled with an actuator line model and field measurements, where generally good agreement is found with respect to the velocity, turbulence intensity and power predictions. Copyright © 2013 John Wiley & Sons, Ltd.
Probabilistic Meteorological Characterization for Turbine Loads

Beyond the existing, limited IEC prescription to describe fatigue loads on wind turbines, we look towards probabilistic characterization of the loads via analogous characterization of the atmospheric flow, particularly for today's "taller" turbines with rotors well above the atmospheric surface layer. Based on both data from multiple sites as well as theoretical bases from boundary-layer meteorology and atmospheric turbulence, we offer probabilistic descriptions of shear and turbulence intensity, elucidating the connection of each to the other as well as to atmospheric stability and terrain. These are used as input to loads calculation, and with a statistical loads output description, they allow for improved design and loads calculations.

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Authors: Kelly, M. C. (Intern), Larsen, G. C. (Intern), Dimitrov, N. K. (Intern), Natarajan, A. (Intern)
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TOPFARM: Multi-fidelity optimization of wind farms

A wind farm layout optimization framework based on a multi-fidelity optimization approach is applied to the offshore test case of Middelgrunden, Denmark as well as to the onshore test case of Stag Holt – Coldham wind farm, UK. While aesthetic considerations have heavily influenced the famous curved design of the Middelgrunden wind farm, this work focuses on demonstrating a method that optimizes the profit of wind farms over their lifetime based on a balance of the energy production income, the electrical grid costs, the foundations cost, and the cost of wake turbulence induced fatigue degradation of different wind turbine components. A multi-fidelity concept is adapted, which uses cost function models of increasing complexity (and decreasing speed) to accelerate the convergence to an optimum solution. In the EU-FP6 TOPFARM project, three levels of complexity are considered. The first level uses a simple stationary wind farm wake model to estimate the Annual Energy Production (AEP), a foundations cost model depending on the water depth and an electrical grid cost function dictated by cable length. The second level calculates the AEP and adds a wake-induced fatigue degradation cost function on the basis of the interpolation in a database of simulations performed for various wind speeds and wake setups with the aero-elastic code HAWC2 and the dynamic wake meandering model. The third level, not considered in this present paper, includes directly the HAWC2 and the dynamic wake meandering model in the optimization loop in order to estimate both the fatigue costs and the AEP. The novelty of this work is the implementation of the multi-fidelity approach in the context of wind farm optimization, the inclusion of the fatigue degradation costs in the optimization framework, and its application on the optimal performance as seen through an economical perspective. Copyright © 2013 John Wiley & Sons, Ltd.
A consistent turbulence formulation for the dynamic wake meandering model in the atmospheric boundary layer

This thesis describes the further development and validation of the dynamic wake meandering model for simulating the flow field and power production of wind farms operating in the atmospheric boundary layer (ABL). The overall objective of the conducted research is to improve the modelling capability of the dynamics wake meandering model to a level where it is sufficiently mature to be applied in industrial applications and for an augmentation of the IEC-standard for wind turbine wake modelling.

Based on a comparison of capabilities of the dynamic wake meandering model to the requirement of the wind industry, four areas were identified as high prioritizations for further research:
1. the turbulence distribution in a single wake
2. multiple wake deficits and build-up of turbulence over a row of turbines
3. the effect of the atmospheric boundary layer on wake turbulence and wake deficit evolution
4. atmospheric stability effects on wake deficit evolution and meandering

The conducted research is to a large extent based on detailed wake investigations and reference data generated through computational fluid dynamics simulations, where the wind turbine rotor has been represented by an actuator line model. As a consequence, part of the research also targets the performance of the actuator line model when generating wind turbine wakes in the atmospheric boundary layer.

Highlights of the conducted research:
1. A description is given for using the dynamic wake meandering model as a standalone flow-solver for the velocity and turbulence distribution, and power production in a wind farm. The performance of the standalone implementation is validated against field data, higher-order computational fluid dynamics models, as well as the most common engineering wake models in the wind industry.
2. The EllipSys3D actuator line model, including the synthetic methods used to model atmospheric boundary layer shear and turbulence, is verified for modelling the evolution of wind turbine wake turbulence by comparison to field data and wind tunnel experiments.
3. A two-dimensional eddy viscosity model is implemented to govern the distribution of turbulent stresses in the wake deficit. The modified eddy viscosity model improves the least-square fit of the velocity field in the wake by ~13% when compared to higher-order models.
4. A method is proposed to couple the increased turbulence level experienced by a turbine operating in waked conditions, to the downstream wake evolution of the wake-affected turbine. The intraturbine turbulence coupling improved the fit of the turbulence distribution by ~40% and the wind speed distribution by ~30% over a row of eight turbines.
5. The effect of the atmospheric shear on the turbulent stresses in the wake is captured by including a local strain-rate contribution for the ambient shear gradient. This results in more realistic turbulent stress levels in regions of small wake deficit gradients; this is particularly important in the far-wake region where atmospheric shear gradients are an important contribution to the local strain-rate.
6. A method to include the effect of atmospheric stability on the wake deficit evolution and wake meandering is described. Including the atmospheric stability effects improved the model prediction of the mean velocity field by ~19% and of turbulence distribution by ~28% in unstable atmospheric conditions compared to actuator line results. The power production by a row of wind turbines aligned with the wind direction is reduced by ~10% in very stable conditions compared to very unstable conditions at the same turbulence intensity. This power drop is comparable to measurements from the North Hoyle and OWEZ wind farms.
Application of OMA to an Operating Wind Turbine: now including Vibration Data from the Blades

The presented study continues the work on application of Output Only Modal Analysis (OMA) to operating wind turbines. It is known from previous studies that issues like the time-varying nature of the equations of motion of an operating wind turbine (in particular the significant harmonic components due to the rotor rotation) as well as the considerable aerodynamic damping make OMA of operating wind turbines a difficult task. While in the previous works OMA was based on data provided by sensors mounted on the wind turbine tower and nacelle, we here attempt to improve the results by instrumenting the blades as well. It is believed that the availability of vibration data from the blades will improve the observability of the main global vibration modes (especially the heavily damped out-of-plane modes), and thus will assure a better estimation of modal parameters, especially the damping. The paper discusses the technical challenges regarding blade instrumentation and data acquisition, data processing applied to eliminate the time-varying nature of an operating wind turbine in the resulting eigenvalue problem and, finally, it presents and discusses the initial results.

Benchmarking of wind farm scale wake models in the EERA - DTOC project

Designing offshore wind farms next to existing or planned wind farm clusters has recently become a common practice in the North Sea. These types of projects face unprecedented challenges in term of wind energy siting. The currently ongoing European project FP7 EERA - DTOC (Design Tool for Offshore wind farm Clusters) is aiming at providing a new type of model work-flow to address this issue. The wake modeling part of the EERA - DTOC project is to improve the fundamental understanding of wind turbine wakes and modeling. One of these challenges is to create a new kind of wake modeling work-flow to combine wind farm (micro) and cluster (meso) scale wake models. For this purpose, a benchmark campaign is organized on the existing wind farm wake models available within the project, in order to identify which model would be the most appropriate for this coupling. A number of standardized wake cases for large offshore wind farms will be analyzed, which provide a reasonable range of conditions likely to be experienced in offshore wind farms. The systematic evaluation is based upon high - quality input data that is selected in the sister project IEA - Task 31 "WakeBench".

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Challenges in wind farm optimization

To achieve the optimal economic output from a wind farm over its lifetime, an optimal balance between capital costs, operation and maintenance costs, fatigue lifetime consumption of turbine components and power production is to be determined on a rational basis. This has implications both for the wind turbine modeling, where aeroelastic models are required, and for the wind farm flow field description, where in-stationary flow field modeling is needed to capture the complicated mixture of atmospheric boundary layer (ABL) flows and upstream emitted meandering wind turbine wakes, which together dictates the fatigue loading of the individual wind turbines.

Within an optimization context, the basic challenge in describing the in-stationary wind farm flow field is computational speed. The Dynamic Wake Meandering (DWM) model includes the basic features of a CFD Large Eddy Simulation approach in an engineering manner by essentially treating wind turbine wakes as passive tracers emitted into an ABL field. Interfacing the DWM model with the aeroelastic code HAWC2 has facilitated development of the wind farm optimization platform TOPFARM. Features of the TOPFARM platform will be described, including full-scale validation examples of key elements as well as example applications, and recent developments and future plans will be touch on.
In this paper, single wake characteristics have been studied both experimentally and numerically. Firstly, the wake is studied experimentally using full-scale measurements from an adapted focused pulsed lidar system, which potentially gives more insight into the wake dynamics as compared to classical studies based on meteorological (met) masts and continuous wave lidar measurements, due to its capability of scanning several cross sections simultaneously. A wake center tracking procedure is used to estimate the sideways wake center displacements, also referred to as lateral meandering of the wake, and it is compared to the predictions from the Dynamic Wake Meandering model, for a selected 10 minutes dataset. Secondly, the average wake expansion in the fixed frame of reference is determined from measurements and compared to results from CFD simulations. The CFD simulations were conducted using the EllipSys3D flow solver using Large Eddy Simulation (LES) and Actuator Line Technique (ACL) to model the rotor. Discrepancies due to the uncertainties on the wake advection velocity are observed and discussed.

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Organisations: Department of Wind Energy, Aeroelastic Design, University of Stuttgart
Authors: Machefaux, E. (Intern), Larsen, G. C. (Intern), Troldborg, N. (Intern), Rettenmeier, A. (Ekstern)
Number of pages: 11
Publication date: 2013
The impact of atmospheric stability on wake losses

General information
State: Published
Organisations: Department of Wind Energy, Aeroelastic Design, Fluid Mechanics, Meteorology
Authors: Larsen, G. C. (Intern), Larsen, T. J. (Intern), Hansen, K. S. (Intern), Chougule, A. S. (Intern), Mann, J. (Intern), Aagaard Madsen, H. (Intern)
Number of pages: 22
Publication date: 2013

The nature of wind turbine fatigue loads in wind farms
The aim of the present paper is to further validate the predictive capability of the DWM/HAWC2 package for simulation of structural loadings in wind farms. The validation in particular focus on tower fatigue loading characteristics (i.e. equivalent moments) as function of turbine relative position, including turbine interspacing.

To accomplish this, comparative studies of predicted and measured fatigue load characteristics are performed. The involved data relates to full-scale measurements from the Danish Rødsand 2 offshore wind farm, where 6 turbines are instrumented with strain gauges providing tower top and bottom bending moments as well as tower the top torsion moment. The numerical predictions are based on a simulation package, where the Dynamic Wake Meandering model is interfaced with the in-house aeroelastic code HAWC2.

Comparing simulated and measured tower fatigue loading, good agreements were found between the extend of wake affected direction regimes. As for the magnitude of the (mean) wake loading, the tower top moments were underestimated with of the order 15%, whereas the tower bottom moments were found to agree well with the measured results.

General information
State: Published
Organisations: Department of Wind Energy, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Larsen, T. J. (Intern), Aagaard Madsen, H. (Intern)
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TOPFARM – A Tool for Wind Farm Optimization
TOPFARM takes the investors perspective and performs an economical optimization of a wind farm layout throughout the lifetime of the wind farm. The economical optimization approach of wind farm layout differs significantly from the traditional power output optimization. The major differences are highlighted, and the TOPFARM platform is described in brief. The capability of the platform is illustrated in two demonstration examples. In the first example we perform a sanity check of basic features of the TOPFARM objective function. The second example demonstrates the power of economical layout optimization, when applied on the Danish Middelgrunden offshore wind farm. The paper concludes by describing planned future developments of TOPFARM.

General information
State: Published
Organisations: Department of Wind Energy, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Réthoré, P. (Intern)
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Publication date: 2013
Main Research Area: Technical/natural sciences

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Web of Science (2016): Indexed yes
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Scopus rating (2013): SJR 0.425 SNIP 0.785 CiteScore 1.02
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Original language: English
Economical optimization, wind farm flow field ;wind farm layout ;aeroelastic codes ;cost models
Electronic versions:
TOPFARM.pdf
DOIs:
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Source: dtu
Source-ID: n:oat:DTIC-ART:elsevier/390737655::31267
Publication: Research - peer-review › Conference article – Annual report year: 2013

TOPFARM - topology optimization as seen from an investor's perspective
TOPFARM is an optimization platform, which takes the investors perspective and performs an economical optimization of the wind farm layout throughout the lifetime of the wind farm. The economical optimization approach differs significantly from the traditional power output optimization. The major differences are highlighted, and the TOPFARM platform is described in some detail. The capability of the platform is illustrated in two demonstration examples. In the first example we perform a sanity check of basic features of the TOPFARM objective function. The second example demonstrates the capability of economical layout optimization, when applied on the Danish Middelgrunden offshore wind farm.

General information
TOPFARM - topology optimization as seen from an investor's perspective

Validation of the dynamic wake meander model for loads and power production in the Egmond aan Zee wind farm

This paper investigates wake effects on load and power production by using the dynamic wake meander (DWM) model implemented in the aeroelastic code HAWC2. The instationary wind farm flow characteristics are modeled by treating the wind turbine wakes as passive tracers transported downstream using a meandering process driven by the low frequent cross-wind turbulence components. The model complex is validated by comparing simulated and measured loads for the Dutch Egmond aan Zee wind farm consisting of 36 Vestas V90 turbine located outside the coast of the Netherlands. Loads and production are compared for two distinct wind directions—a free wind situation from the dominating southwest and a full wake situation from northwest, where the observed turbine is operating in wake from five turbines in a row with 7D spacing. The measurements have a very high quality, allowing for detailed comparison of both fatigue and min–mean–max loads for blade root flap, tower yaw and tower bottom bending moments, respectively. Since the observed turbine is located deep inside a row of turbines, a new method on how to handle multiple wakes interaction is proposed. The agreement between measurements and simulations is excellent regarding power production in both free and wake sector, and a very good agreement is seen for the load comparisons too. This enables the conclusion that wake meandering, caused by large scale ambient turbulence, is indeed an important contribution to wake loading in wind farms.

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Wake effects, Wind turbine, Loads, Power

Benchmarking of Wind Turbine Wake Models in Large Offshore Windfarms

Quantifying accurately wind turbine wakes is a key aspect of wind farm economics in large wind farms. This research compares three engineering wake models with power production data from the Horns Rev and Lillgrund offshore wind farms. Single and multiple wake cases are investigated to verify the performance of the models in different conditions. The simulations reveal that the three wake models have similar behaviours for both wind farms although the turbine spacing and the turbulence intensity are different. The results prove the robustness of the models to provide accurate power predictions when the simulations are averaged over wind direction sectors of 30. However, all models significantly underpredict the power production of a single row of wind turbines using narrow sectors of 3 or 5. This discrepancy is discussed and justified by the wind direction uncertainty included in the datasets.
Experimental and Numerical study of Wake to Wake Interaction in Wind Farms

In this paper, wake interaction between two wind turbines is analyzed using experimental and numerical approaches. Full-scale wake measurements are conducted at Tjæreborg wind farm and are obtained using a continuous wave lidar mounted on the back of the nacelle of a 2MW NM80 turbine. Numerical analyses are conducted for two double wake cases characterized by different turbine spacing, using the in-house EllipSys3D flow solver. Large Eddy Simulation and Actuator Line technique are used for modeling the rotor and the flow field. 10-minute average streamwise velocity and turbulence level are compared, and good agreement is seen between the measurements and the computations despite of a lateral offset and other discrepancies due to uncertainties on the measured inflow conditions and lidar mounting alignment.

Full-scale measurements of aerodynamic induction in a rotor plane

General information
State: Published
Organisations: Department of Wind Energy, Aeroelastic Design, Fluid Mechanics
Authors: Larsen, G. C. (Intern), Hansen, K. S. (Intern)
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Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Conference: EWEA 2012 - European Wind Energy Conference & Exhibition, Copenhagen, Denmark, 16/04/2012 - 16/04/2012
Electronic versions:
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Publication: Research - peer-review › Article in proceedings – Annual report year: 2012

Full-scale measurements of aerodynamic induction in a rotor plane

General information
State: Published
Organisations: Department of Wind Energy, Aeroelastic Design, Meteorology
Authors: Machefaux, E. (Intern), Troldborg, N. (Intern), Larsen, G. C. (Intern), Mann, J. (Intern), Aagaard Madsen, H. (Intern)
Number of pages: 10
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Title of host publication: Proceedings of EWEA 2012 - European Wind Energy Conference & Exhibition
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Conference: EWEA 2012 - European Wind Energy Conference & Exhibition, Copenhagen, Denmark, 16/04/2012 - 16/04/2012
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Full-scale measurements of aerodynamic induction in a rotor plane

General information
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Organisations: Department of Wind Energy, Aeroelastic Design, Meteorology
Authors: Gaumond, M. (Ekstern), Réthoré, P. (Intern), Bechmann, A. (Intern), Ott, S. (Intern), Larsen, G. C. (Intern), Pena Diaz, A. (Intern), Hansen, K. S. (Intern)
Number of pages: 1
Publication date: 2012
Event: Poster session presented at The science of Making Torque from Wind 2012, Oldenburg, Germany.
Main Research Area: Technical/natural sciences
Electronic versions:
Poster_Benchmarking_of_Wind_Turbine_Wake_Models.pdf
Publication: Research - peer-review › Poster – Annual report year: 2012
Full scale verification of wind farm production predictions

General information
State: Published
Organisations: Department of Wind Energy, Aeroelastic Design, Meteorology, Fluid Mechanics
Authors: Larsen, G. C. (Intern), Larsen, T. J. (Intern), Ott, S. (Intern), Hansen, K. S. (Intern), Aagaard Madsen, H. (Intern)
Publication date: 2012

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Main Research Area: Technical/natural sciences
Conference: ICTAM 2012, Beijing, China, 19/08/2012 - 19/08/2012
Electronic versions: Legarth.pdf
Publication: Research - peer-review › Article in proceedings – Annual report year: 2012

Implementation of a Mixing Length Turbulence Formulation Into the Dynamic Wake Meandering Model
The work presented in this paper focuses on improving the description of wake evolution due to turbulent mixing in the dynamic wake meandering (DWM) model. From wake investigations performed with high-fidelity actuator line simulations carried out in ELLIPSY3D, it is seen that the current DWM description, where the eddy viscosity is assumed to be constant in each cross-section of the wake, is insufficient. Instead, a two-dimensional eddy viscosity formulation is proposed to model the shear layer generated turbulence in the wake, based on the classical mixing length model. The performance of the modified DWM model is verified by comparing the mean wake velocity distribution with a set of ELLIPSY3D actuator line calculations. The standard error (defined as the standard deviation of the difference between the mean velocity field of the DWM and the actuator line model), in the wake region extending from 3 to 12 diameters behind the rotor, is reduced by 27% by using the new eddy viscosity formulation.

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Park power deficit due to atmospheric stability

The purpose of this paper is to present a power deficit analysis based on offshore wind farm measurements with respect to the atmospheric stability classification. The result is used to validate wind farm prediction models under different inflow and atmospheric stability conditions.

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State: Published
Organisations: Department of Wind Energy, Fluid Mechanics, Meteorology, Aeroelastic Design, Indiana University-Purdue
Authors: Hansen, K. S. (Intern), Barthelmie, R. (Ekstern), Ott, S. (Intern), Larsen, G. C. (Intern)
Number of pages: 2
Publication date: 2012
Event: Abstract from The science of Making Torque from Wind 2012, Oldenburg, Germany.
Main Research Area: Technical/natural sciences
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State of the art of wind farm optimization

General information
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Wind farm production estimates

In this paper, the Dynamic Wake Meandering (DWM) model is applied for simulation of wind farm production. In addition to the numerical simulations, measured data have been analyzed in order to provide the basis for a full-scale verification of the model performance.

The basic idea behind the DWM model is to model the in-stationary wind farm flow characteristics by considering wind turbine wakes as passive tracers continuously emitted from the wind farm turbines each with a downstream transport process dictated by large scale turbulent eddies (lateral and vertical transportation; i.e. meandering) and Taylor advection.

For the present purpose, the DWM model has been implemented in the aeroelastic code HAWC2 [1], and the performance of the resulting model complex is mainly verified by comparing simulated and measured loads for the Dutch off-shore Egmond aan Zee wind farm [2]. This farm consists of 36 Vestas V90 turbine located outside the coast of the Netherlands. The simulations in this paper were done with a modified version of HAWC2 only including aerodynamics and a rigid rotor in order to reduce the simulation time. With this code a 10min simulation takes approximately 1 minute on a 3GHz pc. The turbine controller is fully implemented. Initially, production estimates of a single turbine under free and wake conditions, respectively, are compared for (undisturbed) mean wind speeds ranging from 3m/s to 25m/s. The undisturbed situation refers to a wind direction bin defined as 270° ±5°, whereas the wake situation refers to the wind direction bin 319° ±5°. In the latter case, the investigated turbine operated in the wake of 6 upstream turbines, with the mean wind direction being equal to the orientation of the wind turbine row.

The production of the entire wind farm has been investigated for a full polar (i.e. as function of mean inflow wind
direction). This investigation relates to a mean wind speed bin defined as 8 m/s ± 1 m/s. The impact of ambient turbulence intensity and turbine inter spacing on the production of a wind turbine operating under full wake conditions is investigated. Four different turbine inter spacings, ranging between 3.8 and 10.4 rotor diameters, are analyzed for ambient turbulence intensities varying between 2% and 20%. This analysis is based on full scale production data from three other wind farms Wieringermeer [3], Horns Rev [4] and Nysted [5]. A very satisfactory agreement between experimental data and predictions is observed.

This paper finally includes additionally an analysis of the production impact caused by atmospheric stability effects. For this study, atmospheric stability conditions are defined in terms of the Monin-Obukhov length. Three different stability classes, including stable, neutral and unstable atmospheric stratification, have been investigated.

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State: Published
Organisations: Department of Wind Energy, Aeroelastic Design, Fluid Mechanics
Authors: Larsen, T. J. (Intern), Larsen, G. C. (Intern), Aagaard Madsen, H. (Intern), Hansen, K. S. (Intern)
Number of pages: 8
Publication date: 2012

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Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Conference: EWEA 2012 - European Wind Energy Conference & Exhibition, Copenhagen, Denmark, 16/04/2012 - 16/04/2012
Electronic versions:
WIND_FARM_PRODUCTION_ESTIMATES.pdf
Presentation
Publication: Research - peer-review › Article in proceedings – Annual report year: 2012

Advancements in Wind Energy Metrology – UPWIND 1A2.3
An overview of wind related metrology research made at Risø DTU over the period of the UPWIND project is given. A main part of the overview is devoted to development of the Lidar technology with several sub-chapters considering different topics of the research. Technical problems are not rare for this new technology, and testing against a traditional met mast have shown to be efficient for gaining confidence with the ground based Lidar technology and for trust in accuracy of measurements. In principle, Lidar measurements could be traceable through the fundamental measurement principles, but at this stage of development it is not found feasible. Instead, traceability is secured through comparison with met masts that are traceable through wind tunnel calibrations of cup anemometers. The ground based Lidar measurement principle works almost acceptable in flat terrain. In complex terrain and close to woods the measurement volume is disturbed because the flow is no longer horizontally homogeneous. These conditions require special attention and correction methods. Due to the large measurement volume, ground based Liders perform a spatial averaging which has the effect of a low pass filter on turbulence measurements. Theory and measurements seem to be in good agreement. Lidar measurements from a rotating spinner have been performed. The analysis show good perspectives for scanning the incoming wind, which may lead to better controlled wind turbines. Liders have also been used to scan the wake of wind turbines. These measurements document the meandering wake pattern. The second part of the overview considers power performance measurements. A new investigation on the influence of wind shear points to a revision of the definition of a power curve. A new measurement method has been developed which has a good chance of being implemented in the present revision of the IEC performance standard. Also, a turbulence normalization method has been tested but not found efficient enough for inclusion in the IEC standard. In relation to the coming IEC standard on performance verification with the use of nacelle anemometry, IEC61400- 12-2-CD, nacelle anemometry has been studied, both with experiments and in theory. An alternative to nacelle anemometry has been developed, the so-called spinner anemometer. This type of sensor measures yaw-error with high absolute accuracy, and avoids the draw-backs of nacelle anemometry because the spinner anemometer is positioned in front of the rotor. Advances in classic mast measurement technologies have also been made. A mast flow distortion correction method has been developed to improve classical state of the art mast measurements. Finally, an optical method for measurements of turbine vibrations is considered.

General information
State: Published
Organisations: Test and Measurements, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Meteorology, Aeroelastic Design
A quasi 3D computation of merging wakes using a boundary layer equation model approach

**General information**
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Aagaard Madsen, H. (Intern), Larsen, G. C. (Intern), Troldborg, N. (Intern), Larsen, T. J. (Intern)
Publication date: 2011
Event: Poster session presented at EWEA Annual Event 2011, Brussels, Belgium.
Main Research Area: Technical/natural sciences
Aeroelastic design methods
Electronic versions:
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Publication: Research › Poster – Annual report year: 2011

Determination of near wake characteristics behind a wind turbine

**General information**
State: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering, Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern)
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Editors: Ivanell, S., Sørensen, J. N.
Main Research Area: Technical/natural sciences
Conference: Wake conference, Visby (SE), 8-9 Jun, 01/01/2011
Aeroelastic design methods
Source: orbit
Source-ID: 279707
Publication: Research › Conference abstract in proceedings – Annual report year: 2011
Light detection and ranging measurements of wake dynamics. Part II: two-dimensional scanning

A nacelle-mounted lidar system pointing downstream has been used to measure wind turbine wake dynamics. The new measurement and data analysis techniques allow estimation of quasi-instantaneous wind fields in planes perpendicular to the rotor axis. A newly developed wake tracking procedure delivers the instantaneous transversal wake position which is quantitatively compared with the prediction of the Dynamic Wake Meandering model. The results, shown for two 10-min time series, suggest that the conjecture of the wake behaving as a passive tracer is a fair approximation; this corroborates and expands the results of one-dimensional measurements already presented in the first part of this paper. Consequently, it is now possible to separate the deterministic and turbulent parts of the wake wind field, thus enabling capturing the wake in the meandering frame of reference. The results correspond, qualitatively and to some extent quantitatively, to the expectations from CFD simulations which are compared in the paper. Copyright © 2010 John Wiley & Sons, Ltd.
Load validation and comparison versus certification approaches of the Risø Dynamic Wake Meandering model implementation in GH Bladed

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Germanischer Lloyd, GL Garrad Hassan
Authors: Schmidt, B. (Ekstern), King, J. (Ekstern), Larsen, G. C. (Intern), Larsen, T. J. (Intern)
Pages: 249-254
Publication date: 2011

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Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Conference: EWEA Annual Event 2011, Brussels, Belgium, 14/03/2011 - 14/03/2011
Aeroelastic design methods
Modelling merging wakes with three different approaches

General information
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Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Aagaard Madsen, H. (Intern), Larsen, G. C. (Intern), Troldborg, N. (Intern), Larsen, T. J. (Intern)
Pages: 56-57
Publication date: 2011

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Editors: Ivanell, S., Sørensen, J. N.
Main Research Area: Technical/natural sciences
Conference: Wake conference, Visby (SE), 8-9 Jun, 01/01/2011

Aeroelastic design methods
Source: orbit
Source-ID: 279709
Publication: Research › Conference abstract in proceedings – Annual report year: 2011

Numerical simulations of wake interaction between two wind turbines at various inflow conditions
The phenomenon of wake interaction between two wind turbines was analysed using the actuator line technique and full unsteady Navier–Stokes computations. Results are presented for varying mutual distances between the two turbines and both full wake and half wake situations were considered. Furthermore, simulations were carried out at different degrees of ambient turbulence intensity representing laminar, offshore and onshore conditions. From the simulations, the main characteristics of the interacting wakes were extracted including the averaged velocity and turbulence fields as well as the development of wake generated vortex structures. Moreover, the influence of the wake of the upstream turbine on the external aerodynamic loading on the blades of the downstream turbine was studied. Copyright © 2010 John Wiley & Sons, Ltd.

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Meteorology, Fluid Mechanics, Department of Mechanical Engineering
Authors: Troldborg, N. (Intern), Larsen, G. C. (Intern), Aagaard Madsen, H. (Intern), Hansen, K. S. (Intern), Sørensen, J. N. (Intern), Mikkelsen, R. F. (Intern)
Pages: 859-876
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Scopus rating (2016): CiteScore 3.37 SJR 1.104 SNIP 2.306
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.196 SNIP 2.086 CiteScore 3.06
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.272 SNIP 3.75 CiteScore 3.42
Web of Science (2014): Indexed yes
Potential load reductions on megawatt turbines exposed to wakes using individual-pitch wake compensator and trailing-edge flaps

Wind turbines located in wind farms experience inflow wind conditions that are substantially modified compared with the ambient wind field that applies for stand-alone wind turbines because of upstream emitted wakes. This has implications not only for the power production of a wind farm, but also for the loading conditions of the individual turbines in the farm. The dynamic wake meandering model (DWM) is believed to capture the essential physics of the wake problem, and thus, both load and production aspects can be predicted, which is contrary to the traditional engineering wake prediction methods that typically focus on either load or power prediction. As a consequence, the wake affected inflow field generated by the DWM formulation opens for control strategies for the individual turbine. Two different control approaches for load reduction on the individual turbines are implemented in the multi-body aero-servo-elastic tool HAWC2, developed at Risø-DTU in Denmark, and their potential load reduction capabilities compared: (1) full-blade ‘individual-pitch controllers’ acting as wake compensators and (2) controllers using trailing-edge flaps. Information on the wake inflow conditions, induced by upstream turbines, is extracted from measurements of the blade-root bending moment and/or one-point recordings of flow angle of attack to the blades (pitot tube) measurements. In the former implementation, the pitch angle of each blade is compensated for as an addition to the collective-pitch, rotor-speed control. In the latter implementation, the (uniform) flap deflection angle is dictated by the particular controller version in question. Copyright © 2010 John Wiley & Sons, Ltd.
The Dynamic Wake Meandering model for Simulation of loads and Power in Wind farms

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Aagaard Madsen, H. (Intern), Larsen, G. C. (Intern), Larsen, T. J. (Intern), Troidborg, N. (Intern), Réthoré, P. M. (Intern)
Publication date: 2011
Event: Abstract from International Conference on Offshore Wind Energy and Ocean Energy, Beijing, China.
Main Research Area: Technical/natural sciences
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TOPFARM - a platform for wind farm topology optimization

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Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Aagaard Madsen, H. (Intern), Larsen, T. J. (Intern), Réthoré, P. M. (Intern), Fuglsang, P. (Intern)
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Publisher: Högskolan på Gotland
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Main Research Area: Technical/natural sciences
Conference: Wake conference, Visby (SE), 8-9 Jun, 01/01/2011
Aeroelastic design methods
Source: orbit
Source-ID: 279710
Publication: Research › Conference abstract in proceedings – Annual report year: 2011

TopFarm: Multi-fidelity optimization of offshore wind farm

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Réthoré, P. M. (Intern), Fuglsang, P. (Intern), Larsen, G. C. (Intern), Buhl, T. (Intern), Larsen, T. J. (Intern), Aagaard Madsen, H. (Intern)
Pages: 516-524
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Publisher: International Society of Offshore and Polar Engineers
Main Research Area: Technical/natural sciences
Aerodynamiske design methods
TOPFARM - next generation design tool for optimisation of wind farm topology and operation

The present report is the publishable final activity report for the EU project TOPFARM. The project has been running from 1st December 2007 to 30th November 2010, and has successfully addressed optimization of wind farm topology and control strategy based on aero-elastic modeling of loads as well as of power production as seen in an economical perspective. Crucial factors in this regard are the overall wind climate at the wind farm site, the position of the individual wind turbines, the wind turbine characteristics, the internal wind farm wind climate, the wind turbine control/operation strategy for wind turbines interacting through wakes, various cost models, the optimization strategy and a priori defined constraints imposed on the wind farm topology. In TOPFARM, the object function used in the optimization platform is formulated in economical terms, thus ensuring the optimal balance between capital costs, operation and maintenance costs, cost of fatigue lifetime consumption and power production output throughout the design lifetime of the wind farm. The report describes the project consortium and the project activities, which has been organized in 9 Work Packages. A summary description of the results is given, and reference is made to a large number of publications resulting from the project.

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TOPFARM - philosophy, results and outlook

General information

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Authors: Larsen, G. C. (Intern), Aagaard Madsen, H. (Intern), Larsen, T. J. (Intern), Troldborg, N. (Intern), Buhl, T. (Intern), Réthoré, P. M. (Intern)
Publication date: 2011

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Title of host publication: Proceedings
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Conference: EWEA Annual Event 2011, Brussels, Belgium, 14/03/2011 - 14/03/2011
Aerialastic design methods
Electronic versions:
Larsen_powerpoint_EWEA2011presentation.pdf
Source: orbit
TOPFARM wind farm optimization tool

A wind farm optimization framework is presented in detail and demonstrated on two test cases: 1) Middelgrunden and 2) Stags Holt/Coldham. A detailed flow model describing the instationary flow within a wind farm is used together with an aeroelastic model to determine production and fatigue loading of wind farm wind turbines. Based on generic load cases, the wind farm production and fatigue evaluations are subsequently condensed in a large pre-calculated database for rapid calculation of lifetime equivalent loads and energy production in the optimization loop. The objective function defining the optimization problem includes elements as energy production, turbine degradation, operation and maintenance costs, electrical grid costs and foundation costs. The objective function is optimized using a dedicated multi fidelity approach with the locations of individual turbines in the wind farm spanning the design space. The results are over all satisfying and are giving some interesting insights on the pros and cons of the design choices. They show in particular that the inclusion of the fatigue loads costs give rise to some additional details in comparison with pure power based optimization. The Middelgrunden test case resulted in an improvement of the financial balance of 2.1 M€ originating from a very large increase in the energy production value of 9.3 M€ mainly counterbalanced by increased electrical grid costs. The Stags Holt/Coldham test case resulted in an improvement of the financial balance of 3.1 M€.
A first attempt to characterize the structure of wake turbulence using a combined experimental and numerical approach

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Meteorology, Fluid Mechanics, Department of Mechanical Engineering, Test and Measurements
Authors: Larsen, G. C. (Intern), Hansen, K. S. (Intern), Trolldborg, N. (Intern), Mann, J. (Intern), Enevoldsen, K. (Intern), Bingöl, F. (Intern)
Publication date: 2010
Main Research Area: Technical/natural sciences
Aeroelastic design methods, Wind Energy
Source: orbit
Source-ID: 267210
Publication: Research › Paper – Annual report year: 2010

Calibration and Validation of the Dynamic Wake Meandering Model for Implementation in an Aeroelastic Code
As the major part of new wind turbines are installed in clusters or wind farms, there is a strong need for reliable and accurate tools for predicting the increased loadings due to wake operation and the associated reduced power production. The dynamic wake meandering (DWM) model has been developed on this background, and the basic physical mechanisms in the wake—i.e., the velocity deficit, the meandering of the deficit, and the added turbulence—are modeled as simply as possible in order to make fast computations. In the present paper, the DWM model is presented in a version suitable for full integration in an aeroelastic model. Calibration and validation of the different parts of the model is carried out by comparisons with actuator disk and actuator line (ACL) computations as well as with inflow measurements on a full-scale 2 MW turbine. It is shown that the load generating part of the increased turbulence in the wake is due almost exclusively to meandering of the velocity deficit, which causes “apparent” turbulence when measuring the flow in a fixed point in the wake. Added turbulence, originating mainly from breakdown of tip vortices and from the shear of the velocity deficit, has only a minor contribution to the total turbulence and with a small length scale in the range of 10–25% of the ambient turbulence length scale. Comparisons of the calibrated DWM model with ACL results for different downstream positions and ambient turbulence levels show good correlation for both wake deficits and turbulence levels. Finally, added turbulence characteristics are compared with correlation results from literature. ©2010 American Society of Mechanical Engineers

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Fluid Mechanics, Department of Mechanical Engineering
Authors: Aagaard Madsen, H. (Intern), Larsen, G. C. (Intern), Larsen, T. J. (Intern), Trolldborg, N. (Intern), Mikkelsen, R. F. (Intern)
Pages: 041014 (14 pages)
Publication date: 2010
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Solar Energy Engineering
Volume: 132
Issue number: 4
ISSN (Print): 0199-6231
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.46 SNIP 0.654 CiteScore 1.37
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.759 SNIP 1.024 CiteScore 1.65
Web of Science (2015): Indexed yes
Comparison between wind tunnel and field experiments on wind turbine wake meandering

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Meteorology
Authors: Aubrun, S. (Ekstern), Tchouaké, T. (Ekstern), Espana, G. (Ekstern), Larsen, G. C. (Intern), Mann, J. (Intern), Bingöl, F. (Intern)
Publication date: 2010
Event: Paper presented at iTi conference on turbulence, Bertinoro, .
Main Research Area: Technical/natural sciences
Aeroelastic design methods, Wind Energy

DOIs: 10.1115/1.4002555
Source: orbit
Source-ID: 268112
Publication: Research - peer-review › Journal article – Annual report year: 2010

BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.737 SNIP 1.214 CiteScore 1.75
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.699 SNIP 1.373 CiteScore 1.35
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.546 SNIP 1.024 CiteScore 1.08
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.469 SNIP 1.25 CiteScore 1.01
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.548 SNIP 1.224
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.679 SNIP 1.123
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.689 SNIP 1.076
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.551 SNIP 0.914
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.169 SNIP 1.368
Scopus rating (2005): SJR 1.113 SNIP 1.138
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.625 SNIP 1.572
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.976 SNIP 1.38
Scopus rating (2002): SJR 0.673 SNIP 0.519
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.712 SNIP 0.954
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.696 SNIP 0.805
Scopus rating (1999): SJR 0.349 SNIP 1.221
Original language: English
Aeroelastic design methods, Wind Energy
Full scale measurements of wind turbine wake turbulence

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Fluid Mechanics, Department of Mechanical Engineering, Meteorology, Test and Measurements
Authors: Larsen, G. C. (Intern), Hansen, K. S. (Intern), Mann, J. (Intern), Enevoldsen, K. (Intern), Bingöl, F. (Intern)
Pages: 391-405
Publication date: 2010

Light detection and ranging measurements of wake dynamics Part I: One-dimensional Scanning
The vast majority of wind turbines are today erected in wind farms. As a consequence, wake-generated loads are becoming more and more important. In this first of two parts, we present a new experimental technique to measure the instantaneous wake deficit directly, thus allowing for quantification of the wake meandering, as well as the instantaneous wake expansion expressed in a meandering frame of reference. The experiment was conducted primarily to test the simple hypothesis that the wake deficit is advected passively by the larger-than-rotor-size eddies in the atmospheric flow, and that the wake at the same time widens gradually, primarily because of mixing caused by small-scale atmospheric eddies. In this first paper, we focus on our new measurement technique, and test if the wake meandering follows the wind direction fluctuations, i.e. if it is advected passively in the lateral direction. The experimental results are used as a preliminary verification of a wake meandering model that essentially considers the wake as a passive tracer. Copyright © 2009 John Wiley & Sons, Ltd.

General information
State: Published
Organisations: Meteorology, Wind Energy Division, Rise National Laboratory for Sustainable Energy, Aeroelastic Design
Authors: Bingöl, F. (Intern), Mann, J. (Intern), Larsen, G. C. (Intern)
Pages: 51-61
Publication date: 2010
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Energy
Volume: 13
Issue number: 1
ISSN (Print): 1095-4244
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.37 SJR 1.104 SNIP 2.306
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.196 SNIP 2.086 CiteScore 3.06
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.272 SNIP 3.75 CiteScore 3.42
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
TOPFARM - next generation design tool for optimization of wind farm topology and operation ... background, vision and challenges

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern)
Pages: 437-448
Publication date: 2010

Host publication information
Title of host publication: Torque 2010 : The science of making torque from wind
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Conference: Torque 2010, Heraklion (GR), 28-30 June, 01/01/2010
Wind energy, Aeroelastic design methods
Source: orbit
**Wind farm topology optimization including costs associated with structural loading**

**General information**
State: Published  
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy  
Authors: Buhl, T. (Intern), Larsen, G. C. (Intern)  
Pages: 449-460  
Publication date: 2010

**Host publication information**
Title of host publication: Torque 2010: The science of making torque from wind  
Publisher: European Wind Energy Association (EWEA)  
Main Research Area: Technical/natural sciences  
Conference: Torque 2010, Heraklion (GR), 28-30 June, 01/01/2010  
Wind energy, Aeroelastic design methods  
Source: orbit  
Source-ID: 265097  
Publication: Research - peer-review › Article in proceedings – Annual report year: 2010

**A quasi 3D computation of multiple wakes using a boundary layer equation BLE model**

**General information**
State: Published  
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy  
Authors: Aagaard Madsen, H. (Intern), Larsen, G. C. (Intern), Troldborg, N. (Intern), Larsen, T. J. (Intern)  
Number of pages: 95  
Pages: 75-76  
Publication date: 2009

**Host publication information**
Title of host publication: Extended Abstracts  
Publisher: Universidad Politecnica de Madrid  
Editors: Crespo, A., Larsen, G. C., Migoya, E.  
ISBN (Print): 978-84-7484-220-3  
Main Research Area: Technical/natural sciences  
Conference: EUROMECH Colloquium 508 on Wind Turbine Wakes, Madrid, Spain, 20/10/2009 - 20/10/2009  
Wind energy, Aeroelastic Design  
Source: orbit  
Source-ID: 251700  
Publication: Research › Conference abstract in proceedings – Annual report year: 2009

**A simple stationary semi-analytical wake model**
We present an idealized simple, but fast, semi-analytical algorithm for computation of stationary wind farm wind fields with a possible potential within a multi-fidelity strategy for wind farm topology optimization. Basically, the model considers wakes as linear perturbations on the ambient non-uniform mean wind field, although the modelling of the individual stationary wake flow fields includes non-linear terms. The simulation of the individual wake contributions are based on an analytical solution of the thin shear layer approximation of the NS equations. The wake flow fields are assumed rotationally symmetric, and the rotor inflow fields are consistently assumed uniform. Expansion of stationary wake fields is believed to be significantly affected by meandering of wake deficits as e.g. described by the Dynamic Wake Meandering model. In the present context, this effect is approximately accounted for by imposing suitable empirical downstream boundary conditions on the wake expansion that depend on the rotor thrust and the ambient turbulence conditions, respectively. For downstream distances beyond approximately 10 rotor diameters (at which distance the calibrated wake expansion boundary conditions are imposed), the present formulation of wake expansion is believed to underestimate wake expansion, because the analytical wake formulation dictates the wake expansion to behave as x¹/³ with downstream distance, whereas wake expansion as primary controlled by wake meandering develops approximately linearly with the downstream distance. The link from a non-uniform wind farm wind field, consisting of linear perturbations on the ambient non-uniform mean wind field, to a fictitious uniform wake generating inflow field is established using two different averaging approaches – a linear and a non-linear. With each of these approached, a parabolic system are described, which is initiated by first considering the most upwind located turbines and subsequently successively solved in the downstream direction. Algorithms for the resulting wind farm flow fields are proposed, and it is shown that in the limit of very large downstream distances, the simulated field is shown to recover to the undisturbed ambient wind field upstream the wind farm.
A tailored eddy viscosity closure consistent with the Dynamic Wake Meandering philosophy

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Aagaard Madsen, H. (Intern), Troldborg, N. (Intern)
Number of pages: 95
Pages: 73-74
Publication date: 2009

Host publication information
Title of host publication: Extended Abstracts
Publisher: Universidad Politecnica de Madrid
Editors: Crespo, A., Larsen, G. C., Migoya, E.
ISBN (Print): 978-84-7484-220-3
Main Research Area: Technical/natural sciences
Conference: EUROMECH Colloquium 508 on Wind Turbine Wakes, Madrid, Spain, 20/10/2009 - 20/10/2009
Wind energy, Aeroelastic Design
Source: orbit
Source-ID: 251697
Publication: Research › Conference abstract in proceedings – Annual report year: 2009

Development and calibration of an engineering model for simulation of wake velocity deficits

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Aagaard Madsen, H. (Intern), Larsen, G. C. (Intern), Larsen, T. J. (Intern)
Publication date: 2009

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Wind energy, Aeroelastic Design
Electronic versions:
2009_76.pdf
Source: orbit
Source-ID: 246704
Publication: Research › Sound/Visual production (digital) – Annual report year: 2009

Do wind farms influence large scale turbulence?

General information
LiDAR measurements of full scale wind turbine wake characteristics

Full scale wind speed measurements, recorded inside the wake of an operating 2MW/80m wind turbine, has been performed during the spring 2009, as part of the EU-TOPFARM project. Longitudinal wind speeds in wake cross sections are measured with a LiDAR system mounted in the rear of the nacelle. The experimental setup, the amount of data, preliminary analysis and limitations of using LiDAR measurements to identify the wake dynamics will be presented. Resolving the wake in the meandering frame of reference further allows for identification of the wake characteristics both in terms of wake deficit and wake turbulence.

General information
State: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering, Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Meteorology, Test and Measurements
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern), Mann, J. (Intern), Enevoldsen, K. (Intern)
Number of pages: 95
Pages: 55-56
Publication date: 2009

LiDAR Measurements of Full-scale Wind Turbine Wake Characteristics

General information
State: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering, Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Meteorology, Test and Measurements
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern), Mann, J. (Intern), Enevoldsen, K. (Intern)
Publication date: 2009
Main Research Area: Technical/natural sciences
Wind energy, Aeroelastic Design
Source: orbit
Source-ID: 246700
Publication: Research › Paper – Annual report year: 2009
Numerical Simulations of Wake Interaction between Two Wind Turbines at Various Inflow Conditions

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Troldborg, N. (Intern), Larsen, G. C. (Intern), Aagaard Madsen, H. (Intern)
Number of pages: 95
Pages: 23-25
Publication date: 2009

Host publication information
Title of host publication: Extended Abstracts
Publisher: Universidad Politecnica de Madrid
Editors: Crespo, A., Larsen, G. C., Migoya, E.
ISBN (Print): 978-84-7484-220-3
Main Research Area: Technical/natural sciences
Conference: EUROMECH Colloquium 508 on Wind Turbine Wakes, Madrid, Spain, 20/10/2009 - 20/10/2009
Wind energy, Aeroelastic Design
Source: orbit
Source-ID: 251690
Publication: Research › Conference abstract in proceedings – Annual report year: 2009

Status on development and validation of the dynamic wake meandering (DWM) model

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, T. J. (Intern), Aagaard Madsen, H. (Intern), Larsen, G. C. (Intern), Troldborg, N. (Intern), Johansen, N. (Ekstern)
Number of pages: 95
Pages: 70-72
Publication date: 2009

Host publication information
Title of host publication: Extended Abstracts
Publisher: Universidad Politecnica de Madrid
Editors: Crespo, A., Larsen, G. C., Migoya, E.
ISBN (Print): 978-84-7484-220-3
Main Research Area: Technical/natural sciences
Conference: EUROMECH Colloquium 508 on Wind Turbine Wakes, Madrid, Spain, 20/10/2009 - 20/10/2009
Wind energy, Aeroelastic Design
Source: orbit
Source-ID: 251696
Publication: Research › Conference abstract in proceedings – Annual report year: 2009

The dependence of wake losses on atmospheric stability characteristics

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Meteorology, DONG Energy A/S
Authors: Larsen, G. C. (Intern), Larsen, T. J. (Intern), Aagaard Madsen, H. (Intern), Mann, J. (Intern), Pena Diaz, A. (Intern), Barthelmie, R. J. (Intern), Jensen, L. (Ekstern)
Number of pages: 95
Pages: 35-37
Publication date: 2009

Host publication information
Title of host publication: Extended Abstracts
Publisher: Universidad Politecnica de Madrid
Editors: Crespo, A., Larsen, G. C., Migoya, E.
ISBN (Print): 978-84-7484-220-3
Main Research Area: Technical/natural sciences
TOPFARM. Background, vision - and challenges

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Meteorology
Authors: Larsen, G. C. (Intern), Aagaard Madsen, H. (Intern), Larsen, T. J. (Intern), Mann, J. (Intern), Bingöl, F. (Intern)
Publication date: 2009

Wind farm optimization with structured and un-structured grids

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Buhl, T. (Intern), Carlén, I. (Ekstern), Larsen, G. C. (Intern)
Number of pages: 95
Pages: 95-95
Publication date: 2009

Comparison of design methods for turbines in wake

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, T. J. (Intern), Larsen, G. C. (Intern), Madsen Aagaard, H. (Intern), Thomsen, K. (Intern)
Publication date: 2008
Fast wake measurements with LiDAR at Risø test field
The vast majority of wind turbines are today erected in wind farms. As a consequence, wake generated loads are becoming more and more important. We present a new and successful experimental technique, based on remote sensing, to measure instantaneously the flow in the wake of wind turbines. Downstream wind speed can be quantified spatially in one and two dimensions. Data analysis allows us to identify the wake transversal position, thus enabling us to quantify the wake meandering as well as the instantaneous wake expansion expressed in a meandering frame of reference. The experimental results are subsequently used in a preliminary verification of the basic conjecture of a wake meandering model that essentially considers the wake as a passive tracer.

General information
State: Published
Organisations: Meteorology, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Aeroelastic Design
Authors: Bingöl, F. (Intern), Trujillo, J. (Ekstern), Mann, J. (Intern), Larsen, G. C. (Intern)
Pages: 012022-012030
Publication date: 2008
Conference: 14th International symposium for the advancement of boundary layer remote sensing, Risø, Denmark, 23/06/2008 - 23/06/2008
Main Research Area: Technical/natural sciences

Publication information
Journal: IOP Conference Series: Earth and Environmental Science
Volume: 1
Issue number: U186-U194
ISSN (Print): 1755-1307
Ratings:
Scopus rating (2016): CiteScore 0.38 SJR 0.186 SNIP 0.567
Scopus rating (2015): SJR 0.253 SNIP 0.358 CiteScore 0.22
Scopus rating (2014): SJR 0.168 SNIP 0.391 CiteScore 0.19
Scopus rating (2013): SJR 0.173 SNIP 0.13 CiteScore 0.06
ISI indexed (2013): ISI indexed no
Scopus rating (2012): SJR 0.338 SNIP 0.141 CiteScore 0.29
ISI indexed (2012): ISI indexed no
Full scale wake measurements

General information
State: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering, Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern)
Publication date: 2008
Event: Paper presented at VindKraftNet seminar on wakes, København, Denmark.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 222943
Publication: Research › Conference article – Annual report year: 2008

Fundamentals for remote condition monitoring of offshore wind turbines
In the future, large wind turbines will be placed offshore in considerable numbers. Since access will be difficult and costly, it is preferable to use monitoring systems to reduce the reliance on manual inspection. The motivation for the effort reported here is to create the fundamental basis necessary for the use of sensors as a structural health monitoring system for wind turbine blades. This includes creating knowledge that will allow sensor signals to be used for remotely identifying the presence and position of any damage, the damage type and severity, and a structural condition assessment of the wind turbine blades that can integrate with existing SCADA tools to improve management of large offshore wind farms, and optimise the manual inspection/maintenance effort. Various sensor types, which have previously been identified as technically (and economically) capable of detecting the early development of significant damage in fibre reinforced composite, are investigated. In each case specific approaches have been proposed, developed and implemented in models or laboratory test specimens. The sensor approaches are based on acoustic emission (various passive and active applications including mobile sensors), fibre optics (including a new microbend transducer design and various Bragg-grating based applications), wireless approaches involving both battery and energy harvesting options, and inertia sensor based system identification approaches able to deal with linear periodic systems. In addition to the sensor investigations, a life-estimate approach for the wind turbines is described based on identifying and characterising critical material failure modes then integrating detailed models of damage progression rates into full scale models of the blade structure under operating loading regimes. The application of sensors is addressed during a full-scale blade test and recommendations are made regarding improvement to the commercial blade certification process of test and inspection, sensor use for monitoring in-service structural response, and the need for dedicated research facilities providing multi-scale and multifunctional testing of structures.

General information
State: Published
Organisations: Composites and Materials Mechanics, Materials Research Division, Risø National Laboratory for Sustainable Energy, Aeroelastic Design, Wind Energy Division
Authors: McGugan, M. (Intern), Larsen, G. C. (Intern), Sørensen, B. F. (Intern), Borum, K. K. (Intern), Engelhardt, J. (Intern)
Number of pages: 48
Publication date: 2008

Publication information
Place of publication: Roskilde
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi
ISBN (Print): 87-55-03662-7
Original language: English

Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1639(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
LIDAR measurement and modelling of wind turbine far-wake dynamics

General information
State: Published
Organisations: Meteorology, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Aeroelastic Design, University of Stuttgart
Authors: Trujillo, J. (Ekstern), Bingöl, F. (Intern), Mann, J. (Intern), Larsen, G. C. (Intern), Kühn, M. (Ekstern)
Pages: 17-17
Publication date: 2008

Host publication information
Title of host publication: Book of abstracts
Publisher: DEWI
Main Research Area: Technical/natural sciences
Conference: 9. German wind energy conference (DEWEK 2008), Bremen (DE), 26-27 Nov, 01/01/2008
Source: orbit
Source-ID: 231746
Publication: Research › Conference abstract in proceedings – Annual report year: 2008

Rational Calibration of Four IEC 61400-1 Extreme External Conditions
Based on a set of asymptotic statistical models on closed form this paper presents a rational and consistent calibration of four extreme external conditions defined in the International Electrotechnical Commission (IEC) 61400-1 standard: extreme operating gust, extreme wind shear, extreme coherent gust with direction change and extreme wind direction change. These four extreme external conditions are used in the definition of six of the IEC 61400-1 ultimate load cases. The statistical models are based on simple and easily accessible mean wind speed and turbulence characteristics of the atmospheric boundary layer. Using the wind climate characteristics prescribed in the IEC 61400-1 standard as input to the set of statistical models ensures consistency between the specified wind climate and the proposed extreme gust magnitudes. Differences and equalities between the present IEC specifications and proposed specifications of the magnitudes of the extreme external wind conditions are highlighted and discussed using an illustrative example based on two selected terrain types. Copyright © 2008 John Wiley & Sons, Ltd.

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Fluid Mechanics, Department of Mechanical Engineering
Authors: Larsen, G. C. (Intern), Hansen, K. S. (Intern)
Pages: 685-702
Publication date: 2008
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Energy
Volume: 11
Issue number: 6
ISSN (Print): 1095-4244
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.37 SJR 1.104 SNIP 2.306
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.196 SNIP 2.086 CiteScore 3.06
This paper presents a rational and consistent calibration of the IEC 61400-1 extreme load cases EOG, EWS and ECD based on a system of asymptotic statistical models on closed form. The models are based on simple and easily accessible mean wind speed and turbulence characteristics of the atmospheric boundary layer. Using the wind climate characteristics prescribed in the IEC 61400-1 code as input to the statistical model complex ensures consistency between the specified wind climate and the proposed extreme gust amplitudes. Differences and equalities between the present IEC specifications and proposed specifications of the extreme load magnitudes are highlighted and discussed using an illustrative example based on two selected terrain types.

**General information**

State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Fluid Mechanics, Department of Mechanical Engineering
Sammenligning af designmetoder for møller i wake

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, T. J. (Intern), Aagaard Madsen, H. (Intern), Larsen, G. C. (Intern)
Publication date: 2008
Main Research Area: Technical/natural sciences
Wind energy
Electronic versions:
2008_66.pdf
Source: orbit
Source-ID: 242032
Publication: Research › Paper – Annual report year: 2008

Simulering af laster på møller i wake

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, T. J. (Intern), Aagaard Madsen, H. (Intern), Larsen, G. C. (Intern)
Publication date: 2008
Main Research Area: Technical/natural sciences
Wind energy
Electronic versions:
2008_135.pdf
Source: orbit
Source-ID: 241996
Publication: Research › Paper – Annual report year: 2008

The distribution of turbulence driven wind speed extremes; a closed form asymptotic formulation

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern)
Publication date: 2008
Event: Abstract from Stochastics in turbulence and finance, Sønderborg (DK), 29 Jan - 1 Feb, .
Main Research Area: Technical/natural sciences
Electronic versions:
2008_04_abstract.pdf
Source: orbit
Source-ID: 235504
Publication: Research › Conference abstract for conference – Annual report year: 2008
The Dynamic Wake Meandering (DWM) model and its future perspectives

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Meteorology
Authors: Larsen, G. C. (Intern), Madsen Aagaard, H. (Intern), Larsen, T. J. (Intern), Mann, J. (Intern), Bingöl, F. (Intern), Trujillo, J. (Intern)
Publication date: 2008
Event: Paper presented at VindKraftNet seminar on wakes, Copenhagen, Denmark.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 223922
Publication: Research › Paper – Annual report year: 2008

Wake deficit-and turbulence simulated with two models compared with inflow measurements on a 2MW turbine in wake conditions

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Fluid Mechanics, Department of Mechanical Engineering
Authors: Madsen Aagaard, H. (Intern), Larsen, G. C. (Intern), Larsen, T. J. (Intern), Mikkelsen, R. (Ekstern), Troldborg, N. (Intern)
Pages: 48-53
Publication date: 2008
Host publication information
Title of host publication: Scientific proceedings
Place of publication: Brussels
Publisher: European Wind Energy Conference and Exhibition
Main Research Area: Technical/natural sciences
Conference: 2008 European Wind Energy Conference and Exhibition, Brussels, Belgium, 31/03/2008 - 31/03/2008
Electronic versions:
Source: orbit
Source-ID: 223067
Publication: Research - peer-review › Article in proceedings – Annual report year: 2008

Wake meandering: A pragmatic approach

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Rise National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Madsen Aagaard, H. (Intern), Thomsen, K. (Intern), Larsen, T. J. (Intern)
Pages: 377-395
Publication date: 2008
Main Research Area: Technical/natural sciences
Publication information
Journal: Wind Energy
Volume: 11
Issue number: 4
ISSN (Print): 1095-4244
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.37 SJR 1.104 SNIP 2.306
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.196 SNIP 2.086 CiteScore 3.06
Wake modeling and simulation

We present a consistent, physically based theory for the wake meandering phenomenon, which we consider of crucial importance for the overall description of wind turbine loadings in wind farms. In its present version the model is confined to single wake situations. The model philosophy does, however, have the potential to include also mutual wake interaction phenomena. The basic conjecture behind the dynamic wake meandering (DWM) model is that wake transportation in the atmospheric boundary layer is driven by the large scale lateral- and vertical turbulence components. Based on this conjecture a stochastic model of the downstream wake meandering is formulated. In addition to the kinematic formulation of the dynamics of the "meandering frame of reference", models characterizing the mean wake deficit as well as the added wake turbulence, described in the meandering frame of reference, are an integrated part the DWM model complex. For design applications, the computational efficiency of wake deficit prediction is a key issue. A computationally low cost model is developed for this purpose. Likewise, the character of the added wake turbulence, generated by the up-stream turbine in the form of shed and trailed vorticity, has been approached by a simple semi-empirical model essentially based on an eddy viscosity philosophy. Contrary to previous attempts to model wake loading, the DWM approach opens for a
unifying description in the sense that turbine power- and load aspects can be treated simultaneously. This capability is a
direct and attractive consequence of the model being based on the underlying physical process, and it potentially opens
for optimization of wind farm topology, of wind farm operation as well as of control strategies for the individual turbine. To
establish an integrated modeling tool, the DWM methodology has been implemented in the aeroelastic code HAWC2, and
example simulations of wake situations, from the small Tjæreborg wind farm, have been performed showing satisfactory
agreement between predictions and measurements

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Fluid
Mechanics, Department of Mechanical Engineering
Authors: Larsen, G. C. (Intern), Madsen Aagaard, H. (Intern), Larsen, T. J. (Intern), Troldborg, N. (Intern)
Number of pages: 28
Publication date: 2008

Publication information
Place of publication: Roskilde
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1653(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1653, Risø-R-1653(EN)
Electronic versions:
ris-r-1653.pdf
Source: orbit
Source-ID: 229233
Publication: Research › Report – Annual report year: 2008

An asymptotic closed form solution for the distribution of combined wind speed and wind direction extremes

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern)
Pages: 20
Publication date: 2007
Conference: 2nd International Conference on "The Science of Making Torque From Wind", Kgs. Lyngby, Denmark,
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Physics: Conference Series (Online)
Volume: 75
ISSN (Print): 1742-6596
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.45 SJR 0.24 SNIP 0.383
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.24 SNIP 0.373 CiteScore 0.35
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.253 SNIP 0.344 CiteScore 0.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.231 SNIP 0.272 CiteScore 0.25
ISI indexed (2013): ISI indexed no
Comparison of methods for load simulation for wind turbines operating in wake

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Aeroelastic Design, Wind Energy Division
Authors: Thomsen, K. (Intern), Madsen Aagaard, H. (Intern), Larsen, G. C. (Intern), Larsen, T. J. (Intern)
Pages: 12
Publication date: 2007
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Physics: Conference Series (Online)
Volume: 75
ISSN (Print): 1742-6596
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.45 SJR 0.24 SNIP 0.383
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.24 SNIP 0.373 CiteScore 0.35
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.253 SNIP 0.344 CiteScore 0.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.231 SNIP 0.272 CiteScore 0.25
ISI indexed (2013): ISI indexed no
Condition monitoring of wind turbine blades

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. M. (Intern), Larsen, G. C. (Intern)
Publication date: 2007
Event: Poster session presented at 2007 European Wind Energy Conference and Exhibition, Milan, Italy.
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 216272
Publication: Research › Poster – Annual report year: 2007

De-trending of turbulence measurements
Traditionally, turbulence is considered as a stationary stochastic process imposed on a given constant mean wind speed. However, measured (raw) turbulence intensities often display the characteristics of a non-stationary process, where the mean wind speed changes slowly with time. The change in mean wind speed appears as a trend in the wind speed time series, and often a linear trend is assumed. Wind resource measurements typically include statistics of ten-minute mean and standard deviation, and for such data it is not possible to calculate the trend contribution directly, because this requires access to the basic time-series. However, including a suitable modelling of the mean wind speed time variation, it is possible to estimate an approximate (linear) trend correction based on statistical data only. This paper presents such an algorithm for de-trending of turbulence standard deviation based on time series statistics only. The performance of the proposed de-trending algorithm is assessed using huge number of time series recorded at different types of terrain and orography. The strategy is the following: Based on the available time series information a conventional (linear) time series de-trending is performed and subsequently compared with the prediction from the proposed algorithm. The de-trended turbulence intensities are reduced in the range of 3 – 15 % compared to the raw turbulence intensity. The performed analysis shows that the proposed model, based on statistical information only, accounts for approximately 80% of the “true” (linear) trend as evaluated on basis of the full time series information.

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Dynamic wake meandering modeling

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Meteorology
Authors: Larsen, G. C. (Intern), Madsen Aagaard, H. (Intern), Bingöl, F. (Intern), Mann, J. (Intern), Ott, S. (Intern), Serensen, J. (Ekstern), Okulov, V. (Ekstern), Troldborg, N. (Ekstern), Nielsen, N. M. (Intern), Thomsen, K. (Intern), Larsen, T. J. (Intern), Mikkelsen, R. (Ekstern)
Number of pages: 84
Publication date: 2007

Publication information
Publisher: Risø National Laboratory
ISBN (Print): 978-87-550-3602-4
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1607(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Electronic versions:
ris_r_1607.pdf
Source: orbit
Source-ID: 216071
Publication: Research › Report – Annual report year: 2007

Full scale experimental analysis of extreme coherent gust with wind direction changes (EOD)

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern)
Pages: 8
Publication date: 2007
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Physics: Conference Series (Online)
Volume: 75
ISSN (Print): 1742-6596
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Laser measurements of wake dynamics

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Meteorology, Aeroelastic Design
Authors: Bingöl, F. (Intern), Mann, J. (Intern), Larsen, G. C. (Intern)
Pages: 103-106
Publication date: 2007

Host publication information
Title of host publication: Scientific proceedings
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 216390
Publication: Research - peer-review › Article in proceedings – Annual report year: 2007
**Lidars in wind energy**

**General information**
State: Published
Organisations: Meteorology, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Test and Measurements, Aeroelastic Design
Publication date: 2007
Event: Abstract from 14. Coherent laser radar conference (CLRC), Snowmass, CO (US),
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 215518
Publication: Research › Conference abstract for conference – Annual report year: 2007

**Simulation of inhomogeneous, non-stationary and non-Gaussian turbulent winds**
Turbulence time series are needed for wind turbine load simulation. The multivariate Fourier simulation method often used for this purpose is extended for inhomogeneous and non-stationary processes of general probability distribution. This includes optional conditional simulation matching simulated series to field measurements at selected points. A probability model for the application of turbine wind loads is discussed, and finally the technique for non-stationary processes is illustrated by turbulence simulation during a front passage.

**General information**
State: Published
Organisations: Meteorology, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Aeroelastic Design
Authors: Nielsen, N. M. (Intern), Larsen, G. C. (Intern), Hansen, K. S. (Intern)
Number of pages: 9
Pages: 012060
Publication date: 2007
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Journal of Physics: Conference Series (Online)
Volume: 75
Issue number: 1
ISSN (Print): 1742-6596
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.45 SJR 0.24 SNIP 0.383
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.24 SNIP 0.373 CiteScore 0.35
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.253 SNIP 0.344 CiteScore 0.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.231 SNIP 0.272 CiteScore 0.25
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.28 SNIP 0.354 CiteScore 0.33
ISI indexed (2012): ISI indexed no
Simulation of low frequency noise from a downwind wind turbine rotor

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Madsen Aagaard, H. (Intern), Johansen, J. (Intern), Sørensen, N. N. (Intern), Larsen, G. C. (Intern), Hansen, M. H. (Intern)
Publication date: 2007
Host publication information
Title of host publication: [Technical papers] presented at the 42. AIAA aerospace sciences meeting and exhibit
Place of publication: Reston, VA
Publisher: American Institute of Aeronautics & Astronautics
Series: AIAA-2007-623
Main Research Area: Technical/natural sciences
Conference: 45th AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV, United States, 08/01/2007 - 08/01/2007
Links:
Source: orbit
Source-ID: 216150
Publication: Research - peer-review › Conference article – Annual report year: 2007

Wake meandering - an analysis of instantaneous 2D laser measurements

General information
State: Published
Organisations: Meteorology, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Aeroelastic Design
Authors: Bingöl, F. (Intern), Larsen, G. C. (Intern), Mann, J. (Intern)
Pages: 8
Publication date: 2007
Main Research Area: Technical/natural sciences
Publication information
Journal: Journal of Physics: Conference Series (Online)
Volume: 75
ISSN (Print): 1742-6596
Aeroelastic response in extreme wind cases

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. S. (Intern), Larsen, T. J. (Intern), Mann, J. (Intern)
Pages: 69-87
Publication date: 2006

Host publication information
Title of host publication: Research in aeroelasticity EFP-2005
Volume: Risø-R-1559(EN)
Editor: Bak, C.
ISBN (Print): 87-550-3521-3
Main Research Area: Technical/natural sciences
Links:
A simplified approach for simulation of wake meandering

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Aeroelastic Design, Wind Energy Division
Authors: Thomsen, K. (Intern), Aagaard Madsen, H. (Intern), Larsen, G. C. (Intern), Larsen, T. J. (Intern)
Number of pages: 6
Publication date: 2006

Publication information
Original language: English
Series: Resultatblad AED-RB
Number: 18(EN)
Main Research Area: Technical/natural sciences
Resultatblad AED-RB-18(EN), Resultatblad AED-RB-18
Links:

Comparison of wake model simulations with offshore wind turbine wake profiles measured by sodar

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Barthelmie, R. (Intern), Folkerts, L. (Ekstern), Larsen, G. C. (Intern), Rados, K. (Ekstern), Pryor, S. (Ekstern), Frandsen, S. T. (Intern), Lange, B. (Ekstern), Schepers, G. (Ekstern)
Pages: 888-901
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Atmospheric and Oceanic Technology
Volume: 23
ISSN (Print): 0739-0572
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 1.521 SNIP 1.425 CiteScore 2.37
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.522 SNIP 1.406 CiteScore 2.23
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.299 SNIP 1.272 CiteScore 1.85
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.598 SNIP 1.386 CiteScore 2.13
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.075 SNIP 1.62 CiteScore 2.13
ISI indexed (2012): ISI indexed yes
De-trending of turbulence measurements

The paper presents the results of a comparison between long term raw and de-trended turbulence intensity values recorded at offshore and coastal sites under different weather systems. Within the traditional framework of turbulence interpretation, where turbulence is considered as a stationary process imposed on a given constant mean wind speed, measured raw turbulence intensities consist of contributions from the atmospheric turbulence as well as from the change in mean wind speed levels. The change in mean wind speed will appear as a trend in the wind speed time series. Wind resource measurements usually include statistics of ten-minute mean and standard deviation, and it is not possible to calculate the trend contribution afterwards, because this requires access to the time-series. A huge amount of time-series, stored in the database WindData.com, are used to calculate the trend contribution to the wind speed turbulence intensity for a number of representative locations. A linear de-trending process has been implemented during indexing of the time-series. The observed de-trended turbulence intensities are reduced 3 – 15 % compared to the raw turbulence intensity. This reduction depends primarily on site characteristics and local mean wind speed variations. Reduced turbulence intensity will result in lower design fatigue loads. This aspect of de-trending is discussed by use of a simple heuristic load model. Finally an empirical model for de-trending wind resource data is presented.

General information

State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern)
Number of pages: 476
Pages: 55-64
Publication date: 2006

Host publication information

Title of host publication: Offshore wind and other marine renewable energies in Mediterranean and European seas.
Proceedings: OWEMES 2006; European Seminar
Volume: Proceedings (March, 2006)
Place of publication: Rome
Fast laser doppler wake measurements

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Mann, J. (Intern), Bingöl, F. (Intern), Ejsing Jørgensen, H. (Intern), Mikkelsen, T. (Intern), Larsen, G. C. (Intern), Coffey, A. (Ekstern), Harris, M. (Ekstern)
Publication date: 2006

Host publication information
Title of host publication: Proceedings (online)
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 309220
Publication: Research › Conference abstract in proceedings – Annual report year: 2006

Laser Doppler scanning of a wind turbine wake

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Mann, J. (Intern), Bingöl, F. (Intern), Larsen, G. C. (Intern)
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: Geophysical Research Abstracts
Volume: 8
Issue number: Abstr. EGU06-A-06888
ISSN (Print): 1607-7962
Ratings:
Web of Science (2014): Indexed yes
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
ISI indexed (2012): ISI indexed no
Web of Science (2012): Indexed yes
ISI indexed (2011): ISI indexed no
Web of Science (2011): Indexed yes
BFI (2009): BFI-level 1
Original language: English
Source: orbit
Source-ID: 309133
Publication: Research › Journal article – Annual report year: 2006

The statistical distribution of turbulence driven velocity extremes in the atmospheric boundary layer - Cartwright/Longuet-Higgins revised

General information
Towards more realistic extreme load predictions (paper and poster)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Mann, J. (Intern), Larsen, G. C. (Intern), Larsen, T. J. (Intern)
Publication date: 2006

Host publication information
Title of host publication: Proceedings (online)
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 309214
Publication: Research › Article in proceedings – Annual report year: 2006

Wake meandering - a pragmatic approach

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Aagaard Madsen, H. (Intern), Thomsen, K. (Intern), Larsen, T. J. (Intern)
Publication date: 2006

Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 309459
Publication: Research › Conference abstract for conference – Annual report year: 2006

Characterising Turbulence Intensity for Fatigue Load Analysis of Wind Turbines
Turbulence in wind velocity presents a major factor for modern wind turbine design as cost reduction as are sort for the dynamic structures. Therefore this paper contains a parameterisation of the turbulence intensity at given sites, relevant for the calculation of fatigue loading of wind turbines. The parameterisation is based on wind speed measurements extracted from the "Database on Wind Characteristics" (www.winddata.com). The parameterisation is based on the LogNormal distribution, which has proven to be suitable distribution to describe the turbulence intensity distribution.

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern)
Pages: 319-329
Publication date: Jun 2005
Statistical Model of Extreme Shear

In order to continue cost-optimisation of modern large wind turbines, it is important to continuously increase the knowledge of wind field parameters relevant to design loads. This paper presents a general statistical model that offers site-specific prediction of the probability density function (PDF) of turbulence driven short-term extreme wind shear events, conditioned...
on the mean wind speed, for an arbitrary recurrence period. The model is based on an asymptotic expansion, and only a few and easily accessible parameters are needed as input. The model of the extreme PDF is supplemented by a model that, on a statistically consistent basis, describes the most likely spatial shape of an extreme wind shear event. Predictions from the model have been compared with results from an extreme value data analysis, based on a large number of full-scale measurements recorded with a high sampling rate. The measurements have been extracted from "Database on Wind Characteristics" (http://www.winddata.com/), and they refer to a site characterised by a flat homogeneous terrain. The comparison has been conducted for three different mean wind speeds in the range 15m/s – 19m/s, and model predictions and experimental results are consistent, given the inevitable uncertainties associated with the model as well as with the extreme value data analysis.

**General information**

State: Published
Organisations: Riso National Laboratory for Sustainable Energy
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern)
Pages: 444-455
Publication date: 2005
Main Research Area: Technical/natural sciences

**Publication information**

Journal: Journal of Solar Energy Engineering
Volume: 127
Issue number: 4
ISSN (Print): 0199-6231
Ratings:
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.46 SNIP 0.654 CiteScore 1.37
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.759 SNIP 1.024 CiteScore 1.65
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.737 SNIP 1.214 CiteScore 1.75
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.699 SNIP 1.373 CiteScore 1.35
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.546 SNIP 1.024 CiteScore 1.08
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.469 SNIP 1.25 CiteScore 1.01
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.548 SNIP 1.224
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.679 SNIP 1.123
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.689 SNIP 1.076
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.551 SNIP 0.914
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.169 SNIP 1.368
Scopus rating (2005): SJR 1.113 SNIP 1.138
The statistical distribution of turbulence driven velocity extremes in the atmospheric boundary layer - Cartwright/Longuet-Higgins revised

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Number of pages: 28
Publication date: 2005

Host publication information
Title of host publication: [Program and abstracts]
Place of publication: Oldenburg
Publisher: ForWind - Center for Wind Energy Research
Main Research Area: Technical/natural sciences
Conference: EUROMECH Colloquium 464b Wind Energy, Oldenburg, Germany, 04/10/2005 - 04/10/2005
Source: orbit
Source-ID: 308785
Publication: Research › Conference abstract in proceedings – Annual report year: 2005

Wake flow characteristics in low ambient turbulence conditions

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Aagaard Madsen, H. (Intern), Larsen, G. C. (Intern), Thomsen, K. (Intern)
Publication date: 2005

Host publication information
Title of host publication: Proceedings (CD-ROM)
Place of publication: Copenhagen
Publisher: Copenhagen Offshore Wind
Main Research Area: Technical/natural sciences
Conference: Copenhagen Offshore Wind 2005, Copenhagen, Denmark, 26/10/2005 - 26/10/2005
Source: orbit
Source-ID: 308856
Publication: Research › Article in proceedings – Annual report year: 2005

Adaptation of existing wind turbines for operation on high wind speed complex terrain sites; KWh cost reduction. The ADAPTURB project

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
A new method can predict detailed response for turbines in wind farms

**General information**

State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Aagaard Madsen, H. (Intern), Thomsen, K. (Intern), Larsen, G. C. (Intern)
Pages: 171-187
Publication date: 2004

**Host publication information**

Title of host publication: IEA Joint Action. Aerodynamics of wind turbines
Volume: FOI-S-0877
Place of publication: Stockholm
Publisher: FOI
Editor: Thor, S.
Main Research Area: Technical/natural sciences
Conference: 16. Symposium, Boulder, CO (US), 5-6 May, 01/01/2003
Source: orbit
Source-ID: 306542
Publication: Research › Article in proceedings – Annual report year: 2004

Assessment of IEC-61400 wind conditions for fatigue calculations. A comparison with complex terrain sites

**General information**

State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Carlén, I. (Ekstern), Larsen, G. C. (Intern), Mourikis, D. (Ekstern), Ritziotis, V. (Ekstern), Winkelaar, D. (Ekstern)
Number of pages: 49
Publication date: 2004

**Publication information**

Place of publication: Sollentuna
Publisher: Teknikgruppen AB
Original language: English
Series: TG-R-02-08
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 306616
Publication: Research › Report – Annual report year: 2004

Database on wind characteristics - Analyses of wind turbine design loads

**General information**

State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Number of pages: 82
Publication date: 2004
Database on wind characteristics - Contents of database bank

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. S. (Intern)
Number of pages: 132
Publication date: 2004

Publication information
ISBN (Print): 87-550-3357-1
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1472(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Electronic versions:
ris_r_1472.pdf
Source: orbit
Source-ID: 307027
Publication: Research › Report – Annual report year: 2004

ENDOW (Efficient Development of Offshore Wind Farms): Modelling wake and boundary layer interactions

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Pages: 225-245
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Energy
Volume: 7
ISSN (Print): 1095-4244
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.37 SJR 1.104 SNIP 2.306
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Fatigue analysis of structures subjected to wind loading. A model for low frequency load cycles

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Carlén, I. (Ekstern), Larsen, G. C. (Intern)
Number of pages: 11
Publication date: 2004

Publication information
Place of publication: Sollentuna
Simulation of extreme gusts

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Nielsen, M. (Intern), Larsen, G. C. (Intern), Mann, J. (Intern), Ott, S. (Intern)
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: Geophysical Research Abstracts
Volume: 6
ISSN (Print): 1607-7962
Ratings:
Web of Science (2014): Indexed yes
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
ISI indexed (2012): ISI indexed no
Web of Science (2012): Indexed yes
ISI indexed (2011): ISI indexed no
Web of Science (2011): Indexed yes
BFI (2009): BFI-level 1
Original language: English
Source: orbit
Source-ID: 306782
Publication: Research › Journal article – Annual report year: 2004

Statistical Model of Extreme Shear

In order to continue cost-optimisation of modern large wind turbines, it is important to continuously increase the knowledge on wind field parameters relevant to design loads. This paper presents a general statistical model that offers site-specific prediction of the probability density function (PDF) of turbulence driven short-term extreme wind shear events, conditioned on the mean wind speed, for an arbitrary recurrence period. The model is based on an asymptotic expansion, and only a few and easily accessible parameters are needed as input. The model of the extreme PDF is supplemented by a model that, on a statistically consistent basis, describe the most likely spatial shape of an extreme wind shear event. Predictions from the model have been compared with results from an extreme value data analysis, based on a large number of high-sampled full-scale time series measurements. The measurements have been extracted from "Database on Wind Characteristics" (http://www.winddata.com/), and they refer to a site characterised by a flat homogeneous terrain. The comparison has been conducted for three different (high wind) mean wind speed, and model predictions and experimental results are consistent, given the inevitable uncertainties associated with model as well as with the extreme value data analysis. Keywords: Statistical model, extreme wind conditions, statistical analysis, turbulence, wind loading, statistical analysis, turbulence, wind loading, wind shear, wind turbines.

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design, Department of Mechanical Engineering, Fluid Mechanics
Authors: Larsen, G. C. (Intern), Hansen, K. S. (Intern)
Pages: 433-444
Publication date: 2004

Host publication information
Title of host publication: Proceedings of the special Topic Conference: The science of making Torque from Wind
Place of publication: Delft
Publisher: Delft University of Technology
Validation of 3D sonic-anemometer against cup anemometer response

Determination and validation of wind turbine power curves traditionally rely on single point wind speed measurements recorded with a calibrated cup-anemometer. The power curve verification process, which is typically performed in different terrain types, does not always result in satisfactory agreement between measured and predicted power curves. The observed disagreement is primarily believed to relate to the cup-anemometers being sensitive to tilted flow, i.e., that the measurement of the horizontal flow component is sensitive to flow in a plane perpendicular to the horizontal plane. Furthermore, the limited cup-anemometer response due to high turbulence can explain some of the deviations. The present paper investigates this problem, by analysing full-scale time series data extracted from "Database on Wind Characteristics" (http://www.winddata.com/), which represents a wide range of sites. Basically, the sampled time series from a 3-D sonic-anemometer are compared with time series recorded by a nearby placed cup-anemometer. The comparison encompasses both wind speeds and the turbulence intensities. Subsequently, the observed deviations in the measured horizontal flow are correlated to the measured vertical flow. Keywords: cup-anemometer, sonic-anemometer, power curve, statistical analysis, turbulence.

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern), Courtney, M. (Intern)
Pages: 267-272
Publication date: 2004

Host publication information
Title of host publication: Proceedings of the special Topic Conference: The Science of making Torque from Wind
Place of publication: Delft
Publisher: Delft University of Technology
Editor: van Kuik, G.
ISBN (Print): 90-76468-10-9
Main Research Area: Technical/natural sciences
Conference: Special topic conference: The science of making torque from wind, Delft (NL), 19-21 Apr, 01/01/2004
Source: orbit
Source-ID: 155850
Publication: Research - peer-review › Article in proceedings – Annual report year: 2004

Windturbine wake flow characteristics - experiment and modelling

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Aagaard Madsen, H. (Intern), Thomsen, K. (Intern)
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: Geophysical Research Abstracts
Volume: 6
ISSN (Print): 1607-7962
Ratings:
Web of Science (2014): Indexed yes
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
ISI indexed (2012): ISI indexed no
Web of Science (2012): Indexed yes
ISI indexed (2011): ISI indexed no
Web of Science (2011): Indexed yes
BFI (2009): BFI-level 1
A new method for prediction of detailed wale loads

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Aagaard Madsen, H. (Intern), Thomsen, K. (Intern), Larsen, G. C. (Intern)
Publication date: 2003
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 306356
Publication: Research › Conference abstract for conference – Annual report year: 2003

A synthesis of results from the Efficient Development of Offshore Windfarms (ENDOW) project

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Publication date: 2003
Host publication information
Title of host publication: Proceedings CD-ROM. CD 2
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Workshop: 2003 European Wind Energy Conference and Exhibition, Madrid, Spain, 16/06/2003 - 16/06/2003
Links:
Source: orbit
Source-ID: 305943
Publication: Research › Article in proceedings – Annual report year: 2003

Conditional simulation or Turning your gaussian wind field simulator into a gust machine

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Ott, S. (Intern), Larsen, G. C. (Intern), Nielsen, M. (Intern), Mann, J. (Intern)
Pages: 47-51
Publication date: 2003
Host publication information
Title of host publication: IEA joint action
Place of publication: Stockholm
Publisher: FOI
Editor: Thor, S.
Series: FOI-S-0822
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 306344
Publication: Research › Book chapter – Annual report year: 2003
ENDOW: Efficient Development of Offshore Windfarms

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Pages: 161-175
Publication date: 2003

Host publication information
Title of host publication: Offshore wind energy in Mediterranean and other European seas. Resources, technology, applications
Place of publication: Naples
Publisher: Univ. of Naples
Main Research Area: Technical/natural sciences
Seminar: European Seminar Offshore Wind Energy in Mediterranean and Other European Seas, Naples, Italy, 10/04/2003 - 10/04/2003
Links:
Source: orbit
Source-ID: 305557
Publication: Research › Article in proceedings – Annual report year: 2003

ENDOW: Efficient development of offshore windfarms. Modelling wake and boundary-layer interactions

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Barthelmie, R. (Intern), Larsen, G. C. (Intern), Bergstrøm, H. (Ekstern), Magnusson, M. (Ekstern), Schlez, W. (Ekstern), Rados, K. (Ekstern), Lange, B. (Ekstern), Vølund, P. (Ekstern), Neckelmann, S. (Ekstern), Mogensen, S. (Ekstern), Schepers, G. (Ekstern), Hegberg, T. (Ekstern), Folkerts, L. (Ekstern)
Publication date: 2003
Event: Abstract from European Geophysical Society / American Geophysical Society joint meeting, Nice (FR), Apr.
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 306355
Publication: Research › Conference abstract for conference – Annual report year: 2003

En ny metode kan forudsige detaljerede laster for møller i parker

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Thomsen, K. (Intern), Aagaard Madsen, H. (Intern), Larsen, G. C. (Intern)
Number of pages: 6
Publication date: 2003

Publication information
Original language: Danish
Series: Resultatblad AED-RB
Number: 16(DA)
Main Research Area: Technical/natural sciences
Resultatblad AED-RB-16(DA)
Source: orbit
Source-ID: 305496
Extreme offshore wind shear

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Hansen, K. (Ekstern), Larsen, G. C. (Intern)
Pages: 129-141
Publication date: 2003

Host publication information
Title of host publication: Offshore wind energy in Mediterranean and other European seas. Resources, technology, applications
Place of publication: Naples
Publisher: Univ. of Naples
Main Research Area: Technical/natural sciences
Seminar: European Seminar Offshore Wind Energy in Mediterranean and Other European Seas, Naples, Italy, 10/04/2003 - 10/04/2003
Source: orbit
Source-ID: 305555
Publication: Research › Article in proceedings – Annual report year: 2003

Fatigue analysis of structure subjected to wind loading. A model for low frequency load cycles

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Carlén, I. (Ekstern), Larsen, G. C. (Intern)
Pages: 121-129
Publication date: 2003

Host publication information
Title of host publication: IEA joint action
Place of publication: Stockholm
Publisher: FOI
Editor: Thor, S.
Series: FOI-S-0822
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 306347
Publication: Research - peer-review › Book chapter – Annual report year: 2003

IEA Annex XVII: Database on wind characteristics. Progress report, April 2003

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Number of pages: 9
Publication date: 2003

Publication information
Place of publication: [s.l.]
Publisher: [s.n.]
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 306369
Publication: Research › Report – Annual report year: 2003

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Number of pages: 11
Publication date: 2003

Publication information
Place of publication: [s.l.]
Publisher: [s.n.]
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 306368
Publication: Research › Report – Annual report year: 2003

Mean gust shapes

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern)
Number of pages: 190
Publication date: 2003

Publication information
ISBN (Print): 87-550-2587-0
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1133(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1133, Risø-R-1133(EN)
Electronic versions:
ris_r_1133.pdf
Source: orbit
Source-ID: 306371
Publication: Research › Report – Annual report year: 2003

Mean Gust Shapes

General information
State: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering
Authors: Larsen, G. C. (Intern), Bierbooms, W. (Ekstern), Hansen, K. S. (Intern)
Publication date: 2003

Publication information
Original language: Danish
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 25753
Publication: Communication › Report – Annual report year: 2003

Mean wake deficit in the near field

General information
State: Published
Organisations: Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Aagaard Madsen, H. (Intern), Sørensen, N. N. (Intern)
Publication date: 2003
On the most likely EOG amplitudes

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design, Department of Mechanical Engineering, Fluid Mechanics
Authors: Larsen, G. C. (Intern), Hansen, K. S. (Intern)
Publication date: 2003

Parameterisation of turbulence intensity
Document is available in the Wind Energy Document Database

General information
State: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern)
Publication date: 2003

Review of recent advances based on "www.WindData.com"

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. S. (Intern)
Pages: 131-147
Publication date: 2003
Spatial coherence of the longitudinal turbulence component

Statistics of Local Extremes

The gust events described in the IEC-standard are formulated as coherent gusts of an inherent deterministic character, whereas the gusts experienced in real situation are of a stochastic nature with a limited spatial extension. This conceptual difference may cause substantial differences in the load patterns of a wind turbine when a gust event is imposed. The Newgust method is a rational way of taking wind speed gust situations into account in a design process. A cornerstone in the method is a cogent algorithm to embed a wind speed gust of a prescribed appearance in a stochastic wind field [Dragt, 1996]. However, dealing with wind turbine design, not only detailed knowledge on the spatial/time structure of the gust event is required. The probability of occurrence of a gust event with a given wind speed amplitude/magnitude is equally important. This theme is addressed in the present report. A theoretical expression for the probability density function associated with local extremes of a stochastic process is presented. The expression is basically based on the lower four statistical moments and a bandwidth parameter. The theoretical expression is subsequently verified by comparison with simulated synthentic wave/wind fields as well as with measured wind fields covering a broad range of mean wind speed situations and terrain conditions. The simulated wave fields represents narrow band processes, whereas the wind fields represent broad-banded processes. The work reported makes part of the project "Modelling of Extreme Gusts for Design Calculations " (NEWGUST), which is co-funded through JOULEIII on contract no. JOR3-CT98-0239.
Validation of the NewGust approach

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern)
Number of pages: 47
Publication date: 2003

Publication information
ISBN (Print): 87-550-2779-2
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1221(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Electronic versions:
ris_r_1221.pdf
Source: orbit
Source-ID: 306370
Publication: Research » Report – Annual report year: 2003

Wind shear extremes at possible offshore wind turbine locations
Positive and negative short-term extreme wind shear distributions (conditioned on the mean wind speed) are determined and compared for a number of offshore sites. The analysis is based on rapidly sampled field measurements (1-8 Hz) extracted from the "Database on Wind Characteristics" (www.winddata.com). Three different averaging periods (2, 5 and 10 seconds) are considered, and for each averaging period a relation between the resulting extreme shear distributions and the averaging time are presented. The short-term extreme shear analysis is based on different spatial distances, and extrapolation to a spatial distance of 100 m has been investigated. Such distances are appropriate for the next generation of offshore wind turbines. The paper concludes with an estimation of the short-term extreme shear values, which are compared to the values specified in the IEC-61400 code. The extreme IEC shear values seems to be rather conservative for an offshore location, compared to the estimated values based on measurements.

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Mechanical Engineering
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern)
Pages: 339-349
Publication date: 2003
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Engineering
Wind Simulation for Extreme and Fatigue Loads

Measurements of atmospheric turbulence have been studied and found to deviate from a Gaussian process, in particular regarding the velocity increments over small time steps, where the tails of the pdf are exponential rather than Gaussian. Principles for extreme event counting and the occurrence of cascading events are presented. Empirical extreme statistics agree with Rice’s exceedence theory, when it is assumed that the velocity and its time derivative are independent. Prediction based on the assumption that the velocity is a Gaussian process underpredicts the rate of occurrence of extreme events by many orders of magnitude, mainly because the measured pdf is non-Gaussian. Methods for simulation of turbulent signals have been developed and their computational efficiency are considered. The methods are applicable for multiple processes with individual spectra and probability distributions. Non-Gaussian processes are simulated by the
correlation-distortion method. Non-stationary processes are obtained by Bezier interpolation between a set of stationary simulations with identical random seeds. Simulation of systems with some signals available is enabled by conditional statistics. A versatile method for simulation of extreme events has been developed. This will generate gusts, velocity jumps, extreme velocity shears, and sudden changes of wind direction. Gusts may be prescribed with a specified ensemble average shape, and it is possible to detect the critical gust shape for a given construction. The problem is formulated as the variational problem of finding the most probable adjustment of a standard simulation of a stationary Gaussian process subject to relevant event conditions, which are formulated as linear combination of points in the realization. The method is generalized for multiple correlated series, multiple simultaneous conditions, and 3D fields of all velocity components. Generalization are presented for a single non-Gaussian process subject to relatively simple conditions, i.e. gusts and velocity jumps. Further generalizations for simulation of multiple correlated non-Gaussian processes are suggested.
Analysis of extreme wind shear events (poster)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, K. (Ekstern), Larsen, G. C. (Intern), Pedersen, B. (Ekstern)
Publication date: 2002

Host publication information
Title of host publication: Proceedings CD-ROM
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 304230
Publication: Research › Article in proceedings – Annual report year: 2002

Comparison of wake models with data

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Rados, K. (Ekstern), Larsen, G. C. (Intern), Barthelmie, R. (Ekstern), Schlez, W. (Ekstern), Lange, B. (Ekstern), Schepers, G. (Ekstern), Hegberg, T. (Ekstern), Magnusson, M. (Ekstern)
Pages: 9-15
Publication date: 2002

Host publication information
Title of host publication: Proceedings
Volume: Risø-R-1326(EN)
Editor: Barthelmie, R.
ISBN (Print): 87-550-3018-1(Internet)
Main Research Area: Technical/natural sciences
Workshop: ENDOW Workshop, Risø, Denmark, 07/03/2002 - 07/03/2002
Links:
http://www.risoe.dtu.dk/rispubl/VEA/veapdf/ris-r-1326.pdf
Source: orbit
Source-ID: 303916
Publication: Research › Article in proceedings – Annual report year: 2002

Constrained Simulation of Critical Windspeed Gusts by means of Wavelets

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design, Fluid Mechanics, Department of Mechanical Engineering
Authors: Larsen, G. C. (Intern), Hansen, K. S. (Intern), Pedersen, B. J. (Ekstern)
Publication date: 2002

Host publication information
Title of host publication: Global Windpower Conference and Exhibition Proceedings
Constrained simulation of critical wind speed gusts by means of wavelets (poster)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern), Pedersen, B. (Ekstern)
Publication date: 2002

Host publication information
Title of host publication: Proceedings CD-ROM
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 62586
Publication: Research › Article in proceedings – Annual report year: 2002

Efficient development of offshore windfarms: Wake and boundary-layer interactions

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Publication date: 2002

Host publication information
Title of host publication: Offshore wind energy (CD-ROM)
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Conference: EWEA Offshore Wind Energy Special Topic Conference, Brussels, Belgium, 10/12/2001 - 10/12/2001
Source: orbit
Source-ID: 304236
Publication: Research › Article in proceedings – Annual report year: 2002

ENDOW: Efficient development of offshore windfarms

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Barthelmie, R. (Intern), Larsen, G. C. (Intern), Bergström, H. (Ekstern), Magnusson, M. (Ekstern), Schlez, W. (Ekstern), Rados, K. (Ekstern), Lange, B. (Ekstern), Vølund, P. (Ekstern), Neckelmann, S. (Ekstern), Christensen, L. (Ekstern), Schepers, G. (Ekstern), Hegberg, T. (Ekstern), Folkerts, L. (Ekstern)
Pages: 4-8
Publication date: 2002

Host publication information
Title of host publication: Proceedings of the ENDOW Workshop Offshore Wakes: measurements and Modelling
Editor: Barthelmie, R.
ISBN (Print): 87-550-3018-1(Internet)
ENDOW: Efficient development of offshore windfarms

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Barthelmie, R. (Intern), Larsen, G. C. (Intern), Bergström, H. (Ekstern), Magnusson, M. (Ekstern), Schlez, W. (Ekstern), Rados, K. (Ekstern), Lange, B. (Ekstern), Vølund, P. (Ekstern), Neckelmann, S. (Ekstern), Christensen, L. (Ekstern), Schepers, G. (Ekstern), Hegberg, T. (Ekstern), Folkerts, L. (Ekstern)
Publication date: 2002

Host publication information
Title of host publication: Proceedings CD-ROM
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences

ENDOW: Efficient development of offshore windfarms

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Publication date: 2002
Event: Abstract from 1st WindWorld conference, Berlin, Germany.
Main Research Area: Technical/natural sciences

ENDOW: Improvement of wake models

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Schlez, W. (Ekstern), Umana E., A. (Ekstern), Barthelmie, R. (Intern), Larsen, G. C. (Intern), Rados, K. (Ekstern), Lange, B. (Ekstern), Schepers, G. (Ekstern)
Pages: 27-32
Publication date: 2002
Fundamentals for remote structural health monitoring of wind turbine blades - a preproject

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Sørensen, B. F. (Intern), Lading, L. (Ekstern), Sendrup, P. (Ekstern), McGugan, M. (Intern), Debel, C. (Ekstern), Kristensen, O. (Ekstern), Larsen, G. C. (Intern), Hansen, A. (Ekstern), Rheinländer, J. (Ekstern), Rusborg, J. (Ekstern), Vestergaard, J. (Ekstern)
Number of pages: 36
Publication date: 2002

Publication information
ISBN (Print): 87-550-3044-0
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1336(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1336, Risø-R-1336(EN)
Electronic versions:
ris_r_1336.pdf
Source: orbit
Source-ID: 304272
Publication: Research › Report – Annual report year: 2002

IEA Annex XVII: Database on wind characteristics. Progress report, April 2002

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Number of pages: 12
Publication date: 2002

Publication information
Place of publication: [s.l.]
Publisher: [s.n.]
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 304993
Publication: Research › Report – Annual report year: 2002

IEA Annex XVII: Database on wind characteristics. Progress report, October 2002

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Number of pages: 15
Publication date: 2002
Konvertering af danske vindmålinger til "Database on Wind Characteristics"

General information
State: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering, Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern)
Publication date: 2002

Modal analysis of wind turbine blades

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, M. (Ekstern), Baumgart, A. (Ekstern), Carlén, I. (Ekstern)
Number of pages: 71
Publication date: 2002

Models for wind turbines - a collection

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Number of pages: 71
Publication date: 2002

Electronic versions:
ris_r_1181.pdf
Source: orbit
Source-ID: 304671
Publication: Research › Report – Annual report year: 2002
Task XVII - Database on wind characteristics

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Publication date: 2002

Host publication information
Title of host publication: IEA Wind Energy annual report 2001
Place of publication: Golden, CO
Publisher: International Energy Agency
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 304992
Publication: Research - peer-review › Book chapter – Annual report year: 2002

Udvikling af vinge afprøvningsmetoder/mondalanalyse

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Hansen, M. (Intern), Carlén, I. (Ekstern), Baumgart, A. (Ekstern), Kristensen, O. (Intern), Pedersen, H. (Intern)
Publication date: 2002
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 303971
Publication: Research › Conference abstract for conference – Annual report year: 2002

A comparison of wake model performances in an offshore environment (poster)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Rados, K. (Ekstern), Larsen, G. C. (Intern), Barthelmie, R. (Intern), Schelz, W. (Ekstern), Hassan, U. (Ekstern), Lange, B. (Ekstern), Waldl, I. (Ekstern), Schepers, G. (Ekstern), Hegberg, T. (Ekstern), Magnusson, M. (Ekstern)
Pages: 781-784
Publication date: 2001

Host publication information
Title of host publication: Wind energy for the new millennium (eds.)
Place of publication: München
Publisher: WIP Renewable Energies
Editors: Helm, P., Zervos, A.
Main Research Area: Technical/natural sciences
Conference: 2001 European Wind Energy Conference and Exhibition (EWEC '01), Copenhagen, Denmark, 02/07/2001 - 02/07/2001
Links:
Source: orbit
Source-ID: 303316
Publication: Research › Article in proceedings – Annual report year: 2001
A probabilistic method for extreme wind turbine loading (poster)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Bierbooms, W. (Ekstern), Cheng, P. (Ekstern), Larsen, G. C. (Intern)
Pages: 104-107
Publication date: 2001

Host publication information
Title of host publication: Contributions European wind energy
Place of publication: Delft
Publisher: Delft University of Technology, Wind Energy Research Institute
Series: Duwind 2001.003
Main Research Area: Technical/natural sciences
Conference: 2001 European Wind Energy Conference and Exhibition (EWEC '01), Copenhagen, Denmark, 02/07/2001 - 02/07/2001
Source: orbit
Source-ID: 303315
Publication: Research › Article in proceedings – Annual report year: 2001

A probabilistic method for extreme wind turbine loading (poster)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Bierbooms, W. (Ekstern), Larsen, G. C. (Intern), Cheng, P. (Ekstern)
Pages: 721-724
Publication date: 2001

Host publication information
Title of host publication: Wind energy for the new millennium. Proceedings
Place of publication: München
Publisher: WIP Renewable Energies
Editors: Helm, P., Zervos, A.
Main Research Area: Technical/natural sciences
Conference: 2001 European Wind Energy Conference and Exhibition (EWEC '01), Copenhagen, Denmark, 02/07/2001 - 02/07/2001
Source: orbit
Source-ID: 303677
Publication: Research › Article in proceedings – Annual report year: 2001

Comparison of wake models with data for offshore wind farms

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Rados, K. (Ekstern), Larsen, G. C. (Intern), Barthelmie, R. (Intern), Schiez, W. (Ekstern), Lange, B. (Ekstern), Schepers, G. (Ekstern), Hegberg, T. (Ekstern), Magnusson, M. (Ekstern)
Pages: 271-280
Publication date: 2001
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Engineering
Volume: 25
ISSN (Print): 0309-524X
Ratings:
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Database on wind characteristics

General information
State: Published
Organisations: Fluid Mechanics, Department of Mechanical Engineering, Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern), Courtney, M. S. (Extern)
Publication date: 2001

Host publication information
Title of host publication: Proceedings of the 2001 European Wind Energy Conference and Exhibition
Place of publication: Munich
Publisher: WIP-Renewable Energies
Main Research Area: Technical/natural sciences
Conference: 2001 European Wind Energy Conference and Exhibition (EWEC '01), Copenhagen, Denmark, 02/07/2001 - 02/07/2001
Source: orbit
Source-ID: 64239
Database on wind characteristics. Contents of database bank

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Number of pages: 75
Publication date: 2001

Publication information
ISBN (Print): 87-550-2964-7
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1301(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1301, Risø-R-1301(EN)
Electronic versions:
ris_r_1301.pdf
Source: orbit
Source-ID: 303627

Database on wind characteristics (poster)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Hansen, K. (Ekstern), Larsen, G. C. (Intern), Courtney, M. (Ekstern)
Pages: 858-860
Publication date: 2001

Host publication information
Title of host publication: Wind energy for the new millennium. Proceedings
Place of publication: München
Publisher: WIP Renewable Energies
Editors: Helm, P., Zervos, A.
Main Research Area: Technical/natural sciences
Conference: 2001 European Wind Energy Conference and Exhibition (EWEC '01), Copenhagen, Denmark, 02/07/2001 - 02/07/2001
Source: orbit
Source-ID: 303320

Database on wind characteristics. Structure and philosophy

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Number of pages: 51
Publication date: 2001

Publication information
ISBN (Print): 87-550-2960-4
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1299(EN)
ISSN: 0106-2840
General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Number of pages: 67
Publication date: 2001

Publication information
ISBN (Print): 87-550-2962-0
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1300(EN)
Main Research Area: Technical/natural sciences
Electronic versions: ris_r_1300.pdf
Source: orbit
Source-ID: 303626
Publication: Research › Conference abstract for conference – Annual report year: 2001

Efficient development of offshore windfarms: A new project for investigating wake and boundary-layer interactions

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Pages: 657-660
Publication date: 2001

Host publication information
Title of host publication: Wind energy for the new millennium. Proceedings
Place of publication: München
Publisher: WIP Renewable Energies
Eksperimentel undersøgelse af ekstreme laster

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Markkilde Petersen, S. (Ekstern)
Publication date: 2001
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 302319
Publication: Research › Conference abstract for conference – Annual report year: 2001

ENDOW: Efficient Development of Offshore Windfarms

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Barthelmie, R. (Intern), Larsen, G. C. (Intern), Bergström, H. (Ekstern), Magnusson, M. (Ekstern), Schlez, W. (Ekstern), Rados, K. (Ekstern), Lange, B. (Ekstern), Volund, P. (Ekstern), Neckelmann, S. (Ekstern), Christensen, L. (Ekstern), Schepers, G. (Ekstern), Hegberg, T. (Ekstern), Folkerts, L. (Ekstern)
Pages: 263-270
Publication date: 2001
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Engineering
Volume: 25
ISSN (Print): 0309-524X
Ratings:
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.267 SNIP 0.515 CiteScore 0.58
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.369 SNIP 0.632 CiteScore 0.63
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.412 SNIP 1 CiteScore 0.78
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.382 SNIP 1.105 CiteScore 0.62
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.325 SNIP 1.095 CiteScore 0.56
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.363 SNIP 0.762 CiteScore 0.74
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
ENDOW: Improvements of wake models within offshore windfarms

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Schlez, W. (Ekstern), Umana, A. (Ekstern), Barthelmie, R. (Intern), Larsen, G. C. (Intern), Rados, K. (Ekstern), Lange, B. (Ekstern), Schepers, G. (Ekstern), Hegberg, T. (Ekstern), Magnusson, M. (Ekstern)
Pages: 281-289
Publication date: 2001
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Engineering
Volume: 25
ISSN (Print): 0309-524X
Ratings:
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.267 SNIP 0.515 CiteScore 0.58
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.369 SNIP 0.632 CiteScore 0.63
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.412 SNIP 1 CiteScore 0.78
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.382 SNIP 1.105 CiteScore 0.62
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.325 SNIP 1.095 CiteScore 0.56
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.363 SNIP 0.762 CiteScore 0.74
ISI indexed (2011): ISI indexed no
Experimental investigation of ultimate loads (poster)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Markkilde Petersen, S. (Ekstern)
Pages: 426-429
Publication date: 2001

Host publication information
Title of host publication: Wind energy for the new millennium. Proceedings
Place of publication: München
Publisher: WIP Renewable Energies
Editors: Helm, P., Zervos, A.
Main Research Area: Technical/natural sciences
Conference: 2001 European Wind Energy Conference and Exhibition (EWEC ’01), Copenhagen, Denmark, 02/07/2001 - 02/07/2001
Source: orbit
Source-ID: 303197
Publication: Research › Article in proceedings – Annual report year: 2001

IEA Annex XVII - Database on wind characteristics. Progress report, March 2001

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Number of pages: 12
Publication date: 2001

Publication information
Place of publication: [s.l.]
Publisher: [s.n.]
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
IEA Annex XVII - Database on wind characteristics. Progress report, September 2001

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Number of pages: 12
Publication date: 2001

Publication information
Place of publication: [s.l.]
Publisher: [s.n.]
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 303629
Publication: Research › Report – Annual report year: 2001

Offshore fatigue design turbulence

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern)
Pages: 107-120
Publication date: 2001
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Energy
Volume: 4
ISSN (Print): 1095-4244
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.37 SJR 1.104 SNIP 2.306
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.196 SNIP 2.086 CiteScore 3.06
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.272 SNIP 3.75 CiteScore 3.42
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.275 SNIP 2.464 CiteScore 2.75
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.126 SNIP 2.39 CiteScore 2.36
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.024 SNIP 2.718 CiteScore 2.49
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Statistical uncertainty in design turbulence intensity - an analytical approximation

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern)
Pages: 27-33
Publication date: 2001

Host publication information
Title of host publication: Structural reliability of wind turbines
Volume: FOI-S-0220-SE
Place of publication: Stockholm
Publisher: FOI Swedish Defence Research Agency
Editor: Thor, S.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 303582
Publication: Research › Conference abstract in proceedings – Annual report year: 2001

Statistics of offshore wind speed gusts

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design, Fluid Mechanics, Department of Mechanical Engineering
Authors: Larsen, G. C. (Intern), Hansen, K. S. (Intern)
Publication date: 2001

Host publication information
Statistics of offshore wind speed gusts (poster)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Hansen, K. S. (Intern)
Pages: 753-756
Publication date: 2001

Host publication information
Title of host publication: Wind energy for the new millennium. Proceedings
Place of publication: München
Publisher: WIP Renewable Energies
Editors: Helm, P., Zervos, A.
Main Research Area: Technical/natural sciences
Conference: 2001 European Wind Energy Conference and Exhibition (EWEC '01), Copenhagen, Denmark, 02/07/2001 - 02/07/2001
Source: orbit
Source-ID: 303196
Publication: Research › Article in proceedings – Annual report year: 2001

Structural reliability of wind turbines

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern)
Pages: 3-9
Publication date: 2001

Host publication information
Title of host publication: Structural reliability of wind turbines
Volume: FOI-S-0220-SE
Place of publication: Stockholm
Publisher: FOI Swedish Defence Research Agency
Editor: Thor, S.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 303580
Publication: Research › Conference abstract in proceedings – Annual report year: 2001

Task XVII - Database on wind characteristics

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Publication date: 2001

Host publication information
Title of host publication: IEA Wind Energy annual report 2000
Place of publication: Golden, CO
Uncertainty in design loads

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Hansen, A. (Intern)
Publication date: 2001

Host publication information
Title of host publication: Structural reliability of wind turbines
Volume: FOI-S-0220-SE
Place of publication: Stockholm
Publisher: FOI Swedish Defence Research Agency
Editor: Thor, S.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 303581
Publication: Research › Conference abstract in proceedings – Annual report year: 2001

Usikkerhed ved opstilling af lastgrundlag

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Hansen, A. (Intern)
Pages: 89-102
Publication date: 2001

Host publication information
Title of host publication: Forskning i aeroelasticitet EFP-2000
Volume: Risør-R-1272(DA)
Editor: Aagaard Madsen, H.
ISBN (Print): 87-550-2891-8
Main Research Area: Technical/natural sciences
Links:
http://www.risoe.dtu.dk/rispubl/VEA/veapdf/ris-r-1272.pdf
Source: orbit
Source-ID: 302825
Publication: Research - peer-review › Book chapter – Annual report year: 2001

Wind Energy Department: Scientific and technical progress 1999-2000

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Skrumsager, B. (ed.) (Intern), Larsen, G. C. (ed.) (Intern)
Number of pages: 51
Publication date: 2001

Publication information
ISBN (Print): 87-550-2818-7
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1239(EN)
Extreme wind characteristics from a Danish offshore site

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, K. (Ekstern), Larsen, G. C. (Intern)
Pages: 441-454
Publication date: 2000

Host publication information
Title of host publication: Offshore wind energy in Mediterranean and other European seas: Technology and potential applications. Proceedings
Place of publication: Roma
Publisher: ENEA
Main Research Area: Technical/natural sciences
Seminar: European Seminar Offshore Wind Energy in Mediterranean and Other European Seas, Siracusa, Italy, 13/04/2000 - 13/04/2000
Source: orbit
Source-ID: 301676
Publication: Research › Article in proceedings – Annual report year: 2000

IEA Annex XVII - Database on wind characteristics. Progress report, April 2000

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Publication date: 2000

Publication information
Place of publication: [s.l.]
Publisher: [s.n.]
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 302112
Publication: Research › Report – Annual report year: 2000

IEA Annex XVII - Database on wind characteristics. Progress report, September 2000

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Publication date: 2000

Publication information
Place of publication: [s.l.]
Publisher: [s.n.]
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 302113
Publication: Research › Report – Annual report year: 2000
Modelling of extreme gusts for design calculations

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Bierbooms, W. (Ekstern), Larsen, G. C. (Intern), Pedersen, B. (Ekstern)
Publication date: 2000
Event: Abstract from Contractors meeting (JOULE), Athens (GR), 3-5 May, .
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 302119
Publication: Research › Conference abstract for conference – Annual report year: 2000

Modelling of extreme gusts for design calculations - NewGust. Publishable final report

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Bierbooms, W. (Ekstern), Cheng, P. (Ekstern), Larsen, G. C. (Intern), Pedersen, B. (Ekstern)
Number of pages: 29
Publication date: 2000

Publication information
Place of publication: Delft
Publisher: TU Delft
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 302114
Publication: Research - peer-review › Report – Annual report year: 2000

Task XVII - Database on wind characteristics

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Pages: 14-16
Publication date: 2000

Host publication information
Title of host publication: IEA Wind Energy annual report 1999
Place of publication: Golden, CO
Publisher: National Renewable Energy Laboratory
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 302133
Publication: Research - peer-review › Book chapter – Annual report year: 2000

Application of DfWC for gust investigations

General information
State: Published
Organisations: Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern)
Publication date: 1999
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 299383
Contributions from the Department of Wind Energy and Atmospheric Physics to EWEC '99 in Nice, France

General information
State: Published
Organisations: Wind Energy Division, Risø National Laboratory for Sustainable Energy
Number of pages: 256
Publication date: 1999

Publication information
ISBN (Print): 87-550-2542-0
Original language: English
Series: Denmark. Forskningscenter Risø. Risø-R
Number: 1114(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1114, Risø-R-1114(EN)
Electronic versions:
RIS_R_1114.pdf
Source: orbit
Source-ID: 300524
Publication: Research › Report – Annual report year: 1999

Cut-in Note: Database on Wind Characteristics

General information
State: Published
Organisations: Department of Energy Engineering
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern)
Pages: 177-181
Publication date: 1999
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Engineering
Volume: 23
Issue number: 3
ISSN (Print): 0309-524X
Ratings:
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.267 SNIP 0.515 CiteScore 0.58
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.369 SNIP 0.632 CiteScore 0.63
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.412 SNIP 1 CiteScore 0.78
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.382 SNIP 1.105 CiteScore 0.62
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.325 SNIP 1.095 CiteScore 0.56
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.363 SNIP 0.762 CiteScore 0.74
ISI indexed (2011): ISI indexed no
Database on wind characteristics

**General information**
State: Published
Organisations: Department of Mechanical Engineering, Risø National Laboratory for Sustainable Energy
Authors: Hansen, K. S. (Intern), Larsen, G. C. (Intern)
Pages: 177-181
Publication date: 1999
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Wind Engineering
Volume: 23
ISSN (Print): 0309-524X
Ratings:
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.267 SNIP 0.515 CiteScore 0.58
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.369 SNIP 0.632 CiteScore 0.63
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.412 SNIP 1 CiteScore 0.78
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.382 SNIP 1.105 CiteScore 0.62
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.325 SNIP 1.095 CiteScore 0.56
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.363 SNIP 0.762 CiteScore 0.74
ISI indexed (2011): ISI indexed no
Database on wind characteristics (http://www.winddata.com/)

General information
State: Published
Organisations: Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Hansen, K. (Ekstern)
Pages: 111-136
Publication date: 1999

Host publication information
Title of host publication: IEA joint action
Place of publication: Lyngby
Publisher: Technical University of Denmark. Department of Fluid Mechanics
Editor: Maribo Pedersen B.
Main Research Area: Technical/natural sciences
Conference: 2nd IEA Symposium on Wind Conditions for Wind Turbine Design, Risø, Denmark, 12/04/1999 - 12/04/1999
Source: orbit
Source-ID: 299665
Publication: Research → Article in proceedings – Annual report year: 1999

Design off-shore wind climate

General information
State: Published
Organisations: Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Ejsing Jørgensen, H. (Intern)
Pages: 73-76
Publication date: 1999

Host publication information
Title of host publication: IEA joint action
Place of publication: Lyngby
Publisher: Technical University of Denmark. Department of Fluid Mechanics
Editor: Maribo Pedersen B.
Main Research Area: Technical/natural sciences
Conference: 2nd IEA Symposium on Wind Conditions for Wind Turbine Design, Risø, Denmark, 12/04/1999 - 12/04/1999
Source: orbit
Design off-shore wind climate

General information
State: Published
Organisations: Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Ejsing Jørgensen, H. (Intern)
Pages: 1038-1041
Publication date: 1999

Host publication information
Title of host publication: Wind energy for the next millennium. Proceedings
Place of publication: London
Publisher: James and James Science Publishers
Editors: Petersen, E., Hjuler Jensen, P., Rave, K., Helm, P., Ehmann, H.
ISBN (Print): 1-902916-00-X
Main Research Area: Technical/natural sciences
Conference: 1999 European Wind Energy Conference and Exhibition, Nice, France, 01/03/1999 - 01/03/1999
Source: orbit
Source-ID: 299892
Publication: Research › Article in proceedings – Annual report year: 1999


General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (ed.) (Intern), Carlén, I. (Ekstern), Schepers, G. (Ekstern)
Publication date: 1999

Host publication information
Title of host publication: European wind turbine standards 2. Project results
Volume: ECN-C-99-073
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 299223
Publication: Research - peer-review › Book chapter – Annual report year: 1999

European wind turbine standards 2. Part 1. Load spectra and extreme wind conditions. Sub B: Complex terrain and fatigue loading

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Publication date: 1999

Host publication information
Title of host publication: European wind turbine standards 2. Project results
Volume: ECN-C-99-073
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 299225
Publication: Research - peer-review › Book chapter – Annual report year: 1999

European wind turbine standards 2. Part 1. Load spectra and extreme wind conditions. Sub C: Extreme wind climate events
Modelling of extreme gusts for design calculations (NewGust)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Bierbooms, W. (Ekstern), Cheng, P. (Ekstern), Larsen, G. C. (Intern), Juul Pedersen, B. (Ekstern), Hansen, K. (Ekstern)
Pages: 1001-1004
Publication date: 1999

Host publication information
Title of host publication: Wind energy for the next millennium. Proceedings
Place of publication: London
Publisher: James and James Science Publishers
Editors: Petersen, E., Hjuler Jensen, P., Rave, K., Helm, P., Ehmann, H.
ISBN (Print): 1-902916-00-X
Main Research Area: Technical/natural sciences
Conference: 1999 European Wind Energy Conference and Exhibition, Nice, France, 01/03/1999 - 01/03/1999
Source: orbit
Source-ID: 299895
Publication: Research › Article in proceedings – Annual report year: 1999

Off-shore wind climate and wake loading

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern)
Publication date: 1999
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 299384
Publication: Research › Conference abstract for conference – Annual report year: 1999

Probabilistic design tool PRODETO. Publishable final report

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Braam, H. (Ekstern), Dam, J. V. (Ekstern), Christensen, C. (Ekstern), Larsen, G. C. (Intern), Thøgersen, M. (Ekstern), Ronold, K. (Ekstern), Argyriadis, K. (Ekstern), Boer, J. D. (Ekstern), Fabian, O. (Ekstern)
Number of pages: 18
Publication date: 1999

Publication information
Original language: English
Series: ECN-C-99-023
Reliability-based design of wind-turbine rotor blades against failure in ultimate loading

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Ronold, K. (Ekstern), Larsen, G. C. (Intern)
Pages: 565-574
Publication date: 1999

Publication information
Journal: Engineering Structures
Volume: 22
ISSN (Print): 0141-0296
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.93 SJR 1.578 SNIP 2.048
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.696 SNIP 2.195 CiteScore 2.59
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.756 SNIP 2.56 CiteScore 2.4
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.049 SNIP 2.853 CiteScore 2.69
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.855 SNIP 2.627 CiteScore 2.23
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.7 SNIP 2.735 CiteScore 2.26
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.76 SNIP 2.343
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.764 SNIP 2.167
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.473 SNIP 2.033
Scopus rating (2007): SJR 1.581 SNIP 2.137
Scopus rating (2006): SJR 1.091 SNIP 1.781
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.33 SNIP 1.985
Scopus rating (2004): SJR 1.286 SNIP 1.647
Scopus rating (2003): SJR 1.176 SNIP 1.342
Ultimate loading of wind turbines

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Ronold, K. (Ekstern), Ejsing Jørgensen, H. (Intern), Argyriadis, K. (Ekstern), Boer, J. D. (Ekstern)
Number of pages: 33
Publication date: 1999

Publication information
ISBN (Print): 87-550-2536-6
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1111(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1111, Risø-R-1111(EN)
Electronic versions:
ris_r_1111.pdf
Source: orbit
Source-ID: 300526
Publication: Research › Report – Annual report year: 1999

Variability of extreme flap loads during turbine operation

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Ronold, K. (Ekstern), Larsen, G. C. (Intern)
Pages: 224-227
Publication date: 1999

Host publication information
Title of host publication: Wind energy for the next millennium. Proceedings
Place of publication: London
Publisher: James and James Science Publishers
Editors: Petersen, E., Hjuler Jensen, P., Rave, K., Helm, P., Ehmann, H.
ISBN (Print): 1-902916-00-X
Main Research Area: Technical/natural sciences
Conference: 1999 European Wind Energy Conference and Exhibition, Nice, France, 01/03/1999 - 01/03/1999
Source: orbit
Source-ID: 299921
Publication: Research › Article in proceedings – Annual report year: 1999

Wind characteristics database

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Courtney, M. (Ekstern), Hansen, K. (Ekstern), Larsen, G. C. (Intern)
Publication date: 1999
European wind turbine standards 2. Part 1 Sub C: Extreme wind climate events

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Winkelaar, D. (Ekstern), Dekker, J. (Ekstern), Chaviaropoulos, P. (Ekstern), Carlén, I. (Ekstern), Larsen, G. C. (Intern)
Publication date: 1998

Host publication information
Title of host publication: European wind turbine standards 2. Draft
Place of publication: Petten (NL)
Publisher: EUREC-Agency
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 297555
Publication: Research - peer-review › Book chapter – Annual report year: 1998

EWTS II - load spectra and extreme wind conditions

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Pages: 294-299
Publication date: 1998

Host publication information
Title of host publication: European wind energy conference. Proceedings
Place of publication: Slane
Publisher: Irish Wind Energy Association
Editor: Watson, R.
ISBN (Print): 0-9533922-0-1
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 298216
Publication: Research › Article in proceedings – Annual report year: 1998

Fatigue life consumption in wake operation

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Carlén, I. (Ekstern), Schepers, G. (Ekstern)
Pages: 605-610
Publication date: 1998

Host publication information
Title of host publication: European wind energy conference. Proceedings
Place of publication: Slane
Publisher: Irish Wind Energy Association
Editor: Watson, R.
ISBN (Print): 0-9533922-0-1
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 298238
Publication: Research › Article in proceedings – Annual report year: 1998
Fatigue life consumption in wake operation

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Carlén, I. (Ekstern), Schepers, G. (Ekstern)
Publication date: 1997
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 296666
Publication: Research › Conference abstract for conference – Annual report year: 1997

A simple approximative procedure for taking into account low cycle fatigue loads

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Thomsen, K. (Intern)
Pages: 17-27
Publication date: 1996

Host publication information
Title of host publication: IEA joint action. Wind turbine fatigue
Place of publication: Lyngby
Publisher: Technical University of Denmark. Department of Fluid Mechanics
Editor: Maribo Pedersen, B.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 295430
Publication: Research › Article in proceedings – Annual report year: 1996

Contributions from the Department of Meteorology and Wind Energy to the EUWEC '96 conference in Göteborg, Sweden

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (ed.) (Intern)
Number of pages: 144
Publication date: 1996

Publication information
ISBN (Print): 87-550-2206-5
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 909(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-909(EN), Risø-R-909
Electronic versions: RIS_R_909.pdf
Source: orbit
Source-ID: 295300
Publication: Research › Report – Annual report year: 1996

Design basis 2

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Low cycle fatigue loads

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Thomsen, K. (Ekstern)
Number of pages: 21
Publication date: 1996

Publication information
ISBN (Print): 87-550-2204-9
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 913(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-913, Risø-R-913(EN)
Electronic versions:
RIS_R_913.pdf
Source: orbit
Source-ID: 295185
Publication: Research › Report – Annual report year: 1996

Wind fields in wakes

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Højstrup, J. (Ekstern), Aagaard Madsen, H. (Intern)
Pages: 764-768
Publication date: 1996

Host publication information
Title of host publication: 1996 European Union wind energy conference. Proceedings
Place of publication: Bedford
Publisher: H.S. Stephens & Associates
Editors: Zervos, A., Ehmann, H., Helm, P.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 294631
Publication: Research › Article in proceedings – Annual report year: 1996

A complex frequency domain model of wind turbine structures

General information
Concept testing of wind turbines

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Schmidt Paulsen, U. (Intern), Larsen, G. C. (Intern), Markkilde Petersen, S. (Ekstern), Pedersen, T. (Ekstern)
Pages: 916-926
Publication date: 1995

Host publication information
Place of publication: Thessaloniki
Publisher: The Hellenic Wind Energy Association; The European Wind Energy Association
Editor: Tsipouridis, J.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 293357
Publication: Research › Article in proceedings – Annual report year: 1995

Contributions from the Department of Meteorology and Wind Energy to the EWEC'94 conference in Thessaloniki, Greece

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (ed.) (Intern)
Number of pages: 136
Publication date: 1995

Publication information
ISBN (Print): 87-550-2055-0
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 797(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-797, Risø-R-797(EN)
Electronic versions:
RISOR797.pdf
Source: orbit
Source-ID: 294201
Publication: Research › Report – Annual report year: 1995

Experimental determination of stiffness distributions and mode shapes of wind turbine blades

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Kretz, A. (Ekstern)
Number of pages: 58
Publication date: 1995

Publication information
ISBN (Print): 87-550-2015-1
Original language: English
Experimental determination of structural properties by non-destructive methods

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Kretz, A. (Ekstern)
Pages: 628-632
Publication date: 1995

Host publication information
Title of host publication: 5th European Wind Energy Association conference and exhibition. Conference proceedings. Oral sessions. Vol. 1
Place of publication: Thessaloniki
Publisher: The Hellenic Wind Energy Association; The European Wind Energy Association
Editor: Tsipouridis, J.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 293374
Publication: Research › Article in proceedings – Annual report year: 1995

Aeroelastiske beregningsprogram DBP2

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern)
Publication date: 1994
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 291754
Publication: Research › Conference abstract for conference – Annual report year: 1994

Concept testing of wind turbines

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design, Test and Measurements
Authors: Schmidt Paulsen, U. (Intern), Larsen, G. C. (Intern), Markkilde Petersen, S. (Ekstern), Friis Pedersen, T. (Intern)
Publication date: 1994
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 292242
Publication: Research › Conference abstract for conference – Annual report year: 1994

Design basis

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern)
Experimental determination of structural properties by non-destructive methods

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Kretz, A. (Ekstern)
Publication date: 1994
Main Research Area: Technical/natural sciences
Source-ID: 292241
Publication: Research › Conference abstract for conference – Annual report year: 1994

Ikke-destruktiv bestemmelse af en vinges massefordeling

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern)
Publication date: 1994
Main Research Area: Technical/natural sciences
Publication: Communication › Journal article – Annual report year: 1994

Stall-beregninger med DesignBasis

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Larsen, G. C. (Intern), Schmidt Paulsen, U. (Intern)
Publication date: 1994
Main Research Area: Technical/natural sciences
Publication: Communication › Journal article – Annual report year: 1994

Verification of design basis program 2. A coupled aeroelastic wind turbine model
Gas Explosion Characterization, Wave Propagation: (Half-Scale Experiments)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern), Roed, J. (Intern), Andersen, S. (Ekstern)
Number of pages: 162
Publication date: 1987

Publication information
ISBN (Print): 87-550-1121-7
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 499
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-499
Electronic versions:
ris_r_499.pdf
Source: orbit
Source-ID: 287209
Publication: Research › Report – Annual report year: 1987

Egenfrekvensberegning af Alternegy's 7,5 m vinge

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern)
Number of pages: 26
Publication date: 1986

Publication information
Place of publication: Roskilde
Publisher: Risø National Laboratory
Original language: Danish
Series: Risø-M
Number: 2573
ISSN: 0418-6435
Main Research Area: Technical/natural sciences
Risø-M-2573
Source: orbit
Source-ID: 279956
Publication: Research › Report – Annual report year: 1986

Egenfrekvensberegning af LM's 8,5 m vinge

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern)
Number of pages: 27
Publication date: 1986

Publication information
Place of publication: Roskilde
Publisher: Risø National Laboratory
Original language: Danish
Elastic-Plastic Fracture Mechanics Analysis of a CT-Specimen - a Two-Dimensional Approach
This report documents the results obtained from an elastic-plastic finite-element analysis of a compact tension specimen. The geometry of the model has been slightly modified compared to the physical specimen, but this is not considered to influence the results. The analysis comprises a plane strain as well as a plane stress approximation. The results presented include applied loads and displacements at certain locations. Moreover, the J-integral and the crack opening displacement have been presented. The plane strain and the plane stress approximation have been compared and the plane stress approximation is believed to deliver the best results. The results have been obtained using the finite element code ADINA and the postprocessor code JINT.

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern)
Number of pages: 23
Publication date: 1986

Numerisk modellering af vindmøllevinger

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Larsen, G. C. (Intern)
Number of pages: 24
Publication date: 1986
Projects:

Large scale atmospheric structures in space-time over flat terrain
Department of Wind Energy
Period: 15/11/2017 → 14/11/2020
Number of participants: 4
Phd Student: 
Alcayaga Romàn, Leonardo Andrès (Intern)
Supervisor: 
Kelly, Mark C. (Intern)
Mann, Jakob (Intern)
Main Supervisor: 
Larsen, Gunner Chr. (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Inflow Characterization based on Remote Sensing using Pitot Tubes
Department of Wind Energy
Period: 01/02/2015 → 31/01/2018
Number of participants: 5
Phd Student: 
Pedersen, Mads Mølgaard (Intern)
Supervisor: 
Larsen, Gunner Chr. (Intern)
Aagaard Madsen, Helge (Intern)
Schmidt Paulsen, Uwe (Intern)
Main Supervisor: 
Larsen, Torben J. (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Wind Farm Layout Optimization in Complex Terrain
The overall objective of the project is to develop and provide new reliable tools for designing wind farms located in complex terrain through full scale measurements in wind farms. For wind farms located in flat terrain, the performance of the wind turbines is significantly influenced by the upstream wind turbines and slightly influenced by the ground. For wind farms located in complex terrain the ground effects are relatively more pronounced, as such effects may bend the wakes created by the upstream turbines significantly. The goal of the present Sino-Danish project is to further develop Danish wind farm technology by using measured wind farm data from complex terrain wind farms in China, which is convenient, as Denmark does not have complex terrain that can be used for developing/validating such technology. To improve the wind turbines' performance within wind farms in complex terrain, there are basically three important steps: (1) develop reliable CFD tools for predicting flow in complex terrain with and without wind turbines; (2) develop simplified flow models for predicting wind turbine performance in complex terrain; and (3) design high efficiency wind turbine parks in complex terrain.
Department of Wind Energy
Fluid Mechanics
Wind turbine loads & control
Resource Assessment Modelling
EMD International A/S
Period: 01/04/2014 → 31/12/2017
Number of participants: 6

Wind Farms
Acronym: FarmOpt
Project ID: EUDP-64013-0405
Project Manager, academic:
Zhu, Wei Jun (Intern)
Hansen, Kurt Schaldemose (Intern)
Bechmann, Andreas (Intern)
Larsen, Gunner Chr. (Intern)
Feng, Ju (Intern)
Project Coordinator:
Shen, Wen Zhong (Intern)

Activities:
Wind farm design in complex terrain - the FarmOpt methodology

Uncertainty Quantification of Wind Farm Flow Models
Department of Wind Energy
Period: 15/12/2013 → 23/03/2017
Number of participants: 7
Phd Student:
Murcia Leon, Juan Pablo (Intern)
Supervisor:
Natarajan, Anand (Intern)
Sørensen, John Dalsgaard (Intern)
Main Supervisor:
Réthoré, Pierre-Elouan (Intern)
Examiner:
Larsen, Gunner Chr. (Intern)
Barthelmie, Rebecca Jane (Intern)
Manuel, Lance (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet

Relations
Publications:
Uncertainty quantification in wind farm flow models
Project: PhD

PhD scholarship in Turbulent Atmospheric Flow with Relevance for Wind Energy
Department of Wind Energy
Period: 01/03/2013 → 29/09/2016
Number of participants: 6
Phd Student:
Lange, Julia (Intern)
Supervisor:
Berg, Jacob (Ekstern)
Main Supervisor:
Mann, Jakob (Intern)
Examiner:
Larsen, Gunner Chr. (Intern)
Aubrun, Sandrine (Ekstern)
Porté-Agel, Fernando (Ekstern)
Financing sources
Source: Internal funding (public)
Name of research programme: 1/3 FUU, 1/3 inst 1/3 Andet

Relations
Publications:
Flow over complex terrain. The secrets of Bolund
Project: PhD

Assessment of extreme design loads for modern wind turbines using the probabilistic approach
Department of Wind Energy
Period: 01/05/2012 → 24/08/2015
Number of participants: 6
Phd Student:
Abdallah, Imad (Intern)
Supervisor:
Sørensen, John Dalsgaard (Intern)
Main Supervisor:
Natarajan, Anand (Intern)
Examiner:
Larsen, Gunner Chr. (Intern)
Manuel, Lance (Ekstern)
Riziotis, Vasilis A. (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: ErhvervsPhD-ordningen VTU
Project: PhD

Multiple Turbine Wakes
Department of Wind Energy
Period: 01/11/2011 → 24/08/2015
Number of participants: 7
Phd Student:
Machefaux, Ewan (Intern)
Supervisor:
Aagaard Madsen, Helge (Intern)
Mann, Jakob (Intern)
Main Supervisor:
Larsen, Gunner Chr. (Intern)
Examiner:
Sørensen, Jens Nørkær (Intern)
Ivanell, Stefan S. A. (Ekstern)
Voutsinas, Spyros (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

The impact of non-neutral atmosphere on offshore wind turbines
Department of Wind Energy
Period: 15/03/2011 → 24/09/2015
Number of participants: 7
Phd Student:
de Mare, Martin Tobias (Intern)
Supervisor:
Larsen, Gunner Chr. (Intern)
Wind Farm
The project will develop a model that describes the turbine wake and how it affects Down Wind turbines. The model can provide a better basis for determining relative positions of turbines, and thereby optimize production.

Department of Wind Energy
Aeroelastic Design
DONG Energy A/S
VESTAS Wind Systems A/S
Period: 01/02/2011 → 31/12/2014
Number of participants: 3
Acronym: 43032 4610-EUDP
Project participant:
Trolleborg, Niels (Intern)
Larsen, Torben J. (Intern)
Project Manager, academic:
Larsen, Gunner Chr. (Intern)
Project

Nystad 2, Wakes
The objective of this project in on basis of simple turbine measurements in a wind farm to identify, model and verify the basic mechanisms driving the increased loading experienced by turbines operating in offshore Wind farm.

Department of Wind Energy
Aeroelastic Design
Department of Applied Mathematics and Computer Science
Test and Measurements
Grontmij A/S
Period: 01/06/2010 → 30/06/2014
Number of participants: 4
Acronym: 43026 4610-PSO
Project participant:
Pedersen, Mads Malgaard (Intern)
Aagaard Madsen , Helge (Intern)
Larsen, Torben J. (Intern)
Project Manager, academic:
Larsen, Gunner Chr. (Intern)
Project

ComWind (Flowcenter) AED
The project concerns the mutual interaction between wind turbine aerodynamics, turbine wakes, terrain affected flow and atmospheric turbulence, which is not accounted for in state of the art modelling.

Department of Wind Energy
Aeroelastic Design

Fluid Mechanics

**Test and Measurements**

Period: 01/01/2010 → 31/12/2016  
Number of participants: 7  
Acronym: 43081-4610  
Project participant:  
Sørensen, Niels N. (Intern)  
Trolldborg, Niels (Intern)  
Réthoré, Pierre-Elouan (Intern)  
Bechmann, Andreas (Intern)  
Zahle, Frederik (Intern)  
Larsen, Gunner Chr. (Intern)  

Project Manager, academic:  
Sørensen, Jens Nørkær (Intern)

**Dynamic wake model for load calculations of wind turbines**

Department of Wind Energy  
Period: 01/11/2009 → 27/05/2013  
Number of participants: 6  
Phd Student:  
Keck, Rolf-Erik (Ekstern)  
Supervisor:  
Larsen, Gunner Chr. (Intern)  
Main Supervisor:  
Aagaard Madsen , Helge (Intern)  
Examiner:  
Hansen, Martin Otto Laver (Intern)  
Madsen, Jens Ingemann (Ekstern)  
Riziotis, Vasilis A. (Ekstern)  

**Financing sources**

Source: Internal funding (public)  
Name of research programme: ErhvervsPhD-ordningen VTU  
Project: PhD

**Integrated design of wind power systems**

Department of Wind Energy  
Period: 01/02/2009 → 18/06/2012  
Number of participants: 8  
Phd Student:  
Barahona Garzón, Braulio (Intern)  
Supervisor:  
Hansen, Anca Daniela (Intern)  
Hansen, Anders Melchior (Intern)  
Cutululis, Nicolaos Antonio (Intern)  
Main Supervisor:  
Sørensen, Poul Ejnar (Intern)  
Examiner:  
Larsen, Gunner Chr. (Intern)  
Carlson, Ola (Ekstern)  
llov, Florin (Ekstern)  

**Financing sources**

Source: Internal funding (public)
Name of research programme: Institut, samfinansiering
Project: PhD