Coordinated control of wind power plants in offshore HVDC grids

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Organisations: Department of Wind Energy, Integration & Planning
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Improvement of grid frequency dynamic characteristic with novel wind turbine based on electromagnetic coupler

A synchronous generator is directly coupled to grid in the novel wind turbine drive train concept based on electromagnetic coupler (WT-EMC). Similarly to conventional power plants, WT-EMC has inherent (inertial) grid frequency support capability, albeit rather limited due to its configuration. Additional power should be generated in response to a grid frequency drop in order to improve the dynamic characteristic of the grid frequency. In this paper, a novel control strategy for WT-EMC to improve the dynamic characteristic of grid frequency is proposed. The principle is to detect active power imbalance in the grid and then rapidly regulate the output power of WT-EMC. Based on the calculated electromagnetic torque of the synchronous generator in WT-EMC acquired faster than the calculated grid frequency the synchronous generator mechanical torque is controlled to track its electromagnetic torque to stabilize the rotor speed, therefore directly
improving the grid frequency. The proposed control strategy effectiveness is firstly tested through simulations and then validated on a specially built experimental platform.

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Organisations: Department of Wind Energy, Integration & Planning, Qingdao University, ETH Zurich, Tsinghua University
Authors: You, R. (Ekstern), Barahona, B. (Ekstern), Chai, J. (Ekstern), Cutululis, N. A. (Intern), Wu, X. (Ekstern)
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Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.965 SNIP 0.948
Technical impacts of high penetration levels of wind power on power system stability

With increasing penetrations of wind generation, based on power-electronic converters, power systems are transitioning away from well-understood synchronous generator-based systems, with growing implications for their stability. Issues of concern will vary with system size, wind penetration level, geographical distribution and turbine type, network topology, electricity market structure, unit commitment procedures, and other factors. However, variable-speed wind turbines, both onshore and connected offshore through DC grids, offer many control opportunities to either replace or enhance existing capabilities. Achieving a complete understanding of future stability issues, and ensuring the effectiveness of new measures and policies, is an iterative procedure involving portfolio development and flexibility assessment, generation cost simulations, load flow, and security analysis, in addition to the stability analysis itself, while being supported by field demonstrations and real-world model validation.
Ultimate design load analysis of planetary gearbox bearings under extreme events

This paper investigates the impact of extreme events on the planet bearings of a 5 MW gearbox. The system is simulated using an aeroelastic tool, where the turbine structure is modeled, and MATLAB/Simulink, where the drivetrain (gearbox and generator) are modeled using a lumped-parameter approach. Three extreme events are assessed: low-voltage ride through, emergency stop and normal stop. The analysis is focused on finding which event has the most negative impact on the bearing extreme radial loads. The two latter events are carried out following the guidelines of the International Electrotechnical Commission standard 61400-1. The former is carried out by applying a voltage fault while simulating the wind turbine under normal turbulent wind conditions. The voltage faults are defined by following the guidelines from four different grid codes in order to assess the impact on the bearings. The results show that the grid code specifications have a dominant role in the maximum loads achieved by the bearings during a low-voltage ride through. Moreover, the emergency brake shows the highest impact by increasing the bearing loads up to three times the rated value.

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Authors: Gallego Calderon, J. F. (Intern), Natarajan, A. (Intern), Cutululis, N. A. (Intern)
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A heuristic for the synthesis of credible operating states in the presence of renewable energy sources

Experience has shown the limitations of deterministic criteria when accommodating the intrinsic uncertainties associated to modern power systems. Hereof, probabilistic risk assessment represent a powerful enhancement in order to ensure the overall power system reliability rather than a worst-case scenario analysis. This paper presents a general-purpose methodology intended to generate plausible operating states. The main focus lies on the generation of correlated random samples using a heuristic of the NORmal-to-Anything (NORTA) method. The proposed methodology was applied to model wind generation in the Danish Western power system, analyzing the effect of the marginal distributions and errors in the correlation matrix definition.

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Organisations: Department of Wind Energy, Integration & Planning
Authors: Nuño Martinez, E. (Intern), Cutululis, N. A. (Intern)
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Wind power, Probabilistic Risk Assessment, NORmal-To-Anything
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Publication: Research - peer-review › Article in proceedings – Annual report year: 2016

Connection of OWPPs to HVDC networks using VSCs and Diode Rectifiers: an Overview
This paper provides an overview of two technologies for connecting offshore wind power plants (offshore WPPs, OWPPs) to high-voltage direct current (HVDC) networks: voltage source converters (VSCs) and diode rectifiers (DRs). Current grid code requirements for the connection of such power plants are also addressed, and their implications when using such technologies are discussed.
Connection of OWPPs to HVDC networks using VSCs and Diode Rectifiers: an Overview

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State: Published
Organisations: Department of Wind Energy, Integration & Planning
Authors: Saborío-Romano, O. (Intern), Bidadfar, A. (Intern), Göksu, Ö. (Intern), Altin, M. (Intern), Cutululis, N. A. (Intern), Sørensen, P. E. (Intern)
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Coordinated Control Scheme for Ancillary Services from Offshore Wind Power Plants to AC and DC Grids

This paper proposes a new approach of providing ancillary services to AC and DC grids from offshore wind power plants (OWPPs), connected through multi-terminal HVDC network. A coordinated control scheme where OWPP’s AC grid frequency modulated according to DC grid voltage variations is used to detect and provide the ancillary service requirements of both AC and DC grids, is proposed in this paper. In particular, control strategies for onshore frequency control, fault ridethrough support in the onshore grid, and DC grid voltage control are considered. The proposed control scheme involves only local measurements and therefore avoids the need of communication infrastructure otherwise required for communication based control, and thus increases the reliability of the control system. The effectiveness of the proposed control scheme is demonstrated on a MTDC connected wind power system developed in DigSILENT PowerFactory.

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Indian Institute of Technology
Authors: Sakamuri, J. N. (Intern), Altin, M. (Intern), Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Rather, Z. H. (Ekstern)
Number of pages: 5
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Coordinated Fast Primary Frequency Control from Offshore Wind Power Plants in MTDC System

In this paper, coordinated fast primary frequency control (FPFC) from offshore wind power plants (OWPPs) integrated to surrounding onshore AC power system through a three terminal VSC HVDC system is presented. The onshore AC grid frequency variations are emulated at offshore AC grid through appropriate control blocks, based on modulation of the DC grid voltage. The proposed FPFC produces a power reference to the OWPP based on the frequency deviation and its rate of change measured in the offshore AC grid. Moreover, the impact of wind speed variations on the OWPP active power output and the dynamics of wind turbine are also discussed. The corresponding impact of OWPPs active power output variation at different wind speeds on the power system frequency control and DC grid voltage is also presented. The results show that the proposed coordinated fast primary frequency control from OWPPs improves the power system frequency while relieving the stress on the other AC grid participating in frequency control.

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Organisations: Department of Wind Energy, Integration & Planning
Authors: Sakamuri, J. N. (Intern), Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Altin, M. (Intern), Sørensen, P. E. (Intern)
Number of pages: 8
Publication date: 2016

Coordinated Voltage Control in Offshore HVDC Connected Cluster of Wind Power Plants

This paper presents a coordinated voltage control scheme (CVCS) for a cluster of offshore wind power plants (OWPPs) connected to a VSC HVDC system. The primary control point of the proposed voltage control scheme is the introduced Pilot bus, which is having the highest short circuit capacity in the offshore AC grid. The developed CVCS comprehends an optimization algorithm, aiming for minimum active power losses in the offshore grid, to generate voltage reference to the Pilot bus. During steady state operation, the Pilot bus voltage is controlled by dispatching reactive power references to each wind turbine (WT) in the WPP cluster based on their available reactive power margin and network sensitivity based participation factors, which are derived from the dV/dQ sensitivity of a WT bus w.r.t the Pilot bus. This method leads to minimization of the risk of undesired effects, particularly overvoltage at the terminals of the WT located far away from the AC collector substation, by dispatching lower reactive power references compared to the ones nearer to the substation. In addition, the paper proposes a control strategy for improved voltage ride through capability of WTs for faults in the offshore grid, thus leading to improved dynamic voltage profile in the offshore AC grid.

General information
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Dynamic Reactive Power Control in Offshore HVDC Connected Wind Power Plants

This paper presents a coordinated reactive power control for a HVDC connected cluster of offshore wind power plants (WPPs). The reactive power reference for the WPP cluster is estimated by an optimization algorithm aiming at minimum active power losses in the offshore AC Grid. For each optimal reactive power set point, the OWPP cluster controller generates reactive power references for each WPP which further sends the AC voltage/ reactive power references to the associated WTs based on their available reactive power margin. The impact of faults at different locations in the offshore grid, such as wind turbine (WT) terminal, collector cable, and export cable, on the dynamic voltage profile of the offshore grid is investigated. Furthermore, the dynamic reactive power contribution from WTs from different WPPs of the cluster for such faults has also been studied.

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State: Published
Organisations: Department of Wind Energy, Integration & Planning
Authors: Sakamuri, J. N. (Intern), Cutululis, N. A. (Intern), Rather, Z. H. (Ekstern), Rimez, J. (Ekstern)
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Framework of Multi-objective Wind Farm Controller Applicable to Real Wind Farms

Optimal wind farm control can mitigate adverse wake effects that can potentially cause up to 40% power loss and 80% increased fatigue loads in wind farms. The aim of this work is to outline a methodological framework of an optimal wind farm controller, which provides improved solutions to critical areas of optimal wind farm control research. The basis of this framework is a review of optimal wind farm control methodologies, which is presented first. It is observed that there is, at present, mainly a need for more advanced wind farm operation models. Thereafter the framework of a multi-objective optimal wind farm controller is outlined with the following key characteristics.

Available control objectives are (i) to maximize the total wind farm power output or (ii) to follow a specified power reference for the wind farm’s total power output while reducing the fatigue loads of the wind turbines in the wind farm. The controller design provides improved solutions for the modelling of wind farm aerodynamics and turbine operation, that is the PossPOW algorithm and a HAWC2-based turbine model, respectively. Moreover, all components of the framework are designed as to enable the applicability of the controller to real wind farms.

Hydropower flexibility and transmission expansion to support integration of offshore wind

In 2013, offshore wind grew over 50%. This increase, concentrated in a relatively small geographical area, can lead to an increased variability of the power produced by offshore wind. The variability is one of the key issues, along transmission, in integrating offshore wind power. Hydro power is one of the fast responding sources of electricity, thus power systems with considerable amounts of flexible hydro power can potentially offer easier integration of offshore wind power. The interaction between offshore wind and hydro power can be beneficial, especially when looking at how the flexibility of hydro generation can match the variability of offshore wind, allowing for larger shares of variable generation to be integrated in the power systems without decreasing its stability. The analysis includes two interrelated models, a market model and a flow-based model. The results show that hydropower systems are a very good option for balancing the natural variability of wind power production, especially when installed offshore. The flexibility of hydropower systems allows power systems with a high share of RES to maintain stability. The analysis presented indicates that the value of hydropower flexibility to the European power system is significant, consequently justifying the investment costs for transmission expansion.
Improved Frequency Control from Wind Power Plants Considering Wind Speed Variation

A fast frequency controller (FFC) for wind power plants (WPPs), which produces a temporary overloading power reference based on frequency deviation and rate of change of frequency, is proposed in this paper. Contrary to standard controllers proposed in the literature, the gains of the FFC are optimized for different wind speeds ensuring an improved frequency control from WPPs over the whole wind speed range. Two options for temporary frequency control implementations from WPPs are analyzed and compared. Moreover, the impact of mechanical, electrical and control limitations at different wind speeds and its effect on frequency control is discussed in the paper. Results show that by optimizing the gains, an improved frequency control can be obtained compared to standard controllers which apply a fixed gain over whole the wind speed range.

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Modeling of the dynamics of wind to power conversion including high wind speed behavior

This paper proposes and validates an efficient, generic and computationally simple dynamic model for the conversion of the wind speed at hub height into the electrical power by a wind turbine. This proposed wind turbine model was developed as a first step to simulate wind power time series for power system studies. This paper focuses on describing and validating the single wind turbine model, and is therefore neither describing wind speed modeling nor aggregation of contributions from a whole wind farm or a power system area. The state-of-the-art is to use static power curves for the purpose of power system studies, but the idea of the proposed wind turbine model is to include the main dynamic effects in order to have a better representation of the fluctuations in the output power and of the fast power ramping especially because of high wind speed shutdowns of the wind turbine. The high wind speed shutdowns and restarts are represented as on–off switching rules that govern the output of the wind turbine at extreme wind speed conditions. The model uses the concept of equivalent wind speed, estimated from the single point (hub height) wind speed using a second-order dynamic filter that is derived from an admittance function. The equivalent wind speed is a representation of the averaging of the wind speeds over the wind turbine rotor plane and is used as input to the static power curve to get the output power. The proposed wind turbine model is validated for the whole operating range using measurements available from the DONG Energy offshore wind farm Horns Rev 2. Copyright © 2015 John Wiley & Sons, Ltd.

General information
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Authors: Litong-Palima, M. (Intern), Bjerge, M. H. (Ekstern), Cutululis, N. A. (Intern), Hansen, L. H. (Ekstern), Sørensen, P. E. (Intern)
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Dynamic wind-to-power conversion, Admittance filter, High-wind, Storm protection, Equivalent wind speed
OffshoreDC DC grids for integration of large scale wind power

The present report summarizes the main findings of the Nordic Energy Research project “DC grids for large scale integration of offshore wind power – OffshoreDC”. The project has been funded by Nordic Energy Research through the TFI programme and was active between 2011 and 2016.

The overall objective of the project was to drive the development of the VSC based HVDC technology for future large scale offshore grids, supporting a standardised and commercial development of the technology, and improving the opportunities for the technology to support power system integration of large scale offshore wind power. This was done by bringing together the key industry stakeholders and competent research organisations in the project.


general information

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Organisations: Department of Wind Energy, Integration & Planning, Department of Electrical Engineering, DONG Energy A/S, NTNU, VTT
Authors: Cutululis, N. A. (ed.) (Intern), Zeni, L. (Ekstern), Endegnanew, A. G. (Ekstern), Stamatiou, G. (Ekstern), El-Khatib, W. Z. (Intern), Helistö, N. (Ekstern)
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Overplanting in offshore wind power plants in different regulatory regimes

Offshore wind power’s journey towards being competitive with other generation technologies relies on technical innovation and maturation, but also on further optimisation of proven and mature solutions. Capacity optimisation or so-called overplanting is one example of optimisation, which is performed by installing a larger wind power capacity than stipulated in the connection agreement with transmission system operators (TSOs). By developing a discounted cash flow (DCF) model, the paper investigates how both regulatory regimes and geographic characteristics of dedicated offshore wind development areas affect the viability of overplanting. The analysis comprises hypothetical scenarios of the distinctive offshore wind markets of the United Kingdom and Denmark and thereby elucidates the key aspects influencing the value of overplanting. This work’s findings show that the UK regulatory framework results more favourable to overplanting. The results indicate that current conceivable offshore wind power plants in the UK can increase their economic value by around 30 mio AC when optimising their capacity setup. In Denmark, current regulations are not suitable for overplanting causing loss of value when optimising the capacity design of wind power plants.

general information

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Possible Improvements for Present Wind Farm Models Used in Optimal Wind Farm Controllers

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Authors: Kazda, J. (Intern), Göçmen, T. (Intern), Giebel, G. (Intern), Cutululis, N. A. (Intern)
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Spatio-temporal analysis of regional PV generation
Photovoltaic (PV) power is growing in importance worldwide and hence needs to be represented in operation and planning of power system. As opposed to traditional generation technologies, it is characterized by exhibiting both a high variability and a significant spatial dependence. This paper presents a fundamental analysis of regional solar generation time series, aiming to potentially facilitate large-scale solar integration. It will focus on characterizing the underlying dependence structure at the system level as well as describing both statistical and temporal properties of regional PV generation.

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Special Section on HVDC Systems for Large Offshore Wind Power Plants

General information
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Organisations: Department of Wind Energy, Integration & Planning, University of Manchester, Cardiff University, Polytechnic University of Catalonia, KU Leuven
Variability in large-scale wind power generation

The paper demonstrates the characteristics of wind power variability and net load variability in multiple power systems based on real data from multiple years. Demonstrated characteristics include probability distribution for different ramp durations, seasonal and diurnal variability and low net load events. The comparison shows regions with low variability (Sweden, Spain and Germany), medium variability (Portugal, Ireland, Finland and Denmark) and regions with higher variability (Quebec, Bonneville Power Administration and Electric Reliability Council of Texas in North America; Gansu, Jilin and Liaoning in China; and Norway and offshore wind power in Denmark). For regions with low variability, the maximum 1 h wind ramps are below 10% of nominal capacity, and for regions with high variability, they may be close to 30%. Wind power variability is mainly explained by the extent of geographical spread, but also higher capacity factor causes higher variability. It was also shown how wind power ramps are autocorrelated and dependent on the operating output level. When wind power was concentrated in smaller area, there were outliers with high changes in wind output, which were not present in large areas with well-dispersed wind power. Copyright © 2015 John Wiley & Sons, Ltd.

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Authors: Kiviluoma, J. (Ekstern), Holttinen, H. (Ekstern), Weir, D. (Ekstern), Scharff, R. (Ekstern), Söder, L. (Ekstern), Menemenlis, N. (Ekstern), Cutululis, N. A. (Intern), Danti Lopez, I. (Ekstern), Lannoye, E. (Ekstern), Estanqueiro, A. (Ekstern), Gomez-Lazarro, E. (Ekstern), Zhang, Q. (Ekstern), Bai, J. (Ekstern), Wan, Y. (Ekstern), Milligan, M. (Ekstern)
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Web of Science (2014): Indexed yes
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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
BFI (2010): BFI-level 2
A New Coordinated Voltage Control Scheme for Offshore AC Grid of HVDC Connected Offshore Wind Power Plants

This paper proposes a coordinated voltage control scheme (CVCS) which enhances the voltage ride through (VRT) capability of an offshore AC grid comprised of a cluster of offshore wind power plants (WPP) connected through AC cables to the offshore voltage source converter based high voltage DC (VSC-HVDC) converter station. Due to limited short circuit power contribution from power electronic interfaced variable speed wind generators and with the onshore main grid decoupled by the HVDC link, the offshore AC grid becomes more vulnerable to dynamic voltage events. Therefore, a short circuit fault in the offshore AC Grid is likely to have significant implications on the voltage of the offshore AC grid, hence on the power flow to the onshore mainland grid. The proposed CVCS integrates individual local reactive power control of wind turbines and of the HVDC converter with the secondary voltage controller at offshore grid level. This secondary voltage controller controls the voltage at the pilot bus, the bus with the highest short circuit capacity in the offshore AC grid. By maintaining voltage at the pilot bus, reflecting the voltage variations of the entire offshore zone, the voltage profile of the offshore grid is indirectly maintained. During steady state operation, the secondary AC voltage controller generates reactive power references for individual wind turbines (WTs) based on their participation factors (PFs) and available
reactive power margins, while during dynamic voltage events; the secondary voltage controller generates additional reactive power reference signals for WTIs and the HVDC converter, to enhance VRT capability of the offshore AC network. The Participation Factor of each WT is calculated from their dV / dQ sensitivities w.r.t. the pilot bus. The WT and the HVDC converter control is modified to accommodate additional reactive power reference from the secondary controller, while maintaining their local VRT capability. A detailed model of 800 MW VSC-HVDC connected OWPP cluster developed in DigSILENT platform is considered in this study. VSC-HVDC transmission system operates at +/- 320 kV with active power balance (hence DC voltage) control assigned to the onshore converter, while frequency and AC voltage control at the offshore substation assigned to the offshore converter.

### General information

**State:** Published  
**Organisations:** Department of Wind Energy, Integration & Planning, University College Dublin  
**Authors:** Sakamuri, J. N. (Intern), Cutululis, N. A. (Intern), Rather, Z. H. (Ekstern), Rimez, J. (Ekstern)  
**Number of pages:** 8  
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**Coordinated Voltage Control, HVDC, LVRT, Offshore Wind Power Plant Control, Reactive Power**  
**Electronic versions:**

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**Publication:** Research - peer-review › Article in proceedings – Annual report year: 2016

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Design tool for offshore wind farm cluster planning

In the framework of the FP7 project EERA DTOC: Design Tool for Offshore wind farm Cluster, a new software supporting the planning of offshore wind farms was developed, based on state-of-the-art approaches from large scale wind potential to economic benchmarking. The model portfolio includes WAsP, FUGA, WRF, Net-Op, LCoE model, CorWind, FarmFlow, EeFarm and grid code compliance calculations. The development is done by members from European Energy Research Alliance (EERA) and guided by several industrial partners. A commercial spin-off from the project is the tool ‘Wind & Economy’. The software has been compared and validated to a wide extent. Around 10 wake models have been compared to SCADA data from the Horns Rev 1 offshore wind farm in the North Sea, and the Lillgrund and Rødsand-2 wind farms in the Baltic Sea. The Rødsand-2 wind farm is located nearby the Nysted-1 wind farm, thus an investigation of the wake influence between dual operation twin farms was possible. Furthermore both micro- and mesoscale wake models have been compared to satellite-based wind farm wake data in the North Sea. Regarding the planning of the electrical grid, both inter-array and long-distance cables were modelled by the software and several tests were performed. The calculations include the smoothing effect on produced energy between wind farms located in different regional wind zones and the short time scales relevant for assessing balancing power. The grid code compliance was tested for several cases and the results are useful for wind farm planning of the grid and necessary components and controls.

### General information

**State:** Published  
**Organisations:** Department of Wind Energy, Meteorology, Wind Energy Systems, Aeroelastic Design, Fluid Mechanics, Energy Research Centre of the Netherlands, Overspeed, University of Strathclyde, SINTEF, University of Porto, Fraunhofer Gesellschaft, Carl Von Ossietzky University Oldenburg, Cornell University, Centre for Renewable Energy Sources, National Technical University of Athens  
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Electromechanical Drivetrain Simulation.
Wind turbines structures are exposed to inclement loading conditions varying from the turbulent wind field to fluctuations in the electric grid. The variation of these conditions, in addition to special events such as emergency stops, has a great impact of the life time of the components. In multi-MW wind turbines, it is common to find a geared drivetrain, which is the interface between the mechanical and electrical domain. Due to the varying conditions, the drivetrain can suffer accelerated damage reducing the target 20 years life of the turbine. This Ph.D. thesis focuses on the implementation of advanced models that consider the electromechanical interaction of the wind turbine structure, namely the main shaft and tower top, along with the gearbox and the generator. This is done with the purpose to advance the integrated analysis of wind turbines; something that is not common until recently. The state-of-the-art in wind turbine simulation is to consider the wind turbine structure with a simplified model of the drivetrain. Therefore, the main purpose of this Ph.D. is to develop a simulation tool capable of estimate the loading in the drivetrain internal components, with special attention to the planet bearings in the planetary stage. In brief, the tool is used for the dynamic analysis of the drive-train components under different loading conditions following certification guidelines. Several numerical simulations demonstrate the capabilities of the tool, and new results show how the lifetime of the bearings are affected by different load cases. The fatigue damage experienced by the planet bearings in the planetary stage is assessed for the normal operation of the wind turbine, by computing the damage equivalent loads for a 20 years period. Several operational modes are identified as the main contributors to the fatigue of the bearings. Second, the ultimate design loads obtained by extreme events such as Low-Voltage Ride through (LVRT), emergency stop and normal stop due to grid loss are investigated. A method to simulate the LVRT based on the grid code requirements from different countries is presented, along with results that highlight the importance of the voltage recovery and its relation to the effect on the bearing loads. Several recommendations are made for the three extreme events in terms of possible load reduction in the bearings. The main goal is to minimize the long-term damage that can be induced by the extreme cases. And finally, reliability analysis using FORM is performed based on two different types of bearing configurations. For this purpose, a bearing stiffness matrix corresponding to each configuration is used in the electromechanical drivetrain simulation tool. Thus, using a parametric study with different dynamic rating values, it is found that this parameter has an important influence in the reliability, and hence, in the preliminary design of the components. Furthermore, the difference between the damage equivalent loads of both types of bearings is minimal. Therefore, the dynamic rating parameter is found to have higher influence on the bearings reliability. The methods presented in this dissertation can be used to model different drivetrain configurations for preliminary design, based on standard load cases used in wind turbine certification. In addition, it is possible to carry out reliability analysis, which ultimately, is one of the main focus areas when analyzing and designing such complex and costsensitive systems.
for the calculation of WT-EMC supplementary torque command. The integrated simulation environment based on the aeroelastic code HAWC2 and software Matlab/Simulink is used to build a 2 MW WT-EMC model and study the frequency support capability of a wind farm consisting of WT-EMC. (C) 2014 Elsevier Ltd. All rights reserved.

**General information**

State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Tsinghua University
Authors: You, R. (Ekstern), Barahona Garzón, B. (Intern), Chai, J. (Ekstern), Cutululis, N. A. (Intern)
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.845 SNIP 2.118 CiteScore 4.51
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Web of Science (2014): Indexed yes
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Scopus rating (2012): SJR 1.852 SNIP 2.745 CiteScore 3.97
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Scopus rating (2011): SJR 1.688 SNIP 2.404 CiteScore 3.9
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BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.494 SNIP 2.215
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.305 SNIP 1.945
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.449 SNIP 1.867
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.214 SNIP 1.65
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.137 SNIP 1.486
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.215 SNIP 1.26
Scopus rating (2004): SJR 0.76 SNIP 1.154
Web of Science (2004): Indexed yes
Modelling of wind power plant controller, wind speed time series, aggregation and sample results

This report describes the modelling of a wind power plant (WPP) including its controller. Several ancillary services like inertial response (IR), power oscillation damping (POD) and synchronising power (SP) are implemented. The focus in this document is on the performance of the WPP output and not the impact of the WPP on the power system. By means of simulation tests, the capability of the implemented wind power plant model to deliver ancillary services is investigated.

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Authors: Hansen, A. D. (Intern), Altin, M. (Intern), Cutululis, N. A. (Intern)
Number of pages: 38
Publication date: 2015

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Number: 0080
Main Research Area: Technical/natural sciences
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Electronic versions:
DTU_Wind_Energy_E_0080.pdf
Publication: Research › Report – Annual report year: 2015

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.

General information
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Number of pages: 48
Technical Feasibility of Ancillary Services provided by ReGen Plants
This report is the first deliverable in WP1 in the project “Ancillary services from renewable power plants” (RePlan). RePlan is funded as PSO project 2015 no. 12347 by the Danish PSO-programme ForskEL, which is administered by Energinet.DK. RePlan is carried out in collaboration between DTU Wind Energy, DTU Elektro, Aalborg University Energy Technology, Aalborg University Wireless Communication Networks and Vestas Wind System A/S. DTU Wind Energy is manager of the project.

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Department of Electrical Engineering, Energy system operation and management, Aalborg University
Authors: Altin, M. (Intern), Han, X. (Intern), Hansen, A. D. (Intern), Løvenstein Olsen, R. (Ekstern), Cutululis, N. A. (Intern), Iov, F. (Ekstern)
Number of pages: 36
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Projects:
Technical Feasibility of Ancillary Services provided by ReGen Plants
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Wind and Photovoltaic Large-Scale Regional Models for hourly production evaluation
This work presents two large-scale regional models used for the evaluation of normalized power output from wind turbines and photovoltaic power plants on a European regional scale. The models give an estimate of renewable production on a regional scale with 1 h resolution, starting from a mesoscale meteorological data input and taking in account the characteristics of different plants technologies and spatial distribution. An evaluation of the hourly forecasted energy production on a regional scale would be very valuable for the transmission system operators when making the long-term planning of the transmission system, especially regarding the cross-border power flows. The tuning of these regional models is done using historical meteorological data acquired on a per-country basis and using publicly available data of installed capacity.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Department of Wind Energy, Wind Energy Systems, Meteorology
Authors: Marinelli, M. (Intern), Maule, P. (Intern), Hahmann, A. N. (Intern), Gehrke, O. (Intern), Nørgård, P. B. (Intern), Cutululis, N. A. (Intern)
Challenges and solutions for energy systems with high shares of wind energy

The focus of this chapter is mostly on short-term integration issues and the corresponding need for ancillary services. Here we should remember that policy and regulation influence the need for balancing. Shorter gate-closure times in the power market, for instance, allow better forecasting and create the opportunity to re-dispatch generators before the need for balancing arises. Allowing new actors into the market, especially from the demand side, also helps providing the required services at the lowest possible cost.

General information
State: Published
Organisations: Department of Management Engineering, Systems Analysis, Energy Systems Analysis, Department of Wind Energy, Wind Energy Systems
Authors: Karlsson, K. B. (Intern), Kitzing, L. (Intern), Katz, J. (Intern), Sørensen, P. E. (Intern), Cutululis, N. A. (Intern), Hansen, A. D. (Intern)
Pages: 63-71
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Host publication information
Title of host publication: DTU International Energy Report 2014 : Wind energy — drivers and barriers for higher shares of wind in the global power generation mix
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Editors: Hvidtfeldt Larsen, H., Sønderberg Petersen, L.
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Main Research Area: Technical/natural sciences
Electronic versions:
Challenges Towards the Deployment of Offshore Grids: the OffshoreDC Project

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Department of Electrical Engineering, Center for Electric Power and Energy, Electric power components, Norwegian University of Science and Technology, Energinet.dk
Authors: Cutululis, N. A. (Intern), Zeni, L. (Intern), El-Khatib, W. Z. (Intern), Holbøll, J. (Intern), Serensen, P. E. (Intern), Stamatiou, G. (Ekstern), Carlson, O. (Ekstern), Tai, V. C. (Ekstern), Uhlen, K. (Ekstern), Kiviluoma, J. (Ekstern), Lund, T. (Ekstern)
Number of pages: 6
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Host publication information
Title of host publication: Proceedings of 13th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power (WIW 2014)
Publisher: Energynautics GmbH
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Challenges_Towards_the_Deployment.pdf

Economic grid Support from Variable Renewables: REserviceS project summary

General information
State: Published
Authors: Van Hulle, F. (Ekstern), Chapalain, F. (Ekstern), Cutululis, N. A. (Intern), Holtinnen, H. (Ekstern), Kiviluoma, J. (Ekstern), Faiella, L. M. (Ekstern), Pineda, I. (Ekstern), Rekinger, M. (Ekstern)
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Host publication information
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Publisher: Energynautics GmbH
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Ancillary (grid support) services, Transmission systems, Distribution systems, Grid codes, Market design
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Bibliographical note
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Economic impact analysis of the demonstrations in task-forces TF1 and TF3 - Deliverable D15.1: WP15. Economic impacts of the demonstrations, barriers towards scaling up and solutions

General information
State: Published
Authors: García-González, J. (Ekstern), Contreras, A. (Ekstern), Formozco, C. (Ekstern), Vallés, M. (Ekstern), Rivero, E. (Ekstern), Lobato, E. (Ekstern), Ramos, A. (Ekstern), Frias, P. (Ekstern), Egido, I. (Ekstern), Sánchez, P. (Ekstern),
Offshore wind power development scenarios are very ambitious. In Europe, it is expected to surpass 100 GW by 2030. As opposed to onshore, offshore wind will be concentrated in relatively small geographical areas, meaning that the geographical smoothening would be diminished. Being able to simulate this variability is important and will assist quantifying the possible impacts of large-scale deployment of offshore wind on the operation of the power system. The analysis of maximum offshore wind power ramping in 2020 and 2030 North Seas shows that wind power variability, at synchronous area level, can exceed the current dimensioning incidents values. This indicates that wind power variability should be considered in frequency stability.

Index for Wind Power Variability

State: Published
Authors: Kiviluoma, J. (Ekstern), Holttinen, H. (Ekstern), Cutululis, N. A. (Intern), Litong-Palima, M. (Intern), Scharff, R. (Ekstern), Milligan, M. (Ekstern), Weir, D. E. (Ekstern)
Number of pages: 5
Publication date: 2014

Host publication information
Title of host publication: Proceedings of 13th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power (WIW 2014)
Technical and economic impact analysis of the demonstrations in task-forces TF2 - Deliverable D15.2: WP15. Economic impacts of the demonstrations, barriers towards scaling up and solutions

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Department of Electrical Engineering, Center for Electric Power and Energy, University of Strathclyde, RTE (TSO France), Energinet.dk, Comillas Pontifical University
Authors: Bell, K. (Ekstern), Houghton, T. (Ekstern), Doquet, M. (Ekstern), Denis, A. (Ekstern), Despouys, O. (Ekstern), Cutululis, N. A. (Intern), Altiparmakis, A. (Intern), Litong-Palima, M. (Intern), Sørensen, P. E. (Intern), Detlefsen, N. (Ekstern), García-González, J. (Ekstern)
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Threats and opportunities on the path to change power systems from fossil fuels to renewables

General information
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Organisations: Department of Energy Engineering, Department of Wind Energy, Wind Energy Systems
Authors: Sørensen, P. (Intern), Cutululis, N. A. (Intern), Hansen, A. D. (Intern), Altin, M. (Intern), Zeni, L. (Intern), Basit, A. (Intern)
Number of pages: 32
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Unbalanced voltage faults: the impact on structural loads of doubly fed asynchronous generator wind turbines

This paper investigates the impact that unbalanced voltage faults have on wind turbine structural loads. In such cases, electromagnetic torque oscillations occur at two times the supply voltage frequency. The objectives of this work are to quantify wind turbine structural loads induced by unbalanced voltage faults relative to those during normal operation; and to evaluate the potential for reducing structural loads with the control of the generator. The method applied is integrated
dynamic analysis. Namely, dynamic analysis with models that consider the most important aeroelastic, electrical, and control dynamics in an integrated simulation environment based on an aeroelastic code (HAWC2) and software for control design (Matlab/Simulink). In the present analysis, 1 Hz equivalent loads are used to compare fatigue loads, whereas maximum–minimum values are used to compare extreme loads. A control concept based on resonant filters demonstrates reduction of the structural loads (shaft torsion and tower top side-to-side moment) induced by an unbalanced voltage fault.

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Weather radars – the new eyes for offshore wind farms?

Offshore wind fluctuations are such that dedicated prediction and control systems are needed for optimizing the management of wind farms in real-time. In this paper, we present a pioneer experiment – Radar@Sea – in which weather radars are used for monitoring the weather at the Horns Rev offshore wind farm, in the North Sea. First, they enable the collection of meteorological observations at high spatio-temporal resolutions for enhancing the understanding of meteorological phenomena that drive wind fluctuations. And second, with the extended visibility they offer, they can provide relevant inputs to prediction systems for anticipating changes in the wind fluctuation dynamics, generating improved wind power forecasts and developing specific control strategies. However, integrating weather radar observations into automated decision support systems is not a plug-and-play task, and it is important to develop a multi-disciplinary approach linking meteorology and statistics. Here, (i) we describe the settings of the Radar@Sea experiment, (ii) we report the experience gained with these new remote sensing tools, (iii) we illustrate their capabilities with some concrete meteorological events observed at Horns Rev and (iv) we discuss the future perspectives for weather radars in wind energy. Copyright © 2013 John Wiley & Sons, Ltd.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical Engineering, Center for Electric Power and Energy, Department of Wind Energy, Meteorology, Wind Energy Systems, Danish Meteorological Institute, DHI Denmark, DONG Energy A/S, Vattenfall A/S
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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
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Scopus rating (2013): SJR 1.275 SNIP 2.464 CiteScore 2.75
Wind Farm Aggregation Method for Dynamic Active Power Studies

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Authors: Rousi, G. (Intern), Hansen, A. D. (Intern), Cutululis, N. A. (Intern)
Number of pages: 6
Publication date: 2014

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Publisher: Energynautics GmbH
ISBN (Print): 978-3-9813870-9-4
Main Research Area: Technical/natural sciences
Wind Turbine and Wind Power Plant Modelling Aspects for Power System Stability Studies

Large amount of wind power installations introduce modeling challenges for power system operators at both the planning and operational stages of power systems. Depending on the scope of the study, the modeling details of the wind turbine or the wind power plant are required to be different. A wind turbine model which is developed for the short-term voltage stability studies can be inaccurate and sufficient for the frequency stability studies. Accordingly, a complete and detailed wind power plant model for every kind of study is not feasible in terms of the computational time and also is not reasonable regarding the focus of the study. Therefore the power system operators should be aware of the modelling aspects of the wind power considering the related stability study and implement the required model in the appropriate power system toolbox. In this paper, the modelling aspects of wind turbines and wind power plants are reviewed for power system stability studies. Important remarks of the models are presented by means of simulations to emphasize the impact of these modelling details on the power system.

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Authors: Altin, M. (Intern), Hansen, A. D. (Intern), Göksu, Ö. (Intern), Cutululis, N. A. (Intern), Sørensen, P. E. (Intern)
Number of pages: 5
Publication date: 2014

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Main Research Area: Technical/natural sciences
Wind turbine models, Wind power plant models, Power system stability, Wind power impact studies
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Analysis of Variability and Uncertainty in Wind Power Forecasting: An International Comparison

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, National Renewable Energy Laboratory, University of Castilla–La Mancha, Kjeller Vindteknik, VTT - Technical Research Centre of Finland
Authors: Zhang, J. (Ekstern), Hodge, B. (Ekstern), Gomez-Lazaro, E. (Ekstern), Lovholm, A. L. (Ekstern), Berge, E. (Ekstern), Miettinen, J. (Ekstern), Holttinen, H. (Ekstern), Cutululis, N. A. (Intern)
Number of pages: 6
Publication date: 2013

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ISBN (Print): 978-3-9813870-7-0
Main Research Area: Technical/natural sciences
Conference: 12th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants, London, United Kingdom, 22/10/2013 - 22/10/2013
Wind power, Forecast errors, Control storm event
Links:
http://www.windintegrationworkshop.org/london2013/
Publication: Research - peer-review › Article in proceedings – Annual report year: 2013
This paper presents a novel type of variable speed wind turbine with a new drive train different from the variable speed wind turbine commonly used nowadays. In this concept, a synchronous generator is directly coupled with the grid, therefore, the wind turbine transient overload capability and grid voltage support capability can be significantly improved. An electromagnetic coupling speed regulating device (EMCD) is used to connect the gearbox high speed shaft and synchronous generator rotor shaft, transmitting torque to the synchronous generator, while decoupling the gearbox side and the synchronous generator, so the synchronous generator torque oscillations during a grid fault are not transmitted to the gearbox. The EMCD is composed of an electromagnetic coupler and a one quadrant operation converter with reduced capability and low cost. A control strategy for the new wind turbine is proposed and a 2 MW wind turbine model is built to study the wind turbine fault ride-through capability. An integrated simulation environment based on the aeroelastic code HAWC2 and software Matlab/Simulink is used to study its fault ride-through capability and the impact on the structural loads during grid three phase and two phase short circuit faults.
Assessment of the impact of frequency support on DFIG wind turbine loads
This study presents models and tools for the assessment of the impact that providing frequency support has on doubly-fed generator (DFIG) wind turbine structural loads and drive train. The focus is on primary frequency support, aiming at quantifying the impact on wind turbines acting as frequency containment reserve and providing inertial response. The sensitivity of wind turbine load indicators—load duration distribution and maximum load values—to inertial response control actions and different torsional models of drive train is investigated. The analysis is done by co-simulations of an aeroelastic code and electrical models. In this simulation framework, the impact that power system conditions can have on wind turbines, and vice versa the support that wind turbines can offer to the power system can be investigated.

Capabilities and costs for ancillary services provision by wind power plants
This report is the deliverable of the third work package of the REserviceS project and describes the technical options and related costs for the provision of ancillary services specifically from wind energy technologies. It is focused on the set of ancillary services defined in the previous work package 2, shown in table 1 below. The information from this deliverable will be used as input to the case studies in subsequent work packages, which are expected to provide additional insights to the actual provision of ancillary services in transmission and distribution networks.
Cost-effective Primary Frequency Response at high Asynchronous Generation Levels

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, VTT - Technical Research Centre of Finland, University College Dublin, XP Wind
Authors: Kiviluoma, J. (Ekstern), Gubina, A. (Ekstern), Van Hulle, F. (Ekstern), Cutululis, N. A. (Intern)
Number of pages: 5
Publication date: 2013

Electromechanical Drivetrain Simulation
The work presented in this paper is another step from the DTU Wind Energy efforts to advance understanding of the electromechanical drive-train loads and its interaction with the rest of the components in the wind turbine. The main objective of the PhD is to investigate the modelling and simulation of a wind turbine’s drivetrain using an integrated simulation approach where different simulation tools are interconnected. Matlab and HAWC2 are used for this purpose. A contribution is expected to be in the study of the interaction between the mechanical loads in the gearbox due to gear mesh and bearing flexibilities, the generator dynamics and the grid, along with the structural loads in the wind turbine. In this paper, two simulation approaches are presented and conclusions are made according to their advantages and disadvantages. The drive-train is described by means of a torsional model composed of the main shaft, gearbox and generator. Special attention is given to the modelling of the gearbox and the generator in order to study the mechanical vibrations caused by turbulent wind and grid dynamics.

General information
State: Published
Organisations: Department of Wind Energy, Wind Turbines, Wind Energy Systems
Authors: Gallego-Calderon, J. (Intern), Branner, K. (Intern), Natarajan, A. (Intern), Cutululis, N. A. (Intern), Hansen, J. C. (Intern)
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Impact of High Wind Speed Shut-down in the Danish Power System

General information
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Authors: Cutululis, N. A. (Intern), Litong-Palima, M. (Intern), Sørensen, P. E. (Intern), Bjerge, M. H. (Ekstern), Detlefsen, N. (Ekstern)
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Main Research Area: Technical/natural sciences
Conference: 12th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants, London, United Kingdom, 22/10/2013 - 22/10/2013
Wind power, Forecast errors, Control storm event
Links:
http://www.windintegrationworkshop.org/london2013/

Relations
Projects:
Impact of High Wind Speed Shut-down in the Danish Power System
Source: dtu
Source-ID: u::9602
Publication: Research - peer-review › Article in proceedings – Annual report year: 2013

Market and system security impact of the storm demonstration in task-forces TF2. Deliverable: D16.6: WP16. EU wide integrating assessment of demonstration replication potential

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Department of Electrical Engineering, Center for Electric Power and Energy, Energinet.dk
Authors: Cutululis, N. A. (Intern), Altiparmakis, A. (Intern), Litong-Palima, M. (Intern), Detlefsen, N. (Ekstern), Sørensen, P. E. (Intern)
Number of pages: 64
Publication date: 2013

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
Market_and_system_security_impact.pdf

Relations
Projects:
Market and system security impact of the storm demonstration in task-forces TF2. Deliverable: D16.6
Source: dtu
Source-ID: u::9910
Publication: Research - peer-review › Report – Annual report year: 2013

Methods for Representations of Wind Power Plants for Active Power Studies

General information
State: Published
Offshore Variability in Critical Weather Conditions in Large-Scale Wind Based Danish Power System

Offshore wind power has a significant development potential, especially in North Europe. The geographical concentration of offshore wind power leads to increased variability and in the case of critical weather conditions it may lead to sudden and considerable loss of production. In this context, the chances of losing several GW of wind power due to critical weather conditions in a very short time period could potentially jeopardize the whole system's reliability and stability. Forecasting such events is not trivial and the results so far are not encouraging. When assessing the impact of the variability for the 2020 Danish power system, one can see that in the worst case, up to 1500 MW of power can be lost in 30 minutes. We present results showing how this issue is partially solved by the new High Wind Storm Controller presented by Siemens in the TWENTIES project.

Regime-based supervisory control to reduce power fluctuations from offshore wind power plants

Wind power fluctuations, especially offshore, can pose challenges in the secure and stable operation of the power system. In modern large offshore wind farms, there are supervisory controls designed to reduce the power fluctuations. Their operation is limited due to the fact that they imply loss of production, hence revenue for the wind farm operator. On the other hand, progresses in short term forecasting, together with the increasing use of probabilistic forecasting can help in achieving efficient power fluctuations reduction with minimum lost production. Here we present supervisory control concepts that consider different wind power regimes to derive control setpoints by using a Markov-Switching AutoRegressive model. We evaluate the performance versus measured data in terms of power ramp characteristics and energy efficiency.
Report on Design Tool on Variability and predictability. D2.8: WP 2: Interconnection optimisation and power plant system services. Task 2.1: Power output variability and predictability

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Authors: Cutululis, N. A. (Intern), Faiella, L. M. (Ekstern), Otterson, S. (Ekstern), Barahona Garzón, B. (Intern), Dobschinski, J. (Ekstern)
Number of pages: 29
Publication date: 2013

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
Report_on_design_tool.pdf

Bibliographical note
FP7-ENERGY-2011-1/ n°282797
Source: dtu
Source-ID: u::9825
Publication: Research › Report – Annual report year: 2013

Report with data for system behaviour at storm passage with original (uncoordinated) and coordinated control: Deliverable no: D2.2

In this report the focus has been on explaining the operational procedures that are important in order to maintain balance in the electricity system to understand how unexpected events are handled. The unexpected events discussed in this demo are sudden unexpected loss of wind power production due to stormy weather conditions. When handling the system it is important both to have good forecasts of wind power production so that the wind power production can be anticipated as precise as possible as early as possible so that regulating power can be activated to restore the anticipated balance. In addition it is important to have access to enough automatic restoration reserves to restore balance when unanticipated deviations from schedules occur. What the trade-off between these two types of reserves should be is an on-going discussion.

During the duration of the project, several high wind speed events were recorded at Horns Rev 2, with both the High Wind Shut Down (HWSD) controller and the High Wind Ride Through™ (HWRT) controller which was developed in this project. The analysis presented in this report has shown that when the wind turbines are equipped with HWRT, the maximal wind power forecast error decreases with more than 50%. Similarly, the energy production during the high wind events increased with the HWRT controller compared to the HWSD controller, although the amounts are negligible compared to the yearly production.

The storm front event on February 7th -8th, 2011, which was followed by the unexpected failure on HVDC line between Western Denmark and Sweden, illustrates the consequences and challenges the power system faced/will face in the future when these events (will) occur. The measured values indicate that the large part of the imbalances caused by storm is compensated by exchanged balancing power, activated from the NOIS list, across Konti-Skan link. This shows the pivotal role of hydro power in the Nordic system to balance large wind power variations in Western Denmark especially during the storm events. However, the frequency in the Nordic system experienced large deviations due to large deviation on exchange across Konti-Skan link.

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Energinet.dk, SINTEF
Technical Capabilities and Challenges for Wind Power to provide Voltage Support Services

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Fraunhofer Gesellschaft, XP Wind
Authors: Faiella, L. M. (Ekstern), Cutululis, N. A. (Intern), Van Hulle, F. (Ekstern)
Number of pages: 6
Publication date: 2013

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Publisher: Energynautics GmbH
ISBN (Print): 978-3-9813870-7-0
Main Research Area: Technical/natural sciences
Conference: 12th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants, London, United Kingdom, 22/10/2013 - 22/10/2013
Wind power, Forecast errors, Control storm event
Links: http://www.windintegrationworkshop.org/london2013/
Publication: Research - peer-review › Article in proceedings – Annual report year: 2013

Using forecast information for storm ride-through control

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Department of Applied Mathematics and Computer Science, Dynamical Systems, Meteorology, Center for Electric Power and Energy
Authors: Barahona Garzon, B. (Intern), Trombe, P. (Intern), Vincent, C. L. (Intern), Pinson, P. (Intern), Giebel, G. (Intern), Cutululis, N. A. (Intern)
Number of pages: 14
Publication date: 2013

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions: Using_forecast_presentation.pdf
Links: http://www.ewea.org/annual2013/
Using forecast information for storm ride-through control

Using probabilistic forecast information in control algorithms can improve the performance of wind farms during periods of extreme winds. This work presents a wind farm supervisor control concept that uses probabilistic forecast information to ride-through a storm with softer ramps of power. Wind speed forecasts are generated with a statistical approach (i.e. time series models). The supervisor control is based on a set of logical rules that consider point forecasts and predictive densities to ramp-down the power of the wind farm before the storm hits. The potential of this supervisor control is illustrated with data from the Horns Rev 1 wind farm, located in the North Sea. To conclude, an overview of ongoing and future research in the Radar@Sea experiment is given. This experiment aims at improving offshore wind power predictability and controllability through the increased use of meteorological information, and particularly weather radar images.

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Department of Applied Mathematics and Computer Science, Dynamical Systems, Meteorology
Authors: Barahona Garzón, B. (Intern), Trombe, P. (Intern), Vincent, C. L. (Intern), Pinson, P. (Intern), Giebel, G. (Intern), Cutululis, N. A. (Intern)
Number of pages: 9
Publication date: 2013

Host publication information
Title of host publication: Proceedings of EWEA 2013
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Conference: European Wind Energy Conference & Exhibition 2013, Vienna, Austria, 04/02/2013 - 04/02/2013
Electronic versions:
Using_forecast_information.pdf
Links:
http://www.ewea.org/annual2013/

Ancillary Services for the European Grid with High Shares of Wind and Solar Power

With significantly increasing share of variable renewable power generation like wind and solar PV, the need in the power system for ancillary services supporting the network frequency, voltage, etc. changes. Turning this issue around, market opportunities will emerge for wind and solar PV technology to deliver such grid services. In the European power system, adequate market mechanisms need to be developed to ensure that there will be an efficient trading of these services. For that purpose a range of (economic) characteristics of wind (and solar) power as providers of grid services need to be better understood. This relates both to the technical capabilities of the plants for delivering specific services and to the quantification of the needs.

The paper presents the approach of the European IEE project REserviceS, aiming at establishing reference guidance for the ongoing developments in Europe of network codes and electricity market design. Economic insights gained from REserviceS will be shaped into recommendations to be used when establishing electricity market mechanisms and Network Codes at EU level.

The project approach presented in the paper consists of two main parts namely (1) conceptually analyzing system needs for ancillary services and at assessing the technical aspects of and cost of delivering these services by solar PV and wind power, in scenarios of high renewable penetration. (2) Investigation of the need for ancillary services in typical transmission and distribution networks, and the cost and options to deliver these services at high penetration. The paper will give an overview of case studies envisaged, together with the intended methods used for the analysis.

The paper also gives some initial project results. It presents the outcome of the assessment of ancillary services that are especially relevant for wind and solar power. These are mainly related to frequency, voltage control and restoration of the system. In addition, based on existing experience and wind integration studies, the paper analyses impacts that high amounts of wind/solar will have on different ancillary services required by the power system.

General information
State: Published
Authors: Van Hulle, F. (Ekstern), Holttinen, H. (Ekstern), Kiviluoma, J. (Ekstern), Cutululis, N. A. (Intern)
Number of pages: 6
Publication date: 2012

Host publication information
Ancillary services: technical specifications, system needs and costs. Deliverable D 2.2

In this report, different ancillary services are described and a table listing main services is presented. While Chapter 2 is describing the services from (renewable) generators point of view, Chapter 3 is considering future system needs for services with increased wind and solar penetration. The table will be used as a starting point in the REServiceS project to see how much these services would cost when provided from wind/PV (WP3/4), and how often these services would be used in systems with higher penetrations of wind and solar (WP5/6).

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, VTT - Technical Research Centre of Finland, University College Dublin, XP Wind
Authors: Holttinen, H. (Ekstern), Cutululis, N. A. (Intern), Gubina, A. (Ekstern), Keane, A. (Ekstern), Van Hulle, F. (Ekstern)
Number of pages: 69
Publication date: 2012

Publication information
Original language: English
Main Research Area: Technical/natural sciences
REserviceS
Electronic versions:
Ancillary_Services.pdf

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Agreement no.:IEE/11/814/SI2.616374
Publication: Research - peer-review › Report – Annual report year: 2013

DC grids for integration of large scale wind power

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Authors: Zeni, L. (Intern), Sørensen, P. E. (Intern), Cutululis, N. A. (Intern)
Number of pages: 27
Publication date: 2012

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
DC_grids.pdf
Source: dtu
Source-ID: u::5427
Publication: Research › Sound/Visual production (digital) – Annual report year: 2012

DTU contributions to IEA Wind Annex 25 Phase 2
The objective of Task 25 is to analyse and further develop the methodology to assess the impact of wind power on power systems. The Task has established an international forum for exchange of knowledge and experiences related to power system operation with large amounts of wind power and has actively followed parallel activities with Transmission System Operators other R&D Task work. The participants have collected and shared information on the experience gained and
the studies made up to and during the task. The case studies have addressed different aspects of power system operation and design, mainly: balancing, grid impacts and capacity credit of wind power.

In the meetings, all participants have made presentations of the wind integration issues in their country, results so far and on-going activities. In the latest meetings presentations have been grouped to different topics to better dwell into the details of modelling challenges. In addition, there has been some telephone/web meetings for the journal articles and Recommendations report. In the Task 25 meetings, updates from other international work are also given (EU/TPWIND and SET-Plan, IEEE, IPCC). TSO collaboration is important for Task 25 work. There has been TSO participation in all meetings, with the participants from Canada, Denmark and Italy in most meetings and some other countries sending TSO participants in fewer meetings.

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Authors: Sørensen, P. E. (Intern), Cutululis, N. A. (Intern), Meibom, P. (Ekstern)
Number of pages: 50
Publication date: 2012

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Publisher: DTU Wind Energy
ISBN (Electronic): 978-87-92896-20-9
Original language: English

Series: DTU Wind Energy E
Number: 0014
Main Research Area: Technical/natural sciences
Electronic versions:
DTU_Wind_Energy_E_0014_EN_.pdf

Bibliographical note
Contract no: 64009-0100; project no: 64009-0100; sponsor: Danish Energy Agency
Publication: Research › Report – Annual report year: 2012

Inertial response from wind turbines: the impact on structural loads
This works evaluates the impact on structural loads of DFIG wind turbines providing inertial response while operating at rated power. The approach is to use an integrated simulation environment to model the most important electrical, structural, and control dynamics. Estimation of the impact is done in terms of 1-Hz equivalent loads, and maximum-minimum loads. It is observed that some structural loads are significantly affected. Therefore the trade off between the amount of inertial response and the cost of loads imposed should be assess from an statistical perspective.

General information
State: Published
Organisations: Wind Energy Systems, Department of Wind Energy
Authors: Barahona Garzon, B. (Intern), Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Sørensen, P. E. (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:
Inertial_response.pdf
Publication: Research - peer-review › Article in proceedings – Annual report year: 2012

Inertial response from wind turbines: the impact on structural loads
This works evaluates the impact on structural loads of DFIG wind turbines providing inertial response while operating at rated power. The approach is to use an integrated simulation environment to model the most important electrical, structural, and control dynamics. Estimation of the impact is done in terms of 1-Hz equivalent loads, and maximum-minimum loads. It is observed that some structural loads are significantly affected. Therefore the trade off between the amount of inertial response and the cost of loads imposed should be assess from an statistical perspective.

General information
Integrated analysis of wind turbines - The impact of power systems on wind turbine design

Megawatt-size wind turbines nowadays operate in very complex environmental conditions, and increasingly demanding power system requirements. Pursuing a cost-effective and reliable wind turbine design is a multidisciplinary task. However nowadays, wind turbine design and research areas such as aeroelastic and mechanical, electrical and control, and grid integration, make use of simulation tools dedicated to specific areas. Practical experience shows there is a need to bridge the expertise from different design areas.

The focus of this Ph.D. study is on the integrated dynamic analysis of operating conditions that stem from disturbances in the power system. An integrated simulation environment, wind turbine models, and power system models are developed in order to take an integral perspective that considers the most important aeroelastic, structural, electrical, and control dynamics.

Applications of the integrated simulation environment are presented. The analysis of an asynchronous machine, and numerical simulations of a fixed-speed wind turbine in the integrated simulation environment, demonstrate the effects on structural loads of including the generator rotor fluxes dynamics in aeroelastic studies. Power system frequency control studies of variable-speed wind turbines with the integrated simulation environment, show that is possible to make a sensible estimation of the contribution of a wind farm to power system frequency control, while studying the impact on wind turbine structural loads.

Finally, studies of the impact that voltage faults have on wind turbine loads are presented. The case of unbalanced faults is addressed, the possibilities and drawbacks for reduction of structural loads using electrical control actions is investigated. Load reduction using resonant damping control is proven and quantified.

General information

North Sea Offshore Wind Power Variability in 2020 and 2030

Wind power is currently the most promising renewable technology and is expected to contribute significantly to achieving the “20-20-20” target set by EU - 20% reduction of greenhouse gases and 20% share of renewables by 2020. The development potential of wind power, especially offshore, is huge. The experience with large offshore wind farms so far has clearly shown that the offshore wind power is significantly more variable than the on-shore wind power, first of all because offshore wind power is more concentrated geographically than existing on-shore wind power. The focus is on time scales of interest for power system operation, thus ranging from minutes to hours. The simulations are based on the offshore wind power development plans developed in the TWENTIES project and includes details such as installed capacity and coordinates for each wind farm existing or planned to be installed in North Europe, by 2020 and 2030. For each target, a base case and a high scenario is simulated. The offshore wind power variability is quantified in terms of ramp rates.

General information
Wind power development scenarios are critical when trying to assess the impact of the demonstration at national and European level. The work described in this report had several objectives. The main objective was to prepare and deliver the proper input necessary for assessing the impact of Demo 4 – Storm management at national and European level. For that, detailed scenarios for offshore wind power development by 2020 and 2030 were required. The aggregation level that is suitable for the analysis to be done is at wind farm level. Therefore, the scenarios for offshore wind power development offer details about the wind farms such as: capacity and coordinates. Since the focus is on the impact of storm fronts passage in Northern Europe, the offshore wind power scenarios were estimated only for the countries at North and Baltic Sea. The sources used are public sources, mentioned in the reference list. The scenarios are split in baseline – the conservative one, most likely to happen, and high – the optimistic scenario. During the time of the work, EWEA has published their estimation for 2020 and 2030. The scenarios estimated in this work are in good accordance with EWEA’s.

A second task described in this work was to create a dataset containing forecast and realised wind power time series with hourly resolution. The database should cover all Europe, i.e. onshore and offshore and it will be further used in the project for the economic assessment impact, Tasks 16.2.2 and 16.2.3. For the onshore wind power development, the approach used in the TradeWind project has been used. This approach considered a first aggregation level for wind power at a grid node, and then a second aggregation at wind power regions. With this approach, wind power for a country can be expressed in one or several wind power nodes and one or several wind power regions. For onshore wind power, the estimated installed capacity was upscaled to meet the number published by EWEA in the Pure Power report.

Wind speed time series were extracted from the WRF dataset available at DTU Wind Energy and interpolated to the exact location of the wind power points with CorWind. Wind speed forecast errors were calculated using the Scenario Tree Tool developed in the WILMAR project.

Finally, wind power time series were simulated using the wind speed time series and adequate power curves. The resulted wind power time series were briefly analysed with respect to the distribution of wind power forecast errors and the results show that the wind power forecast error distribution manages to capture the area smoothing effect.
Offshore Wind Power Production in Critical Weather Conditions

Critical weather conditions, i.e. extreme winds will raise a lot of challenges when it comes to the secure operation of the whole European electric system with the future large scale offshore wind power. This is especially true for Denmark where the target is that wind power should provide 50% of the electricity consumption by 2020.

In the EU funded project TWENTIES, the demonstration #4 STORM MANAGEMENT aims at demonstrating that adequate coordination mechanisms between offshore wind farms and hydro power capacity available in Norway through an existing HVDC link brings viable solutions to securely control the power balance during offshore storm passages. The demonstration will be done on Horns Rev 2 wind farm. In the same project, the impact of a storm front passage over the system security, for the whole Danish system, and with the expected offshore wind power in 2020 will be investigated.

This paper will present the results of up-scaling the impact that a storm front passage will have on the Danish power system in 2020, given that the existing wind turbine storm controller is not replaced. The simulations are done with CorWind and the analysis is focusing on establishing a reference case and quantifying the balancing reserve requirements needed in order to keep the security of the power system.
Wind-induced day-ahead and hour-ahead imbalances in a power system with a significant wind mix: Simulations in the Danish experience

General information
State: Published
Organisations: Wind Energy Systems, Department of Wind Energy, Energinet.dk
Authors: Litong-Palima, M. (Intern), Cutululis, N. A. (Intern), Detlefsen, N. (Ekstern), Sørensen, P. E. (Intern)
Number of pages: 1
Publication date: 2012
Event: Poster session presented at EWEA 2012 - European Wind Energy Conference & Exhibition, Copenhagen, Denmark.
Main Research Area: Technical/natural sciences
Electronic versions: Wind_induced_Day_Ahead_and_Hour_Ahead.pdf

Ancillary Services from Wind Farms
Meeting the EU objectives of sustainable energy supply in the near future involves a dramatic increase of the electricity demand covered by variable renewable sources, among which wind power holds an important role. This important role comes together with ever increasing requirements of wind power plants ability of delivering ancillary services to the power system. The presentation attempts at giving an overview of the present (and future) research on the ability of large (offshore) wind farms to provide power system services.

General information
State: Published
Organisations: Wind Energy Division, Wind Energy Systems, Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. D. (Intern), Margaris, I. (Intern), Zeni, L. (Intern), Sørensen, P. E. (Intern), Cutululis, N. A. (Intern)
Publication date: 2011

Assessment of storm forecast
When wind speed exceeds a certain value, wind turbines shut-down in order to protect their structure. This leads to sudden wind plants shut down and to new challenges concerning the secure operation of the pan-European electric system with future large scale offshore wind power.

This task aims at analysing the ability of existing forecast tools to predict storms at the Horns Rev 2 wind farm. The focus will be on predicting the time where the wind turbine will need to shut down to protect itself, e.g. the time where wind speed exceeds 25 m/s. At the same time, the planned shut-down should cost as little lost wind energy as possible. Therefore, the planned shut down time should be as close as possible to the time where the wind turbine itself would shut down, but still reliable. The forecast systems available to ENERGINET.dk will be applied.

The forecast tools ability of accurately predicting storms was analysed based on historical meteorological data available at Risø DTU and dynamically down-scaled to the Horns Rev 2 wind farm level. This solution was chosen due to the lack of measurements. Moreover, since the project started, there were four events during which Horns Rev 2 wind farm stopped, completely or partially, producing due to extreme wind speeds. Wind speed and power measurements from those events are presented and compared to the forecast available at Energinet.dk. The analysis looked at wind speed and wind power forecast.

The main conclusion of the analysis is that the wind speed forecasts are not very reliable in predicting when Horns Rev 2 wind farm will stop producing due to a storm. One of the reasons for that is the fact that there is no clear and precise definition of Extreme Wind Period (EWP) at wind farm level (how many wind turbines should stop producing in order to consider it an EWP) and that the available wind speed forecasts are given as a mean wind speed over a rather large area. At wind power level, the analysis shows that prediction of accurate production levels from a wind farm experiencing EWP is rather poor. This is partially because the power curve typically used to transform wind speed into power has not been optimised for high wind speeds. This means that today, the wind power forecast error that the TSO’s control room is facing when dealing with EWPs is around 1 p.u.
General information
State: Published
Authors: Cutululis, N. A. (Intern), Hahmann, A. N. (Intern), Huus Bjerge, M. (Ekstern), Gøttig, A. (Ekstern), Hansen, L. H. (Ekstern), Detlefsen, N. (Ekstern), Sørensen, P. E. (Intern)
Number of pages: 35
Publication date: 2011

Publication information
Publisher: www.twenties-project.eu
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
Assessment of storm forecast.pdf

Relations
Projects:
Assessment of storm forecast
Source: orbit
Source-ID: 313962
Publication: Research › Report – Annual report year: 2011

DC grids for integration of large scale wind power

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Electric Components, Department of Electrical Engineering, Norwegian University of Science and Technology, Chalmers University of Technology
Authors: Zeni, L. (Intern), Haileselassie, T. (Ekstern), Stamatiou, G. (Ekstern), Geisler Eriksen, A. (Ekstern), Holbøll, J. (Intern), Carlsson, O. (Ekstern), Uhlen, K. (Ekstern), Sørensen, P. E. (Intern), Cutululis, N. A. (Intern)
Publication date: 2011

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

Relations
Projects:
DC grids for integration of large scale wind power
Source: orbit
Source-ID: 313795
Publication: Research - peer-review › Article in proceedings – Annual report year: 2011

Demo 4: Storm management

General information
State: Published
Organisations: Wind Energy Division, Wind Energy Systems, Risø National Laboratory for Sustainable Energy, Energinet.dk
Authors: Detlefsen, N. (Ekstern), Gøttig, A. (Ekstern), Cutululis, N. A. (Intern), Sørensen, P. E. (Intern)
Publication date: 2011

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Wind power measurement and integration
Electronic versions:
demo4.pdf
Source: orbit
Source-ID: 284170
Impact of fault ride-through requirements on fixed-speed wind turbine structural loads

The emphasis in this article is on the impact of fault ride-through requirements on wind turbines structural loads. Nowadays, this aspect is a matter of high priority as wind turbines are required more and more to act as active components in the grid, i.e. to support the grid even during grid faults. This article proposes a computer approach for the quantification of the wind turbines structural loads caused by the fault ride-through grid requirements. This approach, exemplified for the case of a 2MW active stall wind turbine, relies on the combination of knowledge from complimentary simulation tools, which have expertise in different specialized wind turbines design areas. Two complimentary simulation tools are considered i.e. the detailed power system simulation tool PowerFactory from DIgSILENT and the advanced aeroelastic computer code HAWC2, in order to assess of the dynamic response of wind turbines to grid faults. These two tools are coupled sequently in an offline approach, in order to achieve a thorough insight both into the structural as well as the electrical wind turbine response during grid faults. The impact of grid requirements on wind turbines structural loads is quantified by performing a rainfall and a statistical analysis for fatigue and ultimate structural loads, respectively. Two cases are compared i.e. one where the turbine is immediately disconnected from the grid when a grid fault occurs and one where the turbine is equipped with a fault ride-through controller and therefore it is able to remain connected to the grid during the grid fault. Copyright © 2010 John Wiley & Sons, Ltd.
Impact of wind power in autonomous power systems—power fluctuations—modelling and control issues

This paper describes a detailed modelling approach to study the impact of wind power fluctuations on the frequency control in a non-interconnected system with large-scale wind power. The approach includes models for wind speed fluctuations, wind farm technologies, conventional generation technologies, power system protection and load. Analytical models for wind farms with three different wind turbine technologies, namely Doubly Fed Induction Generator, Permanent Magnet Synchronous Generator and Active Stall Induction Generator-based wind turbines, are included. Likewise, analytical models for diesel and steam generation plants are applied. The power grid, including speed governors, automatic voltage regulators, protection system and loads is modelled in the same platform. Results for different load and wind profile cases are being presented for the case study of the island Rhodes, in Greece. The scenarios studied correspond to reference year of study 2012. The effect of wind fluctuations in the system frequency is studied for the different load cases, and comments on the penetration limits are being made based on the results. Copyright © 2010 John Wiley & Sons, Ltd.
Meso-scale Wind Variability. Final Report

General information
State: Published
Authors: Larsen, S. E. (Intern), Larsén, X. G. (Intern), Vincent, C. L. (Intern), Sørensen, P. E. (Intern), Pinson, P. (Intern), Trombe, P. (Intern), Madsen, H. (Intern), Cutululis, N. A. (Intern)

Wind power measurement and integration, Wind Energy
DOI: 10.1002/we.417
Source: orbit
Source-ID: 269361
Publication: Research - peer-review › Journal article – Annual report year: 2010
Offshore wind power integration in TWENTIES and beyond

General information
State: Published
Organisations: Wind Energy Division, Wind Energy Systems, Risø National Laboratory for Sustainable Energy, Energinet.dk
Authors: Sørensen, P. E. (Intern), Detlefsen, N. (Ekstern), Cutululis, N. A. (Intern)
Publication date: 2011

Relations
Projects:

Offshore wind power prediction in critical weather conditions

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Energinet.dk
Authors: Cutululis, N. A. (Intern), Detlefsen, N. K. (Ekstern), Sørensen, P. E. (Intern)
Publication date: 2011

Host publication information
Title of host publication: Proceedings
Publisher: Energynautics GmbH
Main Research Area: Technical/natural sciences
Workshop: 10th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Farms, Aarhus, Denmark, 25/10/2011 - 25/10/2011
Electronic versions:
Offshore wind power.pdf
Source: orbit
Source-ID: 313791
Publication: Research - peer-review › Article in proceedings – Annual report year: 2011
Operation and Control of Wind Farms in Non-Interconnected Power Systems

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, National Technical University of Athens
Authors: Margaris, I. (Intern), Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Sørensen, P. E. (Intern), Hatziargyriou, N. D. (Ekstern)
Number of pages: 330
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Title of host publication: Wind Farm - Impact in Power System and Alternatives to Improve the Integration
Volume: Chapter 8
Publisher: InTech
Editor: Suvire, G. O.
Main Research Area: Technical/natural sciences
Wind power measurement and integration
Electronic versions:
Operation_and_control_of_wind_farms_in_non_interconnected_power_systems.pdf
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Coupling of HAWC2 and Matlab: Towards an Integrated Simulation Platform

General information
State: Published
Authors: Barahona Garzon, B. (Intern), Henriksen, L. C. (Intern), Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Sørensen, P. E. (Intern)
Publication date: 2010

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Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Conference: 2010 European Wind Energy Conference and Exhibition, Warsaw, Poland, 20/04/2010 - 20/04/2010
Wind power control and integration, Wind energy
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Barahona_poster_ewec_2010.pdf
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Dynamic security issues of autonomous power systems with increasing wind power penetration

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, National Technical University of Athens
Authors: Margaris, I. (Ekstern), Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Sørensen, P. E. (Intern), Hatziargyriou, N. (Ekstern)
Publication date: 2010

Host publication information
Title of host publication: EWEC 2010 Proceedings online
Publisher: European Wind Energy Association (EWEA)
Grid fault and design-basis for wind turbines - Final report

This is the final report of a Danish research project “Grid fault and design-basis for wind turbines”. The objective of this project has been to assess and analyze the consequences of the new grid connection requirements for the fatigue and ultimate structural loads of wind turbines. The fulfillment of the grid connection requirements poses challenges for the design of both the electrical system and the mechanical structure of wind turbines. The development of wind turbine models and novel control strategies to fulfill the TSO’s requirements are of vital importance in this design. Dynamic models and different fault ride-through control strategies have been developed and assessed in this project for three different wind turbine concepts (active stall wind turbine, variable speed doubly fed induction generator wind turbine, variable speed multipole permanent magnet wind turbine). A computer approach for the quantification of the wind turbines structural loads caused by the fault ride-through grid requirement, has been proposed and exemplified for the case of an active stall wind turbine. This approach relies on the combination of knowledge from complimentary simulation tools, which have expertise in different specialized design areas for wind turbines. In order to quantify the impact of the grid faults and grid requirements fulfillment on wind turbines structural loads and thus on their lifetime, a rainfall and a statistical analysis for fatigue and ultimate structural loads, respectively, have been performed and compared for two cases, i.e. one when the turbine is immediately disconnected from the grid when a grid fault occurs and one when the turbine is equipped with a fault ride-through controller and therefore it is able to remain connected to the grid during the grid fault. Different storm control strategies, that enable variable speed wind turbines to produce power at wind speeds higher than 25m/s and up to 50m/s without substantially increasing the structural loads, have also been proposed and investigated during the project. Statistics in terms of mean value and standard deviation have been analysed and rainfall calculations have been performed to estimate the impact over the lifetime of a variable speed wind turbine.
Integrating MATLAB/SIMULINK models for wind power systems into Power Factory

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Constantin, A. (Ekstern), Iov, F. (Ekstern), Hansen, A. D. (Intern), Cutululis, N. A. (Intern)
Publication date: 2010
Event: Abstract from 2010 European Wind Energy Conference and Exhibition, Warsaw, Poland.
Main Research Area: Technical/natural sciences
Wind power measurement and integration, Wind Energy
Source: orbit
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Publication: Research › Conference abstract for conference – Annual report year: 2010

Power fluctuations from offshore wind plants

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Cutululis, N. A. (Intern)
Publication date: 2010
Main Research Area: Technical/natural sciences
Wind energy, Offshore wind energy
Source: orbit
Source-ID: 263835
Publication: Research › Conference abstract for conference – Annual report year: 2010

Reliability indexes for offshore wind power production under extreme wind conditions

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Cutululis, N. A. (Intern), Zeni, L. (Intern), Sørensen, P. E. (Intern)
Publication date: 2010

Host publication information
Title of host publication: EWEC 2010 Proceedings online
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Conference: 2010 European Wind Energy Conference and Exhibition, Warsaw, Poland, 20/04/2010 - 20/04/2010
Wind power control and integration, Wind energy
Electronic versions:
Cutululis_paper_ewec_2010.pdf
Cutululis_poster_ewec_2010.pdf
Source: orbit
Source-ID: 262245
Publication: Research › Article in proceedings – Annual report year: 2010

Reliability of offshore wind production under extreme wind conditions was investigated in this report. The wind power variability from existing and future large offshore wind farms in Western Denmark were simulated using the Correlated Wind model developed at Risø. The analysis was done for five years, with each year simulated with five random seeds, leading to a total of 25 annual wind power time series for six large offshore wind farms, summing up to a little over 330 wind turbines. Two storm control strategies were used. The analysis involved several aspects inspired from reliability studies. The aspects investigated are storm events occurrences and durations, storm control strategy impact on the capacity factor (lost production), the loss of production (power produced from wind drops below a certain threshold due to high wind speeds and storm controller) and finally, the wind power production ramp rates and reserves requirements.

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Cutululis, N. A. (Intern), Zeni, L. (Intern)
Number of pages: 35
Publication date: 2010

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Place of publication: Roskilde
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi
Original language: English
Main Research Area: Technical/natural sciences
Wind power measurement and integration, Wind Energy

Electronic versions:
Cutululis_upwind.pdf
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Source-ID: 268304
Publication: Research › Report – Annual report year: 2010

Simulating Offshore Wind Power Variability over Power Systems Areas

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Cutululis, N. A. (Intern), Sørensen, P. E. (Intern)
Publication date: 2010

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Title of host publication: Proceedings
Main Research Area: Technical/natural sciences
Workshop: 9th International Workshop on Large-Scale Integration of Wind Power into Power Systems, Quebec, Canada, 18/10/2010 - 18/10/2010
Wind power measurement and integration, Wind Energy

Electronic versions:
Cutululis_simulation.pdf
Source: orbit
Source-ID: 268307
Publication: Research › Article in proceedings – Annual report year: 2010

Wind Farms' Spatial Distribution Effect on Power System Reserves Requirements

The wind power development during last millennium was typically based on small wind turbines dispersed over large areas, leading to a significant smoothing of the wind power fluctuations in a power system balancing area. The present development goes towards much larger wind farms, concentrated in smaller areas, which causes the total wind power fluctuations in power system areas to increase significantly. The impact of future large wind farms spatial distribution with respect to the power system reserve requirements is analyzed in this paper. For this purpose, Correlated Wind (CorWind) power time series simulation model developed to simulate wind power variability over a large area is used. As a study case, two scenarios for short term offshore wind power development in the West Danish power system region are used. The first scenario assumes that all the wind farms are built in the region with the best wind resources, whereas the second scenario represents a more dispersed development.

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Cutululis, N. A. (Intern)
Wind model for low frequency power fluctuations in offshore wind farms

This paper investigates the correlation between the frequency components of the wind speed Power Spectral Density. The results extend an already existing power fluctuation model that can simulate power fluctuations of wind power on areas up to several kilometers and for time scales up to a couple of hours, taking into account the spectral correlation between different wind turbines. The modelling is supported by measurements from two large wind farms, namely Nysted and Horns Rev. Measurements from individual wind turbines and meteorological masts are used. Finally, the models are integrated into an aggregated model which is used for estimating some electrical parameters as power ramps and reserves requirements, showing a quite good agreement between simulations and measurement. The comparison with measurements generally show that the inclusion of the correlation between low frequency components is an improvement, but the effect is relatively small. The effect of including the low frequency components in the model is much more significant. Therefore, that aggregated model is useful in the power system planning and operation, e.g. regarding load following and regulation. Copyright © 2009 John Wiley & Sons, Ltd.
Grid integration impacts on wind turbine design and development

This paper presents an overall perspective on contemporary issues like wind power plants and grid integration. The purpose is to present and discuss the impacts of emerging new grid connection requirements on modern wind turbines. The grid integration issue has caused several new challenges to the wind turbine design and development. The survival of different wind turbine concepts and controls is strongly conditioned by their ability to comply with stringent grid connection requirements, imposed by utility companies. Beside its impact on the mechanical design and control of wind turbines, the grid integration aspect has also an effect on wind turbines' role in the power system, on wind turbine technologies' survival on the market, as well as on the wind turbines' loads. Over the last years, it became obviously, that there it is an increasing need for design and research of wind turbines based on an integrated design and control approach.

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Aalborg University
Authors: Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Sørensen, P. E. (Intern), Iov, F. (Ekstern)
Pages: 632-638
Publication date: 2009

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Title of host publication: IEEE Bucharest PowerTech, 2009
Volume: 1-5
Publisher: IEEE Power and Energy Society
Power fluctuations from large wind farms - Final report
Experience from power system operation with the first large offshore wind farm in Denmark: Horns Rev shows that the power from the wind farm is fluctuating significantly at certain times, and that this fluctuation is seen directly on the power exchange between Denmark and Germany. This report describes different models for simulation and prediction of wind power fluctuations from large wind farms, and data acquired at the two large offshore wind farms in Denmark are applied to validate the models. Finally, the simulation model is further developed to enable simulations of power fluctuations from several wind farms simultaneously in a larger geographical area, corresponding to a power system control area.

General information
State: Published
Authors: Sørensen, P. E. (Intern), Pinson, P. (Intern), Cutululis, N. A. (Intern), Madsen, H. (Intern), Jensen, L. E. (Ekstern), Hjerrild, J. (Ekstern), Heyman Donovan, M. (Ekstern), Runge Kristoffersen, J. (Ekstern), Vigueras-Rodríguez, A. (Ekstern)
Number of pages: 49
Publication date: 2009
Modelling of power fluctuations from large offshore wind farms
This paper deals with modelling of power fluctuations from large wind farms. The modelling is supported and validated using wind speed and power measurements from the two large offshore wind farms in Denmark. The time scale in focus is from 1 min to a couple of hours, where significant power fluctuations have been observed from these wind farms. Power and wind speed are measured with 1 s sampling time in all individual wind turbines in almost 1 year, which provides a substantial database for the analyses. The paper deals with diversified models representing each wind turbine individually and with aggregation of a wind farm to be represented by a single large wind turbine model. Copyright (C) 2007 John Wiley & Sons, Ltd.

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State: Published
Authors: Sørensen, P. E. (Intern), Cutululis, N. A. (Intern), Vigueras-Rodriguez, A. (Intern), Madsen, H. (Intern), Pinson, P. (Intern), Jensen, L. (Ekstern), Hjerrild, J. (Ekstern), Donovan, M. (Ekstern)
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Web of Science (2014): Indexed yes
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Scopus rating (2013): SJR 1.275 SNIP 2.464 CiteScore 2.75
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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
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ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.487 SNIP 2.013
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.124 SNIP 1.448
Web of Science (2009): Indexed yes
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Scopus rating (2008): SJR 0.826 SNIP 1.559
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Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.637 SNIP 1.689
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.287 SNIP 0.9
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.528 SNIP 0.846
Web of Science (2004): Indexed yes
Web of Science (2003): Indexed yes
Web of Science (2002): Indexed yes
Web of Science (2001): Indexed yes
Web of Science (2000): Indexed yes
Original language: English
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Relations
Projects:
Modelling of power fluctuations from large offshore wind farms
Source: orbit
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Publication: Research - peer-review › Journal article – Annual report year: 2008

Optimal control of wind energy systems: Towards a global approach

General information
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Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Munteanu, I. (Ekstern), Bratcu, A. (Ekstern), Cutululis, N. A. (Intern), Ceanga, E. (Ekstern)
Number of pages: 283
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Series: Advances in Industrial Control
Main Research Area: Technical/natural sciences
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Publication: Research - peer-review › Book – Annual report year: 2008

Power electronics: Key-enabling technology for grid integration of wind power

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Iov, F. (Ekstern), Ciobotaru, M. (Ekstern), Cutululis, N. A. (Intern), Blaabjerg, F. (Ekstern)
Pages: 242-265
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Main Research Area: Technical/natural sciences
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Authors: Sørensen, P. E. (Intern), Hansen, J. C. (Intern), Cutululis, N. A. (Intern), Meibom, P. (Intern), Østergaard, J. (Intern), Holttinen, H. (Ekstern)
Number of pages: 79
Pages: 33-36
Publication date: 2008

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Place of publication: Roskilde
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratorium for Bæredygtig Energi
Editor: Larsen, H. H.
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1651(EN)
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Main Research Area: Technical/natural sciences
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Publication: Research - peer-review › Book chapter – Annual report year: 2008

Uncertainty on predicted cross border flows caused by wind forecast errors

General information
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Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Meteorology
Authors: Cutululis, N. A. (Intern), Sørensen, P. E. (Intern), Giebel, G. (Intern), Korpås, M. (Ekstern), Warland, L. (Ekstern)
Number of pages: 616
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Publication date: 2008

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Publisher: Energynautics GmbH
Editors: Betancourt, U., Ackermann, T.
Main Research Area: Technical/natural sciences
Workshop: 7th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Farms, Madrid, Spain, 26/05/2008 - 26/05/2008
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Wind turbine cut outs in a power system region

General information
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Wind turbines structural loads during fault ride-through operation

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Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Aeroelastic Design
Authors: Cutululis, N. A. (Intern), Hansen, A. D. (Intern), Larsen, T. J. (Intern), Sørensen, P. E. (Intern), Iov, F. (Ekstern)
Pages: 77-80
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Adaptive modelling of offshore wind power fluctuations

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Pinson, P. (Ekstern), Madsen, H. (Ekstern), Sørensen, P. E. (Intern), Cutululis, N. A. (Intern)
Number of pages: 9
Publication date: 2007

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Publisher: Risø National Laboratory
Editors: Cutululis, N., Sørensen, P.
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Number: 1624(EN)
ISSN: 0106-2840
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Publication: Research › Article in proceedings – Annual report year: 2007
Analysis of the experimental spectral coherence in the Nysted Wind Farm

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Vigueras-Rodriguez, A. (Ekstern), Sørensen, P. E. (Intern), Viedma, A. (Ekstern), Cutululis, N. A. (Intern), Donovan, M. (Ekstern)
Number of pages: 4
Publication date: 2007

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Publisher: Risø National Laboratory
Editors: Cutululis, N. A., Sørensen, P. E.
ISBN (Print): 978-87-550-3640-6
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Main Research Area: Technical/natural sciences
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Relations
Projects:
Analysis of the experimental spectral coherence in the Nysted Wind Farm
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Publication: Research › Article in proceedings – Annual report year: 2007

A survey of interconnection requirements for wind power

General information
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Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Iov, F. (Ekstern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Cutululis, N. A. (Intern)
Number of pages: 9
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Bibliographical note
Risø-R-1624(EN)
Source: orbit
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Dynamic wind turbine models in power system simulation tool DigSILENT
This report presents a collection of models and control strategies developed and implemented in the power system simulation tool PowerFactory DigSILENT for different wind turbine concepts. It is the second edition of Rise-R-1400(EN) and it gathers and describes a whole wind turbine model database built-up and developed during several national research projects, carried out at Risø DTU National Laboratory for Sustainable Energy and Aalborg University, in the period 2001-2007. The overall objective of these projects was to create a wind turbine model database able to support the analysis of the interaction between the mechanical structure of the wind turbine and the electrical grid during different operational modes. The report provides thus a description of the wind turbines modelling, both at a component level and at a system level. The report contains both the description of DigSILENT built-in models for the electrical components of a grid connected wind turbine (e.g. induction generators, power converters, transformers) and the models developed by the user, in the dynamic simulation language DSL of DigSILENT, for the non-electrical components of the wind turbine (wind model, aerodynamic model, mechanical model). The initialisation issues on the wind turbine models into the power system simulation are also presented. The main attention in the report is drawn to the modelling at the system level of the following wind turbine concepts: 1. Fixed speed active stall wind turbine concept 2. Variable speed doubly-fed induction generator wind turbine concept 3. Variable speed multi-pole permanent magnet synchronous generator wind turbine concept These wind turbine concept models can be used and even extended for the study of different aspects, e.g. the assessment of power quality, control strategies, connection of the wind turbine at different types of grid and storage systems. Different control strategies have been developed and implemented for these wind turbine concepts, their performance in normal or fault operation being assessed and discussed by means of simulations. The described control strategies have different goals e.g. fast response over disturbances, optimum power efficiency over a wider range of wind speeds, voltage ride-through capability including grid support. A dynamic model of a DC connection for active stall wind farms to the grid including the control is also implemented and presented.

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State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. D. (Intern), Iov, F. (Ekstern), Sørensen, P. E. (Intern), Cutululis, N. A. (Intern), Jauch, C. (Intern), Blaabjerg, F. (Intern)
Number of pages: 189
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Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1440(ed.2)(EN)
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Main Research Area: Technical/natural sciences
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Electronic versions:
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Source: orbit
Source-ID: 215534
Publication: Research › Report – Annual report year: 2007

Electrical components library for HAWC2
The work presented in this report is part of the EFP project called “A Simulation Platform to Model, Optimize and Design Wind Turbines” partly funded by the Danish Energy Authority under contract number 1363/04-0008. The project is carried out in cooperation between Risø National Laboratory and Aalborg University. In this project, the focus is on the development of a simulation platform for wind turbine systems using different simulation tools. This report presents the electric component library developed for use in the aeroelastic code HAWC2. The developed library includes both steady state and dynamical models for fixed and variable speed wind turbines. A simple steady-state slip model was developed for the fixed speed wind turbine. This model is suitable for aeroelastic design of wind turbines under normal operation. A dynamic model of an induction generator for the fixed speed wind turbine was developed. The model includes the dynamics of the rotor fluxes. The model is suitable for a more detailed investigation of the mechanical – electrical interaction, both under normal and fault operation. For the variable speed wind turbine, a steadystate model, typically used in aeroelastic design, was implemented. The model can be used for normal and, to some extent, for fault operation. The reduced order dynamic model of a DFIG was implemented. The model includes only the active power controller and can be used for normal operation conditions.

General information
Grid faults' impact on wind turbine structural loads

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Aeroelastic Design
Authors: Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Iov, F. (Ekstern), Sørensen, P. E. (Intern), Larsen, T. J. (Intern)
Number of pages: 6
Publication date: 2007

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Title of host publication: Proceedings : Nordic wind power conference (NWPC 2007)
Publisher: Risø National Laboratory
Editors: Cutululis, N., Sørensen, P.
ISBN (Print): 978-87-550-3640-6

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Publication: Research › Article in proceedings – Annual report year: 2007

Mapping of grid faults and grid codes

General information
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Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Iov, F. (Ekstern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Cutululis, N. A. (Intern)
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Modelling of wind turbine cut outs in a power system region

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Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Meteorology
Authors: Sørensen, P. E. (Intern), Larsén, X. G. (Intern), Mann, J. (Intern), Cutululis, N. A. (Intern)
Number of pages: 4
Publication date: 2007

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Title of host publication: Proceedings : Nordic wind power conference (NWPC 2007)
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Editors: Cutululis, N., Sørensen, P.
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Models for assessing power fluctuations from large wind farms

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Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Wind Energy Systems
Authors: Cutululis, N. A. (Intern), Sørensen, P. E. (Intern), Vigueras-Rodriguez, A. (Intern), Jensen, L. (Ekstern), Hjerrild, J. (Ekstern), Donovan, M. (Ekstern), Madsen, H. (Ekstern)
Number of pages: 9
Publication date: 2007

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Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Links:
Power Fluctuations From Large Wind Farms

General information
State: Published
Authors: Sørensen, P. E. (Intern), Cutululis, N. A. (Intern), Vigueras-Rodriguez, A. (Ekstern), Jensen, L. E. (Ekstern), Hjerrild, J. (Ekstern), Donovan, M. H. (Ekstern), Madsen, H. (Intern)
Pages: 958-965
Publication date: 2007
Main Research Area: Technical/natural sciences

Publication information
Journal: IEEE Transactions on Power Systems
Volume: 22
Issue number: 3
ISSN (Print): 0885-8950
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 8.17 SJR 3.757 SNIP 3.624
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 3.602 SNIP 3.486 CiteScore 6.6
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.831 SNIP 3.577 CiteScore 5.31
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.939 SNIP 4.35 CiteScore 6.33
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.177 SNIP 3.516 CiteScore 5.84
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.725 SNIP 3.254 CiteScore 5.34
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.949 SNIP 2.826
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.94 SNIP 2.723
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.537 SNIP 2.448
Web of Science (2008): Indexed yes
Power fluctuations from offshore wind farms; model validation

**General information**
- State: Published
- Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
- Authors: Cutululis, N. A. (Intern), Sørensen, P. E. (Intern), Eisen, S. (Ekstern), Donovan, M. (Ekstern), Jensen, L. (Ekstern), Kristoffersen, J. (Ekstern)
- Number of pages: 6
- Publication date: 2007
- Series: Denmark. Forskningscenter Risoe. Risoe-R
  Number: 1624(EN)
  ISBN: 978-87-550-3640-6
- Main Research Area: Technical/natural sciences
- Risø-R-1624(EN), Risø-R-1624
  Electronic versions: ris_r_1624.pdf

**Bibliographical note**
- Source: orbit
- Source-ID: 215850
- Publication: Research › Article in proceedings – Annual report year: 2007

**Power Quality Issues on Wind Power Installations in Denmark**
This paper introduces the power quality issues of wind power installations in a historic perspective, as the development from a few small wind turbines connected directly to the low voltage grid, to the present system with high penetration on the medium voltage distribution grids and two large offshore wind farms connected at transmission level. In this perspective, the power quality issues are divided into local issues particularly related to the voltage quality in the distribution systems and global issues related to the power system control and stability. Power quality characteristics of wind turbines and wind farms are described according to national and international standards, and measurements from
wind farms are presented.

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Department of Electrical Engineering, Department of Electric Power Engineering, Centre for Electric Technology
Authors: Sørensen, P. E. (Intern), Cutululis, N. A. (Intern), Lund, T. (Intern), Hansen, A. D. (Intern), Sørensen (ftrådt), T. (Intern), Hjerrild, J. (Intern), Donovan, M. H. (Ekstern), Christensen, L. (Ekstern), Nielsen, H. K. (Ekstern)
Pages: 2820-2826
Publication date: 2007

Host publication information
Title of host publication: Power Engineering Society General Meeting, 2007. IEEE
Volume: 1-10
ISBN (Print): 1-4244-1298-6
Main Research Area: Technical/natural sciences
DOIs: 10.1109/PES.2007.385924
Source: orbit
Source-ID: 202187
Publication: Research - peer-review › Article in proceedings – Annual report year: 2007

Proceedings of Nordic wind power conference (NWPC 2007)

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Cutululis, N. A. (ed.) (Intern), Sørensen, P. E. (ed.) (Intern)
Number of pages: 270
Publication date: 2007

Publication information
Publisher: Risø National Laboratory
ISBN (Print): 978-87-550-3640-6
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1624(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1624, Risø-R-1624(EN)
Electronic versions:
ris_r_1624.pdf
Source: orbit
Source-ID: 215860
Publication: Research › Report – Annual report year: 2007

Simulation of a flexible wind turbine response to a grid fault

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Aeroelastic Design
Authors: Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Sørensen, P. E. (Intern), Iov, F. (Ekstern), Larsen, T. J. (Intern)
Number of pages: 7
Publication date: 2007

Host publication information
Title of host publication: Conference proceedings (online)
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Links:
Specification of long-term load measurement technique: Work Package 1B.2 under the European Commission: Integrated wind turbine design (UPWIND)

General information
State: Published
Organisations: Test and Measurements, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Wind Energy Systems
Authors: Schmidt Paulsen, U. (Intern), Cutululis, N. A. (Intern), Sørensen, P. E. (Intern)
Number of pages: 28
Publication date: 2007

Publication information
Place of publication: Roskilde
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi
ISBN (Print): 87-55-03579-5
Original language: English

Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1593(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Electronic versions:
ris-r-1593.pdf
Source: orbit
Source-ID: 234840
Publication: Research › Report – Annual report year: 2007

Dynamic performances of control structures for wind - diesel systems without storage

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Vlad, C. (Ekstern), Cutululis, N. A. (Intern), Lefebvre, J. (Ekstern), Ceanga, E. (Ekstern)
Pages: 150-155
Publication date: 2006

Host publication information
Title of host publication: Proceedings
Publisher: Dunarea de Jos University of Galati
Main Research Area: Technical/natural sciences
Conference: International symposium on electric and electronic engineering (ISEEE 06), Galati (RO), 01/01/2006
Source: orbit
Source-ID: 220709
Publication: Research › Article in proceedings – Annual report year: 2007

LQ optimal control of wind turbines in hybrid power systems

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Cutululis, N. (Intern), Bindner, H. (Intern), Munteanu, I. (Ekstern), Bratcu, A. (Ekstern), Ceanga, E. (Ekstern), Sørensen, P. (Ekstern)
Publication date: 2006

Host publication information
Title of host publication: Proceedings (online)
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Power fluctuations from large offshore wind farms

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Cutululis, N. (Intern), Hjerrild, J. (Ekstern), Jensen, L. (Ekstern), Donovan, M. (Ekstern), Christensen, L. (Ekstern), Madsen, H. (Ekstern), Vigueras-Rodriguez, A. (Ekstern)
Publication date: 2006

Host publication information
Title of host publication: Nordic wind power conference (CD-ROM)
Place of publication: Espoo
Publisher: VTT
Main Research Area: Technical/natural sciences
Conference: Nordic Wind Power Conference, Espoo, Finland, 22/05/2006 - 22/05/2006

Relations
Projects:
Power fluctuations from large offshore wind farms
Source: orbit
Source-ID: 309415
Publication: Research › Article in proceedings – Annual report year: 2006

Robust multi-model control of an autonomous wind power system

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Cutululis, N. A. (Intern), Ceanga, E. (Ekstern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern)
Pages: 399-419
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Energy
Volume: 9
ISSN (Print): 1095-4244
Ratings:
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 1.104 SNIP 2.306 CiteScore 3.37
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
Some results concerning no-storage wind-diesel systems control

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Vlad, C. (Ekstern), Cutululis, N. A. (Intern), Lefebvre, J. (Ekstern), Ceanga, E. (Ekstern)
Pages: 87-93
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: Annals "Dunarea de Jos" Univ. Galati, Fasc. III
Original language: English
Source: orbit
Source-ID: 209513
Publication: Research - peer-review › Journal article – Annual report year: 2006

Using a nonlinear controller to optimise a variable speed wind power system

General information
State: Published
Projects:

Design and optimization of electrical infrastructures in offshore wind power clusters

Department of Wind Energy
Period: 15/05/2017 → 14/05/2020
Number of participants: 4
PhD Student:
Pérez-Rúa, Juan-Andrés (Intern)
Supervisor:
Das, Kaushik (Intern)
Sørensen, Poul Ejnar (Intern)
Main Supervisor:
Cutululis, Nicolaos Antonio (Intern)

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

Control and stability of meshed offshore grids with diode rectifiers and VSC HVDC

Department of Wind Energy
Period: 01/10/2016 → 30/09/2019
Number of participants: 5
PhD Student:
Bidadfar, Ali (Intern)
Supervisor:
Akhmatov, Vladislav (Intern)
Altin, Müfit (Intern)
Cutululis, Nicolaos Antonio (Intern)
Main Supervisor:
Sørensen, Poul Ejnar (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Anden EU-finansiering
Project: PhD

Control and operation of offshore wind power plants connected via HVDC

Department of Wind Energy
Period: 01/09/2016 → 31/08/2019
Number of participants: 5
PhD Student:
Saborío-Romano, Oscar (Intern)
Integrated Baltic offshore wind electricity grid development
The offshore wind energy sector in the Baltic Sea requires coordinated transnational grid planning to realise its full growth potential. Baltic InteGrid promotes the meshed grid approach by creating a professional network for the exchange of expertise and state-of-the-art interdisciplinary research.

Department of Management Engineering
Energy Economics and Regulation
Department of Wind Energy
Integration & Planning
Period: 01/03/2016 → 30/09/2019
Number of participants: 5
Acronym: Baltic InteGrid
Project participant:
Pade, Lise-Lotte (Intern)
Bergaentzlé, Claire (Intern)
Boscán Flores, Luis Rafael (Intern)
Cutululis, Nicolaos Antonio (Intern)
Das, Kaushik (Intern)
Project

PROMOTioN - PROgress on Meshed HVDC Offshore Transmission Networks
The goal of the PROMOTioN project is to develop and demonstrate three key Technologies: diode rectifier offshore converters; multi-vendor high-voltage direct current (HVDC) grid protection system and the full power testing of HVDC circuit breakers. Furthermore, a regulatory and financial framework will be developed for the coordinated planning, construction and operation of integrated offshore infrastructures, including an offshore grid deployment plan (roadmap) for the future offshore grid system in Europe.

DTU is mainly involved in R&D on the first technology using diode rectifiers as offshore converters. DTU leads a work package on Wind turbine - converter interaction studies and a work package on harmonization towards standards and best practices. DTU is also involved in several other work packages.

Department of Wind Energy
Integration & Planning
Period: 01/01/2016 → 31/12/2019
Number of participants: 6
Acronym: PROMOTioN
Project ID: H2020 Grant Agreement-691714
Project participant:
Cutululis, Nicolaos Antonio (Intern)
Serensen, Poul Ejnar (Intern)
Göksu, Ömer (Intern)
Altin, Müfit (Intern)
Phd Student:
Saborío-Romano, Oscar (Intern)
Bidadfar, Ali (Intern)

Relations
Related projects:
- Control and stability of meshed offshore grids with diode rectifiers and VSC HVDC
- Control and operation of offshore wind power plants connected via HVDC

Publications:
- Connection of OWPPs to HVDC networks using VSCs and Diode Rectifiers: an Overview

Project

Multi-objective wind farm control
Department of Wind Energy
Period: 15/12/2015 → 14/12/2018
Number of participants: 3
Phd Student:
Kazda, Jonas (Intern)
Supervisor:
Courtney, Michael (Intern)
Main Supervisor:
Cutululis, Nicolaos Antonio (Intern)

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

Development of an Applied Measurement System for Short Term Power Forecasting and Gust/Ramp Prediction
Department of Wind Energy
Period: 15/11/2015 → 14/11/2018
Number of participants: 3
Phd Student:
Simon, Elliot (Intern)
Supervisor:
Cutululis, Nicolaos Antonio (Intern)
Main Supervisor:
Courtney, Michael (Intern)

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

Relations
Activities:
AMS 97th Annual Meeting
Project: PhD

Impact of wind power uncertainty on electric power system reliability
Department of Wind Energy
Period: 15/11/2014 → 14/11/2017
Number of participants: 3
Phd Student:
Nuño Martinez, Edgar (Intern)
Supervisor:
Serensen, Poul Ejnar (Intern)
Main Supervisor:
Cutululis, Nicolaos Antonio (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD
Coordinated control of wind power plants in offshore HVDC grids

Department of Wind Energy
Period: 15/03/2014 → 14/03/2017
Number of participants: 7
Phd Student: Sakamuri, Jayachandra N. (Intern)
Supervisor: Hansen, Anca Daniela (Intern)
Sørensen, Poul Ejnar (Intern)
Main Supervisor: Cutululis, Nicolaos Antonio (Intern)
Examiner: Nielsen, Arne Hejde (Intern)
Liang, Jun (Ekstern)
Uhlen, Kjetil (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Marie Curie (EU-stipendium)
Project: PhD

GARPUR - Generally Accepted Reliability Principle with Uncertainty modelling and through probabilistic Risk assessment
Power system reliability management aims to maintain power system performance at a desired level, while minimizing the socio-economic costs of keeping the power system at that performance level.

Historically in Europe, network reliability management has been lying on the so-called “N-1” criterion: in case of fault of one relevant element (e.g. one transmission system element, one significant generation element or one significant distribution network element), the elements remaining in operation must be capable of accommodating the new operational situation without violating the network’s operational security limits.

Today, the increasing uncertainty of generation due to intermittent energy sources, combined with the opportunities provided e.g. by demand-side management and energy storage, call for imagining new reliability criteria with a better balance between reliability and costs.

The GARPUR project designs, develops, assesses and evaluates such new reliability criteria to be progressively implemented over the next decades at a pan-European level, while maximising social welfare.

Risø National Laboratory for Sustainable Energy

Department of Wind Energy

Wind Energy Systems
Period: 01/09/2013 → 31/08/2017
Number of participants: 2
Power systems, Reliability, renewables
Acronym: GARPUR
Project participant: Cutululis, Nicolaos Antonio (Intern)
Sørensen, Poul Ejnar (Intern)

Multi-terminal DC grid for offshore wind
A DC grid based on multi-terminal voltage-source converters is a newly emerging technology, which is particularly suitable for the connection of offshore wind farms. The achievements from the project will contribute to integrating offshore wind power into the onshore AC grids in European countries and for the European offshore grid.

The MEDOW network will share complementary expertise, infrastructure and facilities for the training of the next generation of top-quality researchers in this field.

Department of Wind Energy
Wind Energy Systems
Risø National Laboratory for Sustainable Energy
Cardiff University
Katholieke Universiteit
Elia (TSO Belgium)
Universitat Politècnica de Catalunya
University of Porto
Alstom Wind
Period: 01/05/2013 → 31/03/2017
Number of participants: 1
Offshore grids, HVDC, wind power, Control System
Acronym: MEDOW
Number of related Ph.D. students: 1
Project participant:
Cutululis, Nicolaos Antonio (Intern)

Financing sources
Source: EU research programme (public)
Name of research programme: FP7-PEOPLE

Pan European Climate Data
ENTSO-E funded project aimed at evaluating photovoltaic and wind hourly production on regional scale in the whole Europe
Department of Electrical Engineering
Center for Electric Power and Energy
Energy resources, services and control
Department of Wind Energy
Wind Energy Systems
Meteorology
Period: 01/11/2012 → 31/07/2014
Number of participants: 3
Photovoltaic, Wind Energy
Acronym: PECD
Project participant:
Marinelli, Mattia (Intern)
Cutululis, Nicolaos Antonio (Intern)
Hahmann, Andrea N. (Intern)

Offshore Wind Park Control Assessment Methodologies to Assure Robustness and Fault tolerance
Department of Electrical Engineering
Period: 01/09/2012 → 20/01/2016
Number of participants: 9
Phd Student:
Gryning, Mikkel Peter Sidoroff (Intern)
Supervisor:
Andersen, Karsten Hvalkof (Intern)
Niemann, Hans Henrik (Intern)
Sørensen (fratrådt), Troels (Intern)
Wu, Qiuwei (Intern)
Main Supervisor:
Economic grid support from variable renewables
REserviceS (Economic grid support from variable renewables) is the first study to investigate wind and solar based grid support services at EU level. It will provide technical and economic guidelines and recommendations for the design of a European market for ancillary services, as well as for future network codes within the Third Liberalisation Package.

Risø National Laboratory for Sustainable Energy
Department of Wind Energy
Wind Energy Systems
European Wind Energy Association
VTT - Technical Research Centre of Finland
Fraunhofer Institute for Wind Energy and Energy System Technology
3E
EPIA
University College Dublin
Acciona S.A.
Mainstream Renewables
GE
Period: 01/04/2012 → 01/10/2014
Number of participants: 1
Ancillary services, Renewable, Wind, PV, Economic, Grid support
Acronym: REserviceS
Project participant:
Cutululis, Nicolaos Antonio (Intern)

Financing sources
Source: EU research programme (public)
Name of research programme: IEE
Project

Electromechanical Drivetrain Simulation
Department of Wind Energy
Period: 15/03/2012 → 24/08/2015
Number of participants: 8
Phd Student:
Gallego Calderon, Juan Felipe (Intern)
Supervisor:
Branner, Kim (Intern)
Hansen, John Michael (Intern)
Cutululis, Nicolaos Antonio (Intern)
Main Supervisor:
Natarajan, Anand (Intern)
Examiner:
Juul Jensen, Dorte (Intern)
Financing sources
Source: Internal funding (public)
Name of research programme: Forskningsrådsfinansiering
Project: PhD

EERA DTOC: European Energy Research Alliance Design Tools for Offshore wind farm Clusters
The project is funded by the EU – Seventh Framework Programme (FP7) – and runs from January 2012 to June 2015. It is coordinated by the Technical University of Denmark - DTU Wind Energy.

The EERA-DTOC project combines expertise to develop a multidisciplinary integrated software tool for an optimized design of offshore wind farms and clusters of wind farms.

Charlotte Bay Hasager is the daily manager of the project.
Peter Hauge Madsen is coordinator.

Department of Wind Energy
Meteorology
Department of Applied Mathematics and Computer Science
Wind Energy Systems
Aeroelastic Design
Risø National Laboratory for Sustainable Energy

Fluid Mechanics
Period: 01/01/2012 → 30/06/2015
Number of participants: 15
Offshore wind, wind clusters, design, optimization
Acronym: EERA-DTOC
Project participant:
Giebel, Gregor (Intern)
Réthoré, Pierre-Elouan (Intern)
Cutululis, Nicolaos Antonio (Intern)
Badger, Merete (Intern)
Hahmann, Andrea N. (Intern)
Peña, Alfredo (Intern)
Badger, Jake (Intern)
Voßler, Patrick (Intern)
Karagali, Ioanna (Intern)
Maule, Petr (Intern)
vander Laan, Paul (Intern)
Cutululis, Nicolaos Antonio (Intern)
Hansen, Kurt Schaldemose (Intern)

Project Manager, academic:
Hasager, Charlotte Bay (Intern)
Project Coordinator:
Madsen, Peter Hauge (Intern)

Relations
Activities:
Ocean winds from satellites – applications for offshore wind energy
Publications:
Wind Farm Wake: The Horns Rev Photo Case
Offshore winds mapped from satellite remote sensing
Shadowing effects of offshore wind farms - an idealised mesoscale study
EERA Design Tool for Offshore wind farm Cluster (DTOC)
Energy Yield Prediction of Offshore Wind Farm Clusters at the EERA-DTOC European Project
EERA DTOC wake results offshore
Transmission of wave energy through an offshore wind turbine farm

Wind Power Plant System Services
Department of Wind Energy
Period: 15/12/2011 → 19/03/2015
Number of participants: 7
Phd Student:
Basit, Abdul (Intern)
Supervisor:
Altin, Müfit (Intern)
Sørensen, Poul Ejnar (Intern)
Main Supervisor:
Hansen, Anca Daniela (Intern)
Examiner:
Cutululis, Nicolaos Antonio (Intern)
Chen, Zhe (Ekstern)
Molina Garcia, Angel (Ekstern)

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

Enhanced Ancillary Services from Wind Power Plants
The project vision is to provide wind power with similar grid system interaction characteristics as the conventional generation units. The new technical solutions developed in this project will expand the global wind power market, as they will assist in integrating more wind power in high voltage grids. Bringing wind power technology to this level will assist Vestas in remaining both technology and market leader in the global wind industry.
We pursue the vision by developing and demonstrating control features for primary, secondary and tertiary reserve and response provided by wind power plants. In this way the capability of wind farms to provide system services and thus their ability to actively support the power system in a similar way as the conventional power plants is increased. With these new control features the grid operators can allow a large scale penetration of wind power into the power system while increasing the security and reliability of power supply during the transition period from fossil to renewable based power production.

Risø National Laboratory for Sustainable Energy
Department of Wind Energy
Wind Energy Systems
Aalborg University
VESTAS Wind Systems A/S
Period: 01/09/2011 → 31/08/2014
Number of participants: 3
Acronym: EASEWIND
Project participant:
Cutululis, Nicolaos Antonio (Intern)
Hansen, Anca Daniela (Intern)
Altin, Müfit (Intern)

OffshoreDC - DC grids for integration of large scale wind power
Department of Wind Energy
Wind Energy Systems
Risø National Laboratory for Sustainable Energy
Department of Electrical Engineering
Center for Electric Power and Energy
Energinet.dk
DONG Energy A/S
Aalborg University
Norwegian University of Science and Technology
Chalmers University of Technology
ABB Carbon AB
VTT - Technical Research Centre of Finland
Statnett SF
Period: 01/02/2011 → 31/01/2016
Number of participants: 6
Offshore wind, Offshore grids, Wind power, HVDC, Control
Acronym: OffshoreDC
Number of related Ph.D. students: 4
Project participant:
Sørensen, Poul Ejnar (Intern)
Hansen, Anca Daniela (Intern)
Zeni, Lorenzo (Intern)
El-Khatib, Walid Ziad (Intern)
Holbøll, Joachim (Intern)
Project Coordinator:
Cutululis, Nicolaos Antonio (Intern)

Financing sources
Source: Public research programme (public)
Name of research programme: Nordic Energy Research
Web address: http://www.nordicenergy.org/
Amount: 2,500,000.00 Euro
Year of approval: 2010

Relations
Publications:
Generic Models of Wind Turbine Generators for Advanced Applications in a VSC-based Offshore HVDC Network
Active power control with undead-band voltage & frequency droop applied to a meshed DC grid test system
Dynamic Active Power Control with Improved Undead-Band Droop for HVDC Grids
Voltage margin control for offshore multi-use platform integration
An Assessment of Converter Modelling Needs for Offshore Wind Power Plants Connected via VSC-HVDC Networks
Modular Multilevel Converter Modelling, Control and Analysis under Grid Frequency Deviations
Alternatives for Primary Frequency Control Contribution from Wind Power Plants Connected to VSC-HVDC Intertie
Active Power Control with Undead-Band Voltage & Frequency Droop for HVDC Converters in Large Meshed DC Grids
OffshoreDC DC grids for integration of large scale wind power
Coordinated system services from offshore wind power plants connected through HVDC networks
HVDC Connected Offshore Wind Power Plants: Review and Outlook of Current Research
Influence of current limitation on voltage stability with voltage sourced converter HVDC
DC grids for integration of large scale wind power

TWENTIES - Transmission system operation with large penetration of Wind and other renewable Electricity sources in Networks by means of innovative Tools and Integrated Energy Solutions
A group of 6 Transmission System Operators (Belgium, Denmark, France, Germany, The Netherlands and Spain) with 2 generator companies, 5 manufacturers and research organisations, propose 6 demonstration projects to remove, in 3 years, several barriers which prevent the electric system from welcoming more wind electricity, and wind electricity from contributing more to the electric system. The full scale demonstrations aim at proving the benefits of novel technologies
(most of them available from manufacturers) coupled with innovative system management approaches. The contribution of wind energy to the system will show how aggregated wind farms can provide system services (voltage and frequency control) in Spain. The aggregation of wind farms with flexible generation and loads will be demonstrated in Denmark using a scalable IT platform developed by a generator. Increasing the flexibility of transmission networks will be tested in Belgium (existing sensors and coordinated power flow control devices avoiding possible large scale instabilities induced by wind farms in the CWE region) and in Spain (dynamic wind power evacuation capacity using real-time computations based on short-term generation forecasts and use of a mobile Overload Line Controller). Off-shore wind farms are addressed from a security viewpoint. Secure HVDC meshed networks will be validated in France using simulations and full scale experiments of two different HVDC circuit breaker technologies. Off-shore wind farm shut downs under stormy conditions will be demonstrated in Denmark using the world largest off-shore wind farm with balancing power provided by the Norwegian hydro capacities through a HVDC link. The experimental results will be integrated into European impact analyses to show the scalability of the solutions: routes for replication will be provided with benefits for the pan European transmission network and the European electricity market as soon as 2014, in line with the SET plan objectives.

Risø National Laboratory for Sustainable Energy
Department of Wind Energy
Wind Energy Systems
Department of Electrical Engineering
Center for Electric Power and Energy
Period: 01/04/2010 → 31/03/2013
Number of participants: 5
Wind power, TSO, Demonstration, Storm control, Wind turbines, Wind farms
Acronym: TWENTIES
Project participant:
Sørensen, Poul Ejnar (Intern)
Cutululis, Nicolaos Antonio (Intern)
Maule, Petr (Intern)
Litong-Palima, Marisciel (Intern)
Altiparmakis, Argyrios (Intern)

Relations
Publications:
Market and system security impact of the storm demonstration in task-forces TF2. Deliverable: D16.6
Technical and economic impact analysis of the demonstrations in task-forces TF2 - Deliverable D15.2
Economic impact analysis of the demonstrations in task-forces TF1 and TF3 - Deliverable D15.1
North Sea Offshore Wind Power Variability in 2020 and 2030
Managing Critical Weather Conditions in a Large-Scale Wind Based European Power System - The TWENTIES Project
Wind power variability and power system reserve requirements at 2020 at 2030 scenarios for offshore wind power in Northern Europe
Offshore wind power integration in TWENTIES and beyond
Offshore Wind Power Data
Spectral structure of mesoscale winds over the water
Report with data for system behaviour at storm passage with original (uncoordinated) and coordinated control
Impact of High Wind Speed Shut-down in the Danish Power System
Offshore Wind Power Production in Critical Weather Conditions
Assessment of storm forecast
Offshore Variability in Critical Weather Conditions in Large-Scale Wind Based Danish Power System Project

SIMBA - Simulation of balancing
Simba is based on Danish principles for balancing. Simba models the power system analytically and can therefore model a future power system. Simba is expected to be able to investigate other market structures for ancillary services. Gives valuable information on how to balance the system in the future

Department of Wind Energy
Wind Energy Systems
Risø National Laboratory for Sustainable Energy
Power Fluctuations from Large Offshore Wind Farms

The project has developed and verified simulation and prediction models for power fluctuations in large wind farms. The verification is based on extensive measurements in the two large offshore wind farms in Denmark: Horns Rev and Nysted. The models can also be applied to simulation of wind power fluctuations from wind turbines distributed over a larger area than a wind farm. The advantage of the prediction models is that they can be applied in the operation, but these models require a training period before they work in a new system. On the other hand, the simulation model can simulate power fluctuations with possible future wind power developments, based on information about size and location of the individual wind turbines. Thus, the simulation model is a planning tool.

Department of Wind Energy

Wind Energy Systems

Risø National Laboratory for Sustainable Energy

Department of Applied Mathematics and Computer Science

DONG Energy A/S

Vattenfall A/S

Period: 01/10/2004 → 31/03/2007
Number of participants: 4
Project participant:
Cutululis, Nicolaos Antonio (Intern)
Madsen, Henrik (Intern)
Pinson, Pierre (Intern)
Project Manager, academic:
Sørensen, Poul Ejnar (Intern)

Relations
Publications:
- Fluctuations of offshore wind generation: Statistical modelling
- Regime-switching modelling of the fluctuations of offshore wind generation
- Analysis of the experimental spectral coherence in the Nysted Wind Farm
- Models for assessing power fluctuations from large wind farms
- Power Fluctuations From Large Wind Farms
- Power fluctuations from large offshore wind farms
- Modelling of power fluctuations from large offshore wind farms
- Project