Adequacy of Frequency Reserves for High Wind Power Generation

In this article, a new methodology is developed to assess the adequacy of frequency reserves to handle power imbalances caused by wind power forecast errors. The goal of this methodology is to estimate the adequate volume and speed of activation of frequency reserves required to handle power imbalances caused due to high penetration of wind power. An algorithm is proposed and developed to estimate the power imbalances due to wind power forecast error following activation of different operating reserves. Frequency containment reserve requirements for mitigating these power imbalances are developed through this methodology. Furthermore, the probability of reducing this frequency containment reserve requirement is investigated through this methodology with activation of different volumes and speed of frequency restoration reserve. Wind power generation for 2020 and 2030 scenarios for Continental Europe network are investigated based on which recommendations are made for requirements of frequency reserves in these scenarios. It has been observed through simulations that frequency containment reserve requirements reduce exponentially with increase in volume of frequency restoration reserve and remains almost unaffected by increase activation speed of frequency restoration reserve.
Coordinated control of wind power plants in offshore HVDC grids
During the recent years, there has been a significant penetration of offshore wind power into the power system and this trend is expected to continue in the future. The North Sea in Europe has higher potential for offshore wind power; therefore, the North Seas Countries’ Offshore Grid initiative was formed among nine North Sea countries. They agreed on closer energy cooperation to enable development of an efficient and economic offshore grid infrastructure for advantages, interconnectors based on the voltage source converter based high voltage DC (HVDC) transmission system is being used to exchange power between different countries, and different synchronous areas. It is very likely that they will then be combined with offshore wind power plant (OWPP) connections in the North Sea, transforming it in a multi terminal DC (MTDC) grid and, therefore, in a fully meshed offshore DC grid in near future. However, increased penetration of offshore wind power into the power system poses several challenges to its security. This thesis deals with two main research challenges, (1) Develop, and analyze the coordinated control strategies for AC voltage and reactive power control in the cluster of OWPPs connected to common offshore HVDC station, (2). Develop, analyze, and test the control strategies for ancillary services from OWPPs to the AC grid, mainly fast primary frequency control from OWPPs. Moreover, the impact of wind speed on the frequency control from OWPPs is also studied in this thesis. The main results of this research work show that the OWPPs in the HVDC grid can participate in fast primary frequency control of the power system by using the proposed frequency control methods. Also, wind speed has a significant impact on the frequency control, particularly at below rated wind speeds. The proposed methods for AC voltage and reactive power control can improve the steady state and dynamic AC voltage profile of the offshore AC grid with cluster of OWPPs connected to common HVDC station, while minimizing the active power losses in the offshore AC grid. The research work is carried at the Technical University of Denmark (DTU) in the Department of Wind Energy and it is funded by the People Programme (Marie Curie Actions) of the EU FP7/2007-2013/ under REA grants agreement no. 317221, project title MEDOW.

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Coordinated frequency control from offshore wind power plants connected to multi terminal DC system considering wind speed variation

A coordinated fast primary frequency control scheme from offshore wind power plants (OWPPs) integrated to a three terminal high voltage DC (HVDC) system is proposed in this study. The impact of wind speed variation on the OWPP active power output and thus on the AC grid frequency and DC grid voltage is analysed. The removal of active power support from OWPP after the frequency control action may result in second frequency (and DC voltage) dips. Three different methods to mitigate these secondary effects are proposed, such as, (i) Varying the droop gains of the HVDC converter (ii) Releasing the active power support from OWPP with a ramp rate limiter and (iii) An alternative method for the wind turbine overloading considering rotor speed. The effectiveness of the proposed control scheme is demonstrated on a wind power plant integrated into a three terminal HVDC system developed in DgSILENT PowerFactory. The results show that the proposed coordinated frequency control method performs effectively at different wind speeds and minimises the secondary effects on frequency and DC voltage.

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Facing the challenges of distribution systems operation with high wind power penetration

This paper addresses the challenges associated with the operation of a distribution system with high penetration of wind power. The paper presents some preliminary investigations of an ongoing Danish research work, which has as main objective to reduce the network losses by optimizing the reactive power flow in 60kV distribution networks through controlling the ability of wind power plants (WPPs) to generate or absorb reactive power. This paper aims to understand the characteristics of a distribution network with high penetration of distributed generation. A detailed analysis of the active and reactive power flows in a real distribution network under different wind and load conditions based on actual measurements is performed in order to understand the correlation between the consumption, wind power production, and the network losses. Conclusive remarks are presented, briefly expressing the track for the future work.

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Future defence plan requirements with high penetration of renewable generation

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Impact of Innovation and Places on Corporate Governance the Case of Wind Turbine Production

We examine how corporate governance changes over the industrial life cycle when places commit firms to certain governance structures. Focus is on industries where a significant part of the economic value is created by technological knowledge changing the conditions for corporate financing. The article extends this view to include knowledge needed to accumulate governance capabilities. The board is a crucial governance institution emphasized in the study. We find that changes in this institution depend on shareholders’ concern regarding innovation management. We also find that boards are changed over time to improve the conversational exchange, which is attained by extending the boards with directors holding degrees in engineering. The main finding is that the most successful firms recruit board members from the geographic setting in which they were founded at all stages of the industrial life cycle. The Danish wind turbine industry serves as empirical evidence.

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Impact of Wind Power Plants on Voltage Control of Power System

High penetration of renewable energy sources poses numerous challenges on stability and security of power systems. Wind power plants (WPPs) of considerable size when connected to a weak grid by long transmission line results in low short circuit ratio at the point of connection. This may result in both transient voltage fluctuations and poor steady-state voltage profile at the point of connection. In this paper, transient and steady-state voltage support from WPPs are investigated. Low voltage ride through capability of WPP is studied for two different control modes namely, V control and Q control, during transient voltage dips. Steady-state analysis is performed for stressed system conditions. Results are validated through simulation in a detailed power system model.

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Improved Load Shedding Scheme considering Distributed Generation

With high penetration of distributed generation (DG), the conventional under-frequency load shedding (UFLS) face many challenges and may not perform as expected. This article proposes new UFLS schemes, which are designed to overcome the shortcomings of traditional load shedding scheme. These schemes utilize directional relays, power flow through feeders, wind and PV measurements to optimally select the feeders to be disconnected during load shedding such that DG disconnection is minimized while disconnecting required amount of consumption. These different UFLS schemes are
compared in terms of frequency response, amount of consumption and DG disconnected during load shedding.
International Requirements for Large Integration of Renewable Energy Sources
Most European countries have concerns about the integration of large amounts of renewable energy sources (RES) into electric power systems, and this is currently a topic of growing interest. In January 2008, the European Commission published the 2020 package, which proposes committing the European Union to a 20% reduction in greenhouse gas emissions, to achieve a target of deriving 20% of the European Union's final energy consumption from renewable sources, and to achieve 20% improvement in energy efficiency both by the year 2020 [1]. Member states have different individual goals to meet these overall objectives, and they each need to provide a detailed roadmap describing how they will meet these legally binding targets [2]. At this time, RES are an indispensable part of the global energy mix, which has been partially motivated by the continuous increases in hydropower as well as the rapid expansion of wind and solar photovoltaic (PV). The International Energy Agency's 2012 edition of the World Energy Outlook stated that the rapid increases in RES integration are underpinned by falling technology costs as well as rising fossil fuel prices and carbon pricing, but RES integration is also encouraged by continued subsidies: from $88 billion globally in 2011 (compared to $523 billion in fossil-fuel subsidies in 2012 [3], with a share of $131 billion for electricity generation) to an estimated $240 billion in 2035 [4]. According to [3], in 2015 RES accounted for 22% of electricity generation, which was approximately the same level as gas and about one-half the level of coal.

Real-time impact of power balancing on power system operation with large scale integration of wind power
Highly wind power integrated power system requires continuous active power regulation to tackle the power imbalances resulting from the wind power forecast errors. The active power balance is maintained in real-time with the automatic generation control and also from the control room, where regulating power bids are activated manually. In this article, an algorithm is developed to simulate the activation of regulating power bids, as performed in the control room, during power imbalance between generation and load demand. In addition, the active power balance is also controlled through automatic generation control, where coordinated control strategy between combined heat and power plants and wind power plant enhances the secure power system operation. The developed algorithm emulating the control room response, to deal with real-time power imbalance, is applied and investigated on the future Danish power system model. The power system model takes the hour-ahead regulating power plan from power balancing model and the generation and power exchange capacities for the year 2020 into account. The real-time impact of power balancing in a highly wind power integrated power system is assessed and discussed by means of simulations for different possible scenarios.
Suitable Method of Overloading for Fast Primary Frequency Control from Offshore Wind Power Plants in Multi-Terminal DC Grid

Increased penetration of offshore wind power plants (OWPPs) demands frequency control services from them. Overloading the wind turbine, for few seconds after the under frequency event, to utilize its kinetic energy seems promising option for fast primary frequency control. Two methods of overloading the wind turbine (WT), with and without considering the impact of WT dynamics and variation of WT output power during the overload, are proposed in the literature. In this paper, these two methods are applied for fast primary frequency control from OWPPs connected through multi-terminal DC grid considering the operation of the WT at below rated wind speed. Moreover, the impact of release of overload on the dynamics of the wind turbine, therefore on the associated AC and DC grids are studied in this paper. Finally, the suitable overloading method is proposed based on the simulation and experimental results. The time domain simulations for fast primary frequency control are performed on an OWPP connected through a 3-terminal DC grid using DiGSIILENT PowerFactory. The experiments are performed on OWPP model integrated to a laboratory scale 3-terminal DC grid test set up. Based on the simulations and experimental results, overloading method which considers the variation of WT output power during the overload provides better performance during and after release of the overload.
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.

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Wind Turbine Technologies

The wind turbine technology is a very complex technology involving multidisciplinary and broad technical disciplines such as aerodynamics, mechanics, structure dynamics, meteorology as well as electrical engineering addressing the generation, transmission, and integration of wind turbines into the power system. Wind turbine technology has matured over the years and become the most promising and reliable renewable energy technology today. It has moved very fast, since the early 1980s, from wind turbines of a few kilowatts to today's multimegawatt-sized wind turbines [13]. Besides their size, the design of wind turbines has changed from being convention driven to being optimized driven within the operating regime and market environment. Wind turbine designs have progressed from fixed speed, passive controlled
and with drive trains with gearboxes, to become variable speed, active controlled, and with or without gearboxes, using the latest in power electronics, aerodynamics, and mechanical drive train designs [4]. The main differences between all wind turbine concepts developed over the years, concern their electrical design and control. Today, the wind turbines on the market mix and match a variety of innovative concepts, with proven technology for both generators and power electronics [4]. The continuously increased and concentrated electrical penetration of large wind turbines into electrical power systems inspires the designers to develop both custom generators and power electronics [5,6] and to implement modern control system strategies.

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Compensating active power imbalances in power system with large-scale wind power penetration
Large-scale wind power penetration can affect the supply continuity in the power system. This is a matter of high priority to investigate, as more regulating reserves and specified control strategies for generation control are required in the future power system with even more highwind power penetration. This paper evaluates the impact of large-scale wind power integration on future power systems. An active power balance control methodology is used for compensating the power imbalances between the demand and the generation in real time, caused by windpower forecast errors. The methodology for the balance power control of future power systems with large-scale wind power integration is described and exemplified considering the generation and power exchange capacities in 2020 for Danish power system.

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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 ride through 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 DiGSIENT PowerFactory.

**General information**

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Organisations: Department of Wind Energy, Integration & Planning, Indian Institute of Technology, Guwahati
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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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Frequency control modelling - basics

The purpose of this report is to provide an introduction on how the system balance in an island system can be maintained by controlling the frequency. The power balance differential equation, which is fundamental in understanding the effect on the system frequency of the unbalance between generation and consumption, is addressed. Basic topics on the main components of a generating unit, such as generators, prime movers and governors are presented. A simple dynamic model for an island power system, containing realistic dynamic representations of generators, loads, prime movers, governors, is described specifically for the assessment of the performance of frequency droop control loop, i.e. primary control.

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 the whole wind speed range.
Integration of Renewable Generation in Power System Defence Plans

Increasing levels of penetration of wind power and other renewable generations in European power systems pose challenges to power system security. The power system operators are continuously challenged especially when generations from renewables are high thereby reducing online capacity of conventional controllable generations to minimum. In such operation hours, the system is typically more vulnerable to disturbances in general and major disturbances in particular. This was the case in the major disturbance on 4th November 2006, where the Central European power system was split into 3 areas, one of them being the North East area with high share of wind power generation. The aim of this study is to investigate how renewable generations like wind power can contribute to the power system defence plans. This PhD project “Integration of Renewable Generation in Power System Defence Plans” develops a new methodology to analyse the adequacy of reserves for future power systems with high penetration of windpower generation. This methodology assesses the requirements of frequency restoration reserves in order to contain the power imbalance caused by forecast errors within the designed frequency containment reserves. A set of sensitivity studies of the frequency containment process are performed where reserves are deployed from different power plant technologies including wind turbine. Recommendations for protection and control strategies from windturbines during overfrequency emergency are developed and discussed. Optimal underfrequency load shedding schemes for power systems with high penetration of distributed generation are developed and assessed through simulations. Results show the ability of such schemes to prevent additional load shedding, have minimum generation disconnection and better frequency response

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Introduction to wind power models for frequency control studies
This document covers some basic aspects regarding wind power models, which can be used in power system frequency control studies. Different issues like aerodynamic power, power curve, as well as different wind turbine concepts and their methods to optimize or limit the power extracted from the wind, are thus addressed and briefly discussed.

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Power Oscillation Damping from VSC-HVDC Connected Offshore Wind Power Plants

The implementation of power oscillation damping service on offshore wind power plants connected to onshore grids by voltage-source-converter-based high voltage direct current transmission is discussed. Novel design guidelines for damping controllers on voltage-source converters and wind power plant controllers are derived, using phasor diagrams and a test network model and are then verified on a generic power system model. The effect of voltage regulators is analyzed, which is important for selecting the most robust damping strategy. Furthermore, other often disregarded practical implementation aspects regarding real wind power plants are discussed: 1) robustness against control/communication delays; 2) limitations due to mechanical resonances in wind turbine generators; 3) actual capability of wind power plants to provide damping without curtailing production; and 4) power-ramp rate limiters.
Provision of enhanced ancillary services from wind power plants - Examples and challenges

Emphasis in this article is on the power system impact of wind power plants capability to provide enhanced ancillary services, i.e. temporary frequency response (TFR) and power oscillation damping (POD). The main objective of the article is to analyze and justify the challenges in the use of TFR and POD from wind power plants (WPPs). The study is conducted with an aggregated wind power plant model which is integrated into a generic power system model, specifically designed to assess the targeted ancillary services in a relatively simple, but still relevant environment. Various case studies with different wind power penetration levels are considered. The study shows that WPPs can provide additional control features such as TFR and POD to enhance the stability of power systems with large share of wind power. Nevertheless, the results illustrate that the power system stability can be potentially degraded without careful coordination between WPPs, simultaneously providing TFR or POD in power systems with large displacement of conventional power plants by WPPs. The article provides to TSO new insights into the need for service coordination between WPPs into future power systems.

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Understanding IEC standard wind turbine models using SimPowerSystems

This article describes and exemplifies the IEC 61400-27 generic wind turbine models through an interactive multimedia learning environment - Matlab SimPowerSystems. The article aims help engineers with different backgrounds to get a better understanding of wind turbine dynamics and control by easily conducting different study simulations in the SimPowerSystems platform.

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Understanding IEC standard wind turbine models using SimPowerSystems
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Voltage Control Support and Coordination between Renewable Generation Plants in MV Distribution Systems
This paper focusses on voltage control support and coordination between renewable generation plants in medium voltage distribution systems. An exemplary benchmark grid in Denmark, including a number of flexible ReGen plants providing voltage control functionality, is used as a base case. First, voltage sensitivity analysis is performed to quantify node voltage variations due to injections of reactive power for given operational points of the network. The results are then used to develop an adaptive voltage droop control method, where various droop settings are allocated to each ReGen plant according to the sensitivity indices of corresponding node voltages and the location of respective ReGen plants in the distribution system. Case studies are performed in time-domain to analyze the impact of voltage fluctuations due to active power variations of ReGen plants in order to verify the performance of the obtained voltage droop settings. The main outcome of this study is the provision of a generic guidance on how to coordinate the voltage stability support capabilities of ReGen plants in a distribution system with large ReGen penetration in order to ensure a resilient voltage controlled distribution system.

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Aggregated wind power plant models consisting of IEC wind turbine models
The common practice regarding the modelling of large generation components has been to make use of models representing the performance of the individual components with a required level of accuracy and details. Owing to the rapid increase of wind power plants comprising large number of wind turbines, parameters and models to represent each individual wind turbine in detail makes it necessary to develop aggregated wind power plant models considering the simulation time for power system stability studies. In this paper, aggregated wind power plant models consisting of the IEC 61400-27 variable speed wind turbine models (type 3 and type 4) with a power plant controller is presented. The performance of the detailed benchmark wind power plant model and the aggregated model are compared by means of simulations for the specified test cases. Consequently, the results are summarized and discussed in terms of model accuracy, simulation time and modeling assumptions.

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Authors: Altin, M. (Intern), Göksu, Ö. (Intern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern)
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Control of VSC-HVDC in offshore AC islands with wind power plants: Comparison of two alternatives

The subject of this paper is the control of offshore AC collection and export networks behind a voltage source converter based high voltage direct current transmission system. The inertia-less nature of such grids makes the control of voltages and power flows potentially more flexible, but at the same time more prone to instabilities. Focus in this paper is on a voltage source converter based high voltage direct current connected wind power plant. Two state-of-art controllers for the offshore high voltage direct current converter station are compared, both at no-load and when wind turbine converters are producing power and controlled with usual vector current control. Sensitivity analyses help identify critical factors influencing stability. The influence of lumping the wind power plant into one converter is assessed by comparison with the full model. The conclusions identify the preferred control technique.

Impact of advanced wind power ancillary services on power system

The objective of this report is to illustrate and analyse, by means of simulation test cases, the impact of wind power advanced ancillary services, like inertial response (IR), power oscillation damping (POD) and synchronising power (SP) on the power system. Generic models for wind turbine, wind power plant and power system are used in the investigation.
Bibliographical note
This report is elaborated as part of the work done in the project titled "Enhance ancillary services from wind power" (EaseWind). The project was funded by the Danish TSO as PSO project 2011 no. 10653, and it was carried out in collaboration between Vestas Wind System A/S, DTU Wind Energy, DTU Compute and Aalborg University IET. Vestas Wind System A/S has been the manager of the project. The report has been internally reviewed and approved by Vestas and Aalborg University IET.

Integrating Wind Power Plants Control in Automatic Generation Control

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.
Power system integration of VSC-HVDC connected offshore wind power plants

This report presents an overview of challenges and solutions for the integration into the power system of offshore wind power plants (WPPs) connected to onshore grids through a voltage-source converter based high voltage direct current (VSC-HVDC) transmission system. Aspects that are touched upon are (i) principles for the control of offshore alternating current (AC) networks behind offshore VSC-HVDC converters, (ii) power system services that could be featured by VSC-HVDC connected WPPs and (iii) clustering of multiple WPPs to co-ordinately provide desired control actions. After a brief introduction to justify the study, describe the state-of-art and formulate the project’s objectives, the report is essentially divided into three parts, as follows.

Control principles of offshore AC networks

The control of offshore AC networks relies purely on power electronics, especially if Type 4 wind turbine generators (WTGs) are used. Assuming the WTGs are controlled in a “standard” way (based on established literature), two state-of-art control strategies for the offshore HVDC converter are compared in different operational scenarios: (Option 1) nested voltage-current control scheme based on vector control and (Option 2) direct AC voltage control with addition of active damping. The design of controllers at no-load is discussed, after which Option 2 appears superior. Recommendations for enhanced performance with Option 1 are given. Further analysis is performed when a WPP is connected to the network, highlighting the fact that Option 2’s performance is less dependent on the control parameters than Option 1’s. This could be an advantage, since it may allow for independent design of other elements in the network. On the other hand, it may be disadvantageous, since small room for performance improvement is left. The latter point is somehow confirmed by scenarios where multiple HVDC converters are sharing the control of the network. In this situation, Option 1 with proper active and reactive power droop loops appears superior at a first glance. However, Option 2 seems more easily adaptable to different scenarios. Anyhow, a more complete assessment is necessary for a final conclusion on the absolutely best control scheme.

Power system services

First among the power system services under focus is the control of the AC voltage at the onshore HVDC station. In particular, interesting results are derived in terms of AC voltage control for connection to weak AC networks as well as of load-committed WPPs and new voltage-current control strategies are developed. Furthermore, new sensitivity diagrams in the active power – AC voltage plane are drawn for connection to weak grids, shedding light on some peculiarities such as the non-linearity of the continuous short circuit power contribution from the HVDC station and the importance of using AC voltage control when connecting to weak grids. In terms of long-term voltage stability, the focus is on the HVDC converter behaviour when reaching its current limitation while the network approaches its voltage stability limit. The benefits of not prioritising active power during current-limited operation are demonstrated on a simple system and the possible implications on the control of a WPP potentially connected behind the HVDC converter are discussed. Active power balance control is the second service being analysed in this report. In AC-DC grids, this is linked to the control of AC frequency and DC voltage. The two control services are treated one by one. Since the former has already widely been discussed in literature, focus is on formulating recommendations for real-life implementation of the service, by comparing a communication-based scheme with a communication-less one on a point-to-point VSC-HVDC connection of WPP. For most of the cases, use of communication may be considered the best solution. Other inherent limitations that are observed in WPPs are discussed. DC voltage control is briefly analysed from the standpoint of WPPs, once again taking into account their realistic limitations and their implications for the other players in the control of the DC network. Power oscillation damping (POD) is the last service within the scope of this report. In long-term voltage stability, the POD control of the DC network relies purely on power electronics, especially if Type 4 wind turbine generators (WTGs) are used. Assuming the WTGs are controlled in a “standard” way (based on established literature), two state-of-art control strategies for the offshore HVDC converter are compared in different operational scenarios: (Option 1) nested voltage-current control scheme based on vector control and (Option 2) direct AC voltage control with addition of active damping. The design of controllers at no-load is discussed, after which Option 2 appears superior. Recommendations for enhanced performance with Option 1 are given. Further analysis is performed when a WPP is connected to the network, highlighting the fact that Option 2’s performance is less dependent on the control parameters than Option 1’s. This could be an advantage, since it may allow for independent design of other elements in the network. On the other hand, it may be disadvantageous, since small room for performance improvement is left. The latter point is somehow confirmed by scenarios where multiple HVDC converters are sharing the control of the network. In this situation, Option 1 with proper active and reactive power droop loops appears superior at a first glance. However, Option 2 seems more easily adaptable to different scenarios. Anyhow, a more complete assessment is necessary for a final conclusion on the absolutely best control scheme.

Clustering of wind power plants

The proof of concept of clustering significantly different WPPs is conducted in the last part of the report, demonstrating the possibility of implementing coordinated and synchronised active power control. An experimental validation is used to corroborate part of the results, which also provides support for the validity of some of the simulation results provided earlier. Furthermore, the characteristics of the test devices allow supporting some of the recommendations that are proposed earlier in the report, predominantly with regard to the implementation of POD.

General information

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Authors: Zeni, L. (Intern), Sørensen, P. E. (Intern), Hansen, A. D. (Intern), Hesselbæk, B. (Ekstern), Kjaer, P. C. (Forskerdatabase)
Power system studies of new ancillary services

The objective of this report is to illustrate and analyse, by means of simulation test cases, the impact of wind power advanced ancillary services, like inertial response (IR), power oscillation damping (POD) and synchronising power (SP) on the power system. Generic models for wind turbine, wind power plant and power system are used in the investigation.

Primary reserve studies for high wind power penetrated systems

With high penetration of non-synchronous wind generations replacing conventional generators, the inertia of power system will reduce. A large disturbance in such a power system can cause faster frequency change in this power system and might invoke emergency defence strategies like underfrequency load shedding. The impact of low inertia caused due to displacement of conventional generators by wind penetration on the power system frequency is investigated in this paper. The possibilities of improving frequency with increase in primary reserve supplied from conventional generators are analyzed. This paper further explores the capabilities of wind turbines to provide support during underfrequency to prevent load shedding. Maximum wind penetration possible without causing load shedding following a large disturbance is also investigated.
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.

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Publication: Research › Report – Annual report year: 2015

Analysis of Highly Wind Power Integrated Power System model performance during Critical Weather conditions
Secure power system operation of a highly wind power integrated power system is always at risk during critical weather conditions, e.g. in extreme high winds. The risk is even higher when 50% of the total electricity consumption has to be supplied by wind power, as the case for the future Danish power system in 2020. This paper analyses and compares the performance of the future Danish power system during extreme wind speeds, where wind power plants are either controlled through a traditional High Wind Shut Down storm controller or a new High Wind Extended Production storm controller. For this purpose, the power system model has been developed that represents the relevant dynamic features of power plants and compensates for power imbalances caused by the forecasting error during critical weather conditions. The regulating power plan, as an input time series for the developed power system model, is provided by the hour-ahead power balancing model, i.e. Simulation power Balancing model (SimBa). The regulating power plan is prepared from day-ahead power production plan and hour-ahead wind power forecast. The wind power (forecasts and available) are provided by the Correlated Wind power fluctuations (CorWind) model, where the wind turbine storm controllers are also implemented.

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Organisations: Department of Wind Energy, Wind Energy Systems
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Analysis of the short-term overproduction capability of variable speed wind turbines

Emphasis in this article is on variable speed wind turbines (VSWTs) capability to provide short-term overproduction and better understanding of VSWTs’ mechanical and electrical limits to deliver such support. VSWTs’ short-term overproduction capability is of primary concern for the transmission system operators (TSOs) in the process of restoring critical situations during large frequency excursions in power systems with high wind power penetration.

This study is conducted on a simplified generic model for VSWTs with full scale power converter (Type IV), which includes several adjustments and extensions of the Type IV standard wind turbine model proposed by the IEC Committee in IEC 61400-27-1. This modified standard model is able to account for dynamic features relevant for integrating active power ancillary services in wind power plants, such as frequency support capabilities.

The performance of VSWTs during short-term overproduction is assessed and discussed by means of simulations for different wind speed levels, overproduction percentages and durations. The results show that the capability of VSWTs providing short-term overproduction to the grid strongly depends on the initial pre-overproduction conditions.

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Ancillary services from wind power plants: Research results

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Balancing modern Power System with large scale of wind power

Power system operators must ensure robust, secure and reliable power system operation even with a large scale integration of wind power. Electricity generated from the intermittent wind in large proportion may impact on the control of power system balance and thus deviations in the power system frequency in small or islanded power systems or tie line power flows in interconnected power systems. Therefore, the large scale integration of wind power into the power system strongly concerns the secure and stable grid operation. To ensure the stable power system operation, the evolving power system has to be analysed with improved analytical tools and techniques. This paper proposes techniques for the active power balance control in future power systems with the large scale wind power integration, where power balancing model provides the hour-ahead dispatch plan with reduced planning horizon and the real time imbalances are minimized with automatic generation controller and the programmed to regulate active power reserves.

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.
Coordinated system services from offshore wind power plants connected through HVDC networks

This paper presents an overview of power system services in networks involving multiple onshore power systems, a voltage sourced converter (VSC) based high voltage direct current (HVDC) offshore network and an offshore wind power plant (OWPP). A comprehensive list of services regarding onshore as well as offshore network operation – both AC and DC – will be discussed from a state of the art perspective. Among them, the most interesting have been selected and will be treated in more detail and the main contribution of this paper will be to shed light on the most relevant aspects related to their implementation. For example, new findings on onshore AC voltage control are reported, that help the characterisation of potential AC voltage control that a VSC-HVDC station may offer to an onshore AC grid. The HVDC system behind the VSC-HVDC station may connect, through other converters, to another AC power system, or an OWPP, or both. Moreover, the implementation of power oscillation damping (POD) and HVDC voltage control into an OWPP controller is proposed, discussing the main challenges related to their efficient design. Dynamic control challenges are assessed, in particular in relation to the inherent control and communication delays of OWPPs, and their influence on the successful delivery of the targeted services. Furthermore, it is shown that as an HVDC network increases in size from the point-to-point, the handling of onshore short circuits calls for the proper combination of DC chopper(s) and fast DC voltage control, depending on the specific case. All the treated services are crucial from a transmission operator’s (TSO) perspective, to guarantee stability, security of supply and efficiency. For this reason, the paper proposes a qualitative benchmarking of the HVDC station and, when relevant, its combination with OWPPs, against a conventional power station of comparable size. Consequently it will be pointed out what features will be critical for TSOs when partially or completely replacing conventional units with HVDC stations connected to neighbouring systems and/or OWPPs.

General information

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Demand-Side Contribution to Primary Frequency Control With Wind Farm Auxiliary Control

Maintaining a close balance between power generation and demand is essential for sustaining the quality and reliability of a power system. Currently, due to increased renewable energy generation, frequency deviations and power fluctuations of greater concern are being introduced to the grid, particularly in regions that are weakly interconnected with their surrounding areas, such as small islands. This paper addresses the problem of frequency control in isolated power systems with relevant inclusion of wind power generation. With this aim, we have analyzed the contribution of the demand side to the primary frequency control together with an auxiliary frequency control, which is carried out by variable-speed wind turbines through an additional control loop that synthesizes virtual inertia. We have evaluated both the suitability of these two additional control actions counteracting frequency deviation and their potential reserves and compatibility. The results indicate a substantial improvement in both the dynamic performance and grid frequency stability. Simulations also indicate a decrease in the steady-state frequency error, which may relieve the secondary frequency control.
Type IV Wind Turbine Model

This document is created as part of the EaseWind project. The goal of this project is to develop and investigate new control features for primary response provided by wind power plants. New control features as inertial response, synchronising power and power system damping are of interest to EaseWind project to be incorporated in the wind power plant level.

This document describes the Type 4 wind turbine simulation model, implemented in the EaseWind project. The implemented wind turbine model is one of the initial necessary steps toward integrating new control services in the wind power plant level. In the project, this wind turbine model will be further incorporated in a wind power plant model together with the implementation in the wind power control level of the new control functionalities (inertial response, synchronising power and power system damping). For this purpose an aggregate wind power plant (WPP) will be considered. The aggregate WPP model, which will be based on the upscaling of the individual wind turbine model on the electrical part, will make use of an equivalent wind speed.

The implemented model follows the basic structure of the generic standard Type 4 wind turbine model proposed by the International Electrotechnical Commission (IEC), in the IEC61400-27-1 Committee Draft for electrical simulation models for wind power generation, which is currently under review, [1]. The Type 4 wind turbine model described in this report includes a set of adjustments of the standard Type 4 wind turbine model in order account for the dynamic features of interest to EaseWind project.

The document presents a short overview of the overall structure of the wind turbine model. Descriptions of individual submodels as well as some preliminary simulation results are included to illustrate the performance of the model.

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Type IV Wind Turbine Model

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The implemented model follows the basic structure of the generic standard Type 4 wind turbine model proposed by the International Electrotechnical Commission (IEC), in the IEC61400-27-1 Committee Draft for electrical simulation models for wind power generation, which is currently under review, [1]. The Type 4 wind turbine model described in this report includes a set of adjustments of the standard Type 4 wind turbine model in order account for the dynamic features of interest to EaseWind project.

The document presents a short overview of the overall structure of the wind turbine model. Descriptions of individual submodels as well as some preliminary simulation results are included to illustrate the performance of the model.

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Bibliographical note
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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Wind power integration into the automatic generation control of power systems with large-scale wind power

Transmission system operators have an increased interest in the active participation of wind power plants (WPP) in the power balance control of power systems with large wind power penetration. The emphasis in this study is on the integration of WPPs into the automatic generation control (AGC) of the power system. The present paper proposes a coordinated control strategy for the AGC between combined heat and power plants (CHPs) and WPPs to enhance the security and the reliability of a power system operation in the case of a large wind power penetration. The proposed strategy, described and exemplified for the future Danish power system, takes the hour-ahead regulating power plan for generation and power exchange with neighbouring power systems into account. The performance of the proposed strategy for coordinated secondary control is assessed and discussed by means of simulations for different possible future scenarios, when wind power production in the power system is high and conventional production from CHPs is at a minimum level. The investigation results of the proposed control strategy have shown that the WPPs can actively help the AGC, and reduce the real-time power imbalance in the power system, by down regulating their production when CHPs are unable to provide the required response.
Wind power plant system services

Traditionally, conventional power plants have the task to support the power system, by supplying power balancing services. These services are required by the power system operators in order to secure a safe and reliable operation of the power system. However, as in the future the wind power is going more and more to replace conventional power plants, the sources of conventional reserve available to the system will be reduced and fewer conventional plants will be available on-line to share the regulation burden. The reliable operation of highly wind power integrated power system might then beat risk unless the wind power plants (WPPs) are able to support and participate in power balancing services. The objective of this PhD project is to develop and analyse control strategies which can increase the WPPs capability to provide system services, such as active power balancing control, in a modern power system with large scale integration wind power. This study presents the investigation of the real-time balance control in a modern Danish power system, where WPPs can actively contribute to active power balance control. New solutions for the automatic generation control (AGC) dealing with the compensation of the power imbalances between demand and generation in real time, caused by wind power forecast errors, to enhance the security and the reliability of a power system operation with large wind power penetration with the coordination between combined heat and power plants (CHPs) and WPPs are developed and analysed. The main results of this research work show that the WPPs can actively contribute to power balance control through primary and secondary response. The integration of WPPs control into the AGC is of high relevance, particularly in situations when wind power is contributing highly to the total electricity production and conventional power plants are operating on the minimum level. The grid support services from WPPs improve the active power balance control and make power system operation more reliable.
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.

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An Assessment of Converter Modelling Needs for Offshore Wind Power Plants Connected via VSC-HVDC Networks
Modular multilevel cascaded converter (MMCC) based high voltage direct current (HVDC) transmission is technically superior to other technologies, especially in case of connection of offshore wind power plants (OWPPs). Modelling challenges are faced by OWPP developers, who are not acquainted with detailed information regarding the internal behaviour of such complex devices.
This paper presents an investigation of the modelling requirements of the MMCC HVDC system, based on comparison between simulation results using a detailed HVDC representation in PSCAD/EMTDC and two less detailed models realised in EMT and RMS environments in DiGSIILENT PowerFactory, respectively.
The results show that the simplified EMT/RMS models can be trusted for slow dynamic studies like those related to power control considered in this work. The results obtained from the detailed EMT model highlights the necessity for voltage balancing of the distributed capacitor voltages in the MMCC for both steady state operating conditions and during dynamic events such as step changes in the reference signals.

General information
State: Published
Authors: Glasdam, J. (Ekstern), Zeni, L. (Intern), Hjerrild, J. (Ekstern), Kocewiak, L. (Ekstern), Hesselbaek, B. (Ekstern), Sørensen, P. E. (Intern), Hansen, A. D. (Intern), Bak, C. L. (Ekstern), Kjaer, P. C. (Ekstern)
Number of pages: 6
Publication date: 2013
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.

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Tsinghua University
Authors: Barahona Garzón, B. (Intern), You, R. (Ekstern), Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Sørensen, P. E. (Intern)
Number of pages: 6
Publication date: 2013
Control of wind power plants

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Authors: Sørensen, P. E. (Intern), Hansen, A. D. (Intern), Barahona Garzón, B. (Intern)
Number of pages: 68
Publication date: 2013

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Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
ControlOfPowerPlants.pdf
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Dynamic model of frequency control in Danish power system with large scale integration of wind power
This work evaluates the impact of large scale integration of wind power in future power systems when 50% of load demand can be met from wind power. The focus is on active power balance control, where the main source of power imbalance is an inaccurate wind speed forecast. In this study, a Danish power system model with large scale of wind power is developed and a case study for an inaccurate wind power forecast is investigated. The goal of this work is to develop an adequate power system model that depicts relevant dynamic features of the power plants and compensates for load generation imbalances, caused by inaccurate wind speed forecast, by an appropriate control of the active power production from power plants.

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Authors: Basit, A. (Intern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern)
Number of pages: 5
Publication date: 2013

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Title of host publication: China Wind Power (CWP) conference 2013
Main Research Area: Technical/natural sciences
Conference: China Wind Power (CWP) conference, Beijing, China, 16/10/2013 - 16/10/2013
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Dynamic_model_of_frequency_control.pdf
Source: dtu
Source-ID: u::9800
Publication: Research - peer-review › Article in proceedings – Annual report year: 2013

Grid support capabilities of wind turbines
Wind power has gained a significant penetration level in several power systems all over the world. Due to this reason modern wind turbines are requested to contribute to power system support. Power system operators have thus introduced grid codes, which specify a set of requirements for wind turbines, such as fault ride-through and reactive power supply during voltage sags. To date different wind turbine concepts exist on the market comprising different control features in order to provide ancillary services to the power system. In the first place the present chapter emphasizes the most important issues related to wind power grid integration. Then different wind turbine concepts are characterized and their grid support capabilities are analysed and compared. Simulation cases are presented in which the respective wind turbine concepts are subjected to a voltage dip specified in a grid code.
This paper presents a state-of-the-art review on grid integration of large offshore wind power plants (OWPPs) using high voltage direct voltage (HVDC) for grid connection. The paper describes in detail selected challenges hereto and presents how DONG Energy Wind Power (DEWP) is addressing these challenges through three coordinated PhD projects in close collaboration with leading academia within the field. The overall goal of these projects is to acquire in-depth knowledge of relevant operating phenomena in the offshore OWPP grid, rich with power electronics devices (PEDs) such as the HVDC and the PED widely used in the wind turbine generators (WTGs). Challenges hereto include PED control system interaction (from a stability point of view), assessment of the quality of vendor supplied control systems and their robustness against e.g. short circuits and load rejection. Furthermore, the outcome of the projects will be developed and validated models of e.g. the HVDC system, methodologies for assessment of control system stability and fault identification in implemented control system.

Influence of current limitation on voltage stability with voltage sourced converter HVDC
A first study of voltage stability with relevant amount of Voltage Sourced Converter based High Voltage Direct Current (VSC-HVDC) transmission is presented, with particular focus on the converters’ behaviour when reaching their rated current. The detrimental effect of entering the current limitation on the Power-Voltage (PV) curves at a load bus is exemplified on a three-bus system, proposing a method to model the converters in current limiting mode through ideal current sources. The influence of the current magnitude and angle on the reduced stability margin is analysed and results
show that, when the current limit is reached, despite the detrimental effect brought about by an increased equivalent transmission impedance, the loss of stability margin can be minimised by proper control of the converter.

General information
State: Published
Authors: Zeni, L. (Intern), Jóhannsson, H. (Intern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Hesselbæk, B. (Ekstern), Kjær, P. C. (Ekstern)
Number of pages: 5
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Title of host publication: 2013 IEEE PES Innovative Smart Grid Technologies Conference Europe
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Main Research Area: Technical/natural sciences
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DOIs: 10.1109/ISGTEurope.2013.6695271

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Projects:
Influence of current limitation on voltage stability with voltage sourced converter HVDC
Influence of current limitation on voltage stability with voltage sourced converter HVDC
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Publication: Research - peer-review › Article in proceedings – Annual report year: 2013

Methods for Representations of Wind Power Plants for Active Power Studies

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Authors: Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Altin, M. (Intern)
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ISBN (Print): 978-3-9813870-7-0
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Wind power, Forecast errors, Control storm event
Links: http://www.windintegrationworkshop.org/london2013/
Publication: Research - peer-review › Article in proceedings – Annual report year: 2013

Simplified Type 4 wind turbine modeling for future ancillary services

General information
State: Published
Authors: Hansen, A. D. (Intern), Margaris, I. (Intern), Tamowski, G. C. (Ekstern), Iov, F. (Ekstern)
Number of pages: 1
Publication date: 2013
Event: Poster session presented at European Wind Energy Conference & Exhibition 2013, Vienna, Austria.
Main Research Area: Technical/natural sciences
Electronic versions: Simplified_type_4_poster.pdf
Virtual inertia for variable speed wind turbines

Inertia provision for frequency control is among the ancillary services that different national grid codes will likely require to be provided by future wind turbines. The aim of this paper is analysing how the inertia response support from a variable speed wind turbine (VSWT) to the primary frequency control of a power system can be enhanced. Unlike fixed speed wind turbines, VSWTs do not inherently contribute to system inertia, as they are decoupled from the power system through electronic converters. Emphasis in this paper is on how to emulate VSWTs inertia using control of the power electronic converter and on its impact on the primary frequency response of a power system. An additional control for the power electronics is implemented to give VSWTs a virtual inertia, referring to the kinetic energy stored in the rotating masses, which can be released initially to support the system’s inertia. A simple Matlab/Simulink model and control of a VSWT and of a generic power system are developed to analyse the primary frequency response following different generation losses in a system comprising VSWTs provided with virtual inertia. The possibility of substituting a 50% share of conventional power with wind is also assessed and investigated. The intrinsic problems related to the implementation of virtual inertia are illustrated, addressing their origin in the action of pitch and power control. A solution is proposed, which aims at obtaining the same response as for the system with only conventional generation. The range of wind speeds near the power limitation zone seems to be the most critical from a primary response point of view. The theoretical reasons behind this are elucidated in the paper. Copyright © 2012 John Wiley & Sons, Ltd.
A Review of Grid Requirements for Wind Farm in Denmark and China

Large integration of wind power in modern power systems sets new challenges in power system operation raising serious concerns on issues related to dynamic security, stability and reliability of the system. In addition to this, replacement of conventional power plants by wind power plants of similar size increases the risk of system failures. Nowadays, these new challenges in the power systems operation have resulted in continuous revision of the grid codes for wind power plants by the system operators in order to facilitate high penetration levels of wind power in a secure and reliable way. This paper presents an overview of the main technical issues related to the interconnection of large wind power into the grid as well as the main requirements adopted by the system operators in modern grid codes in order to allow large integration of wind power into the power system while ensuring the security and the reliability of the power system. Emphasis in the paper is on the grid requirements in Denmark and China regarding regulation of active power, regulation of reactive power and low voltage ride through capability.

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Authors: Basit, A. (Intern), Hansen, A. D. (Intern), Margaris, I. (Intern), Hansen, J. C. (Intern)
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Main Research Area: Technical/natural sciences
Electronic versions:
A_Review_of_Grid_Requirements.pdf
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Source-ID: u:6023
Publication: Research - peer-review › Journal article – Annual report year: 2012

Frequency Control In Autonomous Power Systems With High Wind Power Penetration

This paper presents an investigation on wind turbine (WT) contribution to the frequency control of noninterconnected island systems. The capability of WTs to participate in the primary frequency control and offer primary reserve is discussed. The investigation includes both transient frequency support (inertial response) and permanent frequency response (droop characteristic), as well as the combined application of these concepts. A quantitative analysis is
presented for the expected benefits and drawbacks of each method, including the appropriate selection of their parameters. The power system of Rhodes Island has been selected as a study case, which includes different types of conventional generation and the three basic WT types, based on Active-Stall Induction Generator (ASIG), Doubly Fed Induction Generator (DFIG), and Permanent Magnet Synchronous Generator (PMSG).

General information
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, National Technical University of Athens
Authors: Margaris, I. D. (Intern), Papathanassiou, S. A. (Ekstern), Hatzigryiou, N. D. (Ekstern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern)
Pages: 189-199
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Main Research Area: Technical/natural sciences

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Scopus rating (2012): SJR 1.355 SNIP 3.731 CiteScore 6.58
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Source: dtu
Source-ID: n::oai:DTIC-ART:iel/363141875::15300
Publication: Research - peer-review › Journal article – Annual report year: 2012

Generic Models of Wind Turbine Generators for Advanced Applications in a VSC-based Offshore HVDC Network
This paper focuses on generic Type 4 wind turbine generators models, their applicability in modern HVDC connections and their capability to provide advanced ancillary services therefrom. A point-to-point HVDC offshore connection is considered. Issues concerning coordinated HVDC and wind farm control as well as the need of a communication link are discussed. Two possible control configurations are presented and compared. The first is based on a communication link transmitting the onshore frequency directly to the wind power plant, while the second makes use of a coordinated control scheme involving the HVDC converters. The performance against frequency disturbances of the two presented configurations is assessed and discussed by means of simulations.

General information
State: Published
This paper presents the implementation of the generic wind turbine generator (WTG) electrical simulation models proposed in the IEC 61400-27 standard which is currently in preparation. A general overview of the different WTG types is given while the main focus is on Type 4B WTG standard models, namely a model for a variable speed wind turbine with full scale power converter WTG including a 2-mass mechanical model. The generic models for fixed and variable speed WTGs models are suitable for fundamental frequency positive sequence response simulations during short events in the power system such as voltage dips. The general configuration of the models is presented and discussed; model implementation and results are provided in order to illustrate the range of applicability of the generic models under discussion.

Inertial response from wind turbines: the impact on structural loads
This work 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.
Inertial response from wind turbines: the impact on structural loads

This work 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 assessed 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: 1
Publication date: 2012
Event: Poster session presented at EWEA 2012 - European Wind Energy Conference & Exhibition, Copenhagen, Denmark.
Main Research Area: Technical/natural sciences
EWEA 2012
Electronic versions:
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Publication: Research - peer-review › Poster – Annual report year: 2012

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
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Aeroelastic Design
Authors: Barahona Garzón, B. (Intern), Sørensen, P. E. (Intern), Hansen, A. M. (Intern), Hansen, A. D. (Intern), Cutululis, N. A. (Intern)
Number of pages: 155
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Introduction to frequency control modeling

General information
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Organisations: Department of Wind Energy, Wind Energy Systems
Authors: Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Margaris, I. (Intern), Zeni, L. (Intern)
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Publication: Research › Report – Annual report year: 2012

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

Publication information
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Remote sensing and measurement technique
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Cutululis_AncillaryServicesWindFarmsx_1_.pdf
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Source-ID: 276099
Publication: Research › Sound/Visual production (digital) – Annual report year: 2011

Dynamic security issues in autonomous power systems with increasing wind power penetration
Technical requirements set by the network operators nowadays include various aspects, such as fault ride-through capability of wind turbines during faults, voltage-reactive power control and overall control of the wind farms as conventional power plants. Detailed models for the power system as well as for the wind farms are therefore essential for power system studies related to these issues, especially when applied to non interconnected systems with high wind power penetration. Detailed generic models for three different wind turbine technologies – Active Stall Induction Generator (ASIG), Doubly Fed Asynchronous Generator (DFAG) and Permanent Magnet Synchronous Generator (PMSG) – are applied and issues regarding interaction with the power system are investigated. This paper provides conclusions about the dynamic security of non-interconnected power systems with high wind power penetration based on a complete model representation of the individual components of the system; three different types of conventional generators are included in the model, while the protection system is also incorporated. The load shedding following faults is finally discussed.

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, National Technical University of Athens
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 DlgsILENT 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 sequentially 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 rainflow 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.
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.

**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.
Model Development for Power System Analysis with a Substantial Wind Energy Capacity Installed in the Nordic grid

The worldwide development of wind power installations now includes planning and construction of large-scale wind farms ranging in magnitudes of 1000 MW and more. As part of the planning and design of such systems, it is well established that the transient and dynamic stability of the electrical power system needs to be studied. Modelling work of the electrical behaviour of wind turbines and wind farms as well as model validation by measurements have been important parts of this project work. The models have been used to study dynamic phenomena during normal operation and fault occasions in the electric system. Fault Ride Through (FRT) measurements have been carried out on new wind parks connected to Estonian power grid and in all of them FRT tests were made. In several wind parks the tests were not successful and the tests will be repeated. In Finland measurements have carried out in 6 MW Högåsa wind farm. Measurement results from real scale tests of frequency control were presented in the project, where different amount of fluctuating wind power were injected into a power system. The allowed limit for system power fluctuation was shown, which is given by the acceptable variation on grid frequency. Results show a strong dependency on the wind turbine operational states as well as on wind speed conditions. Nevertheless it is important to consider the underproduction power and the associated large recovery period that follow a Variable Speed Wind Turbines overproduction operation. Current has work has been carried out to integrate marked and network models. This has been done either directly in the optimization algorithms of the marked model, such as for Samlast, Samnet or PSST, or by providing algorithms and functionality for converting the result of the marked model into a full detailed power flow description. For the PSST (Power System Simulation Tool), which optimizes power flow by minimizing the cost of generation and assumes a perfect market with nodal pricing, focus has been on interpreting the result establishing time series of area prices as well as including power losses in the model. By cooperation within the Nordic countries the existing knowledge has been spread, new knowledge has been created and the results have been transferred to utilities. Over 35 journal or conference publications and five PhD-theses have been presented. Two more PhD theses are on the way next during 2011. Two Nordic Wind Power Conferences have been organized during the project period.

General information
State: Published
Organisations: Electric Energy Systems, Department of Electrical Engineering, Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Chalmers University of Technology, VTT - Technical Research Centre of Finland, Norwegian University of Science and Technology, SINTEF, Tallinn University of Technology
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Wind power, Wind turbine models, Electricity network, Electric system models
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Operation and Control of Wind Farms in Non-Interconnected Power Systems

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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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Research Developments on Power System Integration of Wind Power

This paper presents an overview on the recent research activities and tendencies regarding grid integration of wind power in Denmark and some related European activities, including power electronics for enhancing wind power controllability, wind turbines and wind farms modeling, wind power variability and prediction, wind power plant ancillary services, grid connection and operation, Smart grids and demand side management under market functionality. The topics of the first group of PhD program starting 2011 under the wind energy Sino-Danish Centre for Education & Research (SDC) are also mentioned.

General information
State: Published
Authors: Chen, Z. (Ekstern), Hansen, J. C. (Intern), Wu, Q. (Intern), Hansen, A. D. (Intern), Bak-Jensen, B. (Ekstern)
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Coupling of HAWC2 and Matlab: Towards an Integrated Simulation Platform

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Authors: Barahona Garzon, B. (Intern), Henriksen, L. C. (Intern), Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Serensen, P. E. (Intern)
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Dynamic security issues of autonomous power systems with increasing wind power penetration

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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

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Wind power control and integration, Wind energy
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Dynamic security_EWEC2010presentation.pdf
Source: orbit
Source-ID: 269417
Publication: Research › Article in proceedings – Annual report year: 2010

Evaluation of power control with different electrical and control concept of wind farm: Part 2 – Large systems
This report investigates the impact of wind power in large power systems. The motivation for this investigation is the ever-increasing wind energy penetration into the power systems throughout the world. A generic large power system model delivered by the Danish Transmission System Operator EnergiNet.dk is used in the presented study cases.

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. D. (Intern)
Number of pages: 92
Publication date: 2010

Publication information
Publisher: Project UpWind
Original language: English
Main Research Area: Technical/natural sciences
Wind power measurement and integration, Wind energy
Electronic versions:
UpWind part 2.pdf
Source: orbit
Source-ID: 270786
Publication: Research › Report – Annual report year: 2010

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 doublyfed 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.
Illustration of Modern Wind Turbine Ancillary Services

Increasing levels of wind power penetration in modern power systems has set intensively high standards with respect to wind turbine technology during the last years. Security issues have become rather critical and operation of wind farms as conventional power plants is becoming a necessity as wind turbines replace conventional units on the production side. This article includes a review of the basic control issues regarding the capability of the Doubly Fed Induction Generator (DFIG) wind turbine configuration to fulfill the basic technical requirements set by the system operators and contribute to power system security. An overview of ancillary services provided by wind turbine technology nowadays is provided, i.e., fault ride-through capability, reactive power supply and frequency-active power control.
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.632 SNIP 1.345 CiteScore 2.29
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.874 SNIP 1.54 CiteScore 2.46
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.659 SNIP 1.439 CiteScore 2.24
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.303 SNIP 0.76
Original language: English
Wind power control and integration, Wind energy
Electronic versions:
energies_03_01290.pdf
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10.3390/en3061290

Bibliographical note
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Source: orbit
Source-ID: 265035
Publication: Research - peer-review › Journal article – Annual report year: 2010

Impact of fault ride-through requirements on wind turbine structural loads

General information
State: Published
Authors: Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Barahona Garzon, B. (Intern), Markou, H. (Intern)
Publication date: 2010

Host publication information
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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
Electronic versions:
Hansen_poster_ewec_2010.pdf
Hansen_paper_ewec_2010.pdf
Source: orbit
Source-ID: 262243
Publication: Research › Article in proceedings – Annual report year: 2010

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
Source-ID: 270614
Modelling and control of variable speed wind turbines for power system studies

Modern wind turbines are predominantly variable speed wind turbines with power electronic interface. Emphasis in this paper is therefore on the modelling and control issues of these wind turbine concepts and especially on their impact on the power system. The models and control are developed and implemented in the power system simulation tool DlgSILENT. Important issues like the fault ride-through and grid support capabilities of these wind turbine concepts are addressed. The paper reveals that advanced control of variable speed wind turbines can improve power system stability. Finally, it will be shown in the paper that wind parks consisting of variable speed wind turbines can help nearby connected fixed speed wind turbines to ride-through grid faults. Copyright © 2009 John Wiley & Sons, Ltd.
Evaluation of power control with different electrical and control concept of wind farm: Part 1 – small island grid

This report investigates the impact of wind power in non interconnected power systems with increasing wind power penetration. Issues such as power fluctuations, short circuits and FRT capability of wind turbines and frequency control support are under focus. The study case of Rhodes power system is used to simulate the response of the system in various scenarios.

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)
Number of pages: 139
Publication date: 2009

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
Integrated Design of Wind Power Systems: - DIGSILENT/MATLAB Dynamic Simulation

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Sørensen, P. E. (Intern), Barahona Garzon, B. (Intern)
Number of pages: 370
Pages: 97-105
Publication date: 2009

Host publication information
Title of host publication: Proceedings of SIMS 50
Publisher: Technical University of Denmark. Department of Mechanical Engineering
ISBN (Print): 978-87-89502-88-5
Main Research Area: Technical/natural sciences
Conference: 50th International Conference of Scandinavian Simulation Society, Fredericia, Denmark, 07/10/2009 - 07/10/2009
Wind energy systems, Wind energy
Source: orbit
Source-ID: 251417
Publication: Research - peer-review › Article in proceedings – Annual report year: 2009

Integrated Design of Wind Power Systems: MATLAB - HAWC2 Interface

General information
State: Published
Authors: Barahona Garzon, B. (Intern), Andersen, P. B. (Intern), Hansen, A. D. (Intern), Cutululis, N. A. (Intern), Sørensen, P. E. (Intern)
Number of pages: 370
Pages: 107-113
Publication date: 2009

Host publication information
Title of host publication: Proceedings of SIMS 50
Publisher: Technical University of Denmark. Department of Mechanical Engineering
ISBN (Print): 978-87-89502-88-5
Main Research Area: Technical/natural sciences
Conference: 50th International Conference of Scandinavian Simulation Society, Fredericia, Denmark, 07/10/2009 - 07/10/2009
Integrated electrical design of DFIG wind turbines for power system studies

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), Iov, F. (Ekstern), Barahona Garzon, B. (Intern)
Publication date: 2009

Host publication information
Title of host publication: Future Energy - Bornholm
Publisher: IDA, Steering Group on Future Energy - Bornholm
Main Research Area: Technical/natural sciences

Investigating power control in autonomous power systems with increasing wind power penetration

General information
State: Published
Authors: Margaris, I. (Intern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Hatzigiou, N. (Ekstern)
Number of pages: 740
Pages: 545-552
Publication date: 2009

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Title of host publication: Proceedings
Publisher: Energynautics GmbH
Editors: Betancourt, U., Ackermann, T.
Main Research Area: Technical/natural sciences
Workshop: 8th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Farms, Bremen, Germany, 14/10/2009 - 14/10/2009

Multi-pole permanent magnet synchronous generator wind turbines' grid support capability in uninterrupted operation during grid faults

Emphasis in this paper is on the fault ride-through and grid support capabilities of multi-pole permanent magnet synchronous generator (PMSG) wind turbines with a full-scale frequency converter. These wind turbines are announced to be very attractive, especially for large offshore wind farms. A control strategy is presented, which enhances the fault ride-through and voltage support capability of such wind turbines during grid faults. Its design has special focus on power converters' protection and voltage control aspects. The performance of the presented control strategy is assessed and discussed by means of simulations with the use of a transmission power system generic model developed and delivered by the Danish Transmission System Operator Energinet.dk. The simulation results show how a PMSG wind farm equipped with an additional voltage control can help a nearby active stall wind farm to ride through a grid fault, without implementation of any additional ride-through control strategy in the active stall wind farm.

General information
State: Published
Variable Speed (DFIG) Wind Turbines: Rapid Frequency Response to Power System Disturbances

This paper examines the effect of integrating large number of wind turbines particularly the double fed induction generator (DFIG) on the virtual inertia of the Danish power system network. The virtual inertia refers to the kinetic energy stored in the rotating masses which can be released initially to counteract the frequency change during a power system disturbance. Simulation studies have been carried out on a generic reduced model of a transmission power grid of the Danish TSO Energinet.dk to assess the impact of loss of generation on system frequency. Further, simulation study has been carried out for different scenarios to assess the impact of reduction in capacity of the traditional power plants and also to assess the impact of increased wind power penetration.

General information
State: Published
Authors: Chandrashekhara, D. K. (Intern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Østergaard, J. (Intern)
Publication date: 2009

Host publication information
Title of host publication: EWEC’08
Main Research Area: Technical/natural sciences
Conference: 2008 European Wind Energy Conference and Exhibition, Brussels, Belgium, 31/03/2008 - 31/03/2008
Wind energy systems, Wind energy
Links:
Source: orbit
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Publication: Research - peer-review › Article in proceedings – Annual report year: 2009

Wind farm Control with Power System Support

General information
State: Published
Organisations: Wind Energy Division, Wind Energy Systems, Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. D. (Intern)
Publication date: 2009

Publication information
Original language: English
Main Research Area: Technical/natural sciences
Wind energy systems, Wind energy
Electronic versions:
3Hansen_presentation.pdf
Source: orbit
Source-ID: 256860
Publication: Research › Sound/Visual production (digital) – Annual report year: 2009
Ecogrid.dk Phase 1 WP4 report: New measures for integration of large scale renewable energy

General information
State: Published
Publication date: 2008

Publication information
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi
Main Research Area: Technical/natural sciences
Electronic versions:
EcoGrid.dk - WP4 Report Measures.pdf
Source: orbit
Source-ID: 224237
Publication: Research › Report – Annual report year: 2008

Grid faults impact on the mechanical loads of active stall wind turbine

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Cutululis, N. A. (Intern), Hansen, A. D. (Intern), Iov, F. (Ekstern), Sørensen, P. E. (Intern)
Pages: 234-240
Publication date: 2008

Host publication information
Title of host publication: Proceedings (CD-ROM)
Place of publication: Galati
Publisher: Dunarea de Jos University of Galati
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 231687
Publication: Research › Article in proceedings – Annual report year: 2008

Modelling and control of variable-speed multi-pole permanent magnet synchronous generator wind turbine

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Technical University of Darmstadt
Authors: Hansen, A. D. (Intern), Michalke, G. (Ekstern)
Pages: 537-554
Publication date: 2008
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Energy
Volume: 11
Issue number: 5
ISSN (Print): 1095-4244
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
Modelling and fault ride-through capability of a full converter wind turbine with multi-pole PMSG

General information
Variable speed wind turbines - fault ride-through and grid support capabilities

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Michalke, G. (Ekstern), Hansen, A. D. (Intern), Hartkopf, T. (Ekstern)
Publication date: 2008

Host publication information
Title of host publication: Conference proceedings (online)
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Conference: 2008 European Wind Energy Conference and Exhibition, Brussels, Belgium, 31/03/2008 - 31/03/2008
Source: orbit
Source-ID: 232730
Publication: Research › Article in proceedings – Annual report year: 2008

Variable speed wind turbines - Modeling, control and impact on power systems

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Michalke, G. (Ekstern), Hansen, A. D. (Intern), Hartkopf, T. (Ekstern)
Pages: 100-104
Publication date: 2008

Host publication information
Title of host publication: Scientific proceedings
Place of publication: Brussels
Publisher: European Wind Energy Conference and Exhibition
Main Research Area: Technical/natural sciences
Conference: 2008 European Wind Energy Conference and Exhibition, Brussels, Belgium, 31/03/2008 - 31/03/2008
Source: orbit
Source-ID: 223063
Publication: Research - peer-review › Article in proceedings – Annual report year: 2008

Wind turbines structural loads during fault ride-through operation

General information
State: Published
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
Publication date: 2008

Host publication information
Title of host publication: Scientific proceedings
Place of publication: Brussels
Publisher: European Wind Energy Conference and Exhibition
Advanced induction machine model in phase coordinates for wind turbine applications

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Fajardo, L. (Ekstern), Iov, F. (Ekstern), Hansen, A. D. (Intern), Blaabjerg, F. (Ekstern)
Pages: 1189-1194
Publication date: 2007

Host publication information
Title of host publication: Proceedings
Volume: Vol. 2
Place of publication: Piscataway, NJ
Publisher: IEEE
Main Research Area: Technical/natural sciences
Conference: 2007 IEEE International Electric Machines and Drives Conference, Antalya, Turkey, 03/05/2007 - 03/05/2007
DOI: 10.1109/IEMDC.2007.383599
Source: orbit
Source-ID: 215492
Publication: Research › Article in proceedings – Annual report year: 2007

A Reduced Wind Power Grid Model for Research and Education

A reduced grid model of a transmission system with
a number of central power plants, consumption centers, local
wind turbines and a large offshore wind farm is developed and
implemented in the simulation tool PowerFactory (DlgsILENT).
The reduced grid model is given by Energinet.dk, Transmission
System Operator of Denmark (TSO) for Natural Gas and
Electricity, to the Danish Universities and the Risø National
Laboratory. Its intended usage is education and studying of
interaction between electricity-producing wind turbines and a
realistic transmission system. Focus in these studies is on voltage
stability issues and on the ride-through capability of different
wind turbine concepts, equipped with advanced controllers,
developed by the Risø National Laboratory.

General information
State: Published
Organisations: Department of Electric Power Engineering, Electric Power Engineering, Department of Electrical
Engineering, Department of Wind Energy, Integration & Planning
Authors: Akhmatov, V. (Intern), Lund, T. (Intern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Nielsen, A. H. (Intern)
Pages: 173-180
Publication date: 2007

Host publication information
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Transmission Networks for Offshore Wind Farms
Place of publication: Delft
Publisher: TU Delft
Editors: Hendriks, R., Ummels, B., Ackermann, T.
Main Research Area: Technical/natural sciences
Workshop: 6th International Workshop on Large-Scale Integration of Wind Power and Transmission Networks for Offshore
Wind Farms, Delft, Netherlands, 26/10/2006 - 26/10/2006
Electronic versions:
Torsten Lund A Reduced Wind Power Grid Model for Research and Education.pdf
Source: orbit
Source-ID: 192390
A survey of interconnection requirements for wind power

General information
State: Published
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
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
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1624(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
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Source: orbit
Source-ID: 215853
Publication: Research › Article in proceedings – Annual report year: 2007

Control of a wind park with doubly fed induction generators in support of power system stability in case of grid faults

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Wind Energy Systems
Authors: Michalke, G. (Ekstern), Hansen, A. D. (Intern), Hartkopf, T. (Ekstern)
Number of pages: 6
Publication date: 2007

Host publication information
Title of host publication: Conference proceedings (online)
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 216360
Publication: Research › Article in proceedings – Annual report year: 2007

Control strategy of a variable speed wind turbine with multipole permanent magnet synchronous generator

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Wind Energy Systems
Authors: Michalke, G. (Ekstern), Hansen, A. D. (Intern), Hartkopf, T. (Ekstern)
Number of pages: 8
Publication date: 2007

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Title of host publication: Conference proceedings (online)
Co-ordinated voltage control of DFIG wind turbines in uninterrupted operation during grid faults

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. D. (Intern), Michalke, G. (Ekstern), Sørensen, P. E. (Intern), Lund, T. (Intern), Iov, F. (Ekstern)
Pages: 51-68
Publication date: 2007
Main Research Area: Technical/natural sciences

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Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.37 SJR 1.104 SNIP 2.306
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.196 SNIP 2.086 CiteScore 3.06
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.272 SNIP 3.75 CiteScore 3.42
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.275 SNIP 2.464 CiteScore 2.75
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.126 SNIP 2.39 CiteScore 2.36
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.024 SNIP 2.718 CiteScore 2.49
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
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
BFI (2008): BFI-level 2
Dynamic behaviour of a DFIG wind turbine subjected to power system faults

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Wind Energy Systems
Authors: Michalke, G. (Ekstern), Hansen, A. D. (Intern), Hartkopf, T. (Ekstern)
Number of pages: 6
Publication date: 2007

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Title of host publication: Conference proceedings (online)
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Links:

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 Risø-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

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Source: orbit
Source-ID: 216697
Publication: Research - peer-review › Journal article – Annual report year: 2007

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 Risø-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.

**General information**

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)
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Publication date: 2007

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Series: Denmark. Forskningscenter Risoe. Risoe-R
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ISSN: 0106-2840
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Electronic versions: ris_r_1400_ed2.pdf
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**

State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Aeroelastic Design
Authors: Cutululis, N. A. (Intern), Larsen, T. J. (Intern), Sørensen, P. E. (Intern), Iov, F. (Ekstern), Hansen, A. D. (Intern)
Number of pages: 35
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Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1587(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Electronic versions: ris_r_1587.pdf
Source: orbit
Source-ID: 215535
Publication: Research › Report – Annual report year: 2007
Fault ride-through and voltage support of permanent magnet synchronous generator wind turbines

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Michalke, G. (Ekstern), Hansen, A. D. (Intern), Hartkopf, T. (Ekstern)
Number of pages: 7
Publication date: 2007

Host publication information
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
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1624(EN)
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Main Research Area: Technical/natural sciences
Risø-R-1624, Risø-R-1624(EN)
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Publication: Research › Article in proceedings – Annual report year: 2007

Fault ride-through capability of DFIG wind turbines

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. D. (Intern), Michalke, G. (Ekstern)
Pages: 1594-1610
Publication date: 2007
Main Research Area: Technical/natural sciences
Publication information
Journal: Renew. Energy
Volume: 32
Original language: English
DOI:
10.1016/j.renene.2006.10.008
Source: orbit
Source-ID: 216688
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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

Host publication information
Title of host publication: Proceedings : Nordic wind power conference (NWPC 2007)
Publisher: Risø National Laboratory
Induction generator model in phase coordinates for fault ride-through capability studies of wind turbines

**General information**

**State:** Published  
**Organisations:** Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy  
**Authors:** Fajardo, L. (Ekstern), Iov, F. (Ekstern), Medina, R. (Ekstern), Hansen, A. D. (Intern), Blaabjerg, F. (Ekstern)  
**Publication date:** 2007  
**Host publication information**

**Title of host publication:** Proceedings  
**Publisher:** EPE  
**ISBN (Print):** 978-90-7581-510-8  
**Main Research Area:** Technical/natural sciences  
**Conference:** 12th European Conference on Power Electronics and Applications, Aalborg, Denmark, 02/09/2007 - 02/09/2007  
**Source:** orbit  
**Source-ID:** 215449  
**Publication:** Research › Article in proceedings – Annual report year: 2007

Mapping of grid faults and grid codes

**General information**

**State:** Published  
**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)  
**Publication date:** 2007  
**Publication information**

**Publisher:** Risø National Laboratory  
**ISBN (Print):** 978-87-550-3622-2  
**Original language:** English  
**Series:** Denmark. Forskningscenter Risoe. Risoe-R  
**Number:** 1617(EN)  
**ISSN:** 0106-2840  
**Main Research Area:** Technical/natural sciences  
**Risø-R-1617, Risø-R-1617(EN)  
**Electronic versions:**  
ris_r_1617.pdf  
**Source:** orbit  
**Source-ID:** 216240  
**Publication:** Research › Report – Annual report year: 2007

Market penetration of different wind turbine concepts over the years
Power balancing control with large-scale wind power penetration 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.

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.
Power System Operation with Large Scale Wind Power Integration

The Danish power system starts to face problems of integrating thousands megawatts of wind power, which produce in a stochastic behavior due to natural wind fluctuations. With wind power capacities increasing, the Danish Transmission System Operator (TSO) is faced with new challenges related to the uncertain nature of wind power. In this paper, proposed models of generations and control system are presented which analyze the deviation of power exchange at the western Danish-German border, taking into account the fluctuating nature of wind power. The performance of the secondary control of the thermal power plants and the spinning reserves control from the Combined Heat and Power (CHP) units to achieve active power balance with the increased wind power penetration is presented.

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Suwannarat, A. (Ekstern), Bak-Jensen, B. (Ekstern), Chen, Z. (Ekstern), Nielsen, H. (Ekstern), Hjerrild, J. (Ekstern), Sørensen, P. E. (Intern), Hansen, A. D. (Intern)
Pages: 671-676
Publication date: 2007

Host publication information
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Volume: 1-5
Publisher: IEEE
ISBN (Print): 978-1-4244-2189-3
Main Research Area: Technical/natural sciences
Conference: IEEE Lausanne Powertech, Lausanne, 01/01/2007
DOIs: 10.1109/PCT.2007.4538396
Source: orbit
Source-ID: 236904
Publication: Research - peer-review › Article in proceedings – Annual report year: 2007

Regelung eines Windparks mit doppelt gespeisten Asynchronmaschinen zur Unterstützung der Netzstabilität im Fehlerfall

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Michalke, G. (Ekstern), Hansen, A. D. (Intern), Hartkopf, I. (Ekstern)
Pages: 165-172
Publication date: 2007

Host publication information
Title of host publication: Innovations for Europe. Band 2: Fachtagungsberichte der ETG-GMA-DGBMT
Place of publication: Berlin
Publisher: VDE Verlag
ISBN (Print): 978-3-8007-2979-1
Main Research Area: Technical/natural sciences
Conference: VDE Kongress 2006, Aachen (DE), 01/01/2006
Source: orbit
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Publication: Research › Article in proceedings – 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
Switching transients in wind farm grids

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Wind Energy Systems
Authors: Sørensen, P. E. (Intern), Hansen, A. D. (Intern), Serensen, T. (Ekstern), Nielsen, C. (Ekstern), Nielsen, H. (Ekstern), Christensen, L. (Ekstern), Ulletved, M. (Ekstern)
Number of pages: 6
Publication date: 2007

Voltage grid support of DFIG wind turbines during grid faults

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Wind Energy Systems
Authors: Hansen, A. D. (Intern), Michalke, G. (Ekstern)
Pages: 93-97
Publication date: 2007

Wind turbine concept market penetration over 10 years (1995-2004)

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. D. (Intern), Hansen, L. (Ekstern)
Pages: 81-97
Publication date: 2007
Main Research Area: Technical/natural sciences
Centralised power control of wind farm with doubly fed induction generators

At the moment, the control ability of wind farms is a prime research concern for the grid integration of large wind farms, due to their required active role in the power system. This paper describes the on-going work of a research project, whose overall objective is to analyse and assess the possibilities for control of different wind farm concepts. The scope of this paper is the control of a wind farm made up exclusively of doubly fed induction generators. The paper addresses the design and implementation issues of such a controller and focuses on the ability of the wind farm control strategy to regulate the wind farm power production to the reference power ordered by the system operators. The presented wind farm control has a hierarchical structure with both a central control level and a local control level. The central wind farm control level controls the power production of the whole farm by sending out reference power signals to each individual wind turbine, while the local wind turbine control level ensures that the reference power signal sent by the central control level is reached. The performance of the control strategy is assessed and discussed by means of simulations illustrated both at the wind farm level and at each individual wind turbine level. (c) 2005 Elsevier Ltd. All rights reserved.

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division
Authors: Hansen, A. (Intern), Sørensen, P. E. (Intern), Iov, F. (Ekstern), Blaabjerg, F. (Ekstern)
Pages: 935-951
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: Renewable Energy
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Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 4.83 SJR 1.697 SNIP 2.044
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.845 SNIP 2.118 CiteScore 4.51
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.983 SNIP 2.687 CiteScore 4.51
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.066 SNIP 2.767 CiteScore 4.63
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.852 SNIP 2.745 CiteScore 3.97
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.688 SNIP 2.404 CiteScore 3.9
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.494 SNIP 2.215
Controller design and analysis of a variable speed wind turbine with doubly-fed induction generator

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Gail, G. (Ekstern), Hansen, A. (Intern), Hartkopf, T. (Ekstern)
Publication date: 2006

Host publication information
Title of host publication: Proceedings (online)
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 309896
Publication: Research › Article in proceedings – Annual report year: 2006

Grid support of a wind farm with active stall wind turbines and AC grid connection

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Iov, F. (Ekstern), Blaabjerg, F. (Ekstern)
Pages: 341-359
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Energy
Volume: 9
Modeling of wind farm controllers

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. (Intern), Iov, F. (Ekstern), Blaabjerg, F. (Ekstern)
Publication date: 2006

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Title of host publication: Proceedings (online)
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Links:
Source: orbit
Source-ID: 309198
Publication: Research › Article in proceedings – Annual report year: 2006

Modelling, analysis and control of DC-connected wind farms to grid

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Iov, F. (Ekstern), Hansen, A. (Intern), Sørensen, P. E. (Intern), Blaabjerg, F. (Ekstern)
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: International Review of Electrical Engineering
Issue number: Feb., 10 p.
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Ratings:
Scopus rating (2016): SJR 0.556 SNIP 0.556 CiteScore 0.97
Scopus rating (2015): SJR 0.384 SNIP 0.387 CiteScore 0.59
Scopus rating (2014): SJR 0.469 SNIP 0.503 CiteScore 0.68
Scopus rating (2013): SJR 0.373 SNIP 0.711 CiteScore 0.93
ISI indexed (2013): ISI indexed yes
Scopus rating (2012): SJR 0.32 SNIP 0.529 CiteScore 1.49
ISI indexed (2012): ISI indexed yes
Scopus rating (2011): SJR 0.306 SNIP 0.975 CiteScore 2.07
ISI indexed (2011): ISI indexed no
Scopus rating (2010): SJR 0.261 SNIP 0.269
Scopus rating (2009): SJR 0.15 SNIP 0.252
Web of Science (2009): Indexed yes
Original language: English
Source: orbit
Source-ID: 309895
Publication: Research - peer-review › Journal article – Annual report year: 2006

Modelling and control of VSC based DC connection for active stall wind farms to grid

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Iov, F. (Ekstern), Sørensen, P. E. (Intern), Hansen, A. (Intern), Blaabjerg, F. (Ekstern)
Pages: 622-629
Publication date: 2006
Power control of a wind farm with active stall wind turbines and AC grid connection (paper and poster)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Wind Energy, Integration & Planning
Regelung eines Windparks mit doppelt gespeisten Asynchronmaschinen zur Unterstützung der Netzstabilität im Fehlerfall

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Michalke, G. (Ekstern), Hansen, A. D. (Intern), Hartkopf, I. (Ekstern)
Pages: 4-7
Publication date: 2006
Main Research Area: Technical/natural sciences

Publication information
Journal: ETG Mitgliederinformation
Issue number: 2
Original language: German
Source: orbit
Source-ID: 216133
Publication: Communication › Journal article – Annual report year: 2007

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
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Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.37 SJR 1.104 SNIP 2.306
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.196 SNIP 2.086 CiteScore 3.06
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.272 SNIP 3.75 CiteScore 3.42
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.275 SNIP 2.464 CiteScore 2.75
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.126 SNIP 2.39 CiteScore 2.36
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.024 SNIP 2.718 CiteScore 2.49
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
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
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 0.826 SNIP 1.559
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.053 SNIP 1.453
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
DOIs:
10.1002/we.194
Source: orbit
Source-ID: 309513
Publication: Research - peer-review › Journal article – Annual report year: 2006

Terræn-modellering med CFD

General information
State: Published
Organisations: Wind Energy Systems, Wind Energy Division, Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. D. (Intern)
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 309728
Publication: Research › Conference abstract for conference – Annual report year: 2006

Wind power plants - Wind power installations with grid support

General information
Advanced tools for modeling, design and optimization of wind turbine systems

As wind turbine technology and control has advanced over the last decade, this has led to a high penetration of wind turbines into the power system. Whether it be for a large wind turbine or an offshore wind farm with hundreds of MW power capacity, the electrical system has become more and more important in controlling the interaction between the mechanical system of the wind turbine and the main power system. The presence of power electronics in wind turbines improves their controllability with respect not only to its mechanical loads but also to its power quality [1]. This paper presents an overview of a developed simulation platform for the modeling, design and optimization of wind turbines. The ability to simulate the dynamic behavior of wind turbines and the wind turbine grid interaction using four simulation tools (Matlab, Saber, DiGSIlENT and HAWC) is investigated, improved and extended.

General information

State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Systems, Wind Energy Division
Authors: Iov, F. (Ekstern), Hansen, A. (Intern), Jauch, C. (Ekstern), Sørensen, P. E. (Intern), Blaabjerg, F. (Ekstern)
Pages: 83-98
Publication date: Apr 2005
Main Research Area: Technical/natural sciences

Publication information

Journal: Journal of Power Electronics
Volume: 5
Issue number: 2
ISSN (Print): 1598-2092
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
Scopus rating (2016): SJR 0.321 SNIP 0.639 CiteScore 1.27
Scopus rating (2015): SJR 0.334 SNIP 0.678 CiteScore 1.19
Scopus rating (2014): SJR 0.371 SNIP 0.888 CiteScore 1.09
Scopus rating (2013): SJR 0.389 SNIP 0.823 CiteScore 1.24
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Scopus rating (2012): SJR 0.361 SNIP 0.806 CiteScore 1.21
ISI indexed (2012): ISI indexed yes
Scopus rating (2011): SJR 0.354 SNIP 0.833 CiteScore 1.2
ISI indexed (2011): ISI indexed no
Scopus rating (2010): SJR 0.374 SNIP 0.354
Scopus rating (2009): SJR 0.54 SNIP 1.336
Original language: English
Source: orbit
Source-ID: 308106
Publication: Research - peer-review › Journal article – Annual report year: 2005
Centralised control of wind farm with doubly-fed induction generators

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Wind Energy, Integration & Planning
Authors: Hansen, A. (Intern), Sørensen, P. E. (Intern), Iov, F. (Ekstern), Blaabjerg, F. (Ekstern)
Pages: 845-850
Publication date: 2005

Host publication information
Title of host publication: Proceedings (CD-ROM)
Place of publication: Nürnberg
Publisher: ZM Communications GmbH
Main Research Area: Technical/natural sciences
Conference: International exhibition and conference for power electronics intelligent motion power quality (PCIM Europe 2005), Nuremberg (DE), 7-9 Jun, 01/01/2005
Source: orbit
Source-ID: 308107
Publication: Research › Article in proceedings – Annual report year: 2005

Computational wind power meteorology in complex terrain compared to measurements (poster)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division
Authors: Jørgensen, B. (Intern), Hansen, A. (Intern), Myllerup, L. (Intern), Sørensen, N. N. (Intern), Mann, J. (Intern), Ott, S. (Intern), Badger, J. (Intern)
Publication date: 2005

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Title of host publication: Proceedings CD-ROM
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 307866
Publication: Research › Article in proceedings – Annual report year: 2005

Control design for a pitch-regulated, variable speed wind turbine

General information
State: Published
Authors: Hansen, M. (Intern), Hansen, A. D. (Intern), Larsen, T. J. (Intern), Øye, S. (Ekstern), Sørensen, P. (Ekstern), Fuglsang, P. (Ekstern)
Number of pages: 84
Publication date: 2005

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Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1500(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1500, Risø-R-1500(EN)
Electronic versions:
ris_r_1500.pdf
Source: orbit
Source-ID: 307794
Development of wind turbine technology

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. (Intern), Krogh, T. (Intern)
Pages: 45-62
Publication date: 2005

Host publication information
Title of host publication: Ten year review of the international wind power industry 1995-2004
Place of publication: Ringkøbing
Publisher: BTM Consult ApS
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 308499
Publication: Research - peer-review › Book chapter – Annual report year: 2005

Grid connection of active stall wind farms using a VSC based DC transmission system

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Risø National Laboratory for Sustainable Energy
Authors: Iov, F. (Ekstern), Sørensen, P. E. (Intern), Hansen, A. (Intern), Blaabjerg, F. (Ekstern)
Publication date: 2005

Host publication information
Title of host publication: Proceedings
Publisher: EPE Association
ISBN (Print): 90-75815-08-5
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 309991
Publication: Research › Article in proceedings – Annual report year: 2005

Initial results of local grid control using wind farms with grid support

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. D. (Intern), Iov, F. (Ekstern), Blaabjerg, F. (Ekstern)
Number of pages: 24
Publication date: 2005

Publication information
ISBN (Print): 87-550-3466-7
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1529(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1529, Risø-R-1529(EN)
Electronic versions: ris_r_1529.pdf
Source: orbit
Source-ID: 308508
Publication: Research › Report – Annual report year: 2005
Reduced models of doubly fed induction generator system for wind turbine simulations

This article compares three reduced models with a detailed model of a doubly fed induction generator system for wind turbine applications. The comparisons are based on simulations only. The main idea is to provide reduced generator models which are appropriate to simulate normal wind turbine operation in aeroelastic wind turbine models, e.g. for control system design or structural design of the wind turbine. The electrical behaviour such as grid influence will therefore not be considered. The work presented in this article shows that with an ideal, undisturbed grid the dynamics of the doubly fed induction generator system is very well represented by the dynamics due to the generator inertia and the generator control system, whereas the electromagnetic characteristics of the generator can be represented by the steady state relations. The parameters for the proposed models are derived from parameters typically available from the generator data sheet and from the controller settings. Thus the models are simple to apply in any case where the generator data sheet is available.
Simulation and optimisation of wind farm controllers

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. (Ekstern), Hansen, A. (Intern), Thomsen, K. (Intern), Madsen, H. (Ekstern), Nielsen, H. (Ekstern), Poulsen, N. (Ekstern), Iov, F. (Ekstern), Blaabjerg, F. (Ekstern), Okkels, B. (Ekstern)
Publication date: 2005
Wind farm controllers with grid support

General information
State: Published
Authors: Sørensen, P. E. (Intern), Hansen, A. D. (Intern), Thomsen, K. (Intern), Madsen, H. (Intern), Nielsen, H. A. (Intern), Poulsen, N. K. (Intern), Lov, F. (Ekstern), Bkaabjerg, F. (Ekstern), Donovan, M. H. (Ekstern)
Pages: 157-166
Publication date: 2005

Host publication information
Title of host publication: Proceedings of the 5th International Workshop on Large-Scale Integration of Wind Power and Transmission Networks for Offshore Wind Farms
Place of publication: Stockholm
Publisher: Royal Institute of Technology
Editors: Ackermann, T., Matevosyan, J.
Main Research Area: Technical/natural sciences
Workshop: 5th International Workshop on Large-Scale Integration of Wind Power and Transmission Networks for Offshore Wind Farms, Glasgow, United Kingdom, 07/04/2005 - 07/04/2005
Links:
http://www2.imm.dtu.dk/pubdb/p.php?3643
Source: orbit
Source-ID: 185751
Publication: Research - peer-review › Article in proceedings – Annual report year: 2005

Wind farm models and control strategies

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. D. (Intern), Iov, F. (Ekstern), Blaabjerg, F. (Ekstern), Donovan, M. (Ekstern)
Number of pages: 63
Publication date: 2005

Publication information
ISBN (Print): 87-550-3322-9
Original language: English
Advanced tools for modeling, design and optimization of wind turbine systems

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Wind Energy, Integration & Planning
Authors: Iov, F. (Ekstern), Hansen, A. (Intern), Jauch, C. (Intern), Sørensen, P. E. (Intern), Blaabjerg, F. (Ekstern)
Number of pages: 12
Publication date: 2004

Host publication information
Title of host publication: Grid integration and electrical systems of wind turbines and wind farms (CD-ROM)
Place of publication: Göteborg
Publisher: Chalmers tekniska högskola
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 306623
Publication: Research - peer-review › Article in proceedings – Annual report year: 2004

A new Matlab/Simulink toolbox for wind turbine applications

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Iov, F. (Ekstern), Hansen, A. (Intern), Blaabjerg, F. (Ekstern)
Pages: 19-24
Publication date: 2004

Host publication information
Title of host publication: Proceedings
Place of publication: Søborg
Publisher: COMSOL A/S
ISBN (Print): 87-989426-0-3
Main Research Area: Technical/natural sciences
Conference: Nordic MATLAB Conference, Copenhagen, Denmark, 21/10/2003 - 21/10/2003
Source: orbit
Source-ID: 306659
Publication: Research › Article in proceedings – Annual report year: 2004

Computational wind power meteorology in complex terrain compared to measurements (poster)

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division
Authors: Jørgensen, B. (Intern), Hansen, A. (Intern), Myllerup, L. (Intern), Sørensen, N. N. (Intern), Mann, J. (Intern), Ott, S. (Intern), Badger, J. (Intern)
Publication date: 2004
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 307419
Publication: Research › Poster – Annual report year: 2004
Control strategies of wind turbines during normal operation

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Wind Energy, Integration & Planning
Authors: Sørensen, P. E. (Intern), Hansen, A. D. (Intern), Jauch, C. (Intern)
Publication date: 2004
Event: Abstract from ESB course on wind turbine technology, Dublin (IE), 30-31 Oct, .
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 306661
Publication: Research › Conference abstract for conference – Annual report year: 2004

Dynamic wind turbine models in power system simulation tool DigSILENT

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. (Intern), Jauch, C. (Ekstern), Sørensen, P. E. (Intern), Iov, F. (Ekstern), Blaabjerg, F. (Ekstern)
Number of pages: 80
Publication date: 2004

Publication information
ISBN (Print): 87-550-3198-6
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1400(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1400, Risø-R-1400(EN)
Electronic versions:
ris_r_1400.pdf
Source: orbit
Source-ID: 306591
Publication: Research › Report – Annual report year: 2004

Generators and power electronics for wind turbines

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. (Intern)
Pages: 53-78
Publication date: 2004

Host publication information
Title of host publication: Wind power in power systems
Place of publication: Chichester
Publisher: Wiley
Editor: Ackermann, T.
ISBN (Print): 0-470-85508-8
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 307688
Publication: Research - peer-review › Book chapter – Annual report year: 2004

Modelling and control of wind turbines in DigSILENT power factory

General information
Overall control strategy of variable speed doubly-fed induction generator wind turbine

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Wind Energy, Integration & Planning
Authors: Hansen, A. (Intern), Iov, F. (Ekstern), Sørensen, P. E. (Intern), Blaabjerg, F. (Ekstern)
Publication date: 2004
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 306660
Publication: Research › Conference abstract for conference – Annual report year: 2004

Review of contemporary wind turbine concepts and their market penetration

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. (Intern), Iov, F. (Ekstern), Blaabjerg, F. (Ekstern), Hansen, L. (Ekstern)
Pages: 247-263
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Engineering
Volume: 28
ISSN (Print): 0309-524X
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.267 SNIP 0.515 CiteScore 0.58
Simulation and optimisation of wind farm controllers

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. (Intern), Thomsen, K. (Intern)
Publication date: 2004
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 307686

Simulation model of an active-stall fixed-speed wind turbine controller

General information
Simulation platform to model, optimize and design wind turbines

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Aalborg University
Authors: Iov, F. (Ekstern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Blaabjerg, F. (Ekstern)
Number of pages: 45
Publication date: 2004

Publication information
Place of publication: Aalborg
Publisher: Aalborg University
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 306677
Publication: Research - peer-review › Report – Annual report year: 2004

Transienter i vindmølleparker. Simulering af transiente forhold på nettet ved vindmølleparker

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Bak-Jensen, B. (Ekstern), Nielsen, H. (Ekstern), Sørensen, P. (Ekstern), Hansen, A. (Intern), Bech, J. (Ekstern), Mieritz, M. (Ekstern), Christensen, P. (Ekstern)
Pages: 33-35
Publication date: 2004
Main Research Area: Technical/natural sciences

Publication information
Journal: Elteknik
Issue number: 4
Original language: English
Source: orbit
Source-ID: 307235
Publication: Communication › Journal article – Annual report year: 2004

Wind turbine blockset in Matlab/simulink. General overview and description of the models

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Aalborg University
Authors: Iov, F. (Ekstern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Blaabjerg, F. (Ekstern)
Number of pages: 108
Publication date: 2004

Publication information
Place of publication: Aalborg
Publisher: Aalborg University
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 306676
Publication: Research - peer-review › Report – Annual report year: 2004

Wind turbine blockset in Saber. General overview and description of the models
This report presents a new developed Saber Toolbox for wind turbine applications. This toolbox has been developed during the research project “Simulation Platform to model, optimize and design wind turbines”. The report provides a quick overview of the Saber and then explains the structure of this simulation package, which is different than other tools e.g. Matlab/Simulink. Then the structure of the toolbox is shown as well as the description of the developed models. The main focus here is to underline the special structure of the models, which are a mixture of Saber built-in blocks and new developed blocks. Since the developed models are based on Saber built-in blocks, a description of the libraries from Saber is given. Then some simulation results using the developed models are shown. Finally some general conclusions
regarding this new developed Toolbox as well as some directions for future work are made.

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Aalborg University
Authors: Iov, F. (Ekstern), Timbus, A. V. (Ekstern), Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Blaabjerg, F. (Ekstern)
Number of pages: 41
Publication date: 2004

Publication information
Place of publication: Aalborg
Publisher: Aalborg University
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
model_Wind_Turbine_Blockset.pdf
Source: orbit
Source-ID: 306675
Publication: Research - peer-review › Report – Annual report year: 2004

A case study regarding influence of solvers in Matlab/Simulink for induction machine model in wind turbine simulations

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Wind Energy, Integration & Planning
Authors: Iov, F. (Ekstern), Blaabjerg, F. (Ekstern), Hansen, A. (Intern), Sørensen, P. E. (Intern), Chen, Z. (Ekstern)
Publication date: 2003
Main Research Area: Technical/natural sciences

Bibliographical note
Book series: TRITA-ETS-2002-8
Publisher: Royal Institute of Technology
Source: orbit
Source-ID: 304696
Publication: Research › Paper – Annual report year: 2003

Analysis of a variable-speed wind energy conversion scheme with doubly-fed induction generator

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Iov, F. (Ekstern), Hansen, A. (Intern), Blaabjerg, F. (Ekstern)
Pages: 779-794
Publication date: 2003
Main Research Area: Technical/natural sciences

Publication information
Journal: International Journal of Electronics
Volume: 90
ISSN (Print): 0020-7217
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.279 SNIP 0.67 CiteScore 0.73
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.209 SNIP 0.411 CiteScore 0.57
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.254 SNIP 0.606 CiteScore 0.59
Analysis of reduced order models for large wound-rotor induction generators in wind turbine applications

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Authors: Iov, F. (Ekstern), Hansen, A. (Intern), Blaabjerg, F. (Ekstern), Larsen, T. J. (Intern)
Publication date: 2003

Host publication information
Title of host publication: Proceedings (on CD-ROM)
Place of publication: [s.l.]
Publisher: s.n.
Main Research Area: Technical/natural sciences
Conference: 40th International Intelligent Motion Conference, Nürnberg, Germany, 20/05/2003 - 20/05/2003
Source: orbit
Source-ID: 305591
Publication: Research › Article in proceedings – Annual report year: 2003

A new simulation platform to model, optimize and design wind turbines

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Wind Energy, Integration & Planning
Authors: Iov, F. (Ekstern), Blaabjerg, F. (Ekstern), Chen, Z. (Ekstern), Hansen, A. (Intern), Sørensen, P. E. (Intern)
Publication date: 2003
Comparison of simulations of transient events in wind power installations

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. (Intern), Mieritz, M. (Ekstern), Christensen, P. (Ekstern), Bech, J. (Ekstern), Bak-Jensen, B. (Ekstern), Nielsen, H. (Ekstern)
Pages: 483-488
Publication date: 2003

Initialisation of grid-connected wind turbine models in power-system simulations

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Wind Energy, Integration & Planning
Authors: Hansen, A. (Intern), Sørensen, P. E. (Intern), Iov, F. (Ekstern), Blaabjerg, F. (Ekstern)
Pages: 21-28
Publication date: 2003
Main Research Area: Technical/natural sciences
Modeling of soft-starters for wind turbine applications

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Iov, F. (Ekstern), Hansen, A. (Intern), Blaabjerg, F. (Ekstern), Teodorescu, R. (Ekstern)
Publication date: 2003

Host publication information
Title of host publication: Procedings (on CD-ROM)
Place of publication: [s.l.]
Publisher: s.n.
Main Research Area: Technical/natural sciences
Conference: 40th International Intelligent Motion Conference, Nürnberg, Germany, 20/05/2003 - 20/05/2003
Source: orbit
Source-ID: 305590
Publication: Research › Article in proceedings – Annual report year: 2003

Simulation and verification of transient events in large wind power installations

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. D. (Intern), Christensen, P. (Ekstern), Mieritz, M. (Ekstern), Bech, J. (Ekstern), Bak-Jensen, B. (Ekstern), Nielsen, H. (Ekstern)
Number of pages: 80
Publication date: 2003

Publication information
Comparative study of different implementations for induction machine model in Matlab/Simulink for wind turbine simulations

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Iov, F. (Ekstern), Blaabjerg, F. (Ekstern), Hansen, A. (Intern), Chen, Z. (Ekstern)
Publication date: 2002
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 305940
Publication: Research › Report – Annual report year: 2003

Dynamic modelling of wind farm grid interaction

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning
Authors: Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Blaabjerg, F. (Ekstern), Bech, J. (Ekstern)
Pages: 191-208
Publication date: 2002
Main Research Area: Technical/natural sciences

Publication information
Journal: Wind Engineering
Volume: 26
ISSN (Print): 0309-524X
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.267 SNIP 0.515 CiteScore 0.58
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.369 SNIP 0.632 CiteScore 0.63
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.412 SNIP 1 CiteScore 0.78
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.382 SNIP 1.105 CiteScore 0.62
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.325 SNIP 1.095 CiteScore 0.56
ISI indexed (2012): ISI indexed no
Dynamic models for interaction between wind turbines and power systems

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. (Intern), Blaabjerg, F. (Ekstern), Bech, J. (Ekstern)
Pages: 327-332
Publication date: 2002

Host publication information
Title of host publication: Power and energy systems
Place of publication: Anaheim
Publisher: ACTA Press
Editors: Smedley, K., Karady, G., Koval, D., Edris, A.
ISBN (Print): 0-88986-326-1
Main Research Area: Technical/natural sciences
Conference: IASTED International Conference, Marina del Rey, CA, United States, 13/05/2002 - 13/05/2002
Source: orbit
Source-ID: 304041
Publication: Research - peer-review › Article in proceedings – Annual report year: 2002

Models for simulation of transient events in a wind farm (poster)

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. (Intern), Bindner, H. (Intern), Christensen, P. (Ekstern), Mieritz, M. (Ekstern), Bech, J. (Ekstern), Bak-Jensen, B. (Ekstern), Nielsen, H. (Ekstern)
Publication date: 2002

Host publication information
Title of host publication: Proceedings CD-ROM
Place of publication: Brussels
Publisher: European Wind Energy Association (EWEA)
Simulation of dynamic impact of wind farm on power system

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. (Intern), Janosi, L. (Ekstern), Bech, J. (Ekstern), Blaabjerg, F. (Ekstern), Bak-Jensen, B. (Ekstern), Chen, Z. (Ekstern)
Pages: 145-150
Publication date: 2002

Host publication information
Title of host publication: Large scale integration into the grid
Volume: FOI-S-0219
Place of publication: Stockholm
Publisher: FOI Swedish Defence Research Agency
Editor: Thor, S.
Main Research Area: Technical/natural sciences
Conference: 36. IEA topical expert meeting, Newcastle (GB), Nov, 01/01/2001
Source: orbit
Source-ID: 303738
Publication: Research › Article in proceedings – Annual report year: 2002

Simulation of interaction between wind farm and power system

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. D. (Intern), Janosi, L. (Ekstern), Bech, J. (Ekstern), Bak-Jensen, B. (Ekstern)
Number of pages: 65
Publication date: 2002

Publication information
ISBN (Print): 87-550-2912-4
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1281(EN)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1281, Risø-R-1281(EN)
Electronic versions:
ris_r_1281.pdf
Source: orbit
Source-ID: 303768
Publication: Research › Report – Annual report year: 2002

Wind models for simulation of power fluctuations from wind farms

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. (Intern), Rosas, P. (Ekstern)
Pages: 1381-1402
Publication date: 2002
Main Research Area: Technical/natural sciences

Publication information
Electrical components, control strategies and grid integration

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. (Intern)
Publication date: 2001
Event: Abstract from Risø Course: From wind to power, Copenhagen, Denmark.
Main Research Area: Technical/natural sciences

Elektrisk modellering af vindkraftværker

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. (Intern)
Publication date: 2001
Main Research Area: Technical/natural sciences

Hybrid power systems with photovoltaics and wind power

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Bindner, H. (Intern), Hansen, A. (Intern)
Number of pages: 51
Publication date: 2001

Hybrid power systems with photovoltaics and wind power

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Bindner, H. (Intern), Hansen, A. (Intern)
Number of pages: 51
Publication date: 2001

Host publication information
Title of host publication: Wind Energy Department: Scientific and technical progress 1999-2000
Volume: Risø-R-1239(EN)
Editors: Skrumsager, B., Larsen, G.
ISBN (Print): 87-550-2818-7
Main Research Area: Technical/natural sciences
Links:
http://www.risoe.dtu.dk/rispubl/VEA/veapdf/ris-r-1239.pdf
Source: orbit
Source-ID: 303260
Publication: Research - peer-review › Book chapter – Annual report year: 2001

Models for a stand-alone PV system

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. (Intern), Sørensen, P. E. (Intern), Hansen, L. (Ekstern), Bindner, H. W. (Intern)
Number of pages: 76
Publication date: 2001

Publication information
ISBN (Print): 87-550-2774-1
Original language: English
Series: Denmark. Forskningscenter Risoe. Risoe-R
Power plant characteristics of wind farms

**General information**
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Bak-Jensen, B. (Ekstern), Kristiansen, J. (Ekstern), Hansen, A. (Intern), Janosi, L. (Ekstern), Bech, J. (Ekstern)
Pages: 176-179
Publication date: 2001

**Host publication information**
Title of host publication: Proceedings (on CD-ROM)
Place of publication: München
Publisher: WIP - Renewable Energies
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 302375
Publication: Research - peer-review › Article in proceedings – Annual report year: 2001

Simulation of 12MW wind farm

**General information**
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Department of Wind Energy, Integration & Planning
Authors: Janosi, L. (Ekstern), Blaabjerg, F. (Ekstern), Bak-Jensen, B. (Ekstern), Hansen, A. (Intern), Sørensen, P. E. (Intern), Bech, J. (Ekstern)
Publication date: 2001

**Host publication information**
Title of host publication: Proceedings (on CD-ROM)
Place of publication: [s.l.]
Publisher: [s.n.]
Main Research Area: Technical/natural sciences
Conference: 9. European conference on power electronics and applications (EPE 2001), Graz (AT), 27-29 Aug, 01/01/2001
Source: orbit
Source-ID: 303054
Publication: Research - peer-review › Article in proceedings – Annual report year: 2001

Simulation of wind farm interaction with grid

**General information**
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. (Intern), Janosi, L. (Ekstern), Bak-Jensen, B. (Ekstern), Blaabjerg, F. (Ekstern), Bech, J. (Ekstern)
Pages: 1003-1006
Publication date: 2001

**Host publication information**
Title of host publication: Wind energy for the new millennium. Proceedings
Place of publication: München
Wind energy and windmills

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. (Intern)
Publication date: 2001
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 303205
Publication: Research › Conference abstract for conference – Annual report year: 2001

Wind farm modelling for power quality

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning
Authors: Hansen, A. D. (Intern), Sørensen, P. E. (Intern), Janosi, L. (Ekstern), Bech, J. (Ekstern)
Pages: 1959-1964
Publication date: 2001
Host publication information
Title of host publication: Proceedings (on CD-ROM)
Place of publication: Stoughton, WI
Publisher: Printing House Inc.
ISBN (Print): 0-7803-7110-0
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 303294
Publication: Research - peer-review › Article in proceedings – Annual report year: 2001

Wind models for prediction of power fluctuations from wind farms

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Hansen, A. (Intern), Rosas, P. (Ekstern)
Pages: 9-18
Publication date: 2001
Main Research Area: Technical/natural sciences
Publication information
Journal: J. Wind Eng.
Issue number: 89
Original language: English
Source: orbit
Source-ID: 303055
Publication: Research - peer-review › Conference article – Annual report year: 2001
Power plant characteristics of wind farms

General information
State: Published
Organisations: Department of Wind Energy, Integration & Planning, Risø National Laboratory for Sustainable Energy
Authors: Sørensen, P. E. (Intern), Bak-Jensen, B. (Ekstern), Kristensen, J. (Ekstern), Hansen, A. (Intern), Janosi, L. (Ekstern), Bech, J. (Ekstern)
Publication date: 2000
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 301517
Publication: Research › Conference abstract for conference – Annual report year: 2000

Vindmøller

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. (Intern)
Publication date: 2000
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 301575
Publication: Research › Conference abstract for conference – Annual report year: 2000

Dobbelt styrbar vindmølle - focus på det kritiske reguleringsområde omkring maksimal produktion

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. (Intern)
Publication date: 1999
Event: Abstract from Temadag: Vindkraft i elforsyningen - tekniske muligheder, Risø (DK), 29 Apr. 
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 299328
Publication: Research › Conference abstract for conference – Annual report year: 1999

Improving transition between power optimization and power limitation of variable speed/variable pitch wind turbines

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. (Intern), Bindner, H. (Intern), Rebsdorf, A. (Ekstern)
Pages: 889-892
Publication date: 1999
Event: Wind energy for the next millennium. Proceedings
Place of publication: London
Publisher: James and James Science Publishers
Editors: Petersen, E., Hjuler Jensen, P., Rave, K., Helm, P., Ehmann, H.
ISBN (Print): 1-902916-00-X
Main Research Area: Technical/natural sciences
Conference: 1999 European Wind Energy Conference and Exhibition, Nice, France, 01/03/1999 - 01/03/1999
Source: orbit
Source-ID: 299899
Publication: Research › Article in proceedings – Annual report year: 1999
Spektralfaktorisering

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Authors: Poulsen, N. K. (Intern), Jensen, M. R. (Intern), Hansen, A. D. (Intern), Lauritsen, M. B. (Intern), Ma, X. (Intern), Thygesen, U. H. (Intern)
Number of pages: 42
Publication date: 1999

Publication information
Publisher: Department of Mathematical Modelling, Technical University of Denmark
Original language: Danish
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 201021
Publication: Research - peer-review › Report – Annual report year: 1999

Dobbelt styrbar 3-bladet vindmølle: Reguleringsstrategier

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Hansen, A. (Intern), Bindner, H. W. (Intern)
Number of pages: 46
Publication date: 1998

Publication information
ISBN (Print): 87-550-2440-8
Original language: Danish
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1071(DA)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1071, Risø-R-1071(DA)
Electronic versions:
ris_r_1071.pdf
Source: orbit
Source-ID: 297442
Publication: Research › Report – Annual report year: 1998

Dobbelt styrbar 3-bladet vindmølle: Sammenligning mellem pitchreguleret vindmølle og pitchreguleret vindmølle med variabelt omløbstal

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy
Authors: Bindner, H. (Intern), Hansen, A. D. (Intern)
Number of pages: 40
Publication date: 1998

Publication information
ISBN (Print): 87-550-2441-6
Original language: Danish
Series: Denmark. Forskningscenter Risoe. Risoe-R
Number: 1072(DA)
ISSN: 0106-2840
Main Research Area: Technical/natural sciences
Risø-R-1072, Risø-R-1072(DA)
Electronic versions:
ris_r_1072.pdf
Source: orbit
Source-ID: 297431
**Predictive control and identification: Applications to steering dynamics**

The main objective of the present thesis is to enhance insight into predictive controller design and identification in connection with steering dynamics. In Chapter 2, the dynamics of ship steering are reviewed. Models of different complexity, suitable for control systems design are presented. The influence of wind, waves and currents on the ship motions are also discussed. Chapter 3 deals with the model reduction problem. Some basic concepts are explained, due to their role in the reduction of the dynamic models. Two model reductions techniques, based on singular values, are described. The theoretical properties of these methods are studied and their performance is examined via simulation on a stochastic linear Mariner Class Vessel model. In Chapter 4, the attention is focused on the derivation of an extended GPC. This extended strategy implies a generalization of the model structure and of the loss function, which defines the optimality of the control. Some guidelines on how to choose the design parameters, depending on the type of process to be controlled and on the required control performance, are presented. A predictive track keeping system for a Mariner Class Vessel is formulated based on the minimization of the mean squares prediction errors of the ship's deviation from the desired track. Chapter 5 is concerned with constrained predictive control. The presented algorithm, which is based on Rosen's gradient projection method, minimizes a multi-step quadratic loss function, taking physical constrains systematically into account. The constraints may consist of amplitude constraints (signal level constraints) as well as rate constraints. The influences of the different parameters on the solution are illustrated via simulation experiments on a Mariner Class Vessel model. The results show that the proposed strategy leads to a significant better control than the ad-hoc control strategy. Chapter 6 gives a survey on the so-called forgetting factor methods designed for tracking slowly drifting system parameters. The goal of this chapter is to formulate the identification framework in order to support the understanding of the connection between identification and control, analysed in Chapter 7. Chapter 7 focuses on how to make the on-line identification for predictive control more robust towards unmodelled dynamics. The theory is verified via simulation studies on a Mariner Class Vessel. The effects and the need of a prefilter in the estimation are analysed and illustrated. Based on the idea that the control criterion must be dual to the estimation criterion, an iterative optimal prefilter is designed. This seems to be an appealing way to tune the model towards the objective for which the model is to be used.

**General information**

State: Published
Organisations: Department of Informatics and Mathematical Modeling
Authors: Hansen, A. D. (Intern)
Publication date: 1996

**Publication information**

Original language: English
Series: IMM-PHD-1996-22
Main Research Area: Technical/natural sciences

**Predictive Control Relevant Prefiltering**

**General information**

State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Authors: Hansen, A. D. (Intern), Poulsen, N. K. (Intern)
Number of pages: 40
Publication date: 1996

**Publication information**

Publisher: Department of Mathematical Modelling, Technical University of Denmark
Original language: English
Main Research Area: Technical/natural sciences

**Tracking Keeping Systems with Predictive Control**

**General information**
Level and Rate Constraints in Predictive Control

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Authors: Hansen, A. D. (Intern), Poulsen, N. K. (Intern)
Publication date: 1995

Publication information
Publisher: imsordth
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 200924
Publication: Research - peer-review › Report – Annual report year: 1995

Model Reduction and Gain Scheduling Control

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Authors: Hansen, A. D. (Intern), Christensen, A. (Ekstern), Poulsen, N. K. (Intern)
Publication date: 1995

Publication information
Publisher: imsordth
Original language: English
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 200923
Publication: Research - peer-review › Report – Annual report year: 1995

Projects:

Wind power system support in future distribution networks

Department of Wind Energy
Period: 15/01/2018 → 14/01/2021
Number of participants: 5
Phd Student:
Pediaditis, Panagiotis (Intern)
Supervisor:
Altin, Müfit (Intern)
Das, Kaushik (Intern)
Koivisto, Matti Juhani (Intern)
Main Supervisor:
Hansen, Anca Daniela (Intern)
Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

Modelling of renewable energy under stressed power system stability conditions
Department of Wind Energy
Period: 15/11/2016 → 14/11/2019
Number of participants: 5
PhD Student:
Sarkar, Moumita (Intern)
Supervisor:
Altin, Müfit (Intern)
Hansen, Anca Daniela (Intern)
Jóhannsson, Hjörtur (Intern)
Main Supervisor:
Sørensen, Poul Ejnar (Intern)

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

The use of wind power capabilities to improve the operation of the distribution network
NetVind aims toward the green transition in Denmark, by rethinking the way of using wind power plants in distribution systems. NetVind analyses and demonstrates in a large experimental facility, which technical and financial potentials exist to improve the operation of distribution systems by using wind power plants support control capabilities.
The goal of NetVind is to improve the operation of distribution systems with high wind power penetration by using the wind power plants grid support capabilities. This is accomplished through:
- Digitizing the communication between grid devices (i.e. wind turbine’s inverter) and the net monitoring system in relation to IEC 61850.
- Minimizing grid losses in MV distribution systems with high wind power penetration by optimizing the reactive power flow.
- Making optimal use of the existing net and obtain a benefit of the green transition by using regulation rather than to reinforce the net.
- Exploring which business model can be applied between players.
- Testing the IT security infrastructure for data communication in accordance with IEC 62351.
- Building up know-how on modelling the condition of the MV net.
- Contributing to improvement and qualification of future technical regulations which are under preparation at Energinet.dk and which should bind together the political, technical and financial interests.
The project seeks to achieve effective integration of renewable energy, considering the overall system security by optimizing the wind power transmission upwards in the system so that unnecessary losses due to new production/consumption scenarios are minimized and optimized by using the control capabilities of power electronics in wind turbines.

Department of Wind Energy
Integration & Planning
EnergiMidt A/S
Period: 01/03/2016 → 01/10/2018
Number of participants: 5
Acronym: NetVind
Project participant:
Hansen, Anca Daniela (Intern)
Sørensen, Poul Ejnar (Intern)
Das, Kaushik (Intern)
Altin, Müfit (Intern)
Project Manager, organisational:
Thybo, Gitte Wad (Ekstern)
Project
Ancillary services from renewable power plants

RePlan project is a frontrunner for the integration of large share of renewable energy in the Danish power system. RePlan aims at rethinking the way of using renewable generation resources, as it focuses on enabling a resilient power system by providing ancillary services in a jointly coordinated manner.

The overall objective of this project is to contribute to the integration of large share of renewable energy in the Danish power system and thus to enable a resilient power system in the future by developing technical solutions for the provision of ancillary services by renewable power plants. RePlan focuses on WP and PV plants since they are expected to jointly produce the lion’s share of renewable energy generation capacity needed to reach the Danish government 2050 targets.

With respect to renewable generation (ReGen) plants, investigation of ancillary services, coordinated control, fast communication and forecast of available power are crucial step stones on the route toward a future resilient power system. The ability to provide ancillary services from ReGen plants depends on the communication and the forecast of availability power. In this respect, RePlan develops controllers for the delivery of ancillary services, incorporating communication properties in the control loops of the ReGen plant model and using state-of-the-art methods for simulation of renewable generation patterns and wind power forecast methods. Based on both simulation models and verification in laboratory facilities, this project intends to address this challenge: What is the impact of communication and power availability forecast error in providing coordination and ancillary services from ReGen plants?

The novelty of RePlan consists in the investigation and verification of the ancillary services provision from wind and photovoltaic power plants and of the suitability to coordinate their services provision to power system operator. In this respect, RePlan strives to identify and analyze the strengths and limitations of WP and PV plants, anticipating new challenges and exploring some of the more complex issues and uncertainties related to the coordination of their ancillary services. The services with great concerns in the future include: voltage, frequency and rotor angular stability support.

Department of Wind Energy

Wind Energy Systems
Period: 01/01/2015 → 31/12/2017
Number of participants: 1
Acronym: RePlan
Project Manager, organisational:
Hansen, Anca Daniela (Intern)

Relations
Publications:
Technical Feasibility of Ancillary Services provided by ReGen Plants

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)
Serensen, 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

Blade Dragon 2.0
Analyze & improve Liftra’s Blade Dragon single blade installation system to be able to do single blade installation in higher Wind speeds than today’s approx. 8m/s.

Department of Wind Energy
Aeroelastic Design

Wind Energy Systems

Liftra
Period: 01/07/2013 → 30/06/2016
Number of participants: 6
Acronym: 43195
Project participant:
Gaunaa, Mac (Intern)
Bergami, Leonardo (Intern)
Hansen, Anders Melchior (Intern)
Zahle, Frederik (Intern)
Hansen, Anca Daniela (Intern)
Barlas, Athanasios (Intern)

Integration of wind power and other renewables in power system defence plans

Department of Wind Energy
Period: 01/04/2013 → 04/07/2016
Number of participants: 8
Phd Student:
Das, Kaushik (Intern)
Supervisor:
Abildgaard, Hans (Ekstern)
Hansen, Anca Daniela (Intern)
Margaris, Ioannis (Intern)
Main Supervisor:
Sørensen, Poul Ejnar (Intern)
Examiner:
Iov, Florin (Ekstern)
Uhlen, Kjetil (Ekstern)

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

Relations
Publications:
Integration of Renewable Generation in Power System Defence Plans
Project: PhD

iTesla - Innovative Tools for Electrical System Security within Large Areas
The purpose of the iTESLA project is to develop a toolbox which will support the future operation of the pan-European electricity transmission network. This toolbox shall bring forward a major innovation: carry out operational dynamic simulations in the frame of a full probabilistic approach, thus going further that the current “N-1” approach and optimizing the transit capacities of the grid at different spatial (national, regional, Pan-European) and time (two-days ahead, day-ahead, intra-day, real-time) scales.

The iTesla project is lead by RTE (the French TSO). The total iTesla budget is M€ 19.5. DTUs total budget is M€ 1.1.

The main roles of DTU in iTesla are
- Work Package Leader of WP6: Defence and Restoration (Poul Sørensen)
- PhD in Integration of wind power and other renewables in power system defence plans (Kaushik Das, see related projects)
- Task Leader for Task 3.4. Aggregated dynamic models of variable generation sources (PV and Wind farms) and loads.

Department of Wind Energy
Wind Energy Systems
RTE (TSO France)
Elia (TSO Belgium)
NGC (TSO UK)
REN (TSO Portugal)
Statnett SF
IPTO (TSO Greece)
Regional coordination service center
AIA
Artilyes
Bull
Pepite
Quinary
Imperial College of Science, Technology and Medicine
Instituto de Engenharia de Sistemas e Computadores do Porto
KTH - Royal Institute of Technology
Katholieke Universiteit
Ricerca Sistema Energetico SpA
Tractebel
Period: 01/01/2012 → 31/12/2015
Number of participants: 6
Acronym: iTesla
Project participant:
Sørensen, Poul Ejnar (Intern)
Altin, Müfit (Intern)
Hansen, Anca Daniela (Intern)
Göksu, Ömer (Intern)
Margaris, Ioannis (Intern)
Phd Student:
Das, Kaushik (Intern)

Financing sources
Source: EU research programme (public)
Name of research programme: FP7-ENERGY-2011-1

Relations
Publications:
Primary reserve studies for high wind power penetrated systems
Aspects of Relevance of Wind Power in Power System Defense Plans
Aggregated wind power plant models consisting of IEC wind turbine models
Understanding IEC standard wind turbine models using SimPowerSystems
Wind Turbine and Wind Power Plant Modelling Aspects for Power System Stability Studies
Adequacy of operating reserves for power systems in future european wind power scenarios

Wind Power Plant System Services
Department of Wind Energy
Period: 15/12/2011 → 19/03/2015
Number of participants: 7
Communication and control in clusters of wind power plants connected to HVDC offshore grids

Department of Wind Energy
Period: 01/10/2011 → 22/06/2015
Number of participants: 7
Phd Student:
Zeni, Lorenzo (Intern)
Supervisor:
Hansen, Anca Daniela (Intern)
Kjaer, Philip C. (Ekstern)
Main Supervisor:
Sørensen, Poul Ejnar (Intern)
Examiner:
Rasmussen, Tonny Wederberg (Intern)
Liang, Jun (Ekstern)
Petersson, Andreas (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)

Project

**OffshoreDC - DC grids for integration of large scale wind power**

Department of Wind Energy
Wind Energy Systems
Rise 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/](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
Pre-standardisation of wind power modelling
The purpose of the project is to support the standardisation work in IEC Technical Committee 88 (TC88) Working Group 27 (WG27) on electrical simulation models for wind power generation. This work is done in cooperation between DTU and industry partners. The role of DTU has been to implement the IEC models in Power Factory, and in cooperation with industry to parametrise and validate the models against test results.

Department of Wind Energy

Wind Energy Systems

Department of Electrical Engineering

Center for Electric Power and Energy
Period: 01/05/2009 → 30/06/2013
Number of participants: 4
Project participant:
Margaris, Ioannis (Intern)
Hansen, Anca Daniela (Intern)
Wu, Qiuwei (Intern)

Project Manager, academic:
Sørensen, Poul Ejnar (Intern)

Activities:
IEC TC88 WG27: Wind Turbines - Electrical Simulation Models (External organisation)
Publications:
IEC work on modelling - generic model development. IEC 61400-27 - expected outcome
Implementation of IEC Generic Model Type 1A using RTDS

Integrated design of wind power systems

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

Financing sources
Robust adaptive control
The goal in this project is to investigate and develop robust identification methods and adaptive controllers. The practical application is related to steering of ships (autopilots). Adaptive control is interesting in connection to ships, because these strategies are able to handle time-varying systems operating under unpredictable situations. In the period there has been focused on model reduction in order to obtain reasonable models suitable for control design. In the project there has been developed and investigated methods for designing predictive controllers, which in the design procedure take the restriction into account. Classical system identification is based on the model's ability to predict one step ahead. This ability is not necessarily connected to the control objective and methods for connecting control and system identification has been investigated.

Department of Informatics and Mathematical Modeling
Period: 01/01/1996 → …
Number of participants: 2
Project participant:
Hansen, Anca Daniela (Intern)

Project Manager, organisational:
Poulsen, Niels Kjølstad (Intern)

Project

Robust adaptive control system design for aerospace applications.

Department of Informatics and Mathematical Modeling
Period: 01/02/1992 → 21/03/1997
Number of participants: 7
Phd Student:
Hansen, Anca Daniela (Intern)

Supervisor:
Colding-Jørgensen, Morten (Ekstern)
Mosekilde, Erik (Intern)

Main Supervisor:
Poulsen, Niels Kjølstad (Intern)

Examiner:
Knudsen, Carsten (Intern)
Bakker, Barbara Marleen (Ekstern)
Sørensen, Preben Graae (Ekstern)

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