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.
Wind power variability and power system reserves in South Africa
Variable renewable generation, primarily from wind and solar, introduces new uncertainties in the operation of power systems. This paper describes and applies a method to quantify how wind power development will affect the use of short-term automatic reserves in the future South African power system.

The study uses a scenario for wind power development in South Africa, based on information from the South African transmission system operator (Eskom) and the Department of Energy. The scenario foresees 5% wind power penetration by 2025. Time series for wind power production and forecasts are simulated, and the duration curves for wind power ramp rates and wind power forecast errors are applied to assess the use of reserves due to wind power variability. The main finding is that the 5% wind power penetration in 2025 will increase the use of short-term automatic reserves by approximately 2%.

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

General information
Publication status: Published
Organisations: Department of Wind Energy, Integration & Planning, Resource Assessment Modelling
Contributors: Sørensen, P. E., Litong-Palima, M., Hahmann, A. N., Heunis, S., Ntusi, M., Hansen, J. C.
Publication date: 2016
Media of output: Power Point Presentation

Event information
Event: WINDAc Africa 2016
Location: Cape Town, South Africa
Electronic versions:
Wind_power_variability_and_power_system_reserves_v2.pdf
URLs:
https://www.youtube.com/watch?v=y0wvKVWDkSw
Source: PublicationPreSubmission
Source-ID: 131158371
Research output: Non-textual form » Sound/Visual production (digital) – Annual report year: 2017 » Research

Adequacy of operating reserves for power systems in future european wind power scenarios

Wind power generation is expected to increase in Europe by large extent in future. This will increase variability and uncertainty in power systems. Imbalances caused due to uncertainty in wind power forecast can trigger frequency instability in the system. These imbalances are handled using operating reserves. To study the effects of these imbalances, anticipated wind scenarios for European power systems are modelled for 2020 and 2030. Wind power forecasts for different time scales and real-time available wind power are modelled. Based on these studies, this paper qualitatively analyzes the adequacy of primary and secondary reserves requirements for future European power systems. This paper also discusses the challenges due to the uncertainty in wind power forecasts and their possible solutions for wind installation scenarios for 2020 and 2030.

General information
Publication status: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Contributors: Das, K., Litong-Palima, M., Maule, P., Sørensen, P. E.
Number of pages: 5
Pages: 1-5
Publication date: 2015

Host publication information
Title of host publication: Proceedings of IEEE Power and Energy Society General Meeting 2015
Publisher: IEEE
ISBN (Print): 978-1-4673-8040-9
Economic impact analysis of the demonstrations in task-forces TF1 and TF3 - Deliverable D15.1: WP15. Economic impacts of the demonstrations, barriers towards scaling up and solutions

General information
Publication status: Published
Number of pages: 198
Publication date: 2014

Publication information
Original language: English
Keywords: TWENTIES Transmitting wind
Electronic versions:
Economic_impact_analysis.pdf

Bibliographical note
EC-GA contract no 249812
Project full title: Transmission system operation with large penetration of Wind and other renewable Electricity sources in Networks by means of innovative Tools and Integrated Energy Solutions
Source: dtu
Source-ID: u::10933
Research output: Book/Report › Report – Annual report year: 2014 › Research › peer-review

Impact of Offshore Wind Power Variability on the Frequency Stability of European Power System
Offshore wind power development scenarios are very ambitious. In Europe, it is expected to surpass 100 GW by 2030. As opposed to onshore, offshore wind will be concentrated in relatively small geographical areas, meaning that the geographical smoothening would be diminished. Being able to simulate this variability is important and will assist quantifying the possible impacts of large-scale deployment of offshore wind on the operation of the power system. The analysis of maximum offshore wind power ramping in 2020 and 2030 North Seas shows that wind power variability, at synchronous area level, can exceed the current dimensioning incidents values. This indicates that wind power variability should be considered in frequency stability.

General information
Publication status: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Contributors: Cutululis, N. A., Litong-Palima, M., Sørensen, P. E.
Number of pages: 8
Publication date: 2014

Host publication information
Title of host publication: Proceedings of the International Conference on Wind Energy Grid-Adaptive Technologies 2014
Keywords: Offshore, Wind Power, Variability, Frequency stability
Electronic versions:
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2014 › Research › peer-review
Offshore Variability in Critical Weather Conditions in Large-Scale Wind Based Danish Power System

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

Report with data for system behaviour at storm passage with original (uncoordinated) and coordinated control: Deliverable no: 12.2

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

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

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

General information
Publication status: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Energinet.dk, SINTEF
Contributors: Detlefsen, N., Litong-Palima, M., Cutululis, N. A., Farahmand, H., Huertas-Hernando, D., Sørensen, P. E.
Number of pages: 55
Publication date: 2013

Publication information
Original language: English
Electronic versions:
Report_with_data.pdf

Note re. dissertation
This document has been prepared by TWENTIES project partners as an account of work carried out within the framework of the EC-GA contract no 249812.

Project full title: Transmission system operation with large penetration of Wind and other renewable Electricity sources in Networks by means of innovative Tools and Integrated Energy Solutions
Source: dtu
Source-ID: u::9567
Research output: Book/Report › Report – Annual report year: 2013 › Research › peer-review

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

General information
Publication status: Published
Organisations: Department of Wind Energy, Wind Energy Systems
Contributors: Cutululis, N. A., Litong-Palima, M., Sørensen, P. E.
Number of pages: 4
Publication date: 2012

Host publication information
Title of host publication: Proceedings of 11th International Workshop on Large-Scale Integration of Wind Power into Power Systems
Keywords: Wind Power, Variability, Offshore, Ramp rates
Electronic versions:
North_Sea_Offshore.pdf

Bibliographical note
The works and developments required for the elaboration of this paper/article have been carried out partially within TWENTIES project (www.twenties-project.eu) which belongs to the Seventh Framework Program funded by European Commission under project no. ENER/FP7/EN/249812/"TWENTIES".
Research output: Chapter in Book/Report/Conference proceeding › Article in proceedings – Annual report year: 2012 › Research › peer-review
Offshore Wind Power Data: Deliverable no: 16.1

Wind power development scenarios are critical when trying to assess the impact of the demonstration at national and European level. The work described in this report had several objectives. The main objective was to prepare and deliver the proper input necessary for assessing the impact of Demo 4 – Storm management at national and European level. For that, detailed scenarios for offshore wind power development by 2020 and 2030 were required.

The aggregation level that is suitable for the analysis to be done is at wind farm level. Therefore, the scenarios for offshore wind power development offer details about the wind farms such as: capacity and coordinates. Since the focus is on the impact of storm fronts passage in Northen Europe, the offshore wind power scenarios were estimated only for the countries at North and Baltic Sea. The sources used are public sources, mentioned in the reference list. The scenarios are split in baseline – the conservative one, most likely to happen, and high – the optimistic scenario. During the time of the work, EWEA has published their estimation for 2020 and 2030. The scenarios estimated in this work are in good accordance with EWEA’s.

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

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

Finally, wind power time series were simulated using the wind speed time series and adequate power curves. The resulted wind power time series were briefly analysed with respect to the distribution of wind power forecast errors and the results show that the wind power forecast error distribution manages to capture the area smoothening effect.

General information
Publication status: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Energinet.dk
Contributors: Cutululis, N. A., Litong-Palima, M., Zeni, L., Gøttig, A., Detlefsen, N., Sørensen, P. E.
Number of pages: 35
Publication date: 2012

Offshore Wind Power Production in Critical Weather Conditions

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

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

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

General information
Publication status: Published
Organisations: Wind Energy Systems, Department of Wind Energy
Contributors: Cutululis, N. A., Litong-Palima, M., Sørensen, P. E.
Number of pages: 8
Publication date: 2012
Wind-induced day-ahead and hour-ahead imbalances in a power system with a significant wind mix: Simulations in the Danish experience

General information
Publication status: Published
Organisations: Wind Energy Systems, Department of Wind Energy, Energinet.dk
Contributors: Litong-Palima, M., Cutululis, N. A., Detlefsen, N., Sørensen, P. E.
Number of pages: 10
Publication date: 2012

Host publication information
Title of host publication: Proceedings of EWEA 2012 - European Wind Energy Conference & Exhibition
Publisher: European Wind Energy Association (EWEA)
Electronic versions:
Offshore_Wind_Power_Production.pdf
Presentation

Projects:

SANEDI: System adequacy and reserve margins with increasing levels of variable generation
The project aims at investigating system adequacy and reserve margins with increasing levels of variable generation (wind and photovoltaic mainly) in South Africa
Sørensen, P. E., Project Participant, Department of Wind Energy, Wind Energy Systems
Marinelli, M., Project Participant, Department of Electrical Engineering, Center for Electric Power and Energy, Distributed Energy Resources
Litong-Palima, M., Project Participant, Department of Wind Energy, Wind Energy Systems
Hahmann, A. N., Project Participant, Department of Wind Energy, Meteorology
01/07/2015 → 31/08/2016
Keywords: wind power, Photovoltaic, large scale
Collaborators: EA Energy Analysis A/S
Project: Research

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

Sørensen, P. E., Project Participant, Department of Wind Energy, Wind Energy Systems
Cutululis, N. A., Project Participant, Risø National Laboratory for Sustainable Energy, Department of Wind Energy, Wind Energy Systems
Maule, P., Project Participant, Department of Wind Energy, Wind Energy Systems
Litong-Palima, M., Project Participant, Department of Wind Energy, Wind Energy Systems
Altiparmakis, A., Project Participant, Department of Electrical Engineering, Center for Electric Power and Energy

FP7 Contract ID: 249812
01/04/2010 → 30/09/2013
Keywords: Wind power, TSO, Demonstration, Storm control, Wind turbines, Wind farms
Project: Research

**SIMBA: SIMBA - Simulation of balancing**

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

Sørensen, P. E., Project Participant, Department of Wind Energy, Wind Energy Systems, Risø National Laboratory for Sustainable Energy
Cutululis, N. A., Project Participant, Rise National Laboratory for Sustainable Energy, Department of Wind Energy, Wind Energy Systems
Litong-Palima, M., Project Participant, Department of Wind Energy, Wind Energy Systems
Maule, P., Project Participant, Department of Wind Energy, Wind Energy Systems

01/01/2010 → 31/12/2014
Keywords: Balancing, Power system, Wind, Forecast errors
Collaborators: Energinet.dk
Project: Research

**TWENTIES: Transmission system operation with large penetration of Wind and other renewable Electricity sources in Networks by means of innovative Tools and Integrated Energy Solutions**

A group of Transmission System Operators from Belgium, Denmark, France, Germany, Spain, The Netherlands, have linked with two generator companies, three power technology manufacturers, two wind turbine manufacturers and research and development organisations, in order to bring answers by 2015 to the following questions:

What are the valuable contributions that intermittent generation and flexible load can bring to system services?

What should the network operators implement to allow for off-shore wind development?

How to give more flexibility to the transmission grid?

Overall: how scalable and replicable are the results within the entire pan-European electricity system?

These four intertwined overarching goals have been split into a set of 6 high level demonstration objectives, two replication objectives and one dissemination objective.

Litong-Palima, M., Project Participant, Department of Wind Energy, Wind Energy Systems

FP7 Contract ID: 249812
01/04/2010 → 30/09/2013
Project: Research
Activities:

European Wind Energy Conference & Exhibition 2013
Period: 6 Feb 2013
Marisciel Litong-Palima (Speaker)
Department of Wind Energy
Wind Energy Systems

Description
Impact of Offshore Wind Turbine Controls on Danish Power System 2020 in Critical Weather Situations

Oral Presentation

Related event

European Wind Energy Conference & Exhibition 2013
04/02/2013 → 07/02/2013
Vienna, Austria
Activity: Talks and presentations › Conference presentations

8th WES workshop
Period: 23 Jan 2013
Marisciel Litong-Palima (Speaker)
Department of Wind Energy
Wind Energy Systems

Description
Impact of Offshore Wind Turbine Controls on Danish Power System 2020 in Critical Weather Situations

Related event

8th WES workshop: TWENTIES project - Economic assessment and EU wide replication potential
23/01/2013 → …
Roskilde, Denmark
Activity: Talks and presentations › Conference presentations

EWEA 2012 - European Wind Energy Conference & Exhibition
Period: 16 Apr 2012 → 19 Apr 2012
Marisciel Litong-Palima (Participant)
Department of Wind Energy
Wind Energy Systems

Description
Poster Presentation - Wind-induced day-ahead and hour-ahead imbalances in a power system with a significant wind mix: Simulations in the Danish experience

Related event

EWEA 2012 - European Wind Energy Conference & Exhibition
16/04/2012 → 19/04/2012
Copenhagen, Denmark
Activity: Attending an event › Participating in or organising a conference

6th Wind Energy Systems Workshop ( WES Workshop); 6: SimBa Intra-hour Simulation of the Power Balances
Period: 8 Nov 2011
Marisciel Litong-Palima (Speaker)
Energinet.dk is working to find out how future development of the energy system, which implies a new combination of production sources, will affect the system balance and what the future costs of balancing this system will be. In order to be able to give a qualified answer to these questions, a new model called SimBa has been developed. SimBa models the intra-hour balancing of the power system and is based on the Danish principles of balancing. Traditionally, modelling issues have put the main focus on calculating hourly energy values, while intra-hourly modelling attracted little attention. SimBa has closed this gap.

Place: H.H. Koch Auditorium, DTU - Risø Campus Roskilde

Documents:
SimBa – the (Wind) Forecasts.pdf

Links:
http://www.risoe.dtu.dk/Conferences/VES_Workshop/workshop_six.aspx (REL-OA)
http://www.risoe.dtu.dk/Conferences/VES_Workshop/~/media/Risoe_dk/Conferences/VES_workshop/Documents/workshop_6/3SimBathe_Wind_Forecasts.ashx (DOC-OA)

Related external organisation

Unknown Organization
Keywords: SimBa – the (Wind) FORECASTS
Activity: Talks and presentations › Conference presentations

Planning and Development of Wind Farms
Period: 3 Jan 2011 → 21 Jan 2011
Marisciel Litong-Palima (Participant)

Department of Wind Energy

Description
Participation in a course

Related event

Planning and Development of Wind Farms: DTU Course # 46200
03/01/2011 → 21/01/2011
Roskilde, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.