Wind energy challenges wind resource assessment and large scale integration

Hansen, Jens Carsten

Publication date: 2012

Wind energy challenges
wind resource assessment and large scale integration

Jens Carsten Hansen
Head of Wind Energy Systems Section
Outline

- Introduction – status and challenges
- Wind resource assessment
- Large scale integration of wind power – some projects
- Concluding remarks

The challenge

Cumulative Global Wind Power Development
Actual 1990-2011 Forecast 2012-2016 Prediction 2017-2021

Source: BTM Consult - A Part of Navigant - March 2012
International wind turbine standards - IEC

a) Safety & functional requirements
b) Test methods
c) Certification procedures
d) Interfaces & Component

IEC TC88: IEC 61400 series:
- IEC 61400-1 Design requirements
- IEC 61400-2 Small wind turbines
- IEC 61400-3 Design requirements for offshore wind turbines
- IEC 61400-4 Gears for wind turbines
- IEC 61400-(5) Wind Turbine Rotor Blades
- IEC 61400-11, Acoustic noise measurement techniques
- IEC 61400-12-1 Power performance measurements
- IEC 61400-13 Measurement of mechanical loads
- IEC 61400-14 Declaration of sound power level and tonality
- IEC 61400-21 Measurement of power quality characteristics
- IEC 61400-22 Conformity Testing and Certification of wind turbines
- IEC 61400-23 TR Full scale structural blade testing
- IEC 61400-24 TR Lightning protection
- IEC 61400-25-(1-6) Communication
- IEC 61400-26 TS Availability
- IEC 61400-27 Electrical simulation models for wind power generation

International partnerships such as e.g. TPWIND and EERA in Europe

The EERA Joint Programme on Wind Energy aims at accelerating the realization of the EU SET-plan goals and to provide added value through:
- Strategic leadership of the underpinning research
- Joint prioritisation of research tasks and infrastructure
- Alignment of European and national research efforts
- Coordination with industry, and
- Sharing of knowledge and research infrastructure.

Application areas

- Wind Conditions
- Aerodynamics
- Structures and Materials
- Wind Integration
- Research Infrastructure

Enabling research areas

Wind Farms

SE4All 24 Sep 2012
## Wind energy – Global and Africa

### Installed capacity in 2010 and 2011 (Global)

<table>
<thead>
<tr>
<th>Total</th>
<th>Installed MW 2010</th>
<th>Accu. MW 2010</th>
<th>Installed MW 2011</th>
<th>Accu. MW 2011</th>
<th>% of installed MW 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Americas</td>
<td>6,533</td>
<td>46,999</td>
<td>5,933</td>
<td>56,963</td>
<td>22.9%</td>
</tr>
<tr>
<td>Europe</td>
<td>10,980</td>
<td>87,565</td>
<td>9,573</td>
<td>56,963</td>
<td>24.5%</td>
</tr>
<tr>
<td>South &amp; East Asia</td>
<td>21,130</td>
<td>56,277</td>
<td>21,005</td>
<td>79,290</td>
<td>56.4%</td>
</tr>
<tr>
<td>OECD-Pacific</td>
<td>478</td>
<td>5,368</td>
<td>694</td>
<td>6,092</td>
<td>1.1%</td>
</tr>
<tr>
<td>Africa</td>
<td>98</td>
<td>5,112</td>
<td>131</td>
<td>1,245</td>
<td>0.3%</td>
</tr>
<tr>
<td>Total other continents and areas</td>
<td>79</td>
<td>208</td>
<td>81.6</td>
<td>290</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

### Annual MW installed capacity

- Egypt: 39,404
- Morocco: 41,712
- Tunisia: 199,520

### Total Africa

- Total Africa: 98, 1,112, 131, 1,245

### Source:
BTM Consult - A Part of Navigant - March 2012

## Wind energy forecast – Global and Africa

### Forecast for wind power development 2012-2016 (Global)

<table>
<thead>
<tr>
<th>Total</th>
<th>Forecast for wind power development 2012-2016 (incl. Offshore)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Americas</td>
<td>56,563</td>
</tr>
<tr>
<td>Europe</td>
<td>97,588</td>
</tr>
<tr>
<td>South &amp; East Asia</td>
<td>79,282</td>
</tr>
<tr>
<td>OECD-Pacific</td>
<td>6,045</td>
</tr>
<tr>
<td>Other areas</td>
<td>1,593</td>
</tr>
<tr>
<td>Total</td>
<td>241,029</td>
</tr>
</tbody>
</table>

### Source:
BTM Consult - A Part of Navigant - March 2012
Africa’s challenge

Sustainable, cost efficient and long term solutions are needed.

How can Africa be part of the global wind energy development?

This presentations takes a look at two important issues:

- Wind resource assessment
- Integration of wind power in power systems

Why wind resource assessment - 1?

Traditional climatology and global models (GCM) do not provide the answer

Source: European Center for Medium Range Weather Forecasting (ECMWF) – ERA Interim reanalysis
Why wind resource assessment - 2?

Wind provides the income in cost-benefit

- Investment costs
- Operation and maintenance costs
- Electricity production ~ Wind resources
- Turbine lifetime
- Discount rate
- Environmental benefits

Modelling is necessary and it has to be good

Energy in wind

\[ P = \frac{1}{2} \rho u^3 \]  \([W/m^2]\)

Wind speed \(u\) [m/s]

Measurements + Linear interpolation = NO

DTU Wind Energy, Technical University of Denmark
**Numerical Wind Atlas**
Downscaling from global reanalysis data

- **Global**
- **Regional**
- **Local**

Mesoscale modelling
KAMM/WAsP, MMS, WRF, etc.

Microscale modelling
(WAsP, other linear/nonlinear models)

---

**Wind Atlas for South Africa**
Western Cape and parts of Eastern and Northern Cape

DTU Wind Energy, Technical University of Denmark
Verified Numerical Wind Atlas for South Africa
the database

Wind climate data available every 5 km × 5 km – corresponding to 15000 virtual masts.

Workshops and guidelines describe WASA methods, tools, products and their application.

Data are available through wasadata.csir.co.za/wasa1/WASAData

10 WASA masts and data

High quality wind measurements for verification of modelling www.wasa.csir.co.za
Global Wind Atlas for policy and planning

Initiative by Clean Energy Ministerial (CEM) Multilateral Working Group on Solar and Wind Technologies

- Intended for policy makers, energy planners and Integrated Assessment Modelling (IAM)
- The Global Wind Atlas will provide a unified, high resolution, and public-domain dataset of wind energy resources for the whole world by 2015
- DTU Wind Energy has developed the framework methodology for the project
  • microscale modelling capturing small scale wind speed variability
  • no mesoscale modelling
  • uncertainty estimates
- Results to be published and methodology to ensure transparency (peer review)
  • DK government funds DTU Wind Energy
  • Partners at this stage:
    - International Renewable Energy Agency (IRENA) - coordinator
    - DTU Wind Energy
    - CENER, Spain
    - DLR, Germany
    - NREL and NCAR, USA
    - Other technical partners for creating the infrastructure

Why wind power integration?
The Danish example

- Approximately 20% of electricity consumption met by wind power – annual average
- Around 3GW installed wind power capacity
- For a few hours in a year wind power covers the entire Danish demand

- 50% of electricity consumption to be met by wind power – annual average
- Around 6GW installed wind power capacity
- Wind power production will often exceed the Danish demand

Source: Energinet.dk - EcoGrid
Denmark Demo

**National targets and policy**
25% of electricity from wind energy today
50% of electricity from wind energy by 2020

**Innovation Partnership between Research and Industry (MegaVind)**
...to provide the most effective wind power and wind power plants – that ensure the best possible integration of wind power ...

**A demonstration country for wind energy**
How to reach the targets and a reliable and cost efficient power system

---

**Wind integration: challenges and solutions**

**Challenges**
- Balancing production and consumption
- Power transfer from production to consumers
- Coping with faults
- Requirements for ancillary services

**Solutions and research**
- The grid
  - Enhancing grid infrastructure
  - Smart grids
  - Storage
- Power system modelling
  - Variability
  - Dynamic stability
- Wind power plant capabilities
  - Wind farms behaving more like conventional power stations
  - Low voltage ride through
  - Better prediction of wind power
  - More flexible and controllable turbines
The grid – European perspective
European Synchronous Zones
European DC interconnectors

Source: EWEA

DU Wind Energy, Technical University of Denmark

EU FP7 - TWENTIES

Consortium and budget

10 European Member States
1 Associated Country

United Kingdom (2)
ALSTOM GRID
UNIVERSITY OF STRATHCLYDE

Ireland
UCD

Portugal
INESC-PORTO

Spain (5)
RED ELECTRICA DE ESPAÑA
IBERDROLA
ITT COMILLAS
GAMESA
ABB S.A.

France (2)
RTE
EDF

Germany (3)
FRAUNHOFER IWES
50 Hz T
SIEMENS Wind Power

Norway
SINTEF

The Netherlands
TENNET

Denmark (3)
DONG ENERGY
ENERGINET
DU WIND ENERGY

Belgium (6)
ELIA SYSTEM OPERATOR
EWEA
CORESO
UNIVERSITY LIEGE
UNIVERSITY LEUVEN
UNIVERSITE LIBRE BRUXELLES

Italy
RSE

Total budget: 56.8 M€
EU contribution: 31.8 M€
EU FP7 - 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

EU TWENTIES – WP16.2
(Leader: DTU Wind Energy)

OBJECTIVES
- Study power system balancing and reserve requirements with massive offshore wind power
- Special focus on sudden loss of wind power due to storm passages

RESULTS
- Time series of wind power generation and forecast errors in 2020 and 2030 – development and use of CorWind
- Quantification of reserve requirements

from large scale onshore to massive scale offshore

red: 2020
blue: 2030
DC grids for integration of large scale wind power (NEF OffshoreDC)

Overall objective:
To develop and apply the Voltage Source Converter (VSC) based HVDC grid technologies in the deployment of offshore wind power.

Partners:
- DTU Wind Energy
- Vestas Technology R&D
- ABB
- Chalmers University
- SINTEF
- DTU- Elektro
- DONG Energy
- Energinet.dk
- VTT
- Statnett

Cluster control:
Communication and control in clusters of wind power plants connected to HVDC offshore grids (control system architecture, allocation of control tasks, communication protocol)

Simulation of Balancing (SimBa)
Energinet.dk project
Planning tool to simulate balancing of power

SimBa Overview
SimBa is a multi-module simulation software that Energinet is developing to simulate the balancing and scheduling of the entire power market in Denmark.

Forecast Module Overview
The forecast module of SimBa is configured to calculate the available power and the hour-ahead (HA) forecasted power for the aggregate power output from wind farms in the entire Denmark.
Wind Power Plant capabilities

- Wind farm modeling
- Wind farm control with grid support
- Generic, simplified but realistic power system model delivered by EnergiNet.dk

Ability to control wind farms as wind power plant

Active controllable components in the power system with
  ✓ Fault ride through capabilities
  ✓ Active and reactive power support of the grid
  ✓ Voltage grid support
  ✓ Frequency control (island systems)

Prediction

ANEMOS SafeWind (EU FP7)

- OBJECTIVES
  To improve wind predictability with focus on extremes at various temporal scales (5 min to days ahead) and at various spatial scales (gusts, thunderstorms and fronts)
- RESULTS
  DTU Wind Energy developed a variability forecast for the time scale of variations for the next day or two. DTU Wind Energy also improved data assimilation into the WRF model, using wind farm data directly. For the sister project ANEMOS-plus, DTU Wind Energy implemented the WILMAR model to test probabilistic scheduling for Ireland.
Electrical simulation models for wind power

IEC 61400-27:
- Scope
  - Develop generic models for wind power generation
  - Procedures for validation of models
- Work with new standard initiated in 2009
- Two parts
  - 1. Wind turbines (standard by 2012)
  - 2. Wind farms (standard by 2014)
- 32 members from 14 countries, industry (TSOs, power producers, consultants) and research
- DTU Wind Energy is convener (project manager)

Some concluding remarks

- National wind atlas projects (e.g. in South Africa and Egypt) found new promising resources, geographical coverage, improved accuracy, ...
- Global Wind Atlas for Integrated Assessment Modelling by 2015 – global, needs verification and detail by national activities

- Power system development needed for wind power integration
  - Models for wind power required
  - Link up to European work and lessons learnt in the Denmark Demo
Example module

Case 3c - Modular electrification concept

Possible diesel generator & storage

Control point: power can only flow to the grid. Additional generation installed in the module is able to export power to earn revenue

DTU Wind Energy, Technical University of Denmark
Aspects of the
Modular form of rural electrification project

The ultimate goal:
• To enable rural and semi-urban communities to receive electricity with a high proportion of renewable energy penetration from local resources

The modular concept aims to be:
• a sustainable, low-carbon and intelligent power system
• able to expand, interconnect and grid connect at a later date
• limiting further loading of the conventional grid
• employing smart grid technology
• encouraging informed consumer participation
• empowering consumers to be producers

Thank you for your attention