Wind energy challenges wind resource assessment and large scale integration

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Sustainable Energy for All: Powering Africa
Copenhagen, 24th September 2012

Wind energy challenges
wind resource assessment and large scale integration

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DTU
Fluid Dynamics

DTU
Composite Mechanics

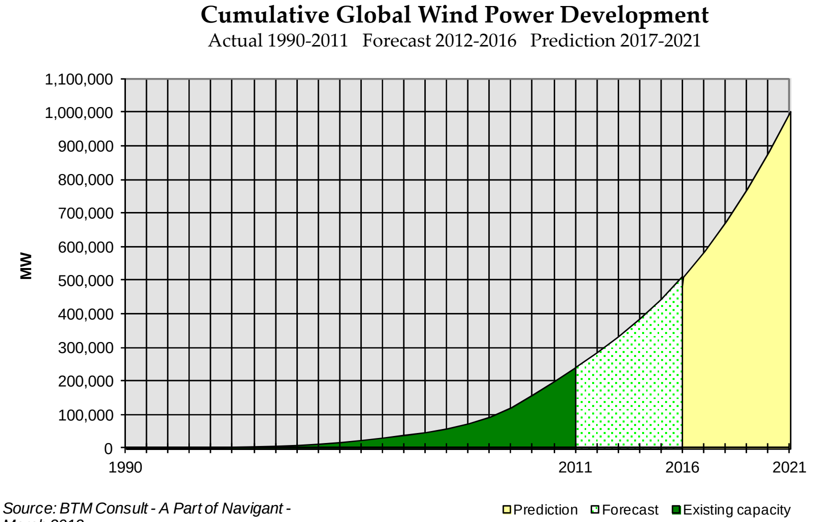
DTU Wind Energy
Department of Wind Energy

- Composites and Materials Mechanics
- Materials Science and Characterisation
- Fluid Mechanics
- Test and Measurements
- Wind Turbines Structures
- Aerolastic Design
- Meteorology
- Wind Energy Systems

Outline

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

The challenge



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

International wind turbine standards - IEC

a) Safety & functional requirements

↓

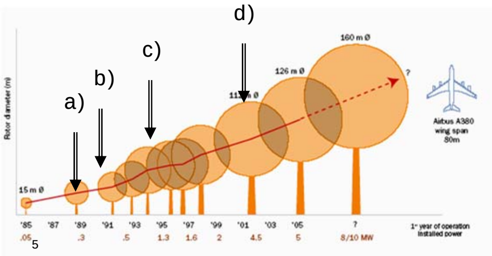
b) Test methods

↓

c) Certification procedures

↓

d) Interfaces & Component



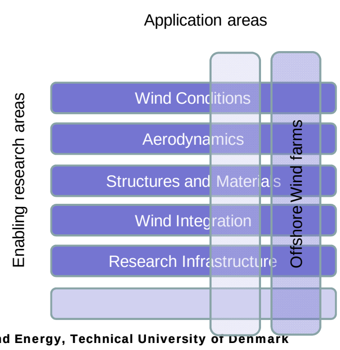
IEC TC88: IEC 61400 series:

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.



EERA European Energy Research Alliance

DTU

Wind energy – Global and Africa

Installed capacity in 2010 and 2011 (Global)

Africa

	Installed MW 2010	Accu. MW 2010	Installed MW 2011	Accu. MW 2011	% of installed MW 2011
Total Americas	6,639	46,990	9,573	56,563	22.9%
Total Europe	10,980	87,565	10,226	97,588	24.5%
Total South & East Asia	21,130	58,277	21,005	79,282	50.4%
Total OECD-Pacific	478	5,368	694	6,062	1.7%
Total Africa	98	1,112	133	1,245	0.3%
Total other continents and areas:	79	208	81.6	290	0.2%
Annual MW installed capacity	39,404		41,712		
Cumulative MW installed in the world		199,520		241,029	

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

Egypt	0	552	0	552
Morocco	9	263	29	292
Tunisia	87	247	30	277
Rest of Africa: Algeria, Cape Verde, Ethiopia, Libya, South Africa, etc.	2	51	74	125
Total Africa	98	1,112	133	1,245

DTU Wind Energy, Technical University of Denmark

DTU

Wind energy forecast – Global and Africa

Forecast for wind power development 2012-2016 (Global)

Africa

	Cumulative installed capacity (MW) by end of 2011	Installed capacity (MW) in 2011	Forecast 2012-2016 (incl. Offshore)					Installed capacity between 2012-2016	Cumulative installed capacity (MW) by end of 2016
	2011	2011	2012	2013	2014	2015	2016	Sum	Accu.
Total Americas	56,563	9,573	11,450	11,700	13,850	14,850	17,350	69,200	125,763
Total Europe	97,588	10,226	11,100	13,075	13,625	16,500	18,750	73,050	170,638
Total South & East Asia	79,282	21,005	19,150	20,400	21,500	21,900	26,500	109,450	188,732
Total OECD-Pacific	6,045	694	900	1,500	2,000	2,650	3,050	10,100	16,145
Total other areas	1,553	215	595	1,130	1,585	2,280	2,455	8,045	9,598
Total MW new capacity every year:		41,712	43,195	47,805	52,560	58,180	68,105	269,845	510,874
Accu. capacity (MW)	241,029		284,224	332,029	384,589	442,769	510,874		

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

DTU Wind Energy, Technical University of Denmark

Africa's challenge

Sustainable, cost efficient and long term solutions are needed.

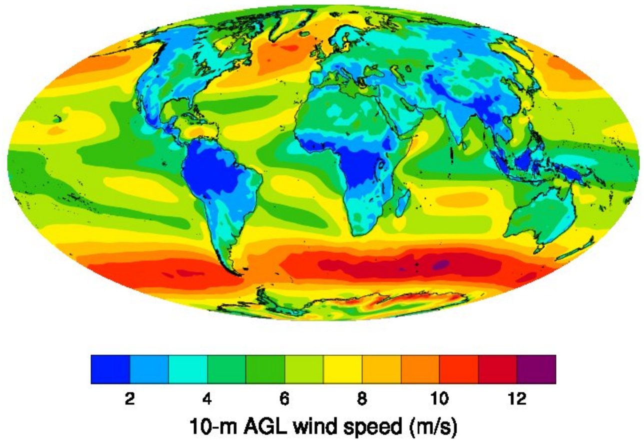
How can Africa be part of the global wind energy development?

This presentations takes a look at two important issues:

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

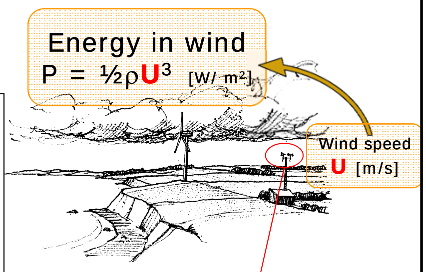
Why wind resource assessment - 1?

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



Source: European Center for Medium Range Weather Forecasting (ECMWF) - ERA Interim reanalysis

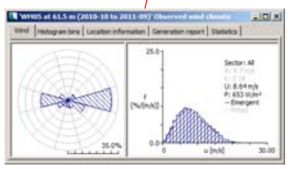
Why wind resource assessment - 2?



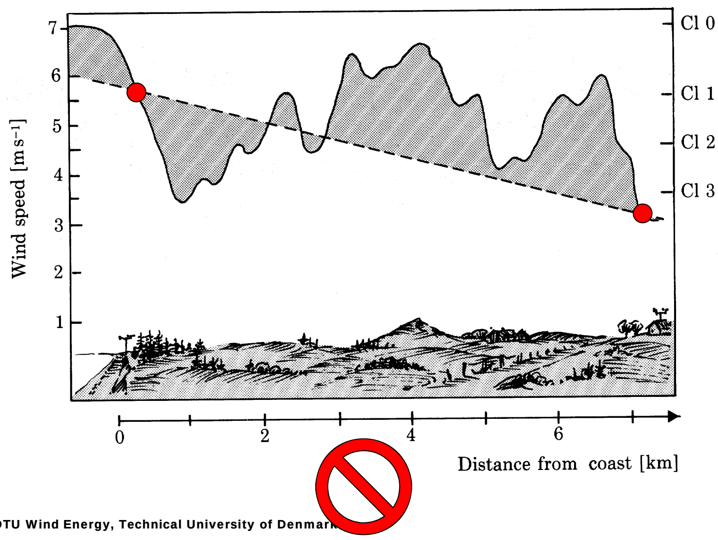
Wind provides the income in cost-benefit

- 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



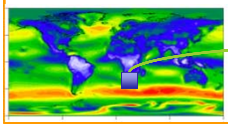
Measurements + Linear interpolation = NO



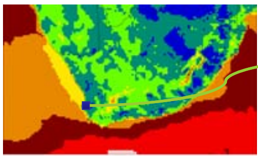
Numerical Wind Atlas

Downscaling from global reanalysis data

Global



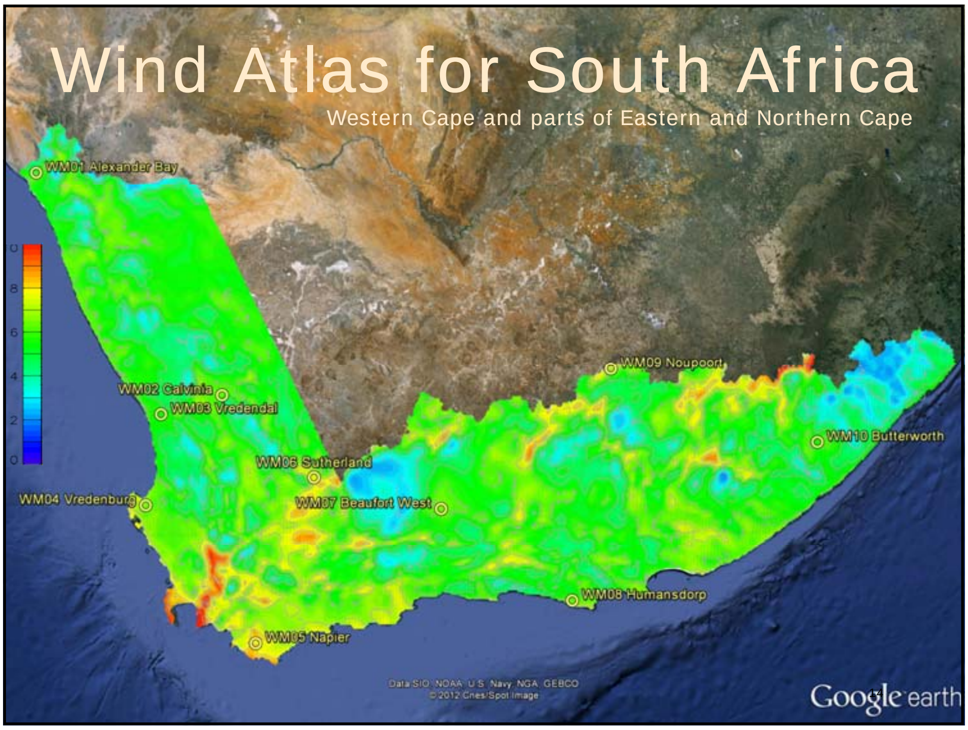
Regional



Local

Mesoscale modelling
KAMM/WAsP, MM5, WRF, etc.

Microscale modelling
(WAsP, other linear/nonlinear models)

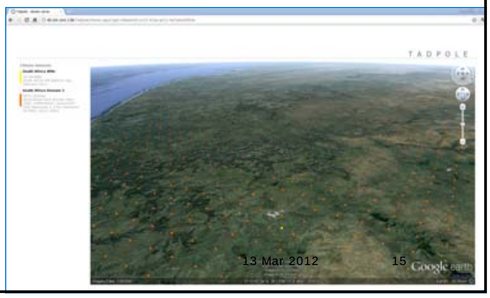


Verified Numerical Wind Atlas for South Africa the database

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

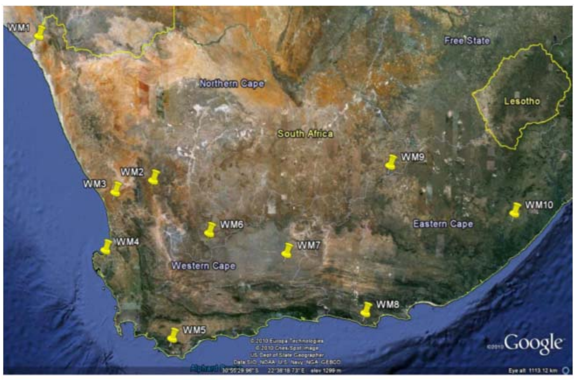
Workshops and guidelines describe WASA methods, tools, products and their application.

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



WASA	Data recovery (%)	U_{mean} @ 61.5m (m/s)
WM01	100.0	5.83
WM02	100.0	6.19
WM03	100.0	7.13
WM04	100.0	6.68
WM05	95.8	8.58
WM06	100.0	7.00
WM07	100.0	6.95
WM08	100.0	7.36
WM09	89.6	7.55
WM10	92.4	6.52

Global Wind Atlas for policy and planning

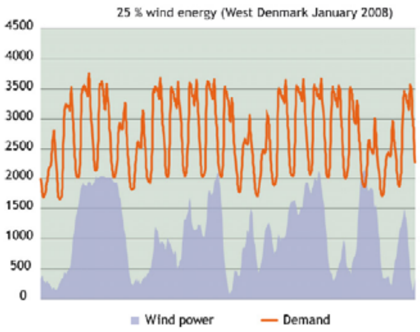
Initiative by Clean Energy Ministerial (CEM) Multilateral Working Group on Solar and Wind Technologies

- 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?

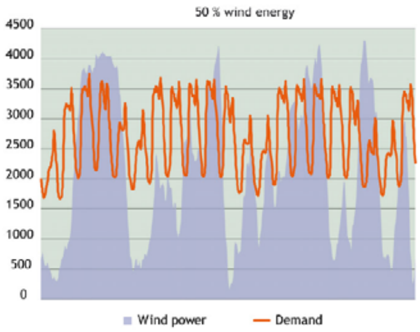
The Danish example

2008



- 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

2020



- 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

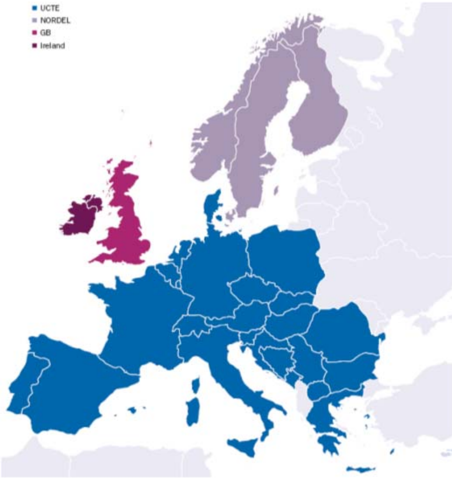
- Balancing production and consumption
- Power transfer from production to consumers
- Coping with faults
- Requirements for ancillary services

Solutions and research

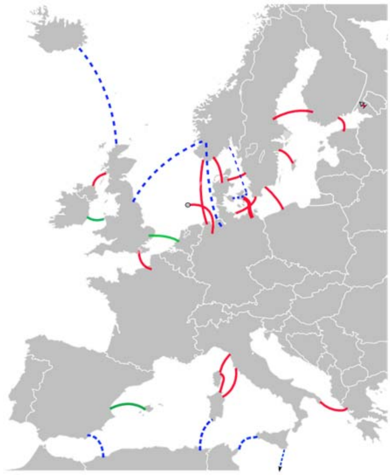
- The grid
  - Enhancing grid infrastructure
  - Smart grids
  - Storage
- Power system modelling
  - Variability
  - Dynamic stability
- Wind power plant capabilities
  - Wind farms behaving more like conventional power stations
  - Low voltage ride through
  - Better prediction of wind power
  - More flexible and controllable turbines

The grid – European perspective

European Synchronous Zones



European DC interconnectors



Source: EWEA

- Existing
- Under construction
- Under consideration

EU FP7 - TWENTIES

Consortium and budget

10 European Member States
1 Associated Country

United Kingdom (2)
ALSTOM GRID
UNIVERSITY OF STRATHCLYDE

France (2)
RTE
EDF

Norway
SINTEF

Denmark (3)
DONG ENERGY
ENERGINET
DTU WIND ENERGY

Ireland
UCD

Portugal
INESC-PORTO

The Netherlands
TENNET

Germany (3)
FRAUNHOFER IWES
50 HzT
SIEMENS Wind Power

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

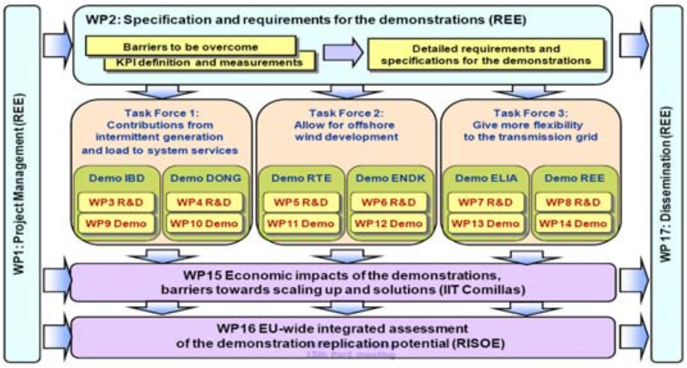
Belgium (6)
ELIA SYSTEM OPERATOR
EWEA
CORESO
UNIVERSITY LIEGE
UNIVERSITY LEUVEN
UNIVERSITE LIBRE BRUXELLES

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



DTU Wind Energy (RISOE)

- WP2 – KPI
- WP6 – Storm control demonstration with WP12 EnergiNet Demo
- WP16 – Up-scaling assessment of demonstrations to EU-wide scale – i.e. modelling

- ✓ **Task force 1:** what are the valuable contributions that intermittent generation and flexible load can bring to system services
- ✓ **Task force 2:** what can the network implement to allow for offshore wind development?
- ✓ **Task force 3:** how to give more flexibility to the transmission grid?
- ✓ **Overall:** how replicable are the results within the entire pan-European electricity system?

Twenties
Transmitting wind

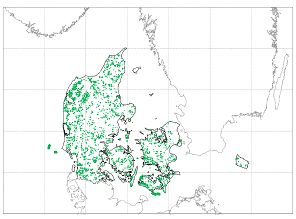
EU TWENTIES – WP16.2 (Leader: DTU Wind Energy)

OBJECTIVES

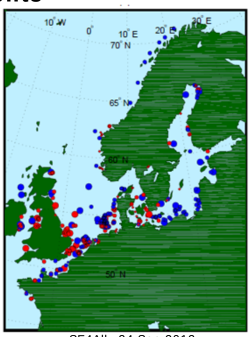
- Study power system balancing and reserve requirements with **massive offshore wind power**
- Special focus on sudden loss of wind power due to storm passages

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

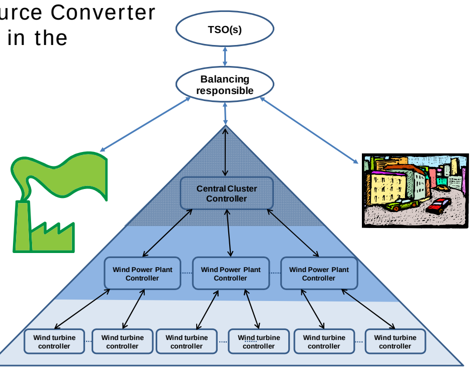


red: 2020
blue: 2030

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



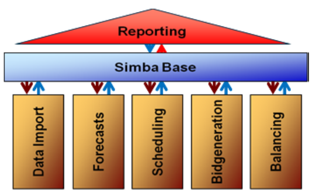
Cluster control:
Communication and control in clusters of wind power plants connected to HVDC offshore grids
(control system architecture, allocation of control tasks, communication protocol)

Simulation of Balancing (SimBa) Energinet.dk project

Planning tool to simulate balancing of power

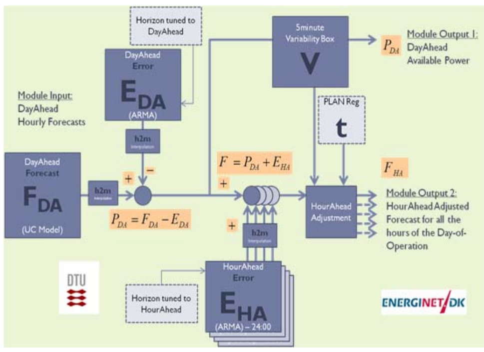
SimBa Overview

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



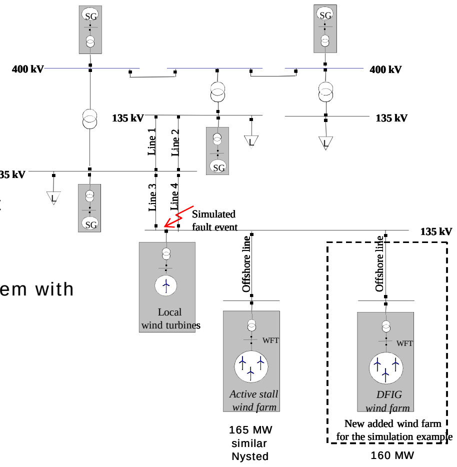
Forecast Module Overview

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

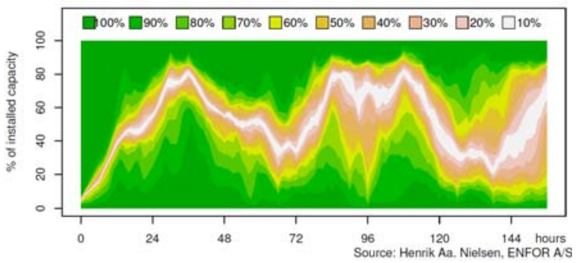
ANEMOS SafeWind (EU FP7)

- **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.



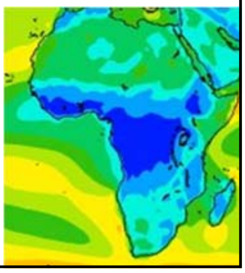
Electrical simulation models for wind power

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



PS: Rural Electrification + RE

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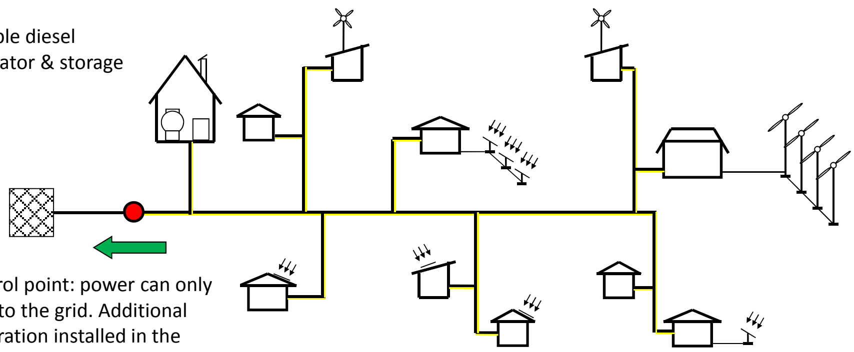
Example module

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

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