AN OVERVIEW OF WIND ENERGY RESEARCH AT TU DELFT

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Professor of Wind Energy Systems
Director of DUWIND
OVERVIEW

• Wind Energy Section
• DUWIND
• Some research highlights
• The EUROS project
• Future initiatives
• Summary
WIND ENERGY GROUP - ACADEMICS

4 professors (one emeritus)
- Simon Watson
- Gerard van Bussel
- Damiano Casalino
- Gijs van Kuik

2 associate professors
- Carlos Ferreira
- Roland Schmehl

6 assistant professors
- Michiel Zaaijer
- Nando Timmer
- Wim Bierbooms
- Francesco Avallone
- Daniele Ragni
- Axelle Viré
WIND ENERGY GROUP – RESEARCHERS AND PHDS

Erik Quaeghebeur
Qingqing Ye
Johannes Oehler

3 research associates

28 PhD candidates
RESEARCH AREAS

• External conditions for wind turbine loading
• Wind turbine aerodynamics
  - rotor aerodynamics
  - load mitigation (adaptive) rotors
• Novel wind energy concepts
• Offshore wind farm optimisation
• Aeroacoustics
PROGRAMME 1: EXTERNAL CONDITIONS FOR WIND TURBINE LOADING

Objective:

Characterisation of offshore wind environment for determination of its impact on wind turbine loads

Highlights:

• Method for constrained stochastic gust simulation
• Six-beam approach for lidar turbulence measurements.
• Novel momentum based extreme turbulent gust modeling
PROGRAMME 2: WIND TURBINE AERODYNAMICS

2a: Rotor aerodynamics

Objective:

Improvement of aerodynamic rotor performance of horizontal and vertical axis rotors in complex flows

Highlights:

• Hybrid Eulerian-Lagrangian code for 3D unsteady simulations

• New vertical axis rotor theory => thick airfoils lead to high rotor performance

• Validated high level CFD tool (open access)
Objectives:

1. Innovative local blade aerodynamic control
   => mitigate load fluctuations
2. Alternatives for blade pitch control
   => lean robust rotor

Highlights:

- Validated blade dynamics code with
  - integrated active flap control
  - non-linear structural dynamics
  - rotor aerodynamics

- Delft smart rotor technology
  => 5-10% load reduction on full scale wind turbines

- DBD (plasma) actuation methodology for load control and alleviation
Programme 3: Novel Wind Energy Concepts

Objectives:
1. Cost reduction through lean design and
2. Reduction of material use

Three Concepts:
- 2 Bladed Downwind Rotor
  - lattice (truss) tower
  - passive load control
- Floating VAWT’s
  - Advanced aero design with improved CP
  - Trifloater and spar buoy
- Airborne Wind Energy Concepts
  - automatic control of kite/wing
  - automated launch and retrieval using drone technology
PROGRAMME 4: OPTIMISATION OF (OFFSHORE) WIND FARMS

Objectives:
1. Multidisciplinary design optimisation for offshore wind farms
2. Optimisation of operation and maintenance

Highlights:
• Multi-agent scenario assessment tool
  => robust implementation paths for offshore wind farms in NL

• Offshore wind farm design emulator
  => efficient component trade-off studies.

• MDO tool with dynamic simulations in the loop
  => up-scaling of offshore wind turbines
Programme 5: Aero-acoustics group

Objectives:

1. Facilitate noise reduction and noise mitigation rotors (both wind turbines and propellers)
2. Develop new concepts through combined numerical and experimental research

Highlights:

• New experimental aero acoustic wind tunnel to be inaugurated in 2017
• Novel design of serrated trailing edges (“flat iron” design)
• Development of tuned porous ceramics for noise mitigation on rotors and auxiliaries
• Inter-faculty research organisation in Wind Energy
• Coordinates wind energy research activities across 5 faculties and 13 groups
• Works closely with external partners including Netherlands Energy Research Foundation ECN
DUWIND PARTICIPANTS

• Aerospace Engineering (Wind Energy, Structural Integrity and Composites, Aerodynamics, Aerospace Structures)
• Civil Engineering and Geosciences (Offshore Wind)
• Electrical Engineering, Mathematics and Computer Science (Electrical Power Processing, Electrical Power Systems)
• Mechanical and Materials Engineering (Delft Center for Systems and Control (DCSC), Engineering Dynamics)
• Technology, Policy and Management (Economic of Infrastructures, Technology Dynamics & Sustainable Development)
WIND TUNNEL FACILITIES

Open Jet Facility

Low speed wind tunnel – testing of DU blade section
HIGH-FIDELITY MODELLING OF FLUID-STRUCTURE INTERACTIONS

- Main team: Dr A. Vire, Dr R. Schmehl, N. Rajan, J. Brandsen, J. Dong, M. Folkersma
- CFD models: **Fluidity** (with Imperial College), **OpenFOAM**
- CSD models: in-house **Python codes** for flexible kites and NURBS-based rigid-body model

- Application to **airborne wind energy**: rigid and flexible kite wings
  - Aerodynamics of kite wings at high Re
  - Validation of RANS and LES models
  - Future work: Kite deformations
- Funding:
  - EU Marie Curie CIG NUMIWING
  - EU ITN AWESCO
HIGH-FIDELITY MODELLING OF FLUID-STRUCTURE INTERACTIONS

- Application to **fixed and floating offshore wind turbines**
  - Aero/hydro-dynamics problem
  - Accurate wave propagation and wave-structure interactions with air-water interface
  - Future work: wind turbine parameterisations
  - Funding: TU Delft cross-departmental scheme

- Application to **add-ons** for wind turbine blades (just started)
  - Partnership with 2B-Energy
  - Funding: Dutch research council
AEROSPACE STRUCTURE AND MATERIALS - BLADES

Reliable manufacturing with rapid throughput; Greener manufacturing processes

Process Simulation & Verification

Rain erosion

Processing new materials

Effect of defects on lifetime

Smart manufacturing

Sustainable processes
SMART ROTOR: MORPHING BLADES

Piezo-electric actuated flexible blade surface controlled to adapt profile to respond to turbulent conditions: load alleviation up to 30%
SMART ROTOR CONTROL
FATIGUE LOAD REDUCTION

LIPC- Linear Individual Pitch Control
LIFC – Linear Individual Flap Control
SPRC- Subspace Predictive Repetitive Control
WIND FARM CONTROL – OPTIMISED YAW (NREL COLLABORATION USING SOWFA MODEL)
Intelligent integrated system development based on big data

**Prognostic maintenance model**

Output 1

**Maintenance plan**

Weather condition
Operation condition etc

**Maritime operation optimization model**

Output 2

Weather condition
Ship operation
Equipment
Spare parts etc

**Implementation optimization**

Ship type&capacity
Ship speed
Sailing route
Push-on forces
Ship drag

**Big data collection and analysis**

Wind turbine
Wind farm
Operating companies
Stocks
Maintenance Sources

INTEGRATED O&M OPERATIONAL SYSTEM
• Modelling impact of future offshore VSC-HVDC grids on AC transmission system stability
• Responsible innovation
• Social innovation
• Energy justice

• Wind energy faces public opposition:
  • How to engage with (local) communities in planning of wind parks?
  • (New) modes of participation in wind energy planning (e.g. financial participation, energy cooperatives)?
  • Design for values: how to incorporate public values in design of technology, institutions and planning procedures?
EUROS: EXCELLENCE IN UNCERTAINTY REDUCTION OF OFFSHORE WIND SYSTEMS

- Design
- Construction
- Logistics

- Over-conservative parameters increase costs
- Safety margins can be reduced by reducing uncertainties
- EUROS aims to lower costs by reducing uncertainties and increasing efficiencies
PARTNERS

Universities

TU Delft

TU/e

Wageningen UR

Research Institutes

CWI

TNO

ECN

Deltares

Companies

DNV-GL

Eneco

Fugro

H

Van Oord

IHC

IQIP

Systems Navigator

Budget = €3.4M
PROJECT 1: EXTERNAL CONDITIONS

Wind Loads

Extended Weather Forecasts

Uncertainty Quantification in Wind and Waves

Wind Farm Wake Effects
PROJECT 2: LOADS AND DAMAGE

Smart Monitoring and Damage Development

Physical Modelling of Service Life Consumption by Pile Driving

Physical Modelling of Crack Initiation and Propagation

Physical Modelling of Scour and Seabed Variations

Uncertainty Propagation
PROJECT 3: WIND FARM DESIGN OPTIMISATION

Smart Logistics

Uncertainty Model of Wind Farms
EUROS - THE BIG PICTURE

- Uncertainty Quantification in Wind and Waves
- Wind Loads
- Extended Weather Forecasts
- Wind Farm Wake Effects
- Physical Modelling of Scour and Seabed Variations
- Smart Monitoring and Damage Development
- Physical Modelling of Crack Initiation and Propagation
- Physical Modelling of Service Life Consumption by Pile Driving
- Smart Logistics
- Uncertainty Model of Wind Farms
- Smart Monitoring and Damage Development
- Physical Modelling of Service Life Consumption by Pile Driving
- Smart Logistics
- Uncertainty Model of Wind Farms
- LCOE
- Uncertainty Propagation
GROW: GROWTH THROUGH RESEARCH, DEVELOPMENT & DEMONSTRATION IN OFFSHORE WIND

Public-private consortium of around 20 partners working to reduce the costs of offshore wind to a competitive level in the near future – successor to FLOW

Budget: 100 Million Euros over five years
PROGRAMME LINES

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<th>Objectives</th>
<th>Value chain steps</th>
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<td>Reduce LCOE</td>
<td>Design/system design</td>
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<tr>
<td>Strengthen Dutch offshore wind</td>
<td>Installation</td>
</tr>
<tr>
<td>sector</td>
<td>O&amp;M</td>
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<tr>
<td>Create added value</td>
<td>Decommissioning</td>
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- Design/system design:
  - Blades
  - Alternative turbines
  - Monopiles
- Installation:
  - Alternative support structures
  - Electrical systems
- O&M:
  - Integration in energy system
  - Symbiosis with other sea users
- Decommissioning:
  - O&M
  - Decommissioning
• GROW: higher TRL demonstrating short term LCOE gains
• Need for lower TRL research
• Dutch NWO planning to fund PhD programme on offshore renewable energy, primarily wind power
• PhD@Sea: Size and duration to be determined
• DUWIND planning to launch a Dutch ‘Doctoral College in Offshore Renewable Energy’ based on EU M-C ITNs and UK CDTs
SUMMARY

• TU Delft has the largest academic wind energy research activity in NL
• Strong connections with industry
• Dutch government keen to see research which lowers the LCOE of offshore wind and strengthens Dutch offshore wind sector
• Potentially large Dutch offshore renewable energy PhD programme to be rolled out
• Only a very small role for other marine renewables