Progress report Task 23
September 2006

OFFSHORE WIND ENERGY TECHNOLOGY AND DEPLOYMENT

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Operating Agents

Supported by Sandy Butterfield and Flemming Øster

Organizational Structure

Annex 23 Operating Agents
Risø and NREL

Subtask 1 (Risø)
Experience with critical deployment issues

- **Research Area # 1**
  Ecological Issues and Regulations
  NL
- **Research Area # 2**
  Grid Connection of Large Scale offshore wind power
  UK
- **Research Area # 3**
  External Conditions, Layouts and Design of Offshore Wind Farms
  DK

Subtask 2 (NREL)
Technical Research for deeper water

- **Research Area # 4**
  Offshore Code Comparison Collaboration
  USA

Annex 23 Participation

Country	Membership Status/ Contracting Party	Organization
United States	Committed/ US Department of Energy	• NREL • MIT • University of Massachusetts • GE Energy
Denmark	Committed/ Danish Energy Authority	• RISØ National Laboratory • Vestas, Siemens • Elsam • DnV, Carlbro
Norway	Committed/ Enova SF	• NTNU-BAT
United Kingdom	Comitted/ Department of Trade and Industry	• Garrad Hassan • Ceasa
Netherlands	Committed/ CenterNovem	• We@sea • ECN • KEMA
Germany	Committed/ Ministry of Environment, Nature Conservation and Nuclear Safety	• University of Stuttgart • GE Energy
South Korea	Committed/ Ministry of Commerce, Industry and Energy	• Inha University
Sweden	Committed/ Swedish Energy Agency	• Chalmers
Spain	TBD	• Cener

2006
Subtask 1 Activities

Activities last period

- Poster at Copenhagen Offshore conference Oct. 26-28 2005
- Meeting #4 of Subtask 2 on Oct. 31 and Nov. 1, 2005 at Risoe National Laboratory Denmark.
- Workshop on combined Research Area #1 External Conditions and Research Area #5 - Wind Facilities Technology and Design in Denmark 12-13 December 2005 Risoe National Laboratory

This period

- **Task 23 presentation at OWEMES 21-22 April**
- **Presentation at DTI seminar June 8. Londaon**
- **Planning meeting on Grid Connection og large scale Wind Farms August 16.**
- **Workshop on Wake Modeling and Benchmarking of Models 6-7 September 2006 in Billund, Denmark (postponed from May)**

Grid Connection of Large Scale offshore wind power

- **The five critical issues included in the work program:**
  - Offshore wind meteorology and impact on power fluctuations and wind forecasting
  - Behavior and modeling of high-voltage cable systems
  - Grid Code and security standards for offshore versus onshore
  - Control and communication systems of large offshore wind farms
  - Technical architecture of offshore grid systems and enabling technologies.

Grid Connections Project Plan

- **The following set up has been decided for the program:**
  - Each participant must supply information from at least one national project
  - The national projects should have a volume of above 100,000 Euro or 1 person-year during the period.
  - Information and results from the national projects must be delivered to the OA and allowed in the final IEA report.
  - Information on the project should include title, purpose of the project (5-10 line description), project period, economic volume and the total effort (person-month)
  - 3 workshops will be arranged in 2007 – 2008
  - An overview of results from national projects and the results of the discussions will be published as an Task 23 report

Grid Connection Meeting Plan

Work item	Initiative	Action
Technical architecture Grid codes	UK	Workshop early 2007
Offshore meteorology and electrical power Connection and control strategies	DK	Workshop late 2007
Transient behavior	NL	Workshop 2008

External Conditions, Layouts and Design of Offshore Wind Farms

Results from workshop at Risø December 2005 (30 experts from 9 countries discussed the following five main areas)

- ***1) Wake modeling and benchmarking of wake models***
- 1. Step: Workshop on status existing works
- 2. Step: Workshop on evaluating the quality of models and results
- ***2) Marine boundary layer characteristics.***
- The marine boundary layer is defined here as the lowest ~1 km of the atmosphere between the height of the geostrophic wind speed and the wave surface of the ocean.
- To review current experience particularly with regard to developing wind farms in coastal areas (~50 km from the coast)
- To assess the reliability of remote sensing methods offshore including satellite observations, sodar and lidar where the aim is to observe wind and turbulence profiles at 100 m and above and to include tall mast measurements where available
- To assess the accuracy of model predictions including local scale, mesoscale and LES models as available.
- ***3) Met-ocean data and loads.***
- To be formulated

Work shop

Wake modelling and benchmarking of models

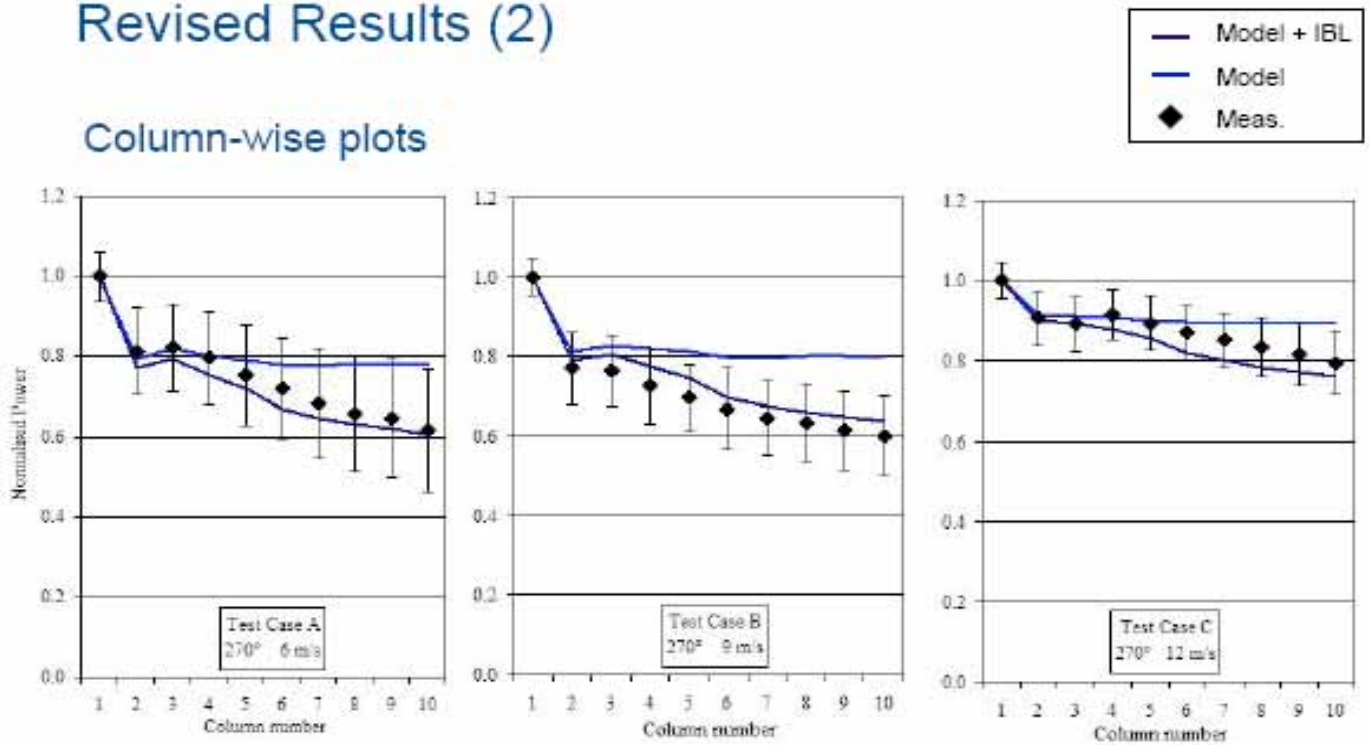
- Risø has organized a workshop in Denmark 6-7 September 2006.
- Wednesday, 6 Sep.
  - Morning: Transport to Høvsøre
  - Afternoon: Structural Loading. Fatigue and extreme loading due to wake effects
  - Test site visit
- Thursday, 7 Sep
  - Morning: Wind Farm Layout. Array efficiency of large offshore wind farms
  - Afternoon: Benchmarking of Models
  - Conclusions

28 participants

Modelling of wake effects

Revised Results (2)

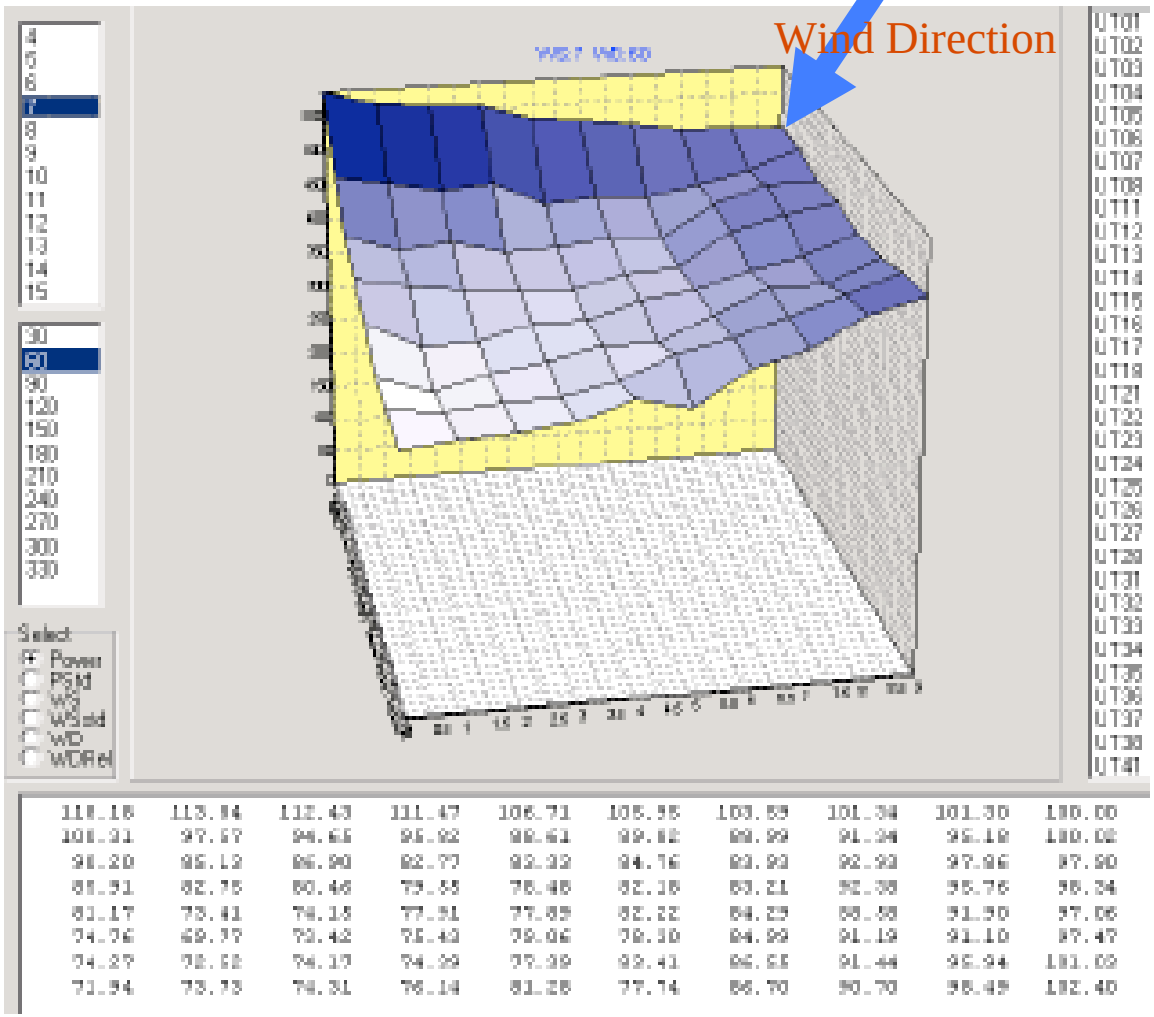
Column-wise plots



IBL: Inner boundary layer theory

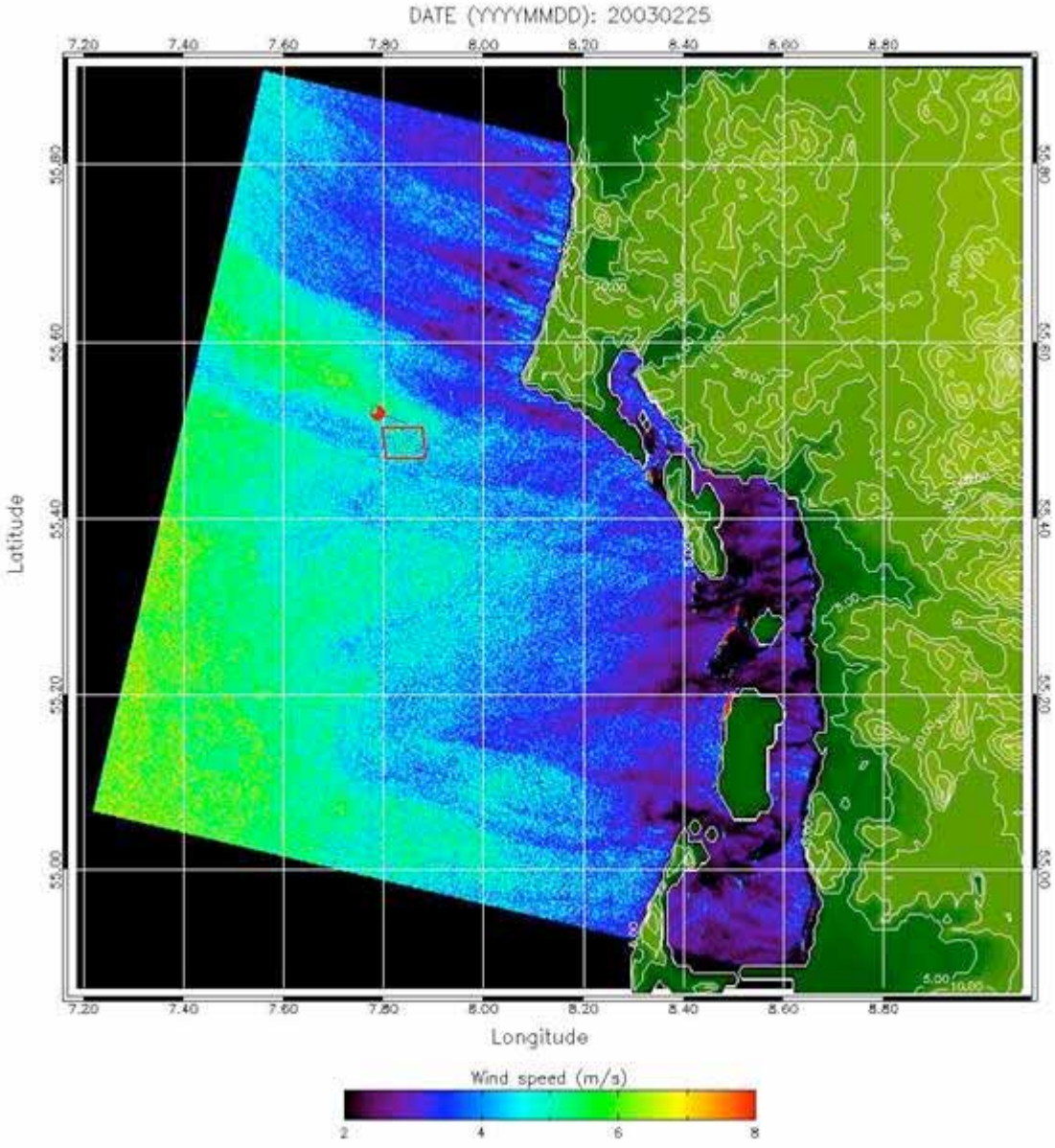
Measured Wake losses at Horns Rev

Corner turbine speed up or land effect?



Wake loss measurements at Horns Rev

European Remote Sensing Satellite -2 Global Measurements and Images including Sea State, Sea Surface Winds, Ocean Circulation, and Sea and Ice Levels.

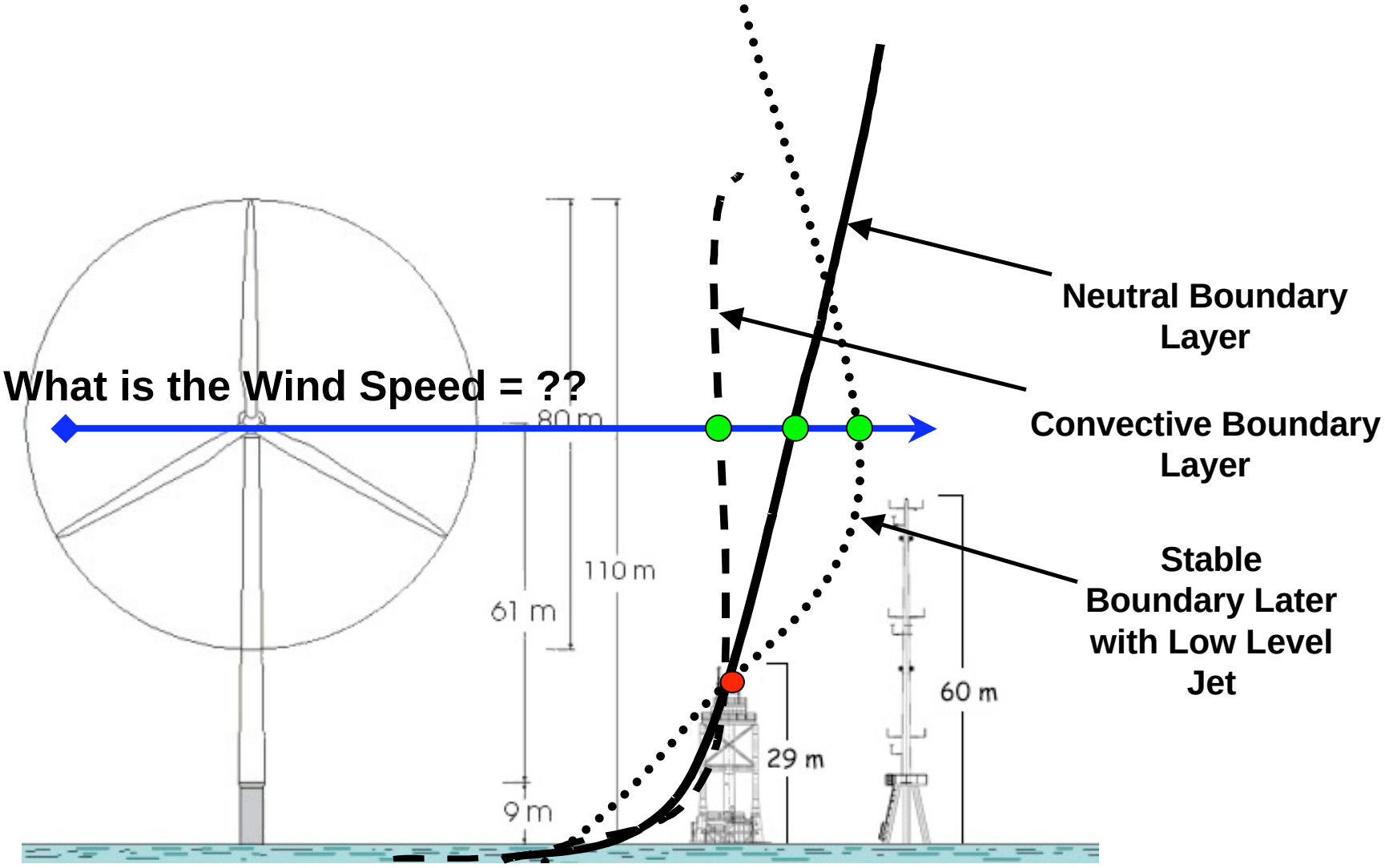


Results

Conclusion

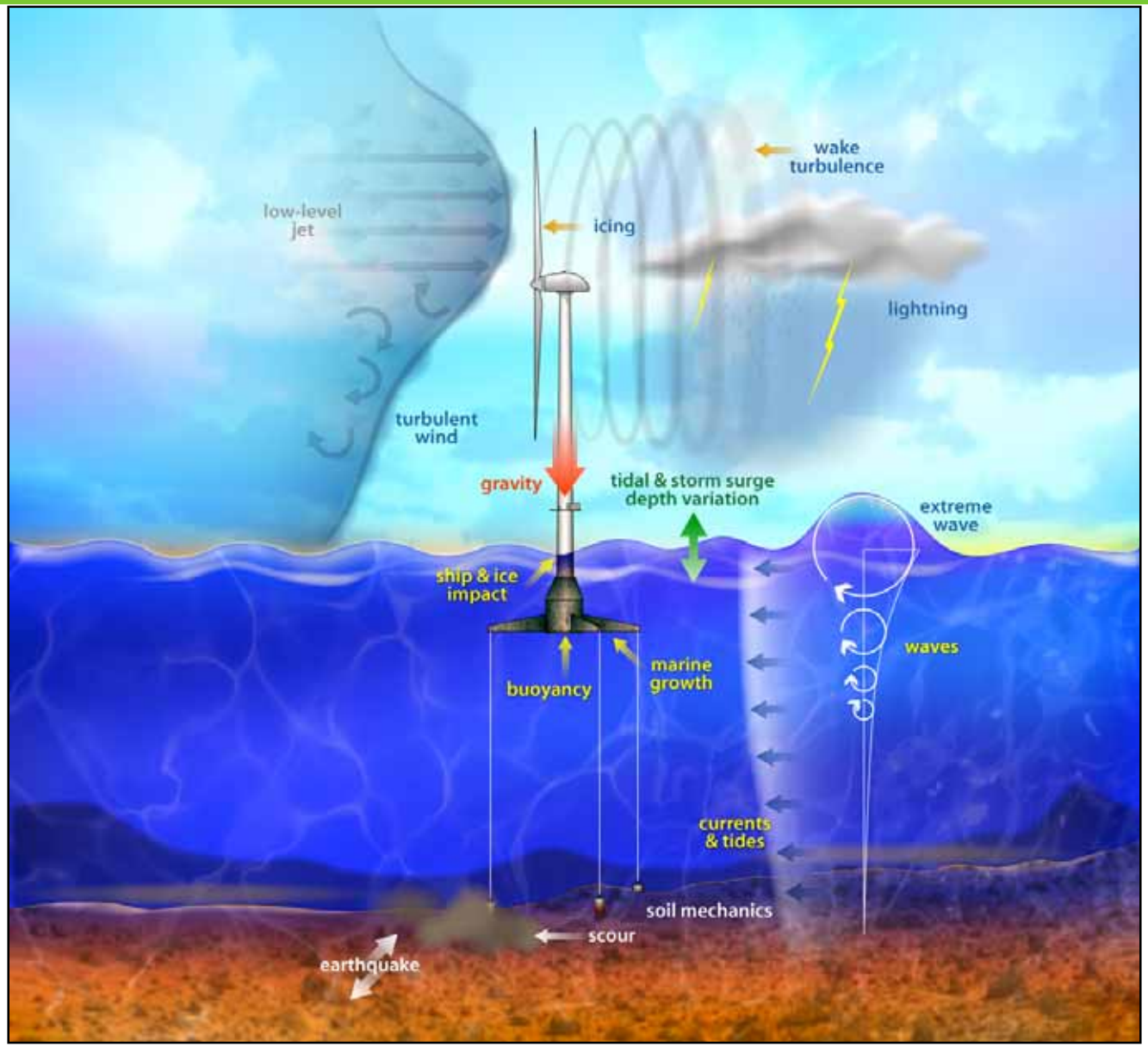
- It was agreed to prepare a format for collecting and benchmarking data related to offshore wind farms and onshore farms in cases when it is considered relevant.
- The format will be suggested to the participants in the workshop and member countries of Task 23.
- The collaboration will be focussed on data which are important for power calculations as well as design loads.
- Within the next year the benchmarking experience and the results obtained from the continued collaboration also with UPWIND will be analysed and discussed at a second workshop
- Risø has the lead in the collaboration

2) Marine boundary layer characteristics

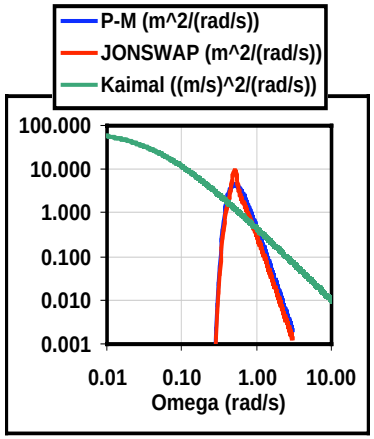


Graphic Credit: Bruce Bailey AWS Truewind

3) Met-ocean data and loads



- Turbulent winds
- Irregular waves
- Gravity / inertia
- Aerodynamics:
  - induction
  - skewed wake
  - dynamic stall
- Hydrodynamics:
  - scattering
  - radiation
  - hydrostatics
- Elasticity
- Mooring dynamics
- Control system
- Fully coupled



Wind and Wave Spectra

Work Planned

- Carry on with the planned work on grid connection and Wake modeling
- Discuss workshop on Ecological and regulatory issues with the Netherlands lead person or with another country.

Offshore Code Comparison: Collaboration (OC3)

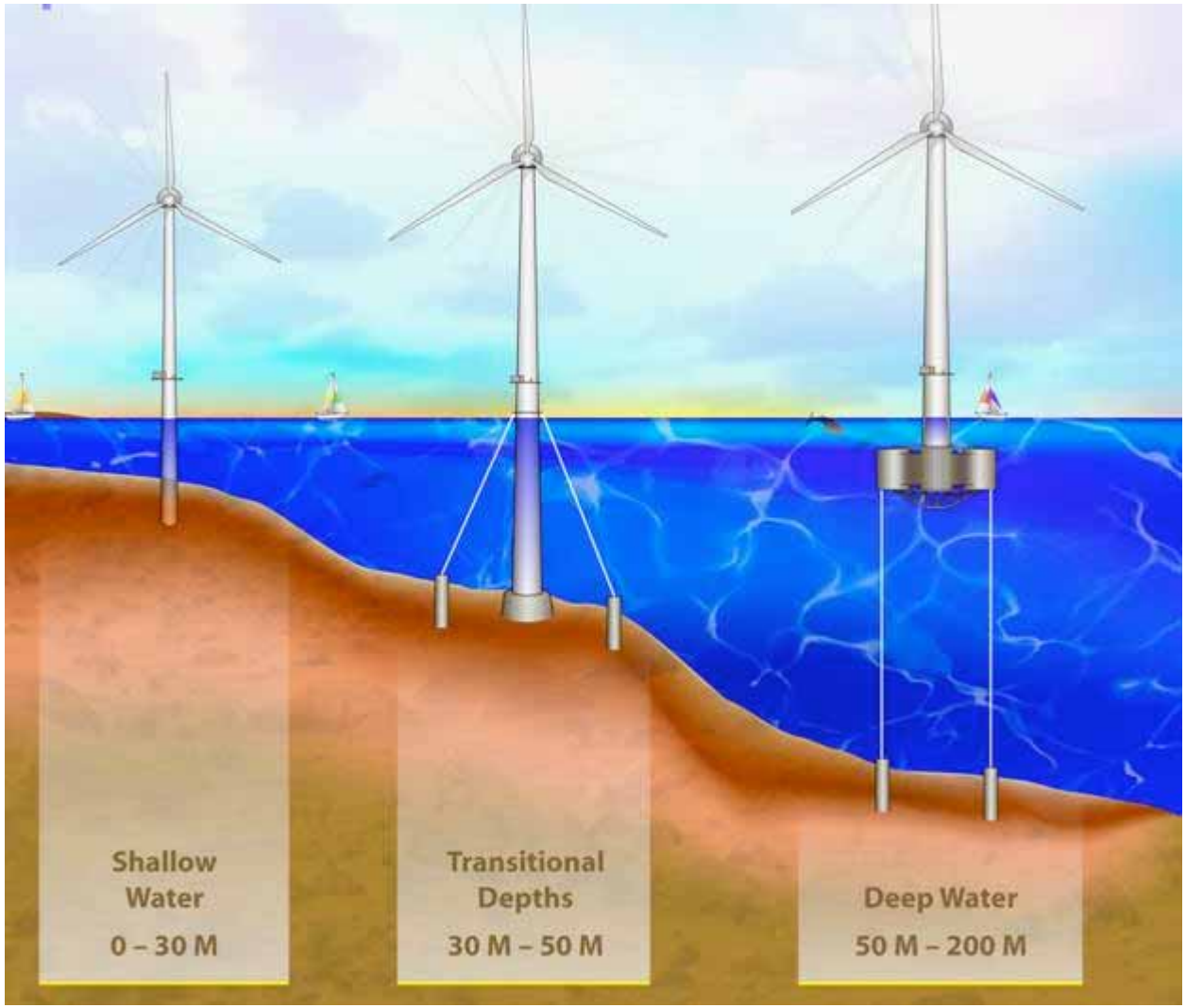
Goal

1. Quantify offshore load prediction capability
2. Identify critical modeling deficiencies common to all codes.

Scope

Code Comparisons for:

- Wave loading
- Support structures
- Geotechnical
- Coupled system dynamics



Lead: Sandy Butterfield-US DOE/NREL

Technology and models

Includes technologies ranging from the current shallow-bottom monopiles to deep water floating platforms.

- **Water depth:** 5 m – greater than 200 meters.
- **Support structures**: monopiles to floating.
- **Wave loading models**: linear and non-linear (breaking).
- **Coupled dynamic models**: FAST, ADAMS, BLADED, HAWC, HAWCB, HAWC2, FLEX5, DHAT

Not included: aerodynamic models, turbulence models, various turbine types, controls.

Approach
Develop baseline turbine model for comparisons

Establish inputs and design load cases (DLC):

- turbulence
- wave states
- geotechnical conditions

Establish three baseline support structures

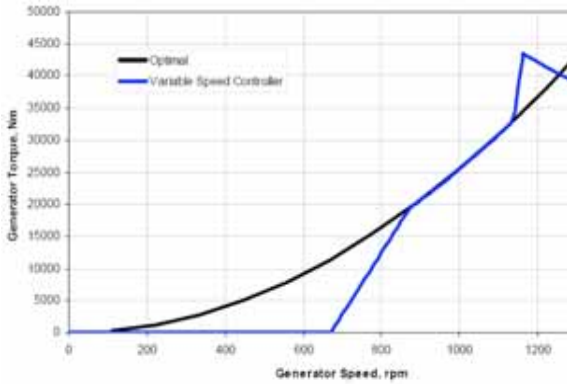
- shallow
- transitional
- deep (floating)

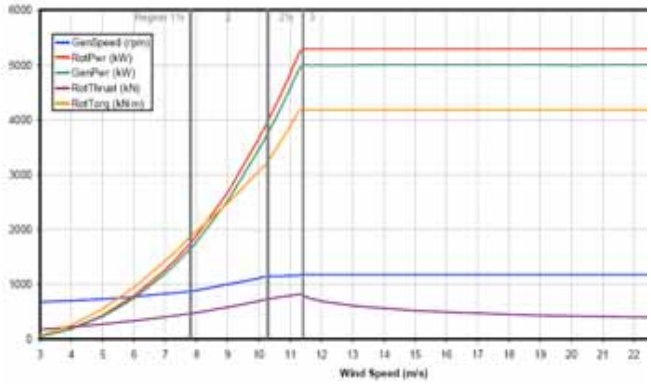
Systematically (step by step) compare model results for each condition and DLC

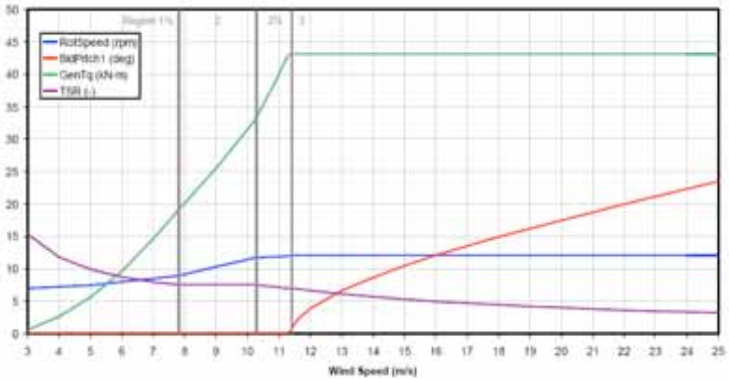
Net meetings used extensively to coordinate efforts and comparisons

NREL 5 MW Baseline Wind Turbine

Nominal power	5 MW
Rotor diameter	126 m
Blade length	61.5 (LM 61.5)
Hub height	90 m
Tower (Deep water)	90 m fixed at bottom
Tower (Shallow water)	80 m tower + 30 m monopile
Power control	Variable speed Collective Pitch
Rated rotor speed	12.1 rpm.
Gear ratio	97:1
Overhang / Shaft Tilt / Precone	5m / 5º / -2.5º
Blade mass	17.7 t
Rotor mass	110 t
Nacelle mass	240 t
Tower mass	348 t / 523 t



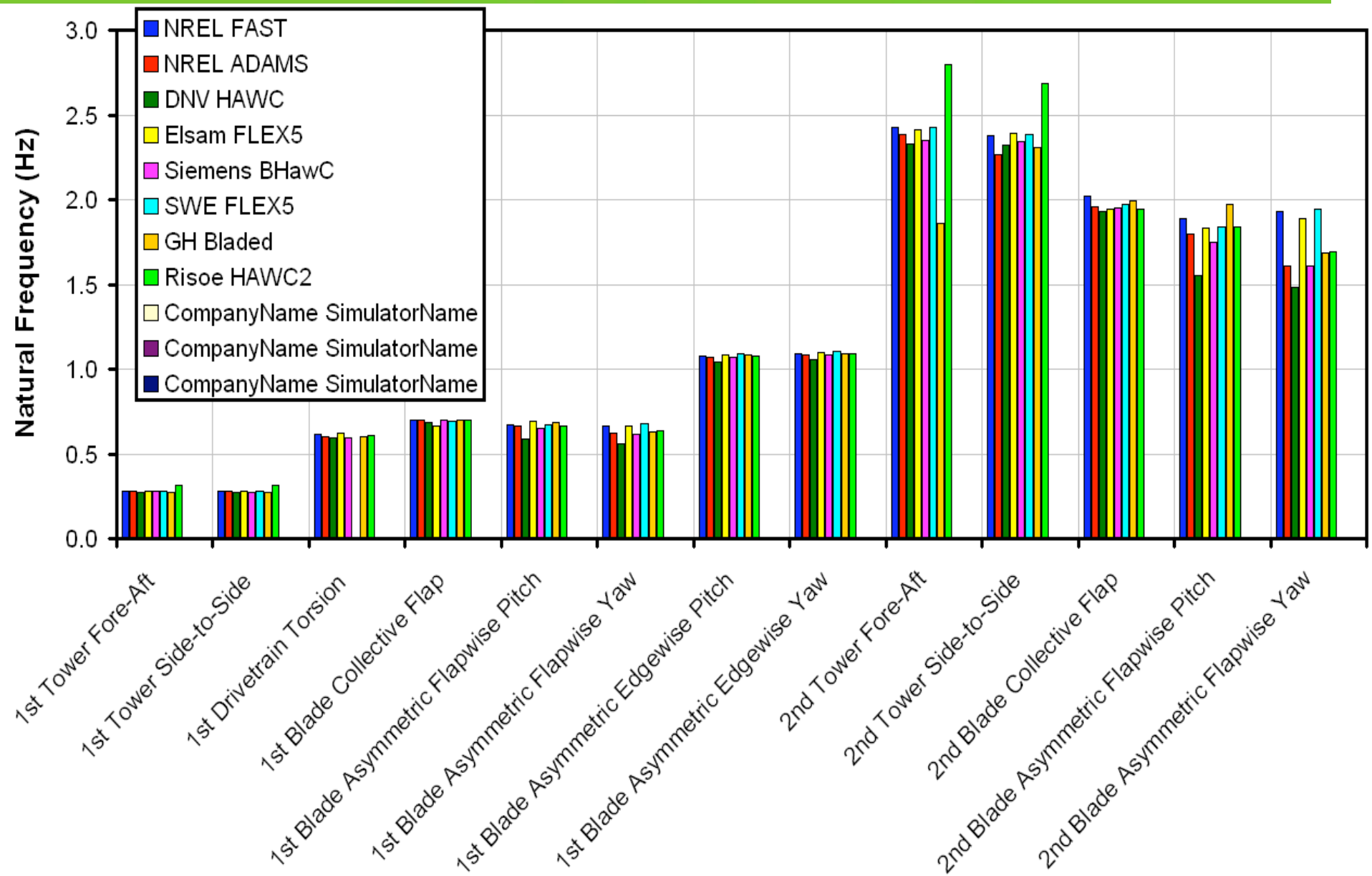




Work done

- **Baseline models complete (rotor, aerodynamics, controls, tower, turbulence model, wave kinematics)**
  - **Baseline model has been adopted for two UpWind Work Packages.**
  - **OC3 work could form basis for UpWind WP 1A1 "Integrated Design and Standards"**
- **Basic turbine dynamics comparison complete.**
- **Monopile and tripod support structure models defined**
- **Geotechnical model defined**

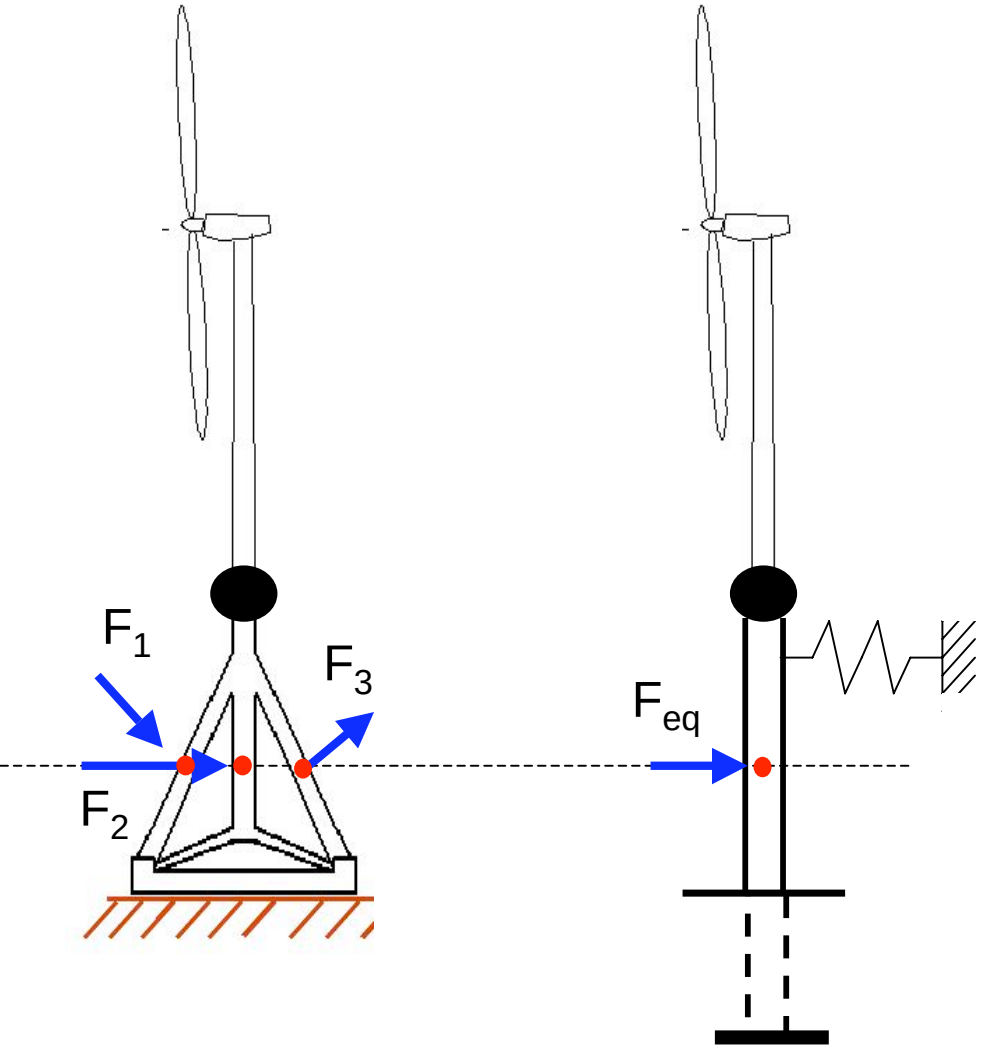
Example Results
Phase 1.1: Baseline Model
dynamics Comparisons (8 codes)

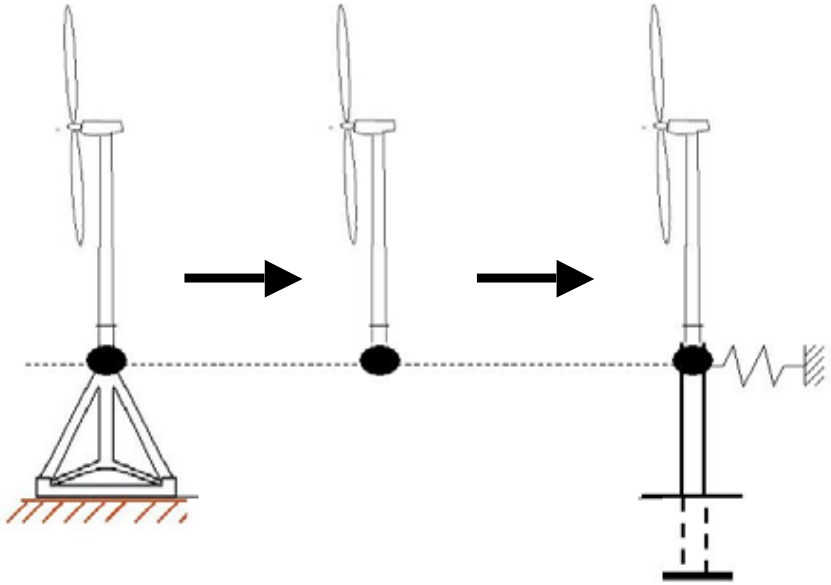


Selected Foundations

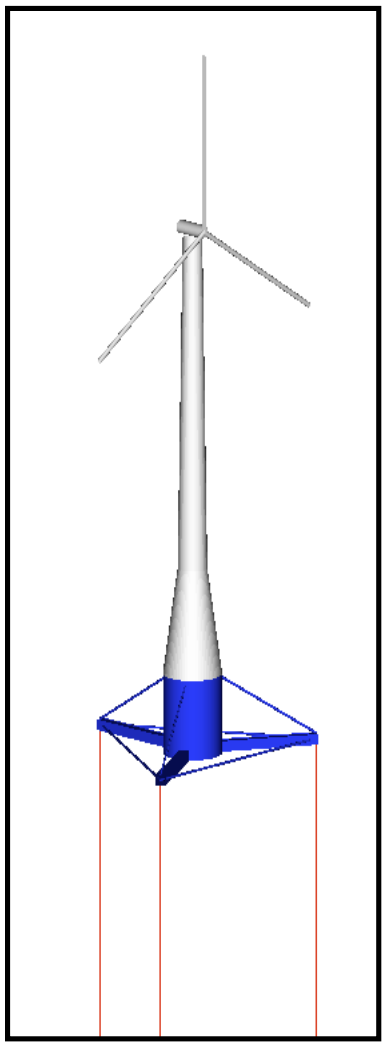
Simplified Support Structure Modeling

Patrik Passon: Stuttgart

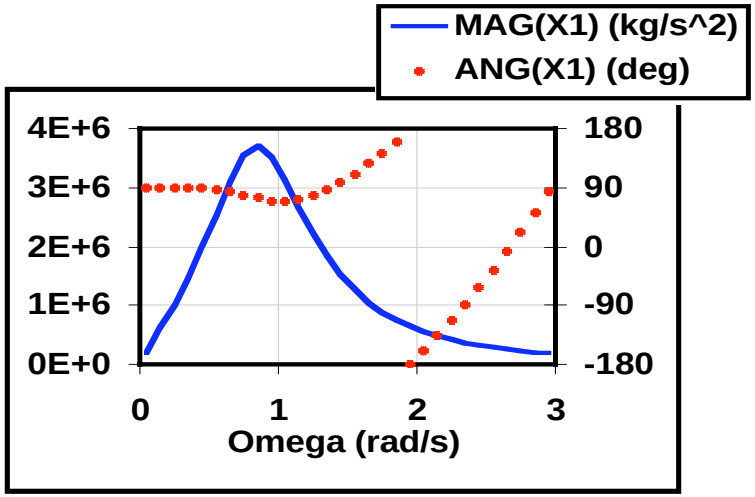




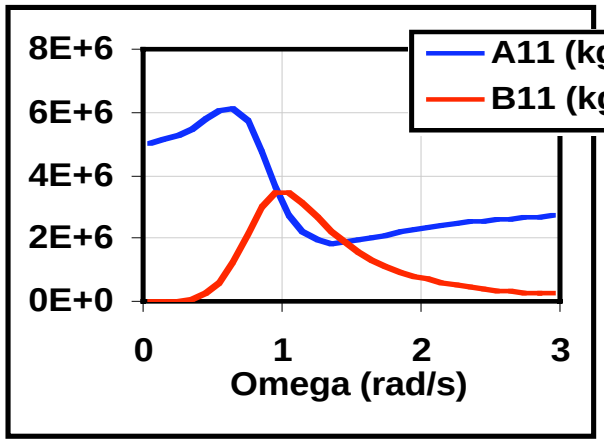
Planned Floating Platform Analysis



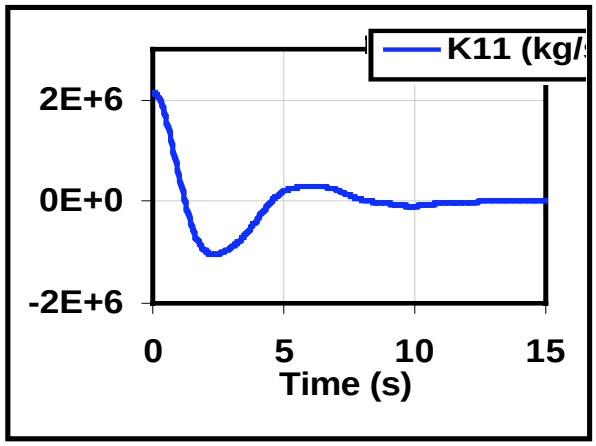
Baseline Wind Turbine with TLP



Wave Excitation in X-Direction



Added Mass and Damping in Surge



Radiation Kernel in Surge

Annex 23 Financing

Estimated Expenses of the Operating Agent – Years 2, 3, & 4 (May 2005 – April 2008) all figures in US Dollars				
Item	**Per Year**	**RISO per year**	**NREL per year**	**Annex Total**
Coordination & management including meetings 1.3 person -months/year/OA	30,000	16,000	14,000	90,000
Travel, hotel, sustenance (3 meetings per year: one ExCo and two R&D) per OA	16,000	8,000	8000	48,000
Preparing proceedings, publication, website maintenance	3,800	1,000	2,800	10,400
Annex Total	49,800	25,000	24,800	149,400

- Costs represent approximately 70% of the actual costs to the operating agents
- Each country will pay a single fee to join all Annex 23 activities
- Multiple participants per country allowed.

OA spending 2005/2006

Period: October 2005 through August 2006	Total budget	Total Actual		
	(US$)	(US$)	(US$)	(US$)
Revenues (8* $6,225)	49,800			
Paid (up to Sept 1.) (6* $6,225)		37,350		
			NREL	Risoe
Coordination & management including meetings	30,000		77,000	27,023
Travel, hotels and sustenance	16,000		3,800	2,426
Meeting arrangements, publication and web site maintenance.	3,800			553
Total	49,800		81,800	30,002

Subtask 1

Subtask 1 accounts (DK 2005 funds) for 2004/2005 and 2006

	2004/2005	2006 until Sep 1.	Total
Budget*	**107,831**	**0**	**107,831**
Spending:			
Coordination & management including meetings and preparing proceedings, publication	**52,640**	**25,755**	**78,395**
Travel	**7,641**	**5,200**	**12,841**
Total US$	**60,281**	**30,955**	**91,236**