Prospects of Large Floating Vertical Axis Wind Turbines

Wind Power R&D seminar – Deep sea offshore wind
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Trondheim, No

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Agenda

- Introduction
- DeepWind concept description
- Dimensions
- Challenges and results from first order investigations
- DeepWind project description and partners
- Conclusions

Agenda

- **Introduction**
  - **Cost of on shore and off shore wind energy**
  - **Hypothesis of the project**
  - **From shore to deep sea**
- DeepWind concept description
- Dimensions and challenges
- Results from first order investigations
- DeepWind project description and partners
- Conclusions

Cost of onshore to offshore wind power

- Offshore wind energy is growing fast. In Europe, new offshore power installation is expected to grow by 28% each year (EWEA report 2009)

....BUT

- In average the cost of offshore wind energy is 2400 Euro/kW versus the 1250 Euro/kW of the on shore wind energy (data 2008, from EWEA report 2009)

- The deployment of new wind resources is limited by the logistic, for example the water depth, the distance from shore, the grid connection…

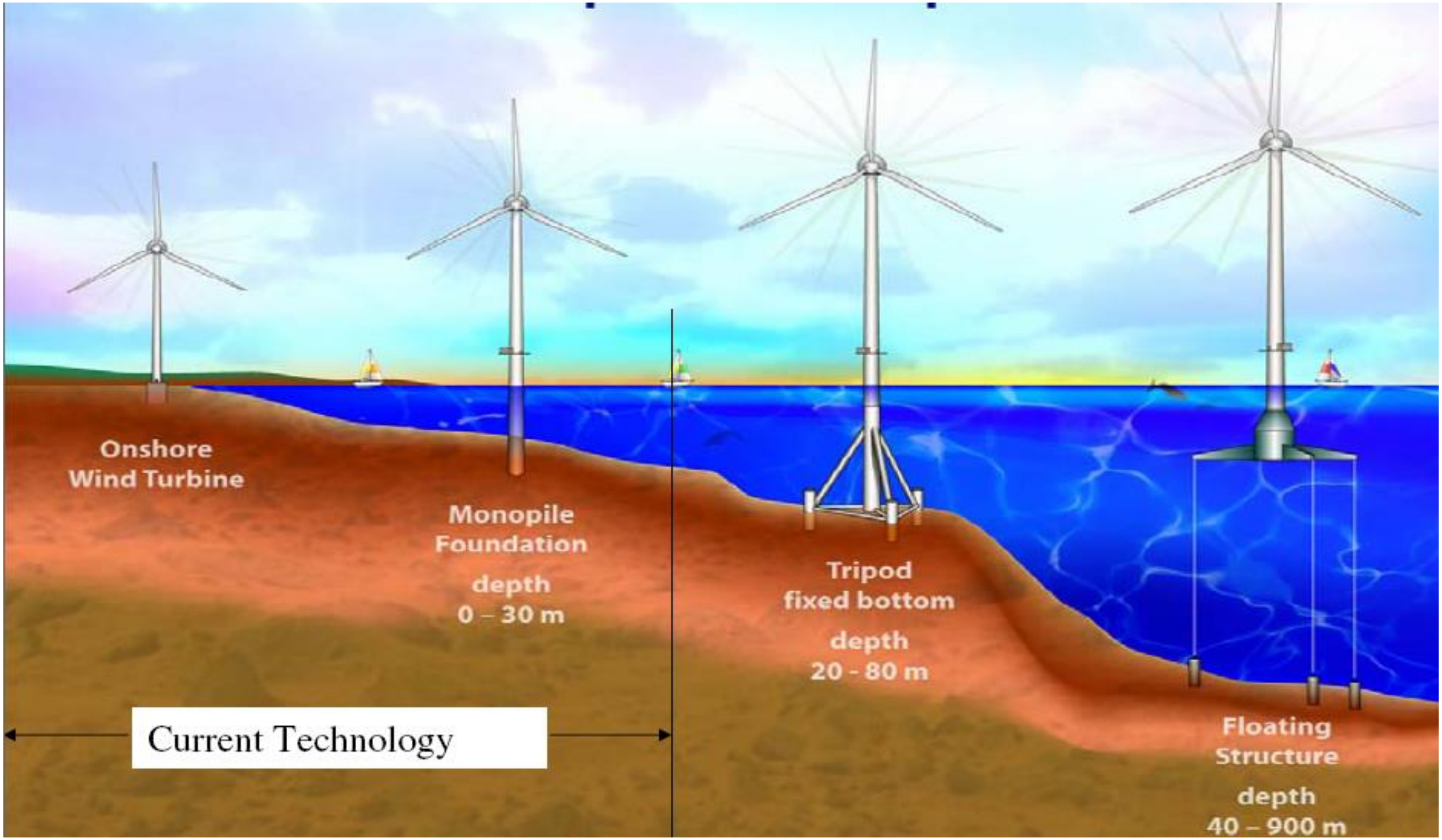
Introduction

DeepWind hypothesis

- So far, offshore wind energy has been mainly based on onshore technology moved in shallow waters
- In order to reduce the cost, offshore wind energy needs new concepts specifically designed for offshore conditions
- Key issues for a successful offshore concept are:
    - ✓ Simplicity
    - ✓ Up-scaling potential
    - ✓ Suitability for deep sites

Introduction

From shore to deep sea



*from NREL and MIT (*Sclavounos*)*

Agenda

- Introduction
- **DeepWind concept description**
  - **General concept description**
  - **Components description**
  - **Upscaling**
  - **Installation and O&M strategies**
- Dimensions and challenges
- Results from first order investigations
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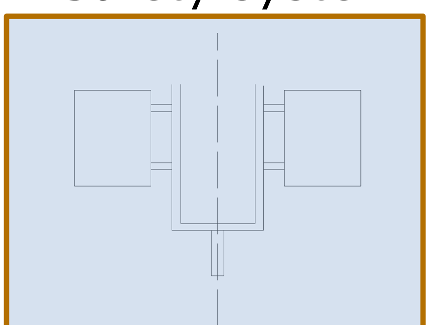
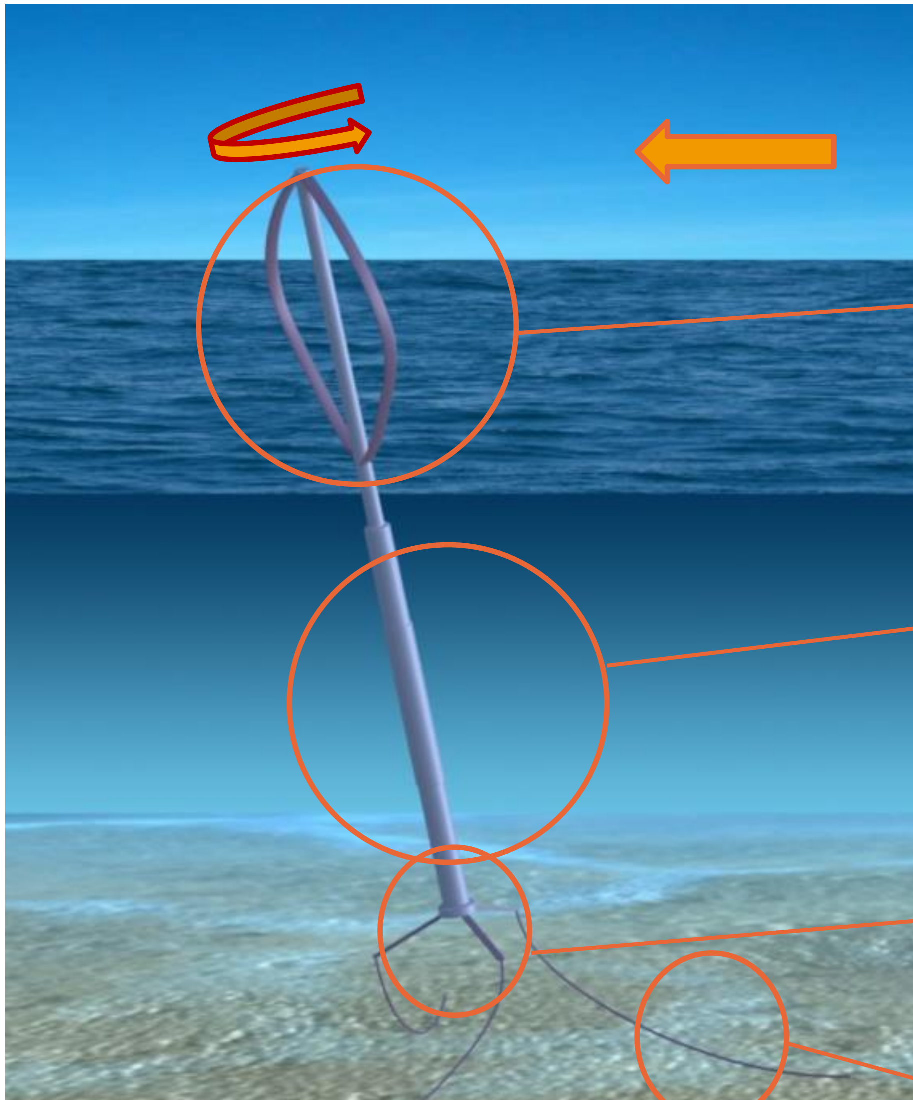
General concept description

- floating and rotating tube as a spar buoy
- No pitch, no yaw system
- C.O.G. very low –counter weight at bottom of tube
- Safety system





Light weight rotor with pultruded blades

Long slender and rotating underwater tube

Torque absorption system

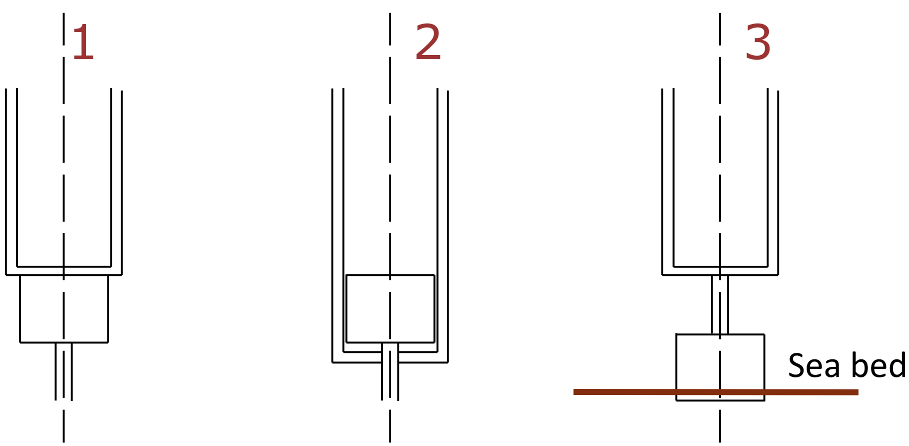
Mooring system

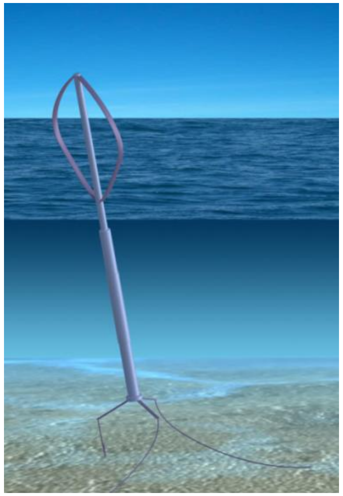
DeepWind concept description

Components - Generator configurations

- The Generator is at the bottom end of the tube; several configuration are possible to convert the energy

- Three selected to be investigated first:
    1. Generator fixed on the torque arms, shaft rotating with the tower
    2. Generator inside the structure and rotating with the tower. Shaft fixed to the torque arms
    3. Generator fixed on the sea bed and tower. The tower is fixed on the bottom (not floating).

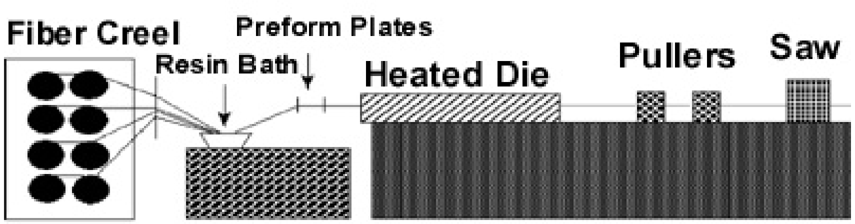


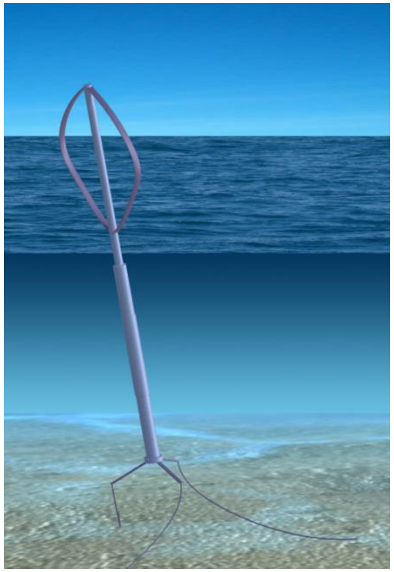


DeepWind concept description

Components – Blades technology

- The blade geometry is constant along the blade length
- The blades can be produces in GRP
- Pultrusion technology:
 11 m chord, several 100 m long blade length

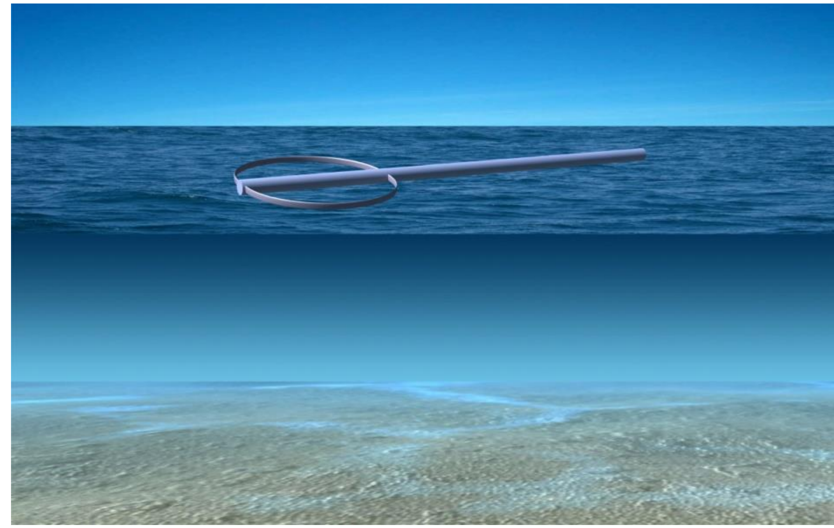




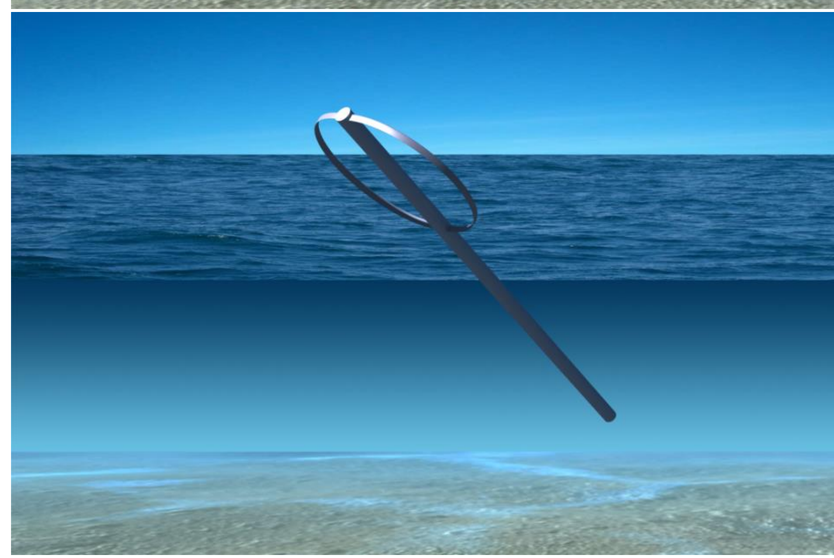
- Pultrusion technology could be performed on a ship at site
- Blades can be produced in modules

Installation, Operation and Maintenance

- INSTALLATION
  - ✓ Using a two bladed rotor, the turbine and the rotor can be towed to the site by a ship. The structure, without counterweight, can float horizontally in the water. Ballast can be gradually added to tilt up the turbine.



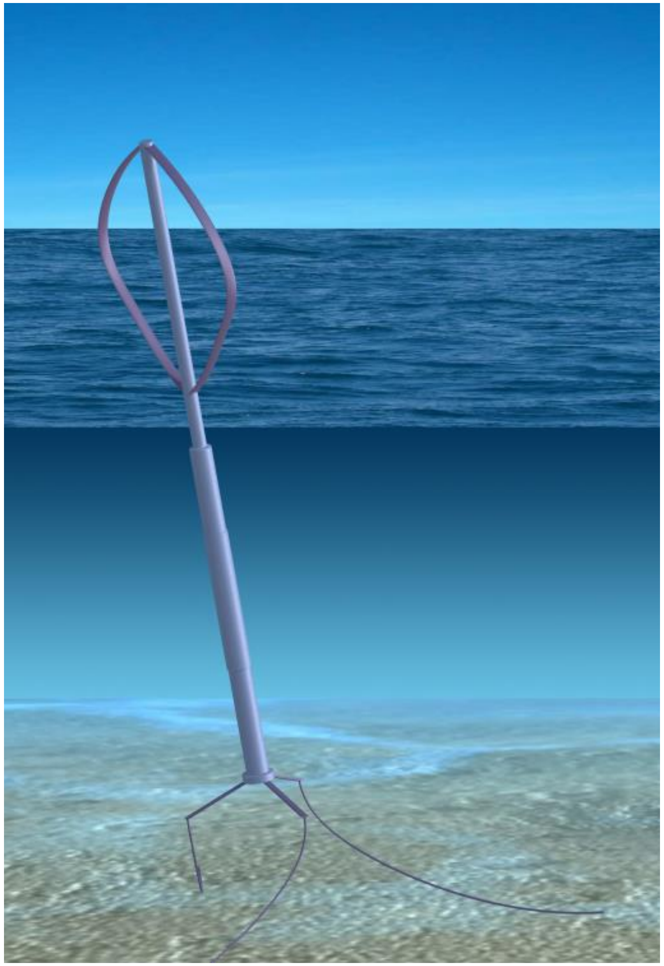
- O&M
  - ✓ Moving the counterweight in the bottom of the foundation is possible to tilt up the submerged part for service.
  - ✓ It is possible to place a lift inside the tubular structure.



Deep Wind Concept
Upscaling

- Pultrusion technology allows for very long and fail-free manufactured blades
- Concept simplicity
- Few components with less down time failures

- Cost-effective different materials for large structure
- Specific requirements to maintain the underwater components



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- Introduction
- DeepWind concept description
- **Dimensions**
  - **2MW design**
  - **2MW VAWT vs HAWT dimension comparison**
  - **Outlook upscale**
- Results from first order investigations
- DeepWind project description and partners
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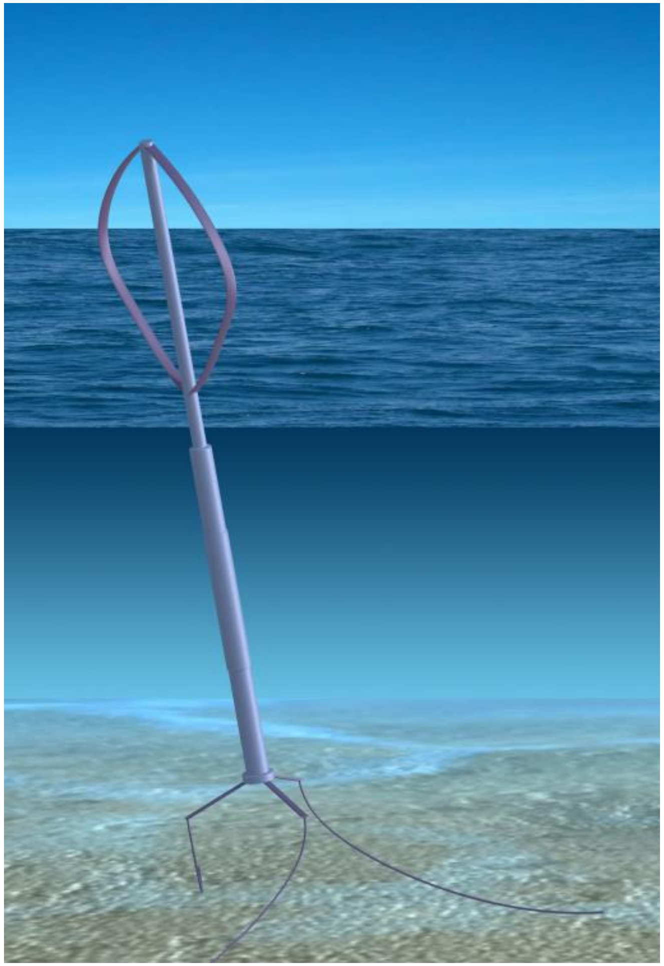
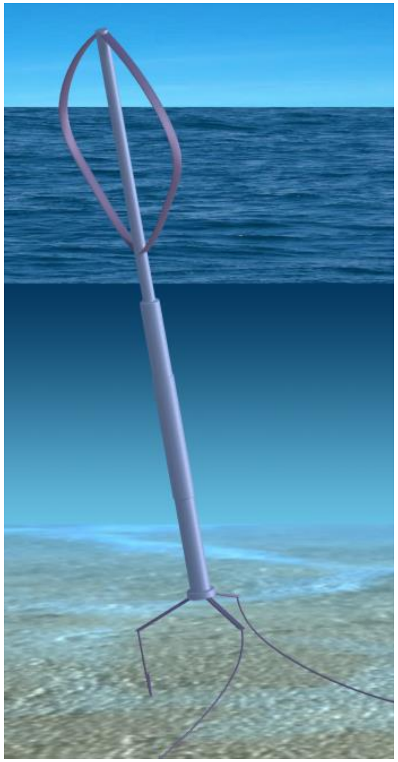
2MW Dimensions

	Deep Wind
Power	2 MW
Rotor Diameter	67 m
Rotor Height	75 m
Chord (blades number)	3.2 m (2)
Rotational speed at rated conditions	15.0 rpm
Radius of the rotor tower	2.0 m
Maximum radius of the submerged part	3.5 m
Total tower length (underwater part)	183 m (93m)
Displacement	3000 tons



Dimensions

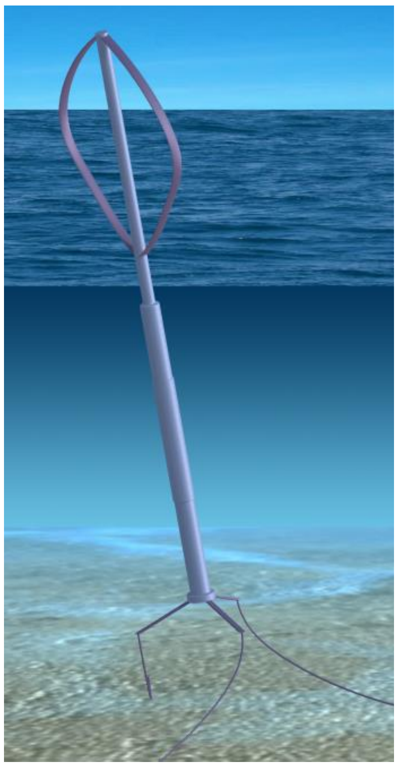
2MW VAWT vs HAWT



	Deep Wind	HyWind *
Power	2 MW	2.3 MW
Rotor Diameter	67 m	82.4 m
Rotor Height	75 m	65.0 m
Chord (blades number)	3.2 m (2)	(3)
Rotational speed at rated conditions	15.0 rpm	16 .0 rpm
Radius of the rotor tower	2.0 m	3.0 m
Maximum radius of the submerged part	3.5 m	4.15 m
Total tower length (underwater part)	183 m (93m)	165 (100)
Displacement	3000 tons	5300 tons

*****"*HYWIND, Concept, challenges and opportunities* ", Statoil

Dimensions
20 MW outlook



	2 MW	20MW
Power	2 MW	20 MW
Rotor Diameter	67 m	240 m
Rotor Height	75 m	240 m
Chord (blades number)	3.2 m (2)	11.0 m(2)
Rotational speed at rated conditions	15.0 rpm	4.1 rpm
Radius of the rotor tower	2.0 m	3.0 m
Maximum radius of the submerged part	3.5 m	6.5m
Total tower length (underwater part)	183 m (93m)	340 (105)
Displacement	3000 tons	13000 tons

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- **Challenges and results from first order investigation**
  - **Challenges**
  - **Cfd calculations**
  - **Time domain simulations with aero-elastic code**
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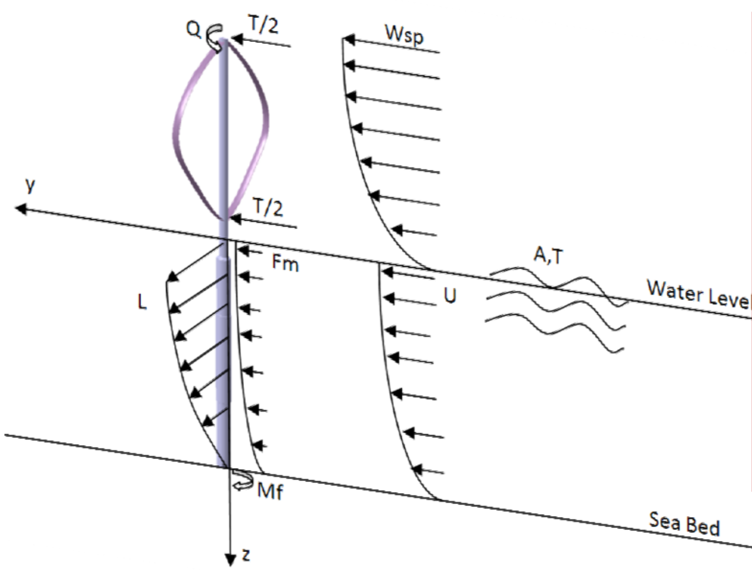
Main challenges connected with the concept

- Very large lateral forces on the underwater part of the rotating structure due to water currents
- Very large torque at the bottom of the structure
- Maintenance operation needed in very deep water



Wsp:	Wind speed
U:	Water current speed
A, T:	Significant wave height and wave period
T:	Aerodynamic force on the rotor
Q:	Aerodynamic torque
L:	Hydrodynamic side force
Fm:	Hydrodynamic forces in oscillatory flow as formulated by Morrison
Mf:	Friction Moment

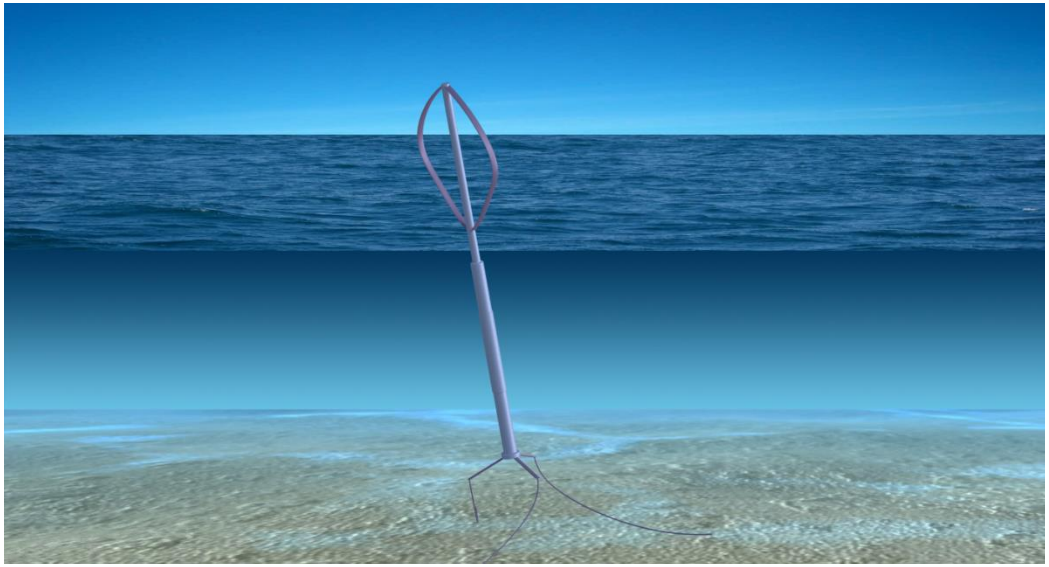
Fluid interaction investigation: loads on the tower and friction losses

$$L = L(\mathrm{Re}, \alpha)$$

$$\alpha = \frac{\omega R}{U}$$

U= 1m/s

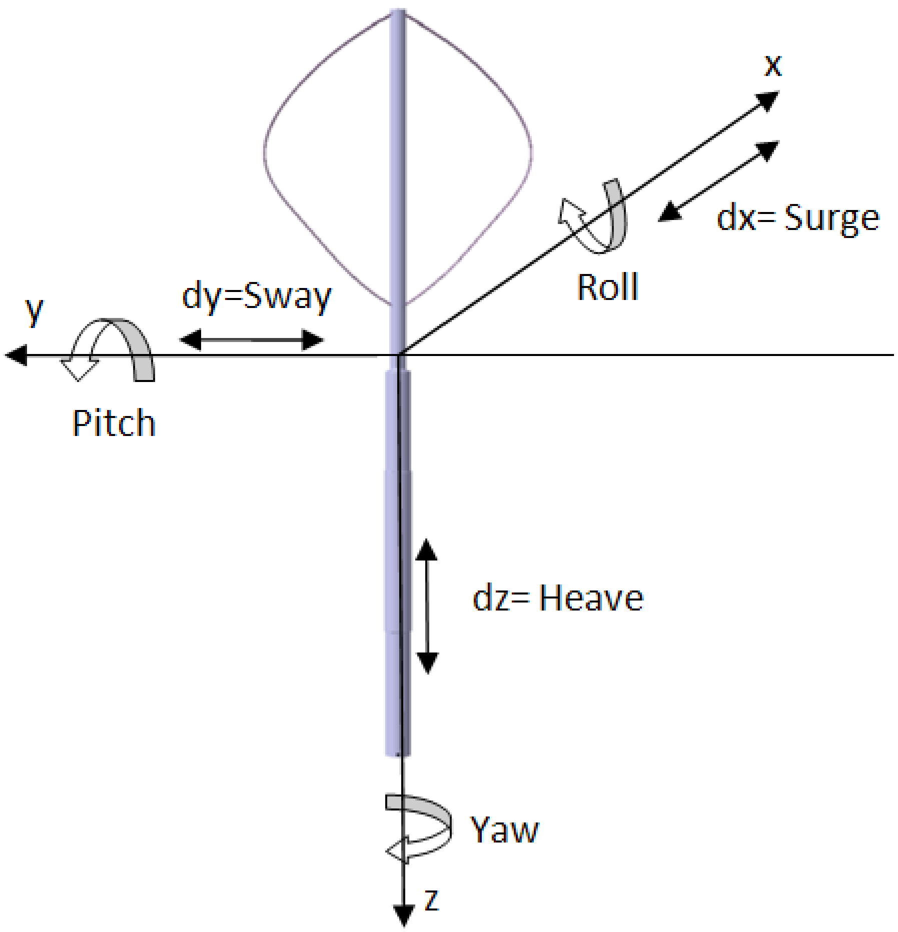
R=3m



α	L per meter [kN/m]	Aerodynamic Thrust [kN]	Friction Power [kW]	Generated Power [kW]	Friction/Generated power
1.4 (5.5rpm)	9.950	65.81	3.71	0.0	/
2.9 (11rpm)	23.72	186.85	16.69	1050	0.012(1.2%)
3.9 (15rpm)	**25.15**	**239.65**	43.20	1960	**0.022(2.2%)**

Challenges and results from first order investigations

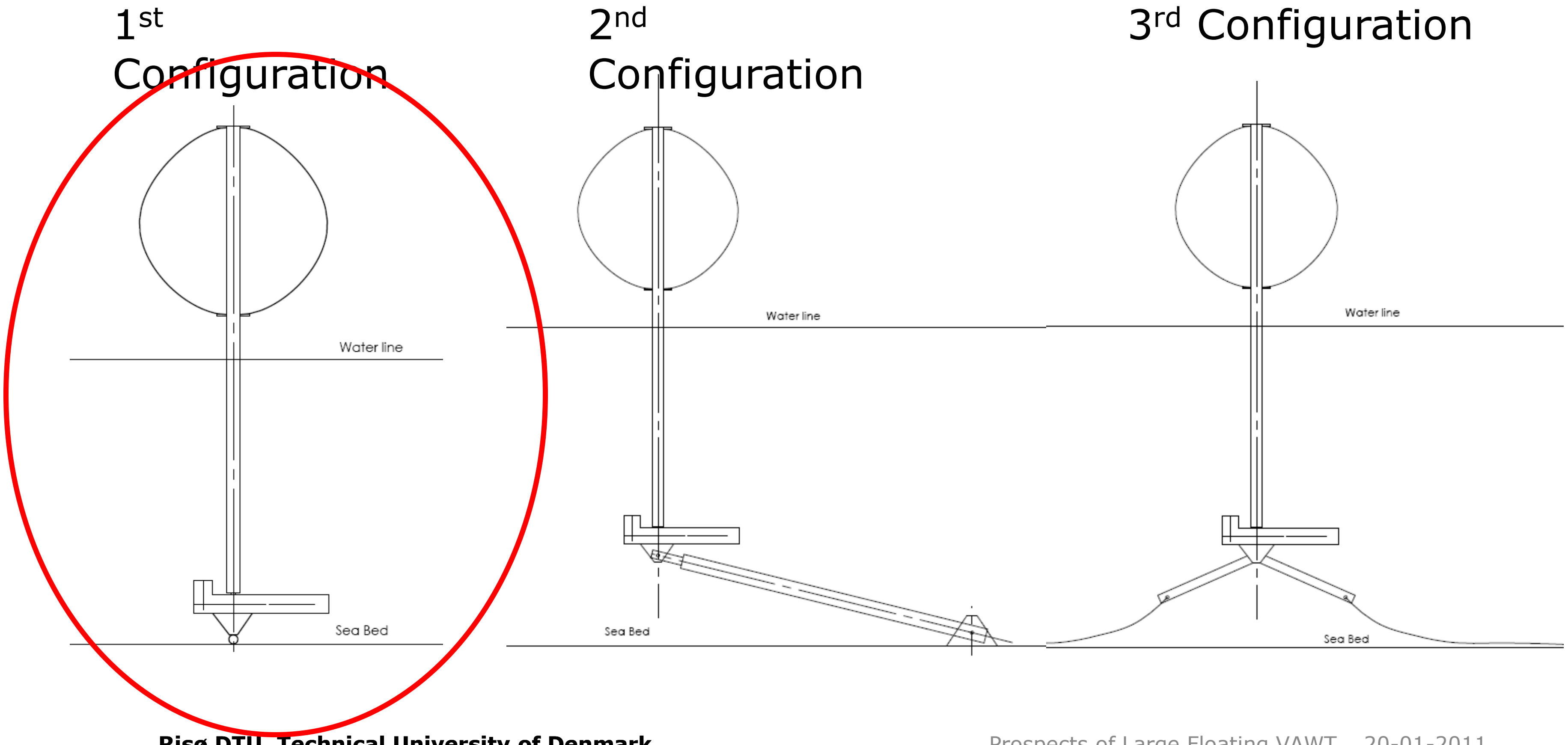
Degrees of freedom of the system



Challenges and results from first order investigations

Selected configuration

	Surge	Sway	Heave	Pitch	Roll
1st Configuration				X	X
2nd Configuration			X	X	X
3rd Configuration	X	X	X	X	X

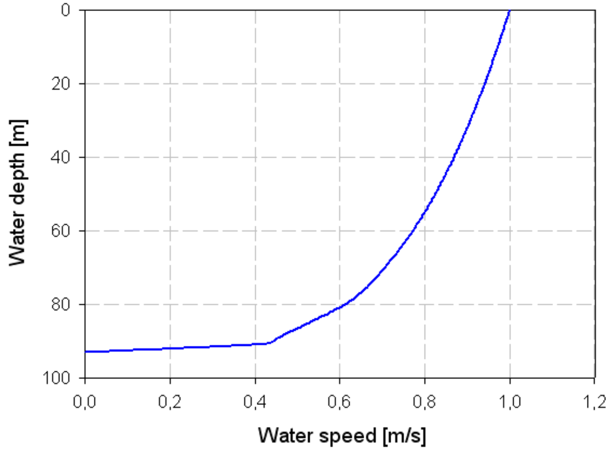


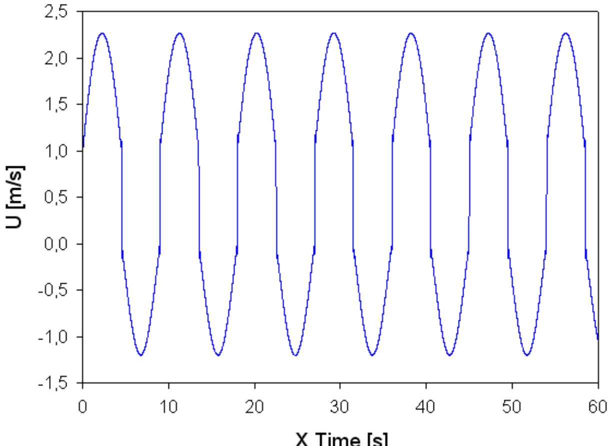
Challenges and results from first order investigations

Selected configuration

	Wind	Waves	Currents
1st load case	X		X
2nd load case	X	X	
3rd load case	X	X	X

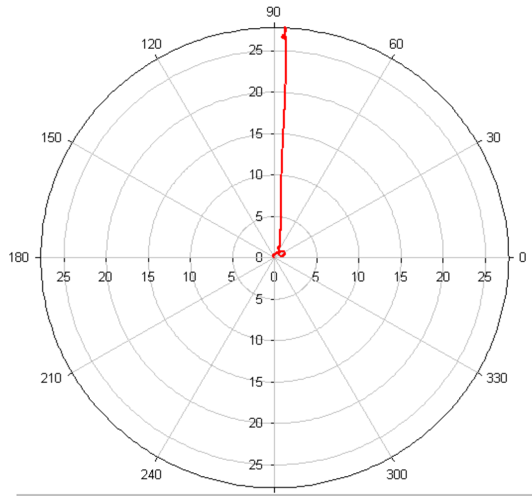
- **Wind speed:**
  - ✓14 m/s constant, no turbulence
  - ✓Direction y axis
  - ✓Wind shear: power law, α=0.14
- **Water currents:**
  - ✓1m/s
  - ✓Direction x axis
- **Waves:**
  - ✓Regular waves
  - ✓Significant height 4.0m
  - ✓Wave Period 9.0s
  - ✓Direction: x axis





Challenges and results from first order investigations

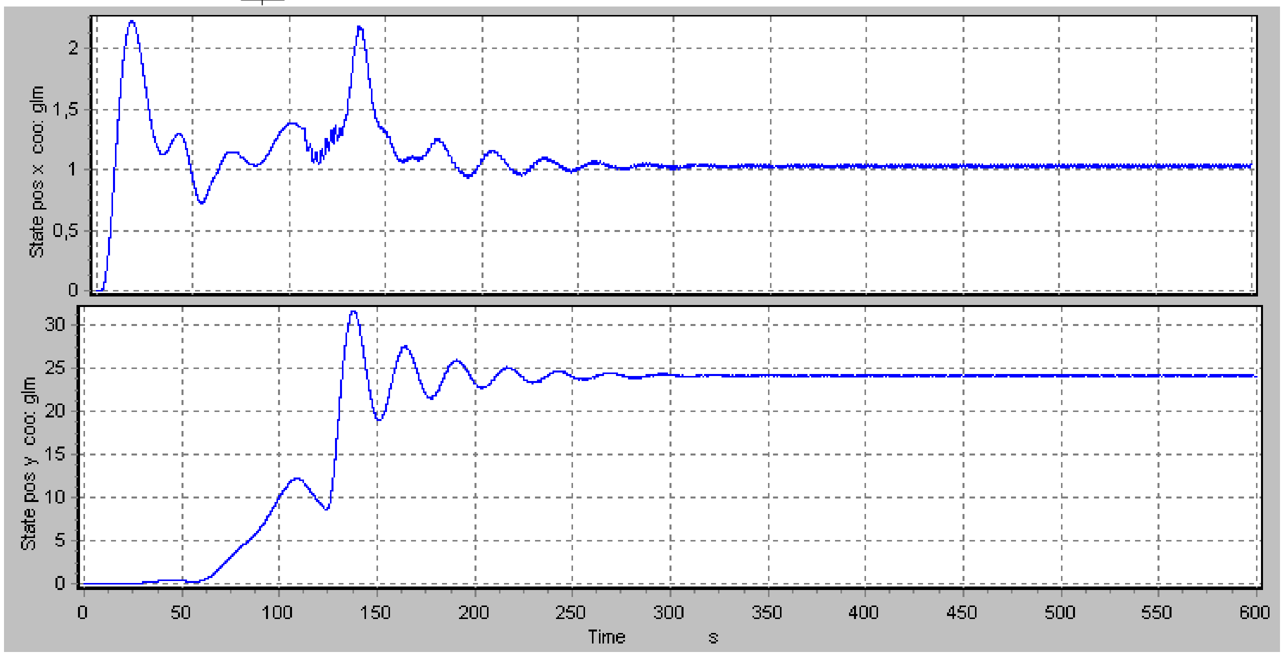
1st load case



	Wind	Waves	Currents
1st load case	X		X
2nd load case	X	X	
3rd load case	X	X	X

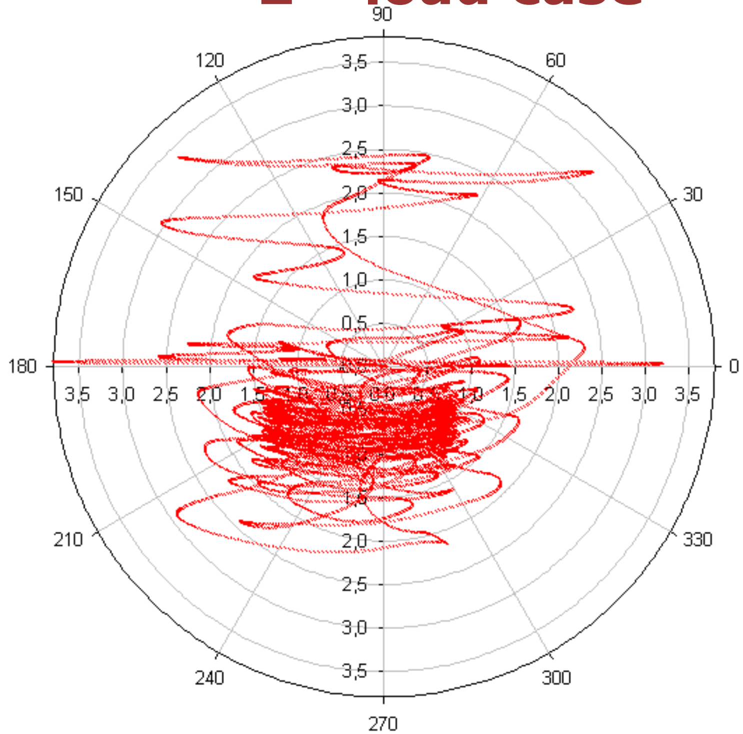
1st load case:

- Y0=24.9m and X0=1m
- Tilt angle of 15.9 degrees



Challenges and results from first order investigations

2nd load case



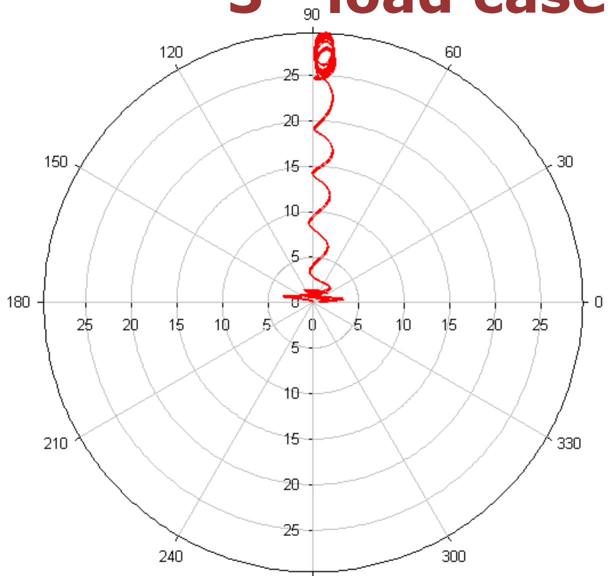
	Wind	Waves	Currents
1st load case	X		X
2nd load case	X	X	
3rd load case	X	X	X

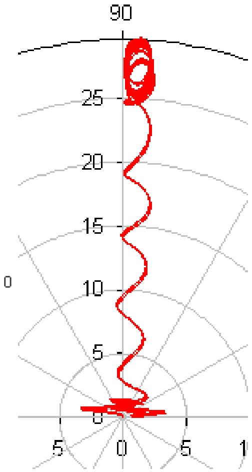
2nd load case:

- Y0=-0.75m and X0=-0.25

- Tilt angle <1 degree

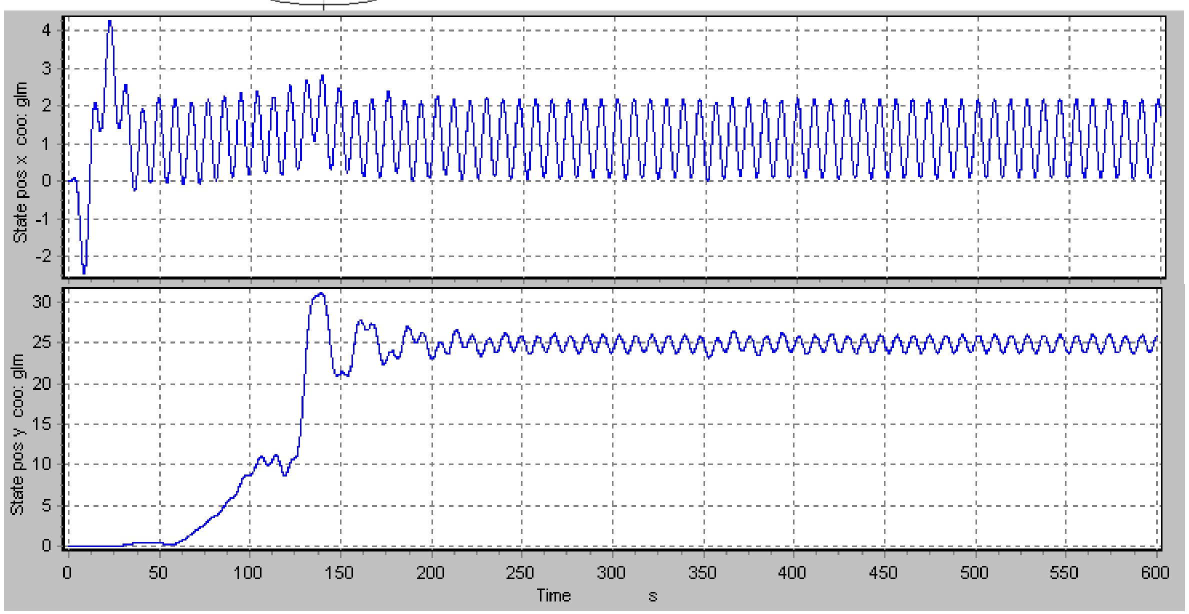
3rd load case





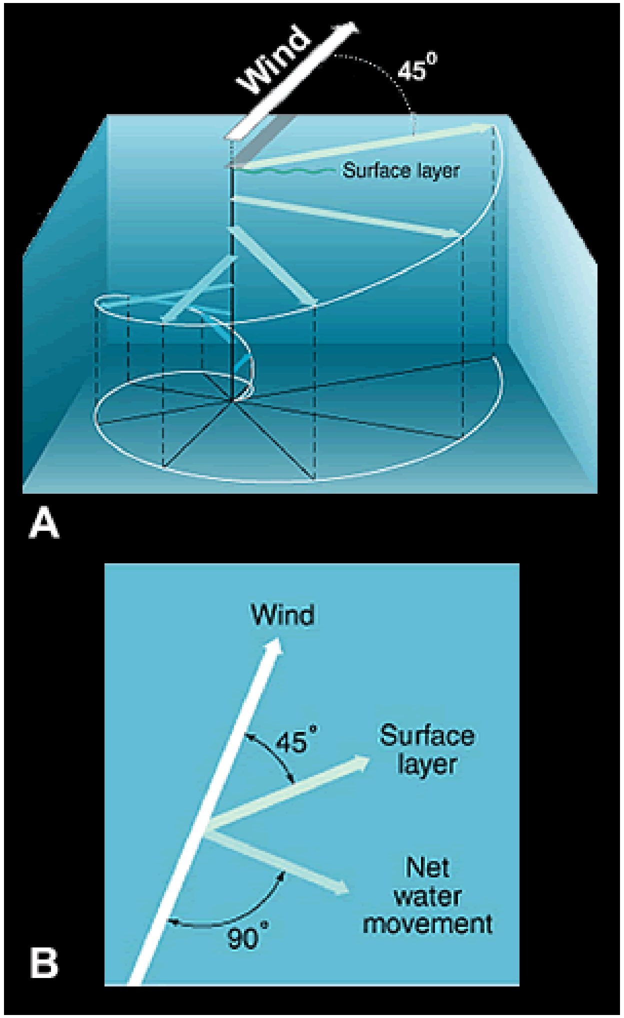
	Wind	Waves	Currents
1st load case	X		X
2nd load case	X	X	
3rd load case	X	X	X

3rd load case:
- Y0=25.0m and X0=1.1m
- Amplitude of the elliptical motion: a=2.1 b=2.0
- Tilt angle of 16.5 degrees



Challenges and results from first order investigations

Currents (in theory)



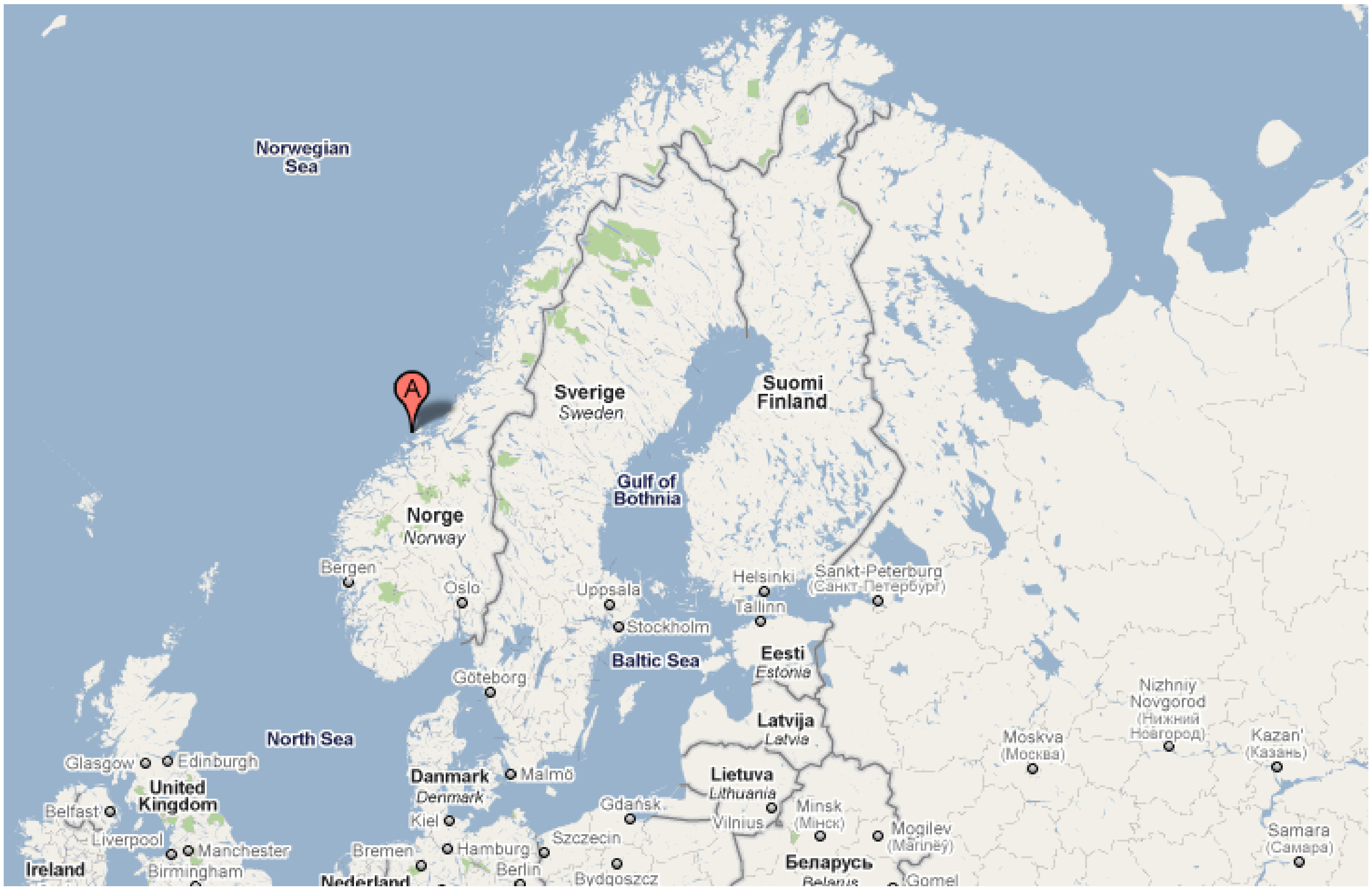
- Coriolis forces deflect each successive layer of water slightly more clockwise. Main water transport, the average of all speeds in all directions, is perpendicular to the wind, Surface flow is theoretically at 45 degrees to the wind.

- In practice, the layers of water are restricted in their flow, particularly near the coasts. Net flow is then in a direction no more than 30 degrees from the direction of the wind

- About 90% of oceanic water currents , below 400m is driven by thermohaline circulation(density driven)

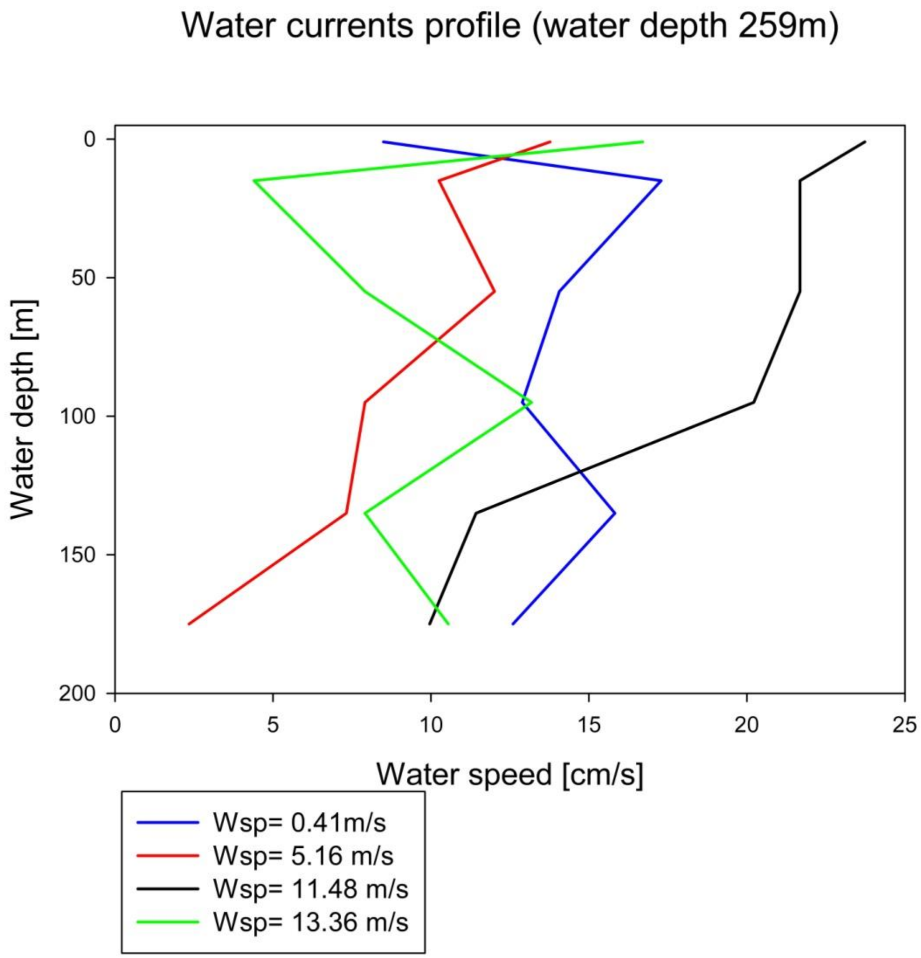
Challenges and results from first order investigations
Currents (Real data)

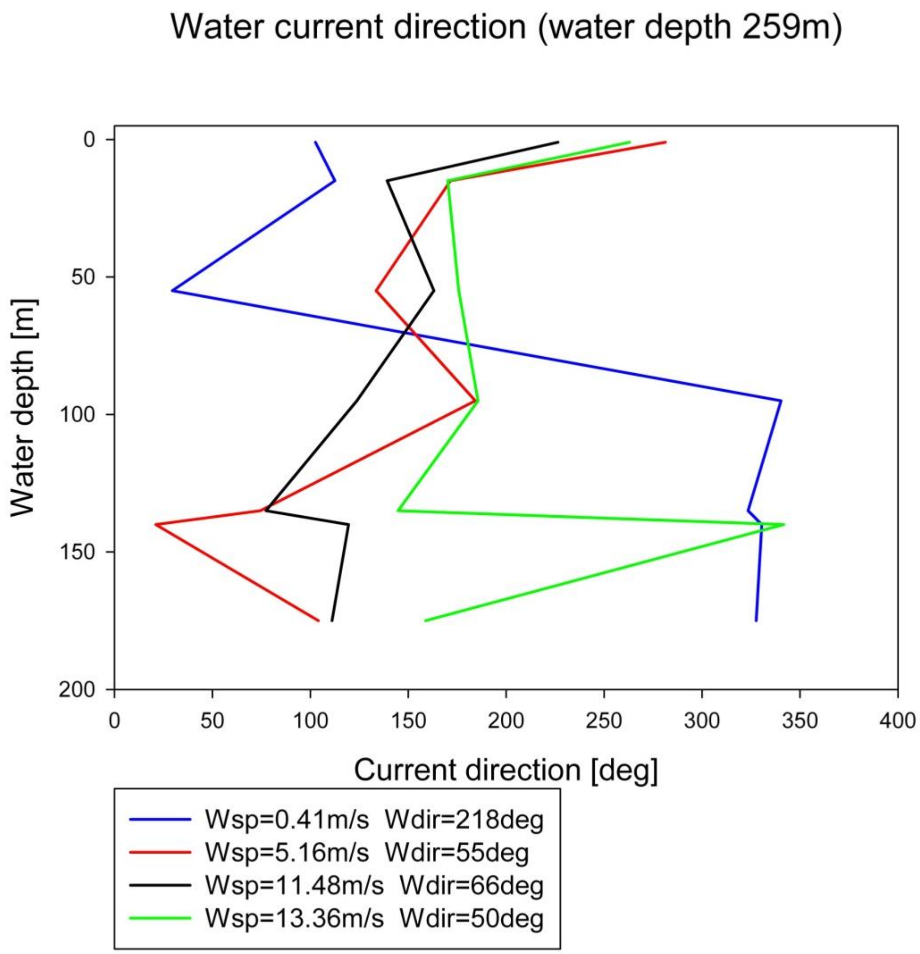
Sletringen site (Thanks to Joachim Reuder and OCEANOR)



Challenges and results from first order investigations

Currents (Real data)





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- **DeepWind project description and partners**
    - **DeepWind project**
    - **Work packages and partners**
- Conclusions

DeepWind project and partners

DeepWind, EU call FP7 Future Emerging Technologies for Energy Applications

- Duration: 4 years (October 2010-2014)
- Cost: 4.18 M€ (2.99 M€ financed by EU)
- Academic: 2PhD and 2 Post doc included
- Project objectives:
  - ✓ Investigation of the feasibility of the concept with a 1kW proof-of-principle turbine
  - ✓ Design of 5MW size including all the components (around 200m water depth)
  - ✓ Outlook for up-scaling possibility to larger sizes (20MW)

DeepWind project and partners

- Work Packages:
  1. Aero-elastic fully coupled code implementation and simulation
  2. Blade technology and blade design
  3. Generator concepts
  4. Turbine system controls
  5. Mooring, floating and torque absorption systems
  6. Exploration of torque, lift and drag on a rotating tube
  7. Proof-of-principle experiments
  8. Integration of technologies and upscaling

Partners:

- ✓ Risø-DTU, MEK-DTU, TUDelft, Aalborg University, DHI, SINTEF, Marintek, Università di Trento, NREL
- ✓ Vestas, Nenuphar, Statoil

Advisory board:

- ✓ L.O.R.C., DNV, Grontmij CarlBro, DS SM A/S, Vatenfall, Vertax Wind LtD

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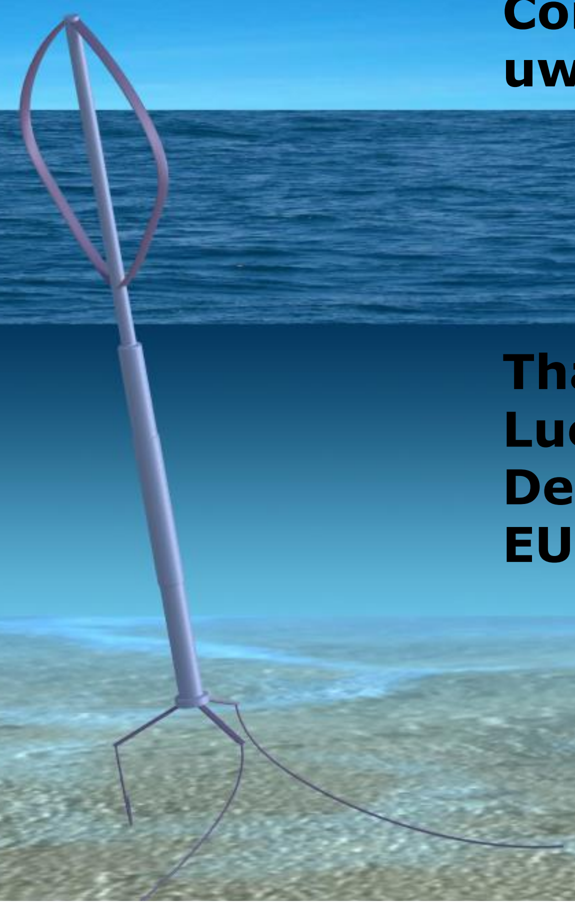
Preliminary conclusions and next steps

- DeepWind aim is to address a solution for offshore wind power at deep sea
- Hydrodynamics forces seem to be dominant in the analysis of the concept
- The choice of the site is crucial for DeepWind concept; a thorough investigation of the met-ocean data at the site is needed
- The simplicity of the design can allow some adaptation strategies to particular sites, if previously investigated
- DeepWind has potential for large up-scaling
- Specific challenges will be investigated in the WPs
- A first experimental study on a small demonstrator will be carried out at Risø fjord at the end of the year

Questions and discussion



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EU