Technical University of Denmark

Concept Testing of a Simple Floating Offshore Vertical Axis Wind Turbine

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Concept Testing of a Simple Floating Offshore Vertical Axis Wind Turbine

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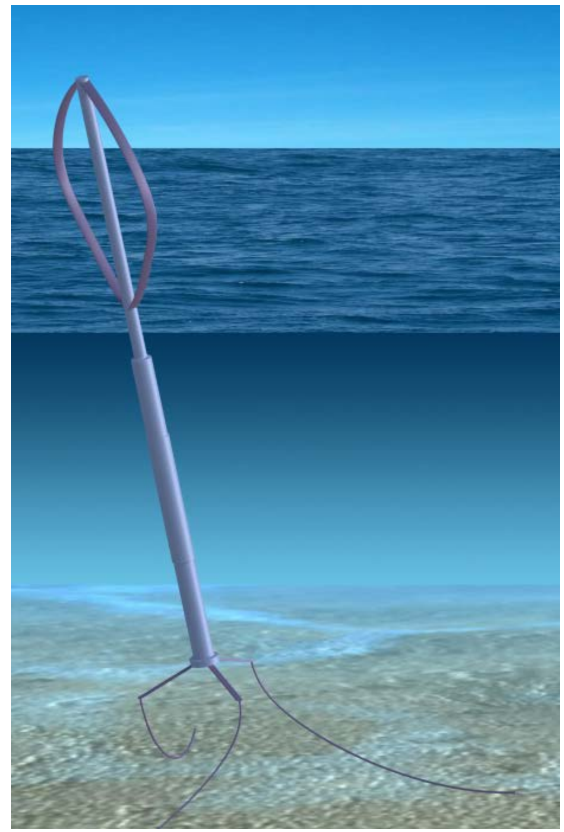
Department of Wind Energy

EU-FP7: DeepWind project



Objectives:

- To explore technologies for concept
- To develop calculation and design tools
- To evaluate the overall concept

Work Package 7: DeepWind demonstrator: evaluate proof of concept under real field conditions 1kW demonstrator

Overview

1. Design and manufacture of a 1kW concept demonstrator
2. Modal analysis and test setup
3. Testing and database of test results

DeepWind demonstrator in front of old Risø test station

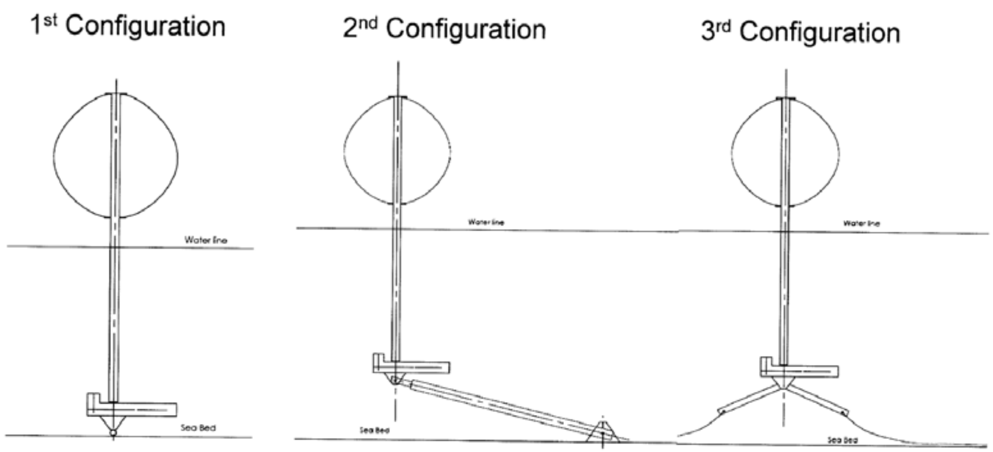
1. Design of a 1kW concept demonstrator

Design considerations:

1. Down-scaled versus small turbine?
2. Test site – field tests and water tank tests!
3. Rotor design – Troposkien, circular, straight with arc
4. Blade design – Profile, chord, 2/3 blades
5. Tube design – material, weight, wall thickness
6. Instrumentation in tube –measurement of movements, weight
7. Generator box design – water tightness, shaft, gimbal joint design
8. Foundation – support for all test components
9. Deployment and maintenance – need of a special sea vessel, safety

1. Design of a 1kW concept demonstrator

Three configurations considered for the DeepWind concept



Second configuration chosen:

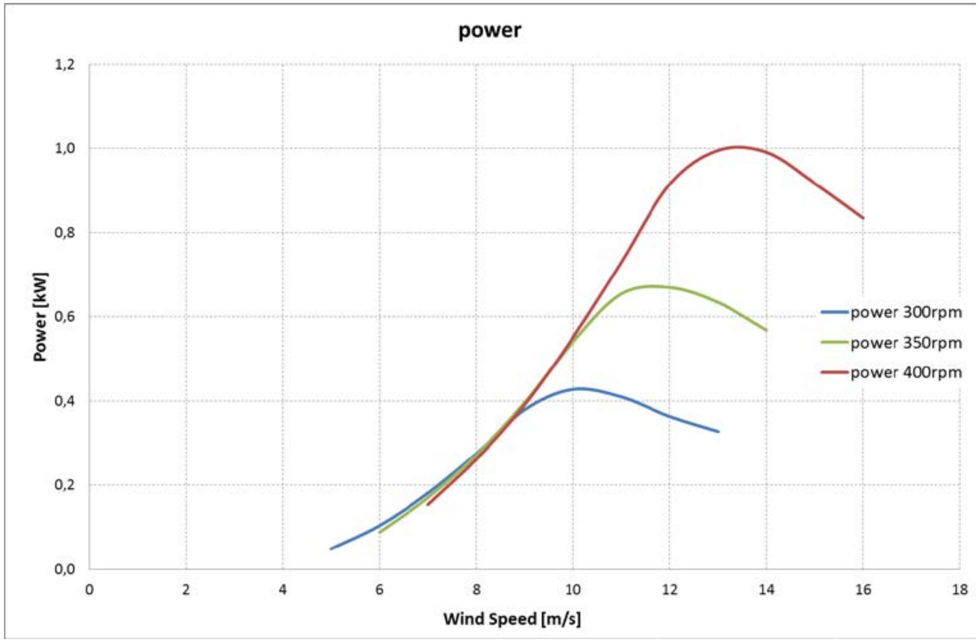
1. **Turbine connected to generator**
2. **Generator mounted on gimbal joint**
3. **Torque arm connected to foundation with met mast**

1. Design of a 1kW concept demonstrator

Turbine rotor design

Type:	Darrieus
Shape:	Circular
Diameter:	2m
Height:	2m
Chord:	0.12m
Profile:	SAND 0018/50
Blade material:	Extruded Al
Blade weight:	2.5kg

Power curve



1. Design of a 1kW concept demonstrator

Rotor tube

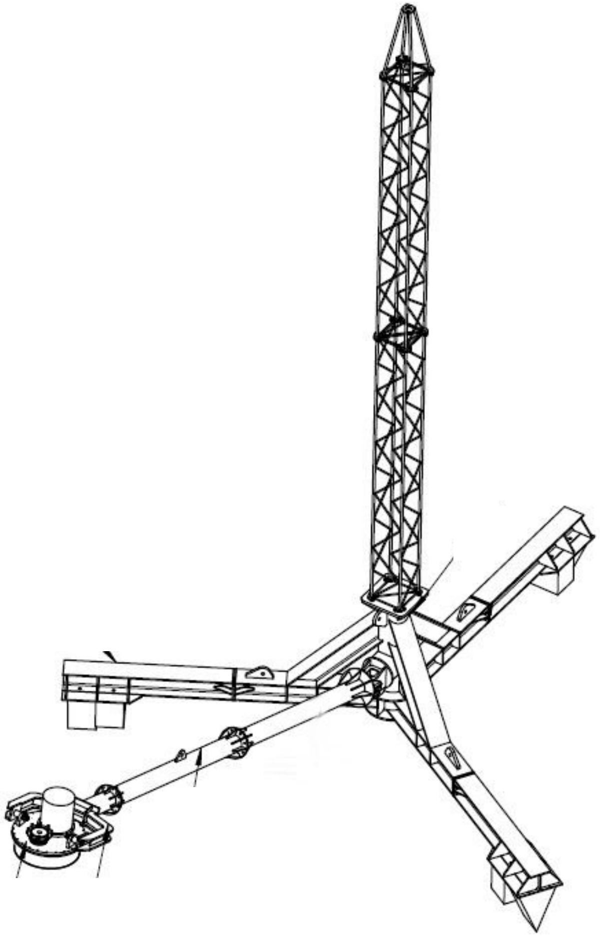
Tube length:	5.00m
Tube diameter:	0.15m
Wall thickness:	5mm
Material:	Extruded Aluminium AW6082 T6
Attachments:	Al blade flanges welded on
Buoyancy:	Foam with glassfiber cover, dia. 0.40m

Rotor end Sea bottom end

1. Design of a 1kW concept demonstrator

Foundation and generator box

Legs:	Steel 3m
Feet:	Concrete 150kg each
Torque arm:	Steel 5m
Gimbal joint:	Steel
Generator box:	Steel
Generator:	1kW asynchronous
Weight:	1.9ton



1. Design of a 1kW concept demonstrator

Instrumentation

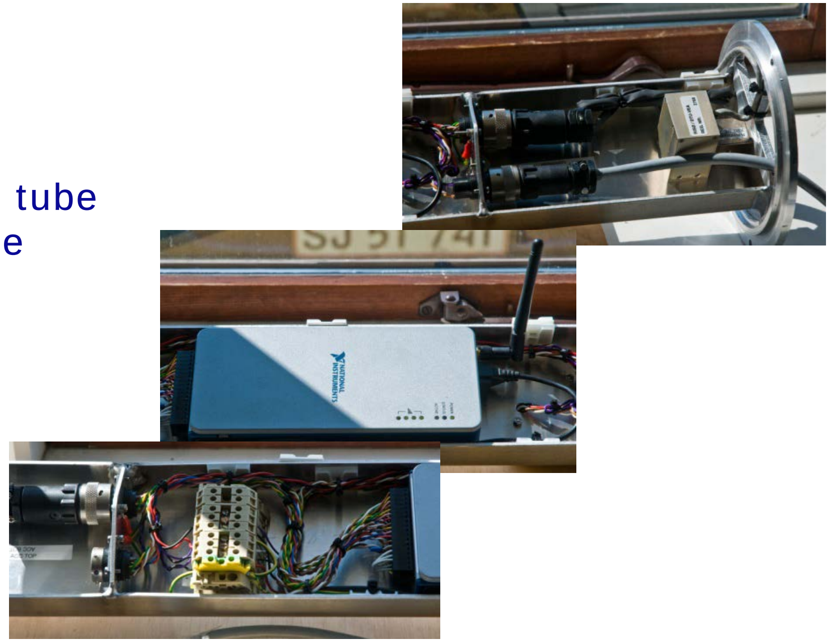
Rotor
3D accelerometer at bottom of tube
3D accelerometer at top of tube
Gyro

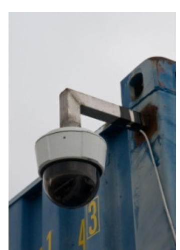
Met mast
3D sonic anemometer at top
Air temperature sensor
Air pressure sensor

Control system
Electrical power
Rotational speed

ADCP
Water currents
Wave heights

Video from pier
Sterable video camera





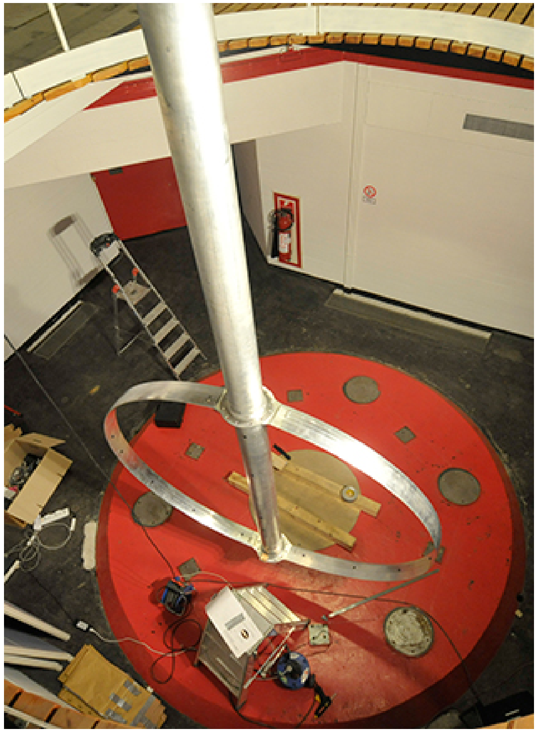
1. Manufacture of 1kW concept demonstrator

Manufacture

Foundation:	Vestas
Concrete feet:	DTU
Torque arm:	Vestas
Generator box:	Aalborg University
Rotor tube:	Vestas
Blades:	WindPowerTree Aps
Control system:	Aalborg University
Mast:	DTU
Instrumentation:	DTU
Cables:	Aalborg University

2. Modal analysis

Modal analysis test setup, mounted upside down



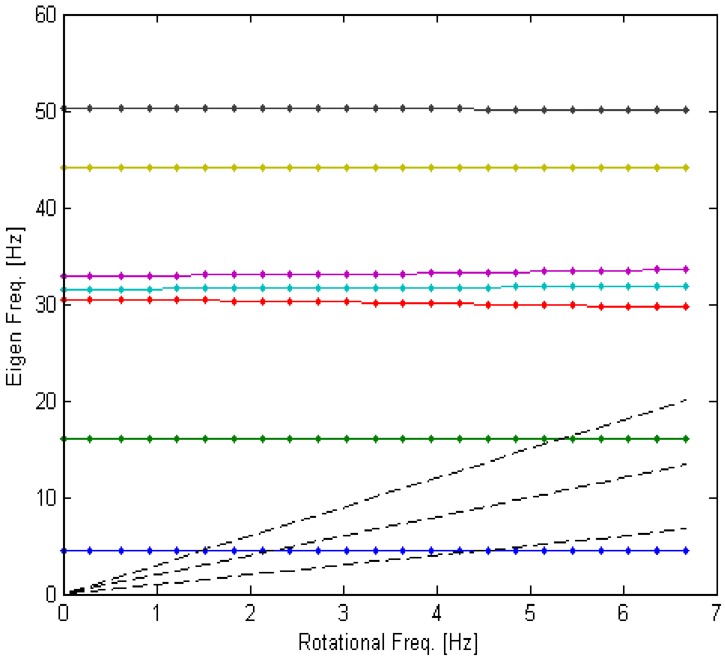
Model of rotor for modal analysis, including blades, tube and generator box

2. Modal analysis

Eigenfrequencies Fixed support versus hinged support

Fixed support frequency [Hz]	Hinged support frequency [Hz]	Mode shape	Key
2.29	4.52	Fore-aft	Blue
2.33	-	Side-side	
19.73	16.04	2nd tube bending side-side	Green
20.41	-	Torsion	
21.45	30.4	2nd tube bending fore-aft	Red
30.12	31.56	1st blade flap bending assym.	Azur
32.58	32.95	1st blade flap bending sym.	Purple
49.34	50.23	1st blade edge bending sym.	Black
62.41	44.16	3rd tube bending side-side	Lime

Campbell diagram

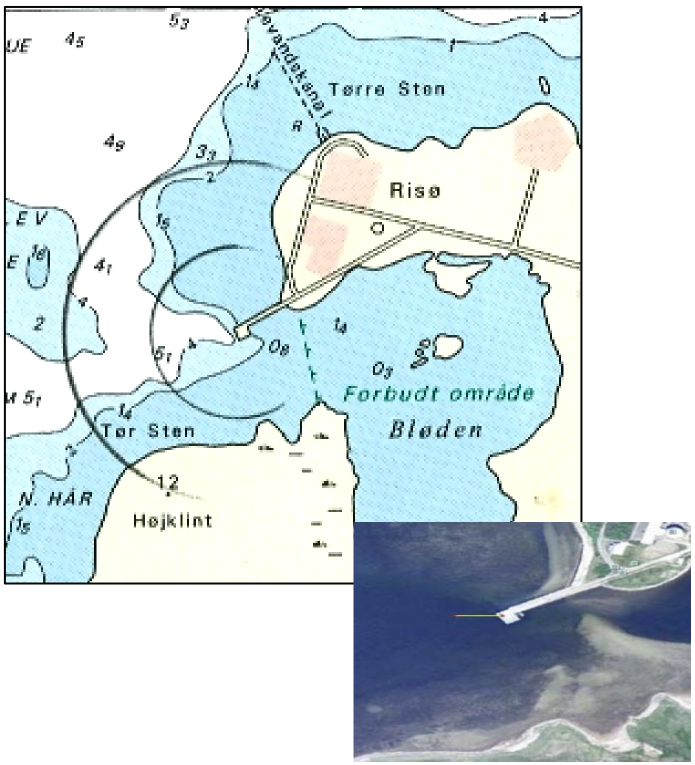


FEM versus modal testing

FEM Frequency	Modal test Frequency	Mode shape
2.78 Hz	2.75 Hz	First bending
23.61 Hz	21.75 Hz	Second bending
69.4 Hz	68.25 Hz	Third bending

2. Test setup

Test site at Risø in Roskilde Fjord



Positions of test equipment:

- Mast 50m west of pier
- Yellow sea mark 25m west of mast
- Generator box (raised) south of mast
- ADCP 25m north of mast (not seen)

2. Test setup deployment

Lifting by crane into water next to pier

Lifting by sea vessel (including three air bags with each 250 liter) and transporting to site

2. Test setup inauguration

DTU

A new offshore concept is born!

Concept seems to work!

DeepWind project coordinator celebrating a milestone

T F Pedersen

3. Tests and measurement database

Testing program

1. Assurance of no bad vibration modes
2. Brake tests
3. Measurement wind and wave matrix

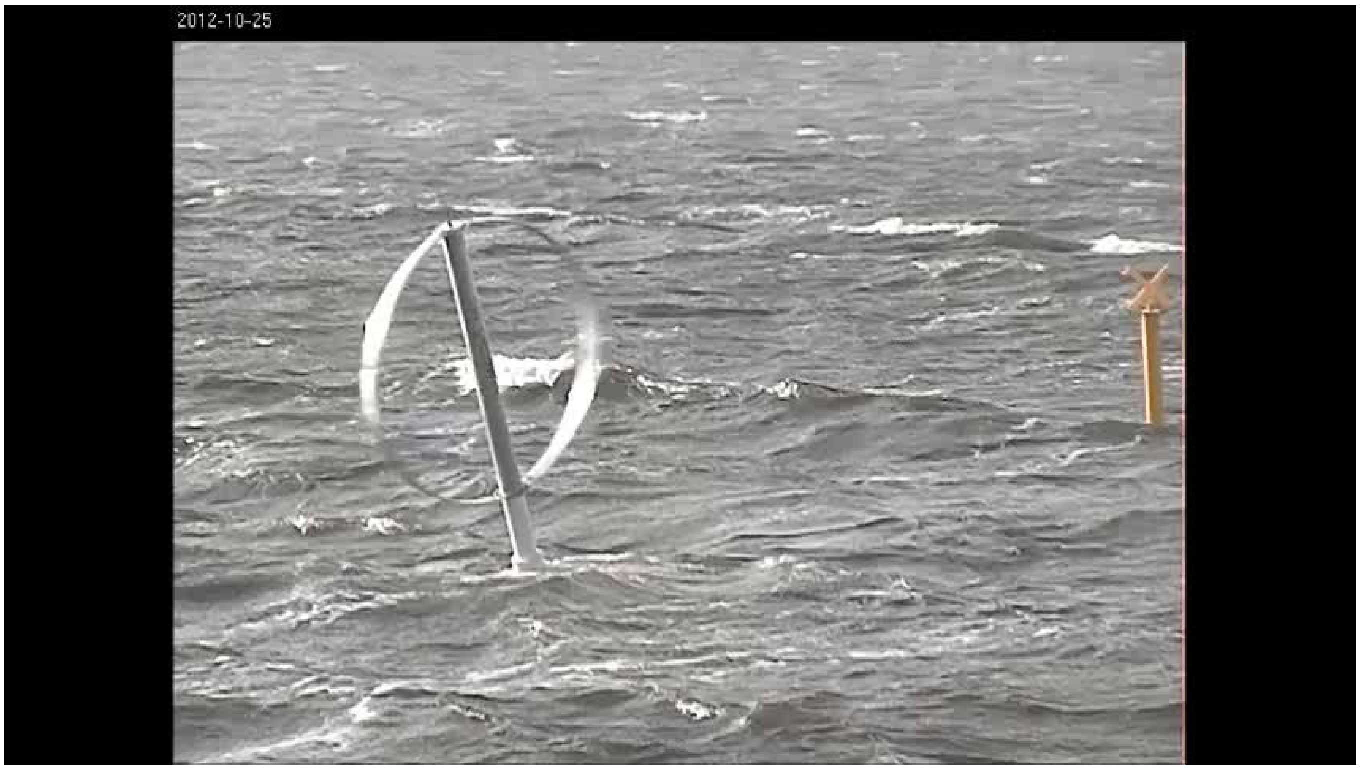
Test matrix – winds and waves

Wind and wave matrix	Low wind below 8m/s	Average wind 8m/s to 11m/s	High wind 11m/s to 16m/s
Winds from E, SE and S (low waves)	Case 1	Case 3	Case 5
Winds from W and NW (high waves)	Case 2	Case 4	Case 6

3. Tests and measurement database

Example of measurements

- Average wind speed 11.4m/s from west (case 6)
- Blades occasionally hitting wave



3. Tests and measurement database

Example of measurements

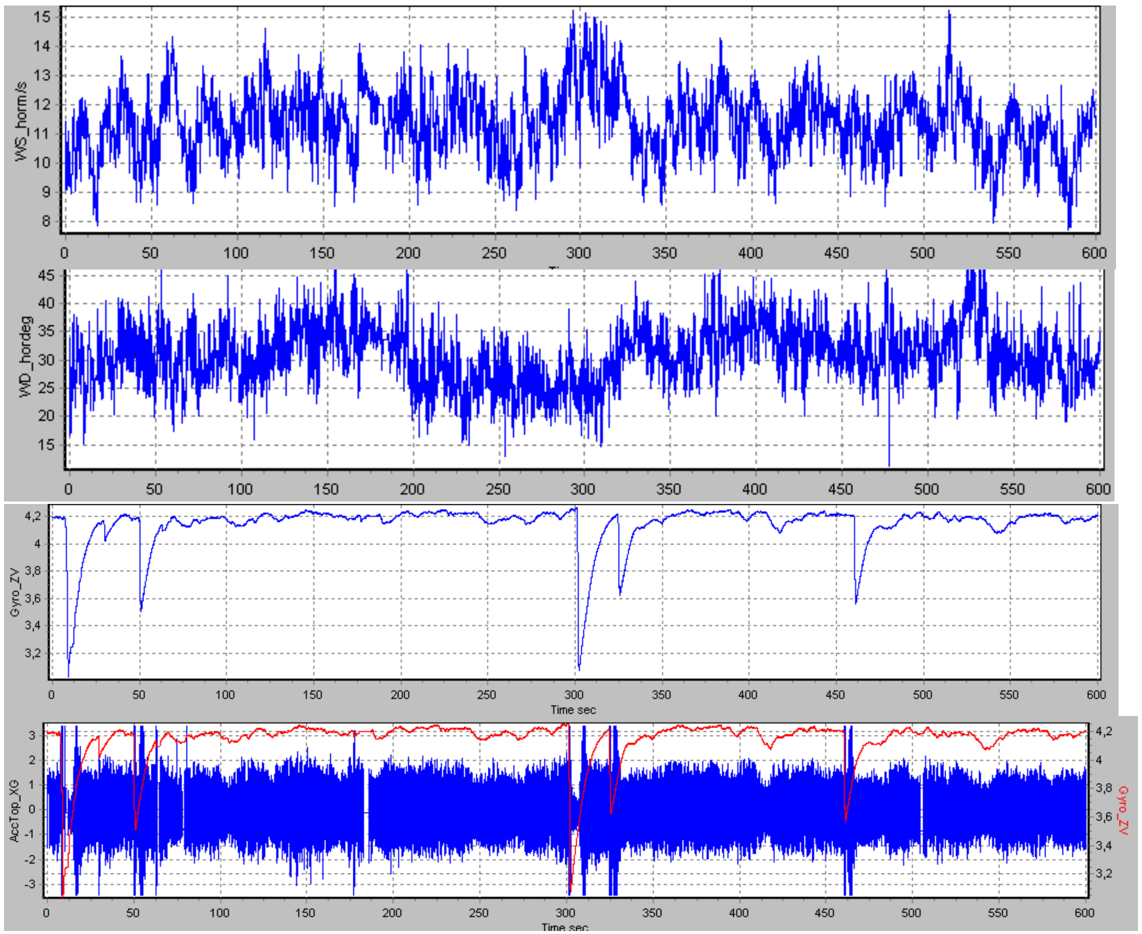
- Average wind speed 11.4m/s from west (case 6)
- Blades occasionally hitting wave

Wsp

Wdr

Rpm

Accel



Conclusions

Concluding remarks

1. A small DeepWind concept wind turbine was designed and built
2. The rotor was not built as originally designed:
   a) alternative blades were provided 50% heavier
   b) rotor tube 40% heavier
3. Mechanical brake safety tests made successfully
4. A test matrix of combinations of winds and waves was performed successfully
5. The wind turbine have operated smoothly during the tests
6. Friction of rotor very high due to large buoyancy part
7. Further plans:
   a) to start analysis of data from database
   b) to compare measurements with simulations
   c) to test demonstrator in water tank at Marin March 2013
   d) new tests in Roskilde Fjord later in 2013 applying other configurations to the turbine

Thank you for your attention!
…..and thanks to the DeepWind family