Hywind – From idea to world’s first wind farm based upon floaters

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Sources

• Olsen, G.P. Floating offshore wind in Statoil, Energy Lab, May 2017
• Statoil.com web-site.
• Private photos by FGN.
The road from here...

The story about the Hywind demo project

Source: Statoil
Via ... 

The story about the Hywind demo project  

Source: Statoil
...to here
An idea is born

- Inspired by floating sailing marks.
  - Could we power offshore installations?

Source: Statoil
On the move from land to deep water

Source: NREL
Shallow water – a scarce resource
Evolution versus disruption

Figure 2.5  Evolution of deep water production capability (from Lee 1980)

wd = water depth
Various floater concepts

Hywind

Gicon

Wind Float

Trifloater

Concrete Star

Ideol

Pelastar
And many more...

WinFlo

WinSea

VertiWind

Aerogenerator X

Mitsubishi Heavy Industries

Mitsui
# The Hywind concept

## Key features

<table>
<thead>
<tr>
<th>Feature</th>
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<tbody>
<tr>
<td>Combines known technologies</td>
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<tr>
<td>Designed for harsh environment</td>
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<tr>
<td>&quot;Standard&quot; offshore turbine</td>
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<tr>
<td>Water depth &gt;100 m</td>
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<tr>
<td>Assembled in sheltered waters, towed to field</td>
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## Relies upon experience from:

- Floating platforms
- Electrical power production
- Onshore wind turbines

Source: Statoil
Offshore wind turbines.

Challenging dynamic system

- Wind loads
- Gyro effects
- Wave and Current forces
- Mooring line dynamics
- Power transmission cable
- Power transmission
- Generator
- Control system
- Structural dynamics
- Fatigue
- Foundation - fixed or floating
MODEL SCALE EXPERIMENTS 2005

- Demonstration of system behaviour
- Validation of numerical tools
- Model scale 1:47
- Irregular waves, turbulent wind, and various control strategies

Source: Statoil
Hywind demonstration unit.
Installed June 2009. Located 10 km West of Karmøy

Main particulars
Siemens turbine: 2.3 MW
Turbine weight: 138 tons
Draft hull: 100 m
Nacelle height: 65 m
Rotor diameter: 82.4 m
Water depth: 150–700 m
Displacement: 5300 t
Mooring: 3 lines
Diameter at water line: 6 m
Diam. submerged body: 8.3 m

Contractors:
Siemens, Technip, Nexans, Haugaland kraft.

Support from Enova.
Source: Statoil
Assembly and installation of Hywind Demo.

Summer 2009

Source: Statoil
Operation in harsh environment

- Max wind velocity: 40 m/sec
- Max sign wave height: 10.5 m
Production during a storm condition

- 24 hour period during storm “Dagmar”, Dec 2011
- Avg. wind speed 16 m/sec
- Max wind speed 24 m/sec
- Max significant wave height 7.1m
- Power production 96.7% of rated

Source: Statoil
From idea to commercial concept

2002
Idea

2003
Concept & theory

2005
Model test

2009
Demo

2017
Onshore connected parks

2017
Pilot park

Market Focus

Cost Focus

Technical Focus

Source: Statoil
Optimization of hull design

Experience and improved tools

Hywind Demo 2.3MW

Hywind 6MW
Hywind Scotland Pilot Park

Primary objective:
Demonstrate cost efficient solution and lower risk for commercial scale floating wind farms

- 5 x 6 MW turbines
- Location: Buchan Deep outside Peterhead
- Agreement for lease with The Crown Estate in 2013
- Consent in 2015
- First deliveries to grid 2017

Source: Statoil
Assembly at Stord, May 2017
Hywind installed on site, August 2017

Source: https://www.tu.no/artikler/her-er-den-forste-dronevideoen-av-verdens-forste-flytende-vindpark/403837
Control challenge
Real turbines – power curves and power coefficient

Variable blade pitch constant speed

Constant blade pitch Variable speed

Idling
Wind turbine thrust.

Conventional Control, over rated speed.

Increased relative wind speed => reduced wind thrust

Reduced relative wind speed => increased wind thrust

\[ V_{rel} = V_{wind} - V_{nac} \]

Wind speed

Vnac

Vnac

Natural period of tower pitch ~ 25 sec.
Natural period of tower surge ~ 120 sec.
Waves ~ 4 – 20 sec
Wind ~ 1 sec – 5 min

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Motion controller for floating foundation

Conventional controller

Motion stabilizing controller

Shut down

Source: Statoil
Marine operations – challenges...