Offshore Wind
NSRI / ORE Event

Foundations and Substructures

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Foundations and Substructures

Agenda

• A look at the mass production of jacket foundations.
• Wikinger and upcoming Beatrice jackets.
  • New ideas to reduce mass.
  • Strategies for deep water sites.
• The role of larger monopiles.
• New ideas – suction buckets, concrete hybrids etc
• Floating solutions.
• Different energy Hybrids.
• O&M Challenges
Atkins

Atkins is one of the world’s leading design, engineering and project management consultancies

- 18,500 employees
- worldwide
- Revenue of £1.8 billion
- (March 2016)
- 75th anniversary 2013
- Corporate Values
  - Safety Leadership
  - Excellence in Delivery
  - Respect for the environment
  - Worldwide community engagement
Our expertise is drawn upon a growing portfolio whereby our ability to contribute to whole life cost savings are now being recognised as these structures are starting to be being installed and commissioned.

- WTG Foundations
- OSPs
- OTMs
- Met Masts
- Floating Wind
- Asset Management
Offshore Wind in the UK

✓ Successful round 1 and 2
✓ Massive pipeline of projects
× Waiting for next CfD
### The European Offshore Wind Industry

#### Key Figures and Statistics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>New offshore wind turbines in wind farms and demonstration projects</td>
<td>408</td>
</tr>
<tr>
<td>MWh of offshore wind capacity connected to the grid</td>
<td>1,483 MW</td>
</tr>
<tr>
<td>Turbines installed and grid connected</td>
<td>2,488</td>
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<tr>
<td>Work carried out in 2014 wind farms</td>
<td>12</td>
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</tbody>
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#### Average Size of Connected Wind Farms

- **Average Size**: 368 MW
- **Average Water Depth**: 22.4 m
- **Average Distance to Shore**: 32.9 km

#### Foundation Types

- **Monopile**: 91%
- **Jacket**: 8.1%
- **Tripod**: 0.9%

#### Manufacturers (2014 Annual Market Shares of Connected MW)

- **Siemens**: 86.2%
- **MHI-Vestas Offshore Wind**: 9.5%
- **Goldwind**: 3%

#### Developers (2014 Annual Market Shares of Connected MW)

- **E On**: 19.4%
- **RWE**: 18.1%
- **DONG Energy**: 14.8%
- **Statoil**: 12.6%
- **SSE**: 11.2%
- **other**: 19.3%
Wind Turbine Generator
Fixed Foundation types
Wind Turbine Generator
Floating Substructure Types

SPAR

SEMI-SUBMERSIBLE

TLP
Jacket Production

- Mass Manufacturing
- Automation
- Standardisation
Early mass fabrication of Jacket foundations at Scottish yard.
Numbers...

- **Eiffel Tower** (320m)
- **Shard (UK Tallest)** (310m)
- **BOWL (60m WD Jacket)** (270m)
- **London Eye** (135m)
- **Big Ben** (96m)
- **Statue of Liberty** (93m)
- **Tower of Pisa** (56m)
Now deep water and a high water depth range.

To date Jackets in shallow 25 to 30m Depth

Beatrice will be in very deep water from 40m up to almost 60m

Ormonde (20m WD Jacket)

Big Ben (60m WD Jacket)

Eiffel Tower
Standardisation and Automation.

- Complex Ground and high water depth range - less standardisation.
- Components for jackets bulky and difficult to manipulate.
- Standard sections less optimum than flat plate and bespoke sizes.
- Welding process very specialist for jackets - difficult for robotics
- Smaller simpler components may require significant R&D.
Optimising transition piece design
Mass Manufacturing techniques.

Shop floor – Use adaptable templates for crosses, bracings, legs and frames.

Requires significant shop floor area and large height assembly hall.

Advanced Planning Techniques.

Continuity of work to allow new investments in plant.

Versatile and reliable material movement system.
New Suction Buckets

Weight of each bucket will be 80 to 140 tons
Suction Buckets:
✓ No driven piles
✓ fabrication
✗ Manoeuvrability
✗ Boulders
Booming monopile industry
Getting larger - 1,300 tons and 83m long
Floating Substructure Types

- SPAR
- SEMI-SUBMERSIBLE
- TLP
Floating Systems

Knowledge Transfer from Oil and Gas Industry
Semi-submersibles

- Semi-submersibles:
  - Simple assembly and installation
  - Flexible to different sites
  - High TRL (Technology Readiness Level) (WindFloat, Fukushima)
  - High structural mass
  - Complex fabrication
Spars

Spars:
✓ Simple design is good for mass production
✓ Excellent motion response
✓ High TRL (Hywind, GOTO, Fukushima)
✗ Constrained to deepwater sites
✗ Complex assembly
TLPs

Tension Leg Platforms:
✓ Low Structural Mass
✓ Excellent motion response
✗ Low TRL (BlueH TLP)
✗ Complex mooring system
Barge Type

Barge structures:
✓ Simple construction
✓ Flexible to different sites
✗ Low TRL (Ideol)
✗ Poor motion response
Multi-Turbine

- Multi-Turbine:
  - Maximise energy yield (MW/km$^2$)
  - Minimise cost/MW
  - Low TRL (Hexicon)
  - Wake effects
  - Complex structure
Hybrid Platforms

• Wind & Wave Devices & Wind & Current Devices:
  ✓ Reduce intermittency of supply
  ✓ Low TRL (FPP)
  ✗ Complex structure and challenging integration
Vertical Axis

- Vertical axis turbines:
  - Reduced heeling moment
  - Lower VCG
  - Smaller substructure
  - **Turbine strength**
  - **Increased dynamic loading**
Atkins are working with Statoil to develop an innovative floating installation aid to improve construction schedule and cost.
DC Substation

Substructure

✓ Similar to O&G.
✓ Round 3 Potential.
✗ Teething problems.
✗ Suitable for only a few yards.
Foundation O&M activity

- Focus on the Turbine.
- Excellent motion response
- Numbers of monopiles with serious defects
- Ongoing scour problems.

Bending moment and shear force diagram
6,000 turbines going offshore that’s
15 million tonnes of steel
..........or ..... 2133 Eiffel Towers !!
Questions
Additional slides
Offshore Wind Farms – Offshore Substation Topsides

- Lincs Offshore Wind Farm Transformer Platform
- Walney III Offshore Wind Farm x 2
- Humber Gateway Offshore Wind Farm
- Thanet Offshore Substation Jacket Design
- Burbo Bank Extension
- LEMs Offshore Wind Farm
- Galloper Array Offshore Wind Farm Transformer Platform
- Race Bank Extension x 2
- Hornsea Offshore Wind Farm x 3
- Gwynt y Mor Wind Farm
- Tyra and Adda Developments
Beatrice Demonstrator
Alpha Ventus
Nordsee Ost
Nordsee Ost
Nordsee Ost
Baltic 2
Wikinger Jackets – Bladt yard
Wikinger
Doggerbank Metmast Suction Bucket
Block Island – split WTG Jacket
Block Island
Block Island
Block Island
Block Island
Block Island
Examples of GBS

- **Rødsand 2 (Denmark)**
  - Water Depth 7.5 to 12.5m

- **Nysted Wind Farm (Denmark)**
  - Water Depth 6.0 to 9.5m

- **Sprogo (Denmark)**
  - Water Depth 6.0 to 16.0m

- **Thornton Bank (Belgium)**
  - Water Depth 21.5 to 27m

- **Lillgrund Wind Farm (Sweden)**
  - Water Depth 4 to 10m
We are currently working with Hexicon to undertake FEED design of a multi-Turbine floating structure at Dounreay Tri, Scotland.
Floating offshore wind
Portugal and Hawaii

Our acquired business, Houston Offshore Engineering, is participating in a range of different alternative energy projects, two of which are funded for prototype design, fabrication and installation:

• Offshore wind turbine using a semisubmersible hull for offshore Portugal
• Ocean thermal energy conversion using a semisubmersible hull for Hawaii
Anchor Selection
Kincardine Demonstrator

- Co-Developer, Owner’s Engineer and Designer
- 50MW floating Offshore Wind Farm SE of Aberdeen (8nm from coast)
- Water depths range from 45 to 143 m
- Currently in planning/consent stage
- Cobra solution – Semi SPAR substructure.
Phase 1
Tow to site
Phase 2
Lift from transition piece rotating about lower pontoon.
Phase 3
Lift to vertical
Phase 4
Lower on to Piles
# Floating Systems

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<td>Hull Structure</td>
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<td>Project Management</td>
<td>Deck Structures</td>
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Engineered and Installed:
- Auger TLP
- Mars TLP
- Ram/Powell TLP
- Marlin TLP
- Ursa TLP
- Nautilus Semi
- Falcon Semi
- Brutus TLP
- NaKika Semi
- Kizomba A TLP
- Magnolia TLP
- Kizomba B TLP
- Mars B TLP
- Tubular Bells Spar
- Moho Nord TLP
- WindFloat