Demonstrating Keystone Engineering's innovative Inward Battered Guide Structure (IBGS) offshore foundation concept at Hornsea

Best practice for private-public cooperation

Phil de Villiers
17 April 2012
Agenda

1. Introduction
   - Carbon Trust Offshore Wind Accelerator (OWA)
   - Foundations competition for 30-60m depths

2. Keystone demonstration project

3. Conclusions
Carbon Trust mission is to accelerate the move to a low carbon economy

Advice
➤ We advise businesses, governments and the public sector on their opportunities in a sustainable, low carbon world

Measurement
➤ We measure and certify the environmental impact of organisations, supply chains and products

Technology
➤ We help develop and deploy low carbon technologies and solutions, from energy efficiency to renewable power
Offshore Wind Accelerator
Objective: Reduce cost of energy by 10% in time for Round 3

- Joint industry project involving 8 developers + Carbon Trust
  - Learn from each other
  - Do more RD&D than would be possible individually

- £45m programme
  - £10m for collaborative R&D
  - Up to £35m for demonstrations
  - Carbon Trust contributes 1/3 using UK Government funding
OWA focuses on five research areas to drive down costs

**Cost of energy**

- **CAPEX**
  - Foundations
- **OPEX**
  - Access systems
  - Electrical systems
  - Cable installation
- **Yield**
  - Wake effects

**Cost of finance**
Projects are becoming more technically challenging
Larger, further from shore, in deeper water, with bigger turbines

Source: UK Ports for the Offshore Wind Industry: Time to Act, DECC / BVG Associates, 5 February 2009, p.17; Financial Times, January 2010; Carbon Trust analysis
70% of Round 3 wind farms will be in water depths >30m

Whereas two-thirds of current wind farms less than 20m deep
Turbine installation rates will need to increase dramatically

Number of turbines installed per year 2003 - 2020

One new turbine installed every 11 days
One new turbine installed per day
2.5 new turbines installed per day

Foundations

Over 6,000 turbines to be installed over 10 years

1. Number of turbines calculated from actual and forecast installed capacity figures, assuming 3MW turbines 2003 – 2013, and 5MW turbines from 2014
Source: Carbon Trust “Offshore wind power: big challenge, big opportunity”, 2008; Carbon Trust analysis 2010
Four foundation designs prioritised for Round 3

Objective: Reduce lifecycle cost of foundations by up to 30% in depths 30-60m

**Shortlist**

**Finalists**

Keystone

Gifford / BMT / Freyssinet

SPT Offshore

Universal Foundation

**Stage II focus**

Fabrication

Installation

Demonstration

Source: Carbon Trust Offshore Wind Accelerator 2010, IHC
Keystone’s Inward Battered Guide Structure (IBGS) ‘twisted jacket’

**Turbine Size**
- Natural Frequency tunable for Siemens 3.6MW and RePower 5MW

**Water Depths**
- Cost competitive within water depth range
  - £0.6/MW
  - £0.4/MW

**MetOcean**
- Suitable for all Round 3 area conditions

**Sand Waves**
- Suitable for varying water depth over life
- Concept tested by Hurricane Katrina

**Geotechnical**
- Suitable for driven pile soil conditions
  - Sand
  - Clay
  - Mud/stone

**Durable**
- Area 5
- Areas 3-4
- Area 9

Source: Keystone Engineering, Offshore Wind Accelerator 2009-12
Twisted jacket promises to be cheaper to fabricate and install
Designed for 30-60m depths and Round 3 conditions

Keystone’s Inward Battered Guide Structure ‘twisted jacket’

Benefits

Less steel: 20% less than an optimised jacket

Fewer welds: only 9 nodes

Easier to fabricate

More units per installation vessels

Design scales well for larger turbines

Source: Keystone, Universal Foundation 2012
Agenda

1. Introduction

2. Keystone demonstration
   - Mainstream, Keystone, Bladt, Hochtief
   - Project execution

3. Conclusions
Mainstream Renewable Power
Co-developer of Hornsea

**Offshore wind portfolio**

- **Hornsea, 4GW**
  - UK Round 3
  - JV partner of Siemens in SMartWind consortium

- **Neart na Gaoithe, 450MW**
  - Scottish Territorial Waters
  - Mainstream Renewable Power

- **Horizont, 1.2GW**
  - German North Sea
  - Mainstream Renewable Power
Keystone Engineering Inc
Inward Battered Guide Structure (IBGS) designer

Engineering consulting firm based out of Louisiana, USA

Designed two similar IBGS foundation concepts to support drilling platforms in Gulf of Mexico – both installed 2005

- ExxonMobil West Delta 30 Field Redevelopment Project
- West Delta 30 BB
Bladt Industries
Fabricator

Danish offshore wind foundation fabricator

Specialists in monopiles, transition pieces, jackets

Experience includes
- Anholt, Gwynt y Môr, Walney 2, London Array, Baltic 1, Belwind, Mobile Met Mast, Horns Rev 2, Egmond aan Zee, Samsø
Hochtief
EPC contractor and installer

Germany offshore wind EPC contractor

Strategic partner to SMartWind at Hornsea

Installation experience at
  - Alpha Ventus
  - Lillgrund
  - Amrumbank West
  - Global Tech I
# Scope of demonstration project

De-risk the design as much as possible

## In scope

**Fabrication of**
- Inward battered guide structure
- Central caisson
- Piles

**Installation of**
- Central caisson
- Inward battered guide structure

**Driving the angled piles**

**Measuring loadings**

## Out of scope

**Pre-installed piles in inward battered guide structure**
- Not possible given the vessel crane capacity

**Shotcrete node**
- Only required for turbines – and certified by DNV
Responsibilities

**Funders**
- Foundation

**Designers**
- Monitoring
- Topside

**EPC contractor**
- Fabrication
- Installation

**Operator**
- Foundation

Logos and names of companies involved in each category.
## Project Schedule

Less than 9 months from design to installation

<table>
<thead>
<tr>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec</td>
<td>Jan</td>
</tr>
</tbody>
</table>

**Project Idea**

- **2010**: December
- **2011**: January

**Letters of Intent**

- **2010**: December
- **2011**: January

**Contracts Signed**

- **2011**: January

**Design**

- **2011**: February to June

**Fabrication**

- **2011**: July to September

**Installation**

- **2011**: September

**Monitoring**

- **2011**: October
Fabrication
Caisson sleeve and battered pile sleeve

Source: Jan Matthiesen, Carbon Trust 2011
Transporting the IBGS to Rotterdam

Source: Keystone Engineering 2009; Heiko Lindenthal, REpower 2011; Mainstream 2011; SeaEnergy 2011
Lifting the inward battered guide structure

Source: Zachary Finucane, Keystone Engineering 2011
Installing the IBGS onto the central caisson

Source: Zachary Finucane, Keystone Engineering 2011
Installing the P1s

Source: Zachary Finucane, Keystone Engineering 2011
Driving the P2s
No issues driving the piles

Source: Zachary Finucane, Keystone Engineering 2011
Successfully installed at Hornsea
October 2011

- First foundation installed for Round 3

Source: Mainstream Renewable Power 2011
Potential design improvements
For consideration

Fabrication
- Optimise plate transitions to streamline fabrication
- Develop serial fabrication production lines for fabrication yards

Installation
- Consider pre-installing central caissons
- Specify single piles if vessel has sufficient lift capacity
What next?

Ambition is to demonstrate the twisted jacket supporting a turbine, ideally
- 2013 or 2014
- 5MW+ turbine
- 30m+ water depth
- North sea metocean conditions

Source: SeaEnergy, 2011
Agenda

1. Introduction

2. Keystone demonstration

3. Conclusions
Conclusions
Keystone Engineering ‘twisted jacket’

Fabricator feedback
– Keystone should be 20% cheaper to fabricate than optimised jackets
– IBGS is well-suited to serial fabrication
– Keystone should be safer to manufacturer as it is fabricated horizontally, not vertically

Installer feedback
– Keystone should be as least as quick to install as an optimised pre-piled jacket
– We see scope for optimising the installation process

Keystone feedback
– Design improvements have been identified that should make the design cheaper to fabricate and install

Source: Project lessons learned workshop, 2012
Conclusions
Private-public cooperation

- Joint industry projects like OWA can be effective at identifying new innovations to address specific technical challenges.

- However, commercialising new innovations requires demonstration – and there is a shortage of demonstration sites.
  - Capacity, consents, schedule are major issues.

- Policy makers can address this in two ways:
  1. Accelerating development of European test centres; or
  2. Aligning innovation needs with commercial projects can unlock demonstrations.

- The first is likely to require changes to planning regimes.

- The second requires public funding and industry collaboration to ensure that rewards compensate for additional commercial risks.

- Joint industry projects ensure that the ideas most relevant to industry are tested, increasing the probability of success for commercialisation.
Questions

Phil de Villiers
Offshore Wind Accelerator Manager, Carbon Trust
phil.devilliers@carbontrust.co.uk