TetraSpar

Industrialized Floating Foundation

Pepe Carnevale, March 29th 2017
Introduction – Henrik Stiesdal

Former CTO of Siemens Wind Power, retired end 2014
Low LCOE is the target

Source: DoE, NREL, IEA

Lines/markers indicate the median expert response for the **median LCOE scenario**
Shaded areas show the 1st-3rd quartiles of expert responses
Existing solutions
Existing solutions
Existing solutions
Existing solutions

Picture credit: MHI
Proposed solutions

Picture credit: Ideol
Existing floating wind concepts

Shared characteristics

• Very heavy

• Construction from shipbuilding and O&G sector

• Fabrication typically at port of floater launch

• Build times typically measured in months

• Tens of thousands of man-hours per foundation

Picture credits: Siemens, Principle Power, Hitachi, U.Maine, MHI, Mitsui
This should be done in a different way!

Imagine if we could

• Build floating offshore foundations with a weight of ~1000 tons for 6 MW class turbines
• Have build times on the order of weeks instead of months
• Reach cost levels of fixed foundations at 100-200 m depth
The TetraSpar floating concept

• Offers disruptive reduction in Cost of Energy from floating offshore wind
• Combines benefits from known floater concepts
• Is suitable for genuine industrialization
  • Applies proven technologies
  • Can be configured for installation at water depths from 10 m to more than 1000 m
  • Facilitates local manufacturing and truly global application
Solution element #1 - concept

- Offers disruptive reduction in Cost of Energy from floating offshore wind
- Combines benefits from known floater concepts
- Is suitable for genuine industrialization
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- Can be configured for installation at water depths from 10 m to more than 1000 m
- Facilitates local manufacturing and truly global application
The well-known family of concepts
Taking the best, leaving the rest...

**Spar buoy**
- Advantages
  - Simplest overall concept
  - Moderate wave loads
  - Simple mooring
  - Moderate dynamics
  - Proven
- Disadvantages
  - Heavy
  - Requires minimum 80 m water depth
  - Turbine installation location that can be up-ended, on-site installation vessel

**Semisubmersible**
- Advantages
  - Wide range of water depth
  - Turbine can be installed at quayside and towed to site
  - Simple mooring
  - Proven
- Disadvantages
  - Heavy
  - Complex steel structure
  - Requires either ballast or quite large dimensions to be transported
  - Large wave loads, lively motion

**Tension Leg Platform**
- Advantages
  - Low weight
  - Turbine can be installed at quayside and towed to site
  - Moderate wave loads
  - Low dynamics
- Disadvantages
  - Demanding (and expensive) tether arrangements
  - Complex steel structure
  - Limitations on depth range unless supplementary mooring used
  - Installation typically requires assistance from purpose-built vessel
… Leads to TetraSpar

- Simple tetrahedral structure with a keel
- Keel has ballasted tanks that float when air-filled
- In harbor and during towing keel is air-filled, floating with foundation, requiring no more than 6-8 m depth
- Floater has semisub stability during towing
- On site keel is ballasted, pulling the foundation below the surface to act as spar
TetraSpar installation process

Tow-out  Hook up  Lower keel  Ballast keel
Solution element #2 - industrialization

• Offers disruptive reduction in Cost of Energy from floating offshore wind
• Combines benefits from known floater concepts
• **Is suitable for genuine industrialization**
• Applies proven technologies
• Can be configured for installation at water depths from 10 m to more than 1000 m
• Facilitates local manufacturing and truly global application
Reversed the conventional thinking for inventive step:

From:
We have designed this structure – now, how do we build it?

To:
We need to manufacture this way – now, how do we design it?
The learning curve, Li-ion batteries and crystalline PV modules

Source: Bloomberg New Energy Finance
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The keyword for TetraSpar – Industrialization the onshore way

Concept

- Modular – all components factory-made, transported by road
- Components assembled at quayside with bolts (not exposed to sea water)
- Turbine mounted in harbor and towed to site, no installation vessels
- Weight 1000-1500 t for 6 MW turbine
Taking advantage of a world champion …

The humble wind turbine tower

• Probably the world’s lowest cost per kg of any large steel structure
• High quality welds and surface protection
• More than 20,000 towers manufactured annually in highly industrialized processes

How did we get there?

• Separation of fabrication and installation
• Modularization and standardization
• No IP of any significance – costs kept low through open competition

Picture credit: Danish Wind Turbine Manufacturers’ Association
How an assembly and installation area might look
The consequences of Industrialization the onshore way

Supply chain
• Low investments – supply chain already exists
• Volume effects – benefiting from onshore wind volumes
• Fast ramp-up – moderate added volume in existing supply chain

Cost implications
• Short delivery time, low financing costs
• Low weight and low specific cost ($/kg) due to industrialized manufacturing
• Low mobilization and assembly costs
• Low installation costs
DNV GL Concept Feasibility Evaluation

Conclusion from Evaluation Report

“At the present stage of development, DNV GL has not identified any unsolvable development barriers and thus believes the concept is well suited for further conceptual development”.

Source: DNV GL
Expected project stages, target timeline

Stage 1 - 2016
- Concept
- Initial validation

Stage 2 - 2017
- Design
- Tank test

Stage 3 - 2018
- Prototype
- Full validation

Stage 4 - 2020
- Pilot projects
- Release

€ 10m
Thanks for your attention
A practical example of a floater made with onshore technology

- Cast TP, wind turbine hub technology
- Tapered, welded center column, wind turbine tower technology
- Cylindrical, welded braces, wind turbine tower technology
- Cast nodes, wind turbine hub technology
- Steel or GRP tanks, industrial technology
Spar buoy

Advantages
• Simplest overall concept, Inherently stable
• Moderate wave loads, well suited for typhoon conditions
• Simple mooring
• Moderate dynamics
• Proven

Disadvantages
• Heavy
• Requires minimum 80 m water depth from turbine installation location to site, or turbine that can be up-ended, or very special installation vessel

Picture credit: Statoil
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Semisubmersible

Advantages
• Wide range of water depth (40 m →)
• Turbine can be installed at quayside and towed to site
• Simple mooring
• Proven

Disadvantages
• Heavy
• Complex steel structure
• Requires either ballast compensation or quite large dimensions to limit tilt
• Large wave loads, lively dynamics
Tension Leg Platform

Advantages
• Low weight
• Turbine can be installed at quayside and towed to site
• Moderate wave loads
• Low dynamics

Disadvantages
• Demanding (and expensive) tether arrangements
• Complex steel structure
• Limitations on depth range unless supplementary mooring used
• Installation typically requires assistance from purpose-built vessel
The power of industrialization is huge

Source: Ford Motor Company
TetraSpar can be installed at water depths from 10 m to >1000 m

Applies the full range of technologies -

• Floated out as semisubmersible
• Can be installed as fixed foundation at low water depths
• Can be Installed as TLP variant at 40-100+ m water depth
• Can be installed as spar variant at water depths above 80 m
TetraSpar Concept, floater maintenance

- The installation process can be reversed for maintenance purposes.
- The structure may be raised to the surface for inspection at 2-5 year intervals, and may be towed to port for main component replacement.
Launching floater using land-based crane
## Project status

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