Innovations in integrated floating offshore wind systems
<table>
<thead>
<tr>
<th>Time</th>
<th>Presenter</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:00-15:05</td>
<td>Sabina Potestio, WindEurope</td>
<td>Introduction</td>
</tr>
<tr>
<td>15:05-15:10</td>
<td>Lizet Ramirez, WindEurope</td>
<td>State of play of EU offshore policy</td>
</tr>
<tr>
<td>15:10-15:20</td>
<td>Jose Luis Dominguez, IREC</td>
<td>Introduction to Corewind</td>
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<tr>
<td>15:20-15:30</td>
<td>Mohammad Youssef Mahfouz, University of Stuttgart and Climent Molins, UPC</td>
<td>A FAST model of the UPC concrete spar floater and the 15 MW IEA WIND reference turbine</td>
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<tr>
<td>15:30-15:40</td>
<td>Valentin Arramounet, Innosea</td>
<td>Optimized mooring system for the ActiveFloat concrete semisub floater for the 15 MW IEA WIND reference wind turbine</td>
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<td>15:40-15:50</td>
<td>Marie-Antoinette Schwarzkopf, Ramboll</td>
<td>O&amp;M for commercial scale floating wind – Opportunities for maintenance strategies</td>
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<td>15:50-16:00</td>
<td>Jose I. Rapha, IREC</td>
<td>Presentation on the LCOE evaluation tool FOWApp</td>
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<tr>
<td>16:00-16:10</td>
<td>Pablo Necochea, Vestas</td>
<td>Floating offshore wind innovations for cost reduction</td>
</tr>
<tr>
<td>16:10-16:30</td>
<td>Sabina Potestio, WindEurope</td>
<td>Q&amp;A</td>
</tr>
</tbody>
</table>
Got a question?

Press + to expand the question box

Type your question and hit ‘Send’
Sate of play of EU offshore policy

25 February 2021

Lizet Ramírez
Analyst, Offshore Wind
Europe is leading the floating wind movement

Windfloat Atlantic
24 MW
Portugal

Photo courtesy of Principle Power. Artist name: Dock90
The Offshore Renewable Energy Strategy: Focus on scale-up

Released on November 19, 2020

60 GW by 2030
300 GW by 2050
Europe needs both floating and fixed-bottom offshore wind

30% Floating
Floating Offshore Wind about to take off

**CAPACITY OUTLOOK**

- **2020**
  - UK: 30 MW
  - Portugal: 25 MW
  - Other: 7 MW

- **2022**
  - UK: 80 MW
  - Portugal: 25 MW
  - Other: 10 MW

- **2030**
  - 7 GW

**Cost**

- €40-60/MWh
Delivering the right offshore framework

1. Clear auction timetable
2. Technology-specific auctions
3. Contracts for Difference
4. One-stop shop for permitting
5. Private/Public grid development
6. Ensure happy co-existence
Delivering the right offshore framework
Introduction to Corewind

25 February 2021
Project partners and advisory board
COREWIND looks beyond the state of the art of the floating technology with the aim of accelerating the path towards its commercial deployment by developing and validating innovative and cost-effective solutions that allows to solve the most critical barrier of floating offshore wind technology, the cost.
Project approach

**COREWIND**

**COST**
- LCOE and LCA tools

**Reliability**
- Multi-fidelity advanced models
- Improved condition monitoring

**Lifetime**
- Digitalization: Digital Twin + BIM toolbox

**Industralization**
- Development of innovative cost-effective and reliable solutions
- Mooring & dynamic cable design optimization
- Standardization and certification
- O&M planning & assessment tools

**Experimental testing validation:**
- Laboratory scale: Hybrid HIL Test: Wave Tank + Wind Tunnel
- Field testing: Synthetic lines & cable coating degradation (biofouling, corrosion) in marine environment

**COREWIND OUTCOMES and ADVANCES**
- Open data and models available
- Novel mooring and anchoring designs
- Optimized mooring and power cable designs
- Concrete-based semisub & spar prototypes at TRL 5
- Exploitation plan for innovations
- Guidelines and Best Practices

corewind.eu
Project expected impacts and outcomes

Advanced tools (DIGITALIZATION)
- Reference models:
  - 15 MW WT reference model
  - 2 floater (semi-sub & spar) models
- Design and operation tools:
  - 1 BIM toolbox for floating wind industry
  - 1 Open and agnostic Digital Twin for floating wind
  - 1 O&M planning and assessment tool
- Economic tools:
  - 1 LCOE and LCA calculation tool
  - Floating Wind Farm optimization modules for cost minimization

Key reference documents:
- Technologies State of the art
- Standards revision:
- Development guidelines
- Testing and design procedures recommendations.
Current outcomes and developments

- Reference models:
  - 15 MW WT reference model
  - 2 floater (semi-sub & spar) models

- Economic tools:
  - 1 LCOE and LCA calculation tool

- Number of public deliverables:
  - Several reports have been made available
Current outcomes and developments

• **Public Deliverables:**
  o They can be found at: [http://corewind.eu/publications/](http://corewind.eu/publications/)
  - D6.1: General frame of the analysis and description of the new FOW assessment app
  - D4.1: Identification of floating-wind-specific O&M requirements and monitoring technologies
  - D2.1: Review of the state of the art of mooring and anchoring designs, technical challenges and identification of relevant DLC
  - D3.1: Review of the state of the art of dynamic cable system design
  - D1.2: Design Basis
  - D1.1: Definition of the 15MW reference wind turbine

• **Public models (available under different CC licenses):**

  https://zenodo.org/communities/corewind/?page=1&size=20
  - UPC-WindCRETE OpenFAST – Grand Canary Island
  - COREWIND - ACTIVEFLOAT OpenFAST model 15 MW FOWT Grand Canary Island site
  - Other locations to come soon
Join the conversation
#corewind

Stay tuned and follow us for updates
https://twitter.com/corewindeu
https://www.linkedin.com/company/corewind/
Introduction to the OpenFAST model of the WindCrete spar floater

25 February 2021

Climent Molins
Mohammad Youssef Mahfouz

Professor UPC
Researcher USTUTT
WindCrete concept

Integrated concept of an offshore wind floating platform plus tower to support the wind turbine, without any joint.

Made of reinforced and post-tensioned concrete.

Spar type platform (ballast stabilized)
WindCrete ballast

Ballast aggregate: black slag from electrical furnace

- Bulk-specific weight: 25kN/m³

- Estimated cost: €35/ton
Construction in horizontal position

With or without drydock

Horizontal transport with tugboat
Up ending: - Water ballasting
- Dynamic control

Turbine installation with a crane-less technology
windcrete
Spar buoy

Monolithic concrete platform (buoy + tower) without joints

Variable Draft (80 m – 160 m)

Operational depth (100 m to >1000 m)

Adapative design, able to support wind turbines up to 15 MW

Reduced OPEX

Low cost – reduced CAPEX

Life-span >50 years

Reduced LCOE
WindCrete design for Gran Canaria

- Monolithic spar design
- Draft 155m
- Hub height 135m
- **Tower:**
  - Height: 129.5m
  - Radius: 6.6m->3.25m
  - Thickness: 0.4m
- **Buoy** *(semi-sphere + cylinder + transition piece)*
  - Draft: 155m
  - Radius: 9.3m->6.6m
  - Thickness: 0.5m
OpenFAST model of WindCrete

IEA Wind 15MW RNA

WindCrete (floater + tower)

OpenFAST model

Mooring system

Tuned ROSCO controller
Natural frequencies

<table>
<thead>
<tr>
<th></th>
<th>Surge</th>
<th>Heave</th>
<th>Pitch</th>
<th>Yaw</th>
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</thead>
<tbody>
<tr>
<td>Hz</td>
<td>0.012</td>
<td>0.031</td>
<td>0.024</td>
<td>0.092</td>
</tr>
<tr>
<td>seconds</td>
<td>81.9</td>
<td>32.8</td>
<td>41.0</td>
<td>10.9</td>
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</tbody>
</table>
• The WindCrete model is opensource and available at:
  https://zenodo.org/record/4322446
• More details about the floater and its performance can be found in
  https://zenodo.org/record/4385727
Optimized mooring system for the ActiveFloat concrete semisub floater for the 15 MW IEA WIND reference wind turbine

25 February 2021

corewind.eu

Valentin Arramounet

Innosea
Mooring design optimisation methodology

- Objective: minimize costs
- Constraints: criteria satisfied & limited motions/acceleration
- Design parameters (diameters, line length, steel grade, etc.)

- Environmental conditions
- Mooring configuration (Number of Lines, Materials, Number of Sections, etc.)

- Parameters configuration (Boundaries, Initial Values, etc.)

- Model set up
- Design criteria verification
- Motions (excursions & angles) & accelerations calculations
- Costs estimation

- Python interface

- Isight model configuration
- Isight Optimization

- Orcaflex model definition
- Orcaflex simulation
- FAST simulation
- FAST model definition

- Parameters configuration

corewind.eu
Cases studies

- DLC 6.1 and 6.2 (DNVGL-ST-0437)
- Start of Life and End of Life configuration
- Mooring systems are checked in ULS, FLS and ALS in a second step

<table>
<thead>
<tr>
<th></th>
<th>West of Barra</th>
<th>Gran Canaria</th>
<th>Morro Bay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Depth [m]</td>
<td>100</td>
<td>200</td>
<td>870</td>
</tr>
<tr>
<td>EWM Wind Speed at 100m 10min averaged [m/s]</td>
<td>47.63</td>
<td>27.35</td>
<td>35.38</td>
</tr>
<tr>
<td>Wind current speed 50 years @ surface [m/s]</td>
<td>1.15</td>
<td>0.57</td>
<td>0</td>
</tr>
<tr>
<td>Deep Water current speed 50 years @ surface [m/s]</td>
<td>0.94</td>
<td>0.49</td>
<td>0</td>
</tr>
<tr>
<td>Hs 50years [m]</td>
<td>15.6</td>
<td>5.11</td>
<td>9.9</td>
</tr>
<tr>
<td>Tp min 50 years [s]</td>
<td>12</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Tp max 50 years [s]</td>
<td>18</td>
<td>11</td>
<td>18</td>
</tr>
</tbody>
</table>
Results: Gran Canaria

- 3 Lines - Catenary
- Upwind: 832m – Chain R3 - 120mm bar diameter – 286 kg/m
- Downwind: 832m - Chain R3 - 70mm bar diameter – 97 kg/m
- Estimated cost: 865 k€ (- 60% VS initial configuration)
Results: West of Barra

• 12 Lines - Catenary: 6 lines upwind & 3 lines downwind

• Upwind:
  ➢ 90m – Nylon
  ➢ 1300m – Chain R5 – 125mm bar diameter – 310 kg/m
  ➢ Clump weights (Harsh conditions)

• Downwind
  ➢ 150m – Nylon
  ➢ 1200m – Chain R5 – 125mm bar diameter – 310 kg/m
  ➢ Clump weights

• Estimated cost: 14800 k€
Results: Morro Bay

- 3 Lines – Semi Taut

- Upwind:
  - 50m top / 142m bottom – Chain R4S - 92mm bar diameter – 168 kg/m
  - 810 m – Polyester – 141mm

- Downwind:
  - 50m top / 130m bottom – Chain R4 - 90mm bar diameter – 161 kg/m
  - 722 m – Polyester – 126mm

- Estimated cost: 634 k€ (-55% VS initial configuration)
Comparisons

• Gran Canaria
  ➢ Optimised cost: 865 k€
  ➢ Initial cost:
    ➢ 2156 k€ for grade R3
    ➢ 3161 k€ for grade R5

• West of Barra: No comparison as initial mooring is not fulfilling design criteria

• Morro Bay
  ➢ Optimised cost: 634 k€
  ➢ Initial cost: 1399 k€
Ongoing work

• Peak load reduction systems
  ➢ Peak loads reduction
  ➢ Fatigue reduction

• Shared anchors and mooring lines
"My experience with seasickness is that at first you are afraid you will die, then after a few hours you are afraid you will not. “

G. Yancey Mebane, M.D.
Further developed methodology to determine the Workability Index\(^1\) for the floating wind turbine in accordance with ISO 2631-1:1997- „Evaluation of human exposure to whole-body vibration”.

\(^1\) Scheu et al., 2018. Human exposure to motion during maintenance on floating offshore wind turbines. Ocean Engineering.
Interviewed External Stakeholders

Including one offshore wind turbine OEM (anonymous).

All findings published in:

Deliverable D4.1
“Identification of floating-wind-specific O&M requirements and monitoring technologies”
Download link: http://corewind.eu/publications/
O&M Focus Areas

Workability

Accessibility

Large Component Exchange

Mooring Lines

IA & Export Cables

Subsea Inspections
Accessibility challenges

- **Prevailing swell waves** for sites in Atlantic Ocean challenge Hs-limits of access systems
- **Increased Relative motions** between vessel and platform
- **Maintenance friendly design**
Large Component Exchange

Tow-in for Repair
- Distance
- Harbor capacity
- Cable and Mooring Line de- and reconnection
- Substructure type

Floating to Floating
- Relative motions
- Two-lift operation
- Exchange performed on same reference system as crane

Self-hoisting/climbing Crane
- Onshore Wind technology
- Development for Offshore ongoing
- Crane base hosted from floater platform
- Reduced relative motions for lift
Mooring Lines

- **ROVs** used for visual damage inspection & marine growth measurement

- **External threats**: fishing nets, boats, seabed contact, ROV collision

- Difficult to justify **sample population** of mooring line inspections.

- **Wet-storage** of mooring line during floater-tow-in problematic for fibre rope:
  - Dynamic seabed contact causes abrasion
  - Retrieval operations and re-installation are expensive

- **Hybrid ropes** (steel and fibre combination) increase robustness
Outlook O&M Task 4.2

Evaluation of relative motions and compensation requirements for:

1. Two access methods simulating bow-transfer with a CTV and walk-to-work from an SOV

2. Two substructure concepts with generic semi-sub and mono-hull crane vessel

Simulation of the O&M phase with the commercial cost modelling and strategy optimisation tool Shoreline.

Optimizing Resources, Availability and OPEX for each reference site and floater scenario.
Introducing FowApp

February 2021
What is FowApp?

AEP: Annual Energy Production

LCC: Life-Cycle Costs

LCA: Life-Cycle Assessment

LCOE: Levelized Cost of Energy
Why is it important?

- New technologies
- New strategies
- Cost reduction

= Complexity

Floating Offshore Wind Farms

FOWAT

Fow App

Other applications

- Poor AEP calculation
- Generic
- Financial-based

= Opportunity
The concept

Library
- Environments
- Components
- Auxiliary means
- Materials
- Fuels

Project
- Arrangement
  - Environment and components selection
  - Layout definition
  - Electrical connection definition
- Life cycle
  - Development
  - Construction
  - Operation and maintenance
  - Decommissioning and end of life

Results
- LCC
- LCOE
- AEP
- LCA
- LCIA
Results details

AEP
- Energy produced, delivered and loss details
- Detailed wake and subsystems efficiencies
- Capacity factor

LCC
- Detailed costs by phase
- Analysis per component and per process
- Time-based maintenance costs

LCOE
- Summary of energy delivered
- Summary of costs
- LCOE calculation
- LCOE contribution per phase

LCA
- Impact of components
- Impact of the auxiliary means
- Effect of the end of life treatment
- Summarised results
### Highlights

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<tr>
<th>Features</th>
<th>Advantages</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Built from scratch specifically for the floating wind industry</td>
<td>+ User friendly</td>
<td>❖ Early project development</td>
</tr>
<tr>
<td>✓ Possibility to import data from MS Excel</td>
<td>+ Variable level of input details as per user needs</td>
<td>❖ Technology assessment</td>
</tr>
<tr>
<td>✓ Data consistently stored in SQLite database</td>
<td>+ Multiple substation concepts allowed</td>
<td>❖ Environmental impacts evaluation</td>
</tr>
<tr>
<td>✓ Integrated power flow and wake calculations</td>
<td>+ Dependable results</td>
<td>❖ Performance analysis</td>
</tr>
<tr>
<td>✓ Full project overview</td>
<td>+ Combined economic and environmental analysis</td>
<td></td>
</tr>
</tbody>
</table>
Screenshots

Layout

Electrical connection

Project summary

AEP
Next steps

- App under registration process
- LCA module being finished
- Official testing: March 2021
- First use in the COREWIND project
- Commercial deployment: end of 2021
Join the conversation #corewind

Stay tuned and follow us for updates

https://twitter.com/corewind.eu
https://www.linkedin.com/company/corewind/