Offshore Wind 101
Maine Offshore Research Array Project
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Parts of an Offshore Wind Farm

- Wind farms north of Cape Cod will be floating, not fixed
  - Floating can be more economical than fixed because FOWTs can be constructed shoreside
- Growth Rate: 10MW prototype → 50MW test field → 300MW to 500MW wind farm (Hall, 2020)

MIN: 7x Rotor Diam = 7*220m = 0.96 miles
Offshore Wind Turbine Foundations

**Fixed Foundations:**
- Monopile
- Tripod/jacket

**Floating Foundations:**
- Tension Leg Platform (TLP)
- Semi-submersible (Semi-sub)
- Spar Buoy (Spar).

Jacket foundations for Block Island Wind Farm *(Providence Journal, 2015)*

EWEA (2013)
Source: Principle Power

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<table>
<thead>
<tr>
<th>Depth</th>
<th>Turbine Power Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-100 feet</td>
<td>Monopile 0.30m, 1-2 MW</td>
</tr>
<tr>
<td>80-150 feet</td>
<td>Jacket/Tripod 25-50m, 2.5 MW</td>
</tr>
<tr>
<td>&gt;150 feet</td>
<td>Floating Structures &gt;50m, 5-10 MW</td>
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<tr>
<td>&gt;400 feet</td>
<td>Floating Structures &gt;120m, 5-10 MW</td>
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</tbody>
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Mooring Components

Catenary mooring

Note: only two legs shown for clarity

Multi-catenary
(2 mooring leg options)

Sinker
Chain (example)

Buoy

Wire or Fiber (example)

Semi-taut mooring

Pile / Suction Pile Anchor

Fiber

Deadweight Anchor

Figure 35 Spread Mooring Configuration Options

Sound & Sea Technology, 2009
Mooring Materials: Chain, Wire & Synthetic Rope

High Tensile UHMWPE Rope
12 Strand Mooring Rope, ROPENET GROUP CO., LTD, China

Anchor, 3” studlink chain (MMC)

Stud Link Chain Properties (Paduca, 2020)

<table>
<thead>
<tr>
<th>Wire Size (inches)</th>
<th>Length of 6 Links (in.)</th>
<th>Weight of Link (lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>160</td>
<td>80</td>
</tr>
</tbody>
</table>

Source: API RP 2SK
Anchor Types

DEA - Surface

DEA - Deep

Gravity block

Pile (↑L, ↓D)

Plate anchor

Suction caisson (↓L, ↑D)

Drag embedment anchors (DEAs)

Gravity blocks, Piles/Caissons, Plate anchors

Gravity blocks, Piles/Caissons, Plate anchors

(Landon, 2019)
What is a Wind Turbine’s Footprint?

Rectangular Footprint:
Lat/Long, around all anchors

Anchor Safety Zone

Chain on Seabed

Pull mooring lines out of line until nylon breaking load

Extreme Footprint:
Circle around all anchors

Pull on Wind Turbine until mooring line load limit. Trace chain locations.
Electrical Connection

Baring-Gould, 2014

Illustration by Joshua Bauer, NREL
Power Lines to Shore

• Typical shore cable
  – 6”-7” diameter
  – Buried 6-feet deep

Approx. 5.5” diameter 34.5 kV, three conductors with fiber-optic communications cable (Plourde, 2017).

AC Line from other Turbines (typ. 34.5 kV)

HVDC (or HVDV)
Line to shore
Trenching the Power Cable

Jet plow on Town Beach in preparation for connecting Block Island to Wind Farm. Photo by K. Curtis (Shuman, 2016)

Block Island Cable Installation (Henrikson, 2017)

Sedimentation

Cable

(Van den Berghe, 2008)
Protecting the Power Cable

- Cables are trenched and laid in place
  - Jet the trench, then drop cable in behind jet
  - 6' underground (2M)
  - Use mechanical plow to minimize impact in sensitive areas
- If trenching not feasible (or near shore) use cast iron armor, 10" to 12" diameter
  - Small anchors won’t catch, heavy anchors won’t damage
- Use polyurethane bend restrictors for dynamic cable
- Trenches allow lobstering
  - Only precludes fixed gear trawlers

Polyurethane Vertebrae Bend Restrictor (*ABCO Subsea, 2020*)

Articulated concrete mat. (*Kokosing, 2018*)

Cast iron, articulated bend restrictor. (*PCS Italiana, 2017*)
References

- Hall, Dick. SGC (private conversation with author, 3/2020).
- Shuman, C. Deepwater Wind connects its cable at Fred Benson Town Beach. Block Island Times. 05/20/2016 https://www.blockislandtimes.com/article/deepwater-wind-connects-its-cable/46346
QUESTIONS?