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> If technical problems arise, please contact Sal.Graven@nyserda.ny.gov

You'll see when your microphone is muted
Learning from the Experts

This webinar series is hosted by NYSERDA’s offshore wind team and features experts in offshore wind technologies, development practices, and related research.

DISCLAIMER: The views and opinions expressed in this presentation are those of the presenter and do not represent the views or opinions of NYSERDA or New York State.
Offshore Wind Submarine Power Cables – An Introduction

Duncan Sokolowski – Sr Project Manager, Submarine Cable Services at Tetra Tech
The potential scale of the industry

The American Wind Energy Association estimates that by 2030, the USA will have between 20,000 and 30,000 MW of installed offshore wind power.

20,000 MW of offshore wind power will require approximately 1,650 turbines (of 12 MW each):
- Approximately 50 export cables (~3,000 miles)
- 2,000 inter array cables (~2,000 miles).
Offshore Wind Submarine Cabling

An overview of the cabling.

HVAC Cable
Array Cable and Export Cable cross sections

HVDC Cable ‘slices’
Neptune project on the left, Basslink (Tasmania) on the right
<table>
<thead>
<tr>
<th>Parameter</th>
<th>HVAC Arrays</th>
<th>HVAC Export</th>
<th>HVDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer Diameter Range</td>
<td>4.25 in – 6.3 in</td>
<td>10 in – 13 in</td>
<td>Approx. 6 in (150 mm) NOTE: Return cable is of smaller diameter</td>
</tr>
<tr>
<td></td>
<td>(110 mm – 160 mm)</td>
<td>(250 mm – 320 mm)</td>
<td></td>
</tr>
<tr>
<td>Weight in Air</td>
<td>13 lbs/ft – 34 lbs/ft</td>
<td>Up to approx. 85 lbs/ft</td>
<td>Approx. 40 lbs/ft (60 kg/m) for entire bundle</td>
</tr>
<tr>
<td></td>
<td>(20 kg/m – 51 kg/m)</td>
<td>(125 kg/m)</td>
<td></td>
</tr>
<tr>
<td>Conductor Cross-Section</td>
<td>3 x 120 mm² – 800 mm²</td>
<td>3 x 800 mm² – 1400 mm²</td>
<td>Up to approx. 1800 mm²</td>
</tr>
<tr>
<td>Voltage Rating (approx.)</td>
<td>&lt; 66 kV</td>
<td>132 – 345 kV</td>
<td>Up to approx. +/- 600 kV</td>
</tr>
<tr>
<td>Electrical Losses</td>
<td></td>
<td>Medium (at the longest lengths)</td>
<td>Low</td>
</tr>
<tr>
<td>Practical Maximum Length</td>
<td>~60-70 miles (100-120km)</td>
<td>Theoretically unlimited, currently the longest submarine HVDC cable is 720 km (450 miles) for North Sea Link</td>
<td></td>
</tr>
<tr>
<td>Max power per cable</td>
<td></td>
<td>~400 MW</td>
<td>Currently ~2,200MW for Western Link</td>
</tr>
</tbody>
</table>
## Offshore Wind Submarine Cabling

### Impacts/Risks to and from Cabling

<table>
<thead>
<tr>
<th>Party</th>
<th>Risk/Impact</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable Owner</td>
<td>Cable damage</td>
<td>Loss of revenue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost of repair operation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased insurance premiums</td>
</tr>
<tr>
<td>Insurer</td>
<td>Insurance claim either to cable owner or commercial/fishing vessel that impacts cable</td>
<td>Insurance payout, future risks on other insured assets</td>
</tr>
<tr>
<td>Shipping Industry</td>
<td>Possible legal liability if deemed to be at fault, vessel delays/arrest.</td>
<td>Commercial and legal impacts.</td>
</tr>
<tr>
<td></td>
<td>Health and Safety</td>
<td>Health and Safety</td>
</tr>
<tr>
<td>Fishing Industry</td>
<td>Possible legal liability if deemed to be at fault, vessel delays/arrest.</td>
<td>Commercial and legal impacts.</td>
</tr>
<tr>
<td></td>
<td>Lost fishing gear</td>
<td>Health and Safety</td>
</tr>
<tr>
<td>Grid Operator</td>
<td>Generating source goes offline</td>
<td>Consequential grid operational implications</td>
</tr>
<tr>
<td>Regulatory Authorities</td>
<td>Processes and reputation</td>
<td>Changes to the permitting process</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Public perception</td>
</tr>
<tr>
<td>Environment</td>
<td>Turbidity during installation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EMF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heating effects</td>
<td></td>
</tr>
</tbody>
</table>
## Offshore Wind Submarine Cabling
### Vineyard Wind Final Environmental Impact Statement – A Summary of Mitigation Measures

<table>
<thead>
<tr>
<th>Measure Number &amp; name</th>
<th>Description</th>
<th>Expected Effect on Impacts</th>
<th>Authority</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 – Dredging &amp; Cable Installation Methods &amp; Timing</td>
<td>Requires cable installation activities to use the least environmentally harmful method – also defines installation window restrictions</td>
<td>Will reduce the expected minor to moderate temporary impacts on coastal habitats and benthic resources</td>
<td>MassDEP, NMFS EFH</td>
</tr>
<tr>
<td>12 – Anchoring Plan</td>
<td>Requires an anchoring plan in all areas where anchoring is planned</td>
<td>Reduces the impact on the seafloor etc. Any applicable if anchor barges etc are planned</td>
<td>BOEM</td>
</tr>
<tr>
<td>14 – Final cable protection in hard bottom</td>
<td>Natural or engineered stone that mimics the surrounding seafloor, nature inclusive designs</td>
<td>Reduces the expected moderate impacts and improve possible minor benefits</td>
<td>Mass CZM, BOEM</td>
</tr>
<tr>
<td>15 – Evaluation of benthic habitat prior to cable laying</td>
<td>A minimum of 75 benthic samples &amp; 60 video transects to be taken along the export cable corridor. Information to be used to update habitat maps etc</td>
<td>Wouldn’t change the rating but would allow sensitive areas to be avoided</td>
<td>BOEM</td>
</tr>
<tr>
<td>18 – Post-installation cable monitoring</td>
<td>Export and IA cable surveys at years 1, 2 and every 3 years thereafter, as well as after a ‘major storm event’. A DTS system also required.</td>
<td>Wouldn’t affect the impacts on benthic resources but could reduce the impacts on commercial fisheries by detecting reduced burial</td>
<td>BOEM</td>
</tr>
<tr>
<td>74 – Providing electronic charting information</td>
<td>Make available information on the as-built location of cables</td>
<td>Would allow the fishing industry to make informed decisions re fishing grounds etc</td>
<td>Voluntary by VW</td>
</tr>
<tr>
<td>75, 76 &amp; 77 – Compensation funds</td>
<td>Create funds held in ESCROW to compensate the fishing industry for direct impacts</td>
<td>Doesn’t change the impact rating</td>
<td>Various</td>
</tr>
<tr>
<td>80 – Submarine cable system burial plan</td>
<td>Location and burial depths of the entire cable system to be submitted as a part of final documentation</td>
<td>To be reviewed by USCG &amp; BOEM to aid planning etc</td>
<td>USCG, BOEM</td>
</tr>
</tbody>
</table>
Offshore Wind Submarine Cabling

So how are submarine cables protected from external aggression, and how are external users protected from cables? How are environmental impacts minimized?

1- Careful route planning, avoid as far as possible areas of high risk and environmental sensitivity. Shipping lanes, anchorages, fishing grounds, steep slopes & hard seabeds, dumping sites & borrow areas, areas of high seabed sediment mobility, other seabed assets (cables, pipelines etc), cultural sites, eel grass and fish-spawning areas (for example) and more

2- Cable Burial. The deeper the cable is buried, the safer it is from external impact and the less impact it will have on other users and the environment (except during installation)

3- Externally applied protection. Used where burial may be difficult or impossible such as areas of bedrock or areas of reduced burial such as at crossings
Offshore Wind Submarine Cabling

Cable Burial is always the primary method of protection for cables.

What drives the specified or recommended cable burial depth?

- Requirements from Federal and state agencies (e.g., USACE in federally maintained shipping channels requires 15' depth below authorized, maintained channel depth)
- Industry guidance from (for example) standards agency such as DNV GL, experience from organizations such as the North American Submarine Cable owners Association (NASCA) etc.
- Risk appetite of asset owners/insurers/regulatory bodies

There is a balancing act between too deep (expensive, environmental impacts, ampacity issues) and too shallow (risk both to and from the cable).

So how is a recommended target burial depth derived?
Offshore Wind Submarine Cabling

Cable Burial Risk Assessment (CBRA)

A CBRA is a risk-based methodology used to determine the minimum recommended Depth Of Lowering (DOL) for a submarine cable. The CBRA was developed by the U.K’s Carbon Trust which commissioned a group of subject matter experts to create a method of determining risk to a submarine cable system and therefore specify a DOL that will reduce risk ‘As Low As is Reasonably Practicable’ (ALARP).

The CBRA will determine a minimum recommended DOL (A) at each point along the cable route. To achieve this, the installation contractor will select a burial method to achieve a target DOL (B). This allows for a slight margin of error in case of unexpected hard soils, for example.
A target trench depth (C) will help to ensure that the minimum DOL is attained by accounting for any potential backfill.
Offshore Wind Submarine Cabling

What goes into a CBRA?
Any external factor that can damage the cable, or in turn can be damaged by the cable is taken into consideration, these are a mix of natural and human (anthropogenic) factors.

- Commercial vessel activity
- Commercial (& recreational) fishing activity
- Dumping areas
- Dredging activity
- Obstructions (wrecks etc.)
- Cultural sites
- UXO
- Existing seabed assets
- Steep slopes, shoals, ravines, hard seafloor
- Sediment mobility
- Wind, waves, tides, currents
- Environmentally sensitive areas

Proper route planning will avoid challenging geophysical conditions (steep slopes, hard sediments etc.) as well as areas of human activity where possible. Where this isn’t possible, the CBRA will ensure that risk to the cable is reduced as far as is reasonably practicable.
Offshore Wind Submarine Cabling

What goes into a CBRA?

Seabed Bathymetry

Sediment Mobility

Seabed Geology
Offshore Wind Submarine Cabling

What goes into a CBRA?

Fishing Activity
(Hydraulic surf clam dredging, 2015 & 2016 VMS data)

Shipping Activity
(2019 AIS Data, Mid-Atlantic Ocean Data Portal)

Analysis of fishing types & commercial vessel types encountered
### Offshore Wind Submarine Cabling

#### CBRA Output

<table>
<thead>
<tr>
<th>Rank</th>
<th>Category</th>
<th>Risk Level</th>
<th>Probability</th>
<th>Impact</th>
<th>Threats</th>
<th>Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Material</td>
<td>High</td>
<td>4</td>
<td>5</td>
<td>20</td>
<td>High</td>
</tr>
<tr>
<td>2</td>
<td>Installation</td>
<td>Low</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Low</td>
</tr>
<tr>
<td>3</td>
<td>Submarine Cabling</td>
<td>Medium</td>
<td>3</td>
<td>4</td>
<td>12</td>
<td>Medium</td>
</tr>
<tr>
<td>4</td>
<td>CBRA Output</td>
<td>High</td>
<td>4</td>
<td>5</td>
<td>20</td>
<td>High</td>
</tr>
</tbody>
</table>

#### Risk Assessment

- **Depth Of Lowering recommendations**

- **Offshore Wind Submarine Cabling**

- **CBRA Output**

  - **Risk Level**
    - High
    - Medium
    - Low

- **Threats**
  - Material
  - Installation
  - Submarine Cabling

- **Risk Score**
  - High
  - Medium
  - Low
Offshore Wind Submarine Cabling

When can cable installation commence?

The permitting of an offshore wind farm is a process coordinated by BOEM under the National Environmental Policy Act (NEPA) of 1969.

Part of the permit requirements will include installation windows that will limit construction activities to times that won’t impact migratory species, fish spawning, etc.
Offshore Wind Submarine Cabling

Cable Installation And Burial – Two common methods

Simultaneous Lay and Burial

The Cable Lay Vessel (CLV) lays and buries the cable in a single operation.

Only one vessel required so saves on vessel day rates, however, the lay operations are a lot slower than if the cable is laid with no burial (surface lay). Therefore, longer weather windows are required.

Post Lay Burial

The CLV lays the cable on the seabed, it is then buried via a separate operation (usually by a different vessel).

Two vessels required but a lot of flexibility with regard to making the full use out of weather windows.
Offshore Wind Submarine Cabling

Simultaneous Lay and Burial

Towed Plow
~3m/10’ burial depth
15m long, 6.5m wide
Weighs approx. 50T

Towed jetting sled
~3m/10’ burial depth
For shallower water & softer soils

Large Towed jetting sled
~8m/25’ burial depth
For shallower water, has optional chain cutter for harder soils
Offshore Wind Submarine Cabling

Simultaneous Lay and Burial

Vertical Injector
Up to 10m/33’ burial depth
Deployed from a barge
Shallow water, softer soils

Tracked Trencher
Deepoceans T3200
Weighs 170T, jetting and chain cutting up to 3.5m burial depth

Tracked Trencher
Van Oord’s ‘Deep Dig-It’
Weighs 125T, jetting and chain cutting up to 5.0m burial depth
Offshore Wind Submarine Cabling

**Post Lay Burial**

**ROV**
- Canyon's T1200
  - Up to 3m/10’ burial depth
  - Water jetting only

**ROV**
- Enshore's T1000
  - Up to 3m/10’ burial depth
  - Water jetting only

**ROV in ‘free-flying’ mode**
- For softer sediments where tracks would sink and cause a loss in maneuverability
Offshore Wind Submarine Cabling

Other burial techniques

Mass Flow Excavator (MFE)

Multimode plow can clear boulders (route clearance mode), cut a trench into which the cable is laid, then can backfill the trench after cable lay. Typically, can cut a ‘V’ or ‘Y’ shaped trench between 1.0 and 2.0m in depth, depending upon soil conditions.
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Other Cable Protection

Rock Dumping

Grout/Rock Bags
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Other Cable Protection

Concrete Mattresses

Frond Matts/Nature Inclusive Designs
Offshore Wind Submarine Cabling

Other Cable Protection

Articulated Split Pipe

Uraduct

Cable Protection Systems
Offshore Wind Submarine Cabling

Cable Repairs

Cable joint being lifted out of jointing container

Cable joint being deployed from vessel
Cables are surveyed to ensure that the target depth of lowering has been achieved (after burial) and at periodic intervals to ensure that the cable isn’t becoming too shallow or conversely, that the cable isn’t becoming too deeply buried.

Cables that get shallower (mobile sediments move away for example) are at risk of damage. Cables that get deeper reduce the current carrying capability due to the reduction in thermal conductivity.

How often?
It depends on site-specific conditions (e.g., how mobile the seabed is) as well as regulatory permitting requirements. It may be that initially, surveys are carried out every 1 to 2 years to establish baseline data, then the frequency can be reduced once the cable burial depth trend is more understood.
Cable Sensing

Distributed Temperature Sensing

- Equipment located in the control room & offshore substation
- Utilizes one of the optical fibers
- Monitors the temperature at approximately 1 to 5m intervals along the cable
- Benefits?
  - Cable can be operated closer to 90°C (dynamic rating)
  - Temperature trends monitored, data analyzed to monitor depth of burial
  - Strain sensing also possible
Offshore Wind Submarine Cabling

Cable Sensing

Distributed Vibration Sensing

- Equipment located in the control room & offshore substation
- Utilizes one of the optical fibers
- Monitors the acoustics at 1m intervals along the cable
- Benefits?
  - Increased noise implies reduced burial
  - Advance warning of anchoring, fishing etc
  - Certain types of fault can be located
Offshore Wind Submarine Cabling

Thank you, Any Questions?

Duncan Sokolowski
duncan.sokolowski@tetratech.com
Coming Next:

June 9, 1:00 p.m. ET
Digital Aerial Surveys to Inform Offshore Wind Development
Julia Robinson Willmott, Normandeau Associates

June 23, 1:00 p.m. ET
The Science of Visibility
Gordon Perkins & Kiva VanDerGeest, Environmental Design & Research

Visit wind.ny.gov to register

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