Offshore Wind Submarine Power Cables – An Introduction

Duncan Sokolowski – Sr Project Manager, Submarine Cable Services at Tetra Tech
Europe installed their first offshore wind farm in 1991, off Denmark. This was a 5 MW project consisting of 11 turbines. As of 2019, there were 22,000 MW of installed offshore wind power, generated by 5,000 turbines.

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) and 2,000 inter array cables (~2,000 miles).

Growth is driven by renewable energy/greenhouse gas reduction targets set by the various states. One example - NY has set a goal of 9,000 MW of installed offshore wind generation by 2035.
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An overview of the cabling.

Array Cable and Export Cable cross sections

<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 (110 mm – 160 mm)</td>
<td>10 in – 13 in (250 mm – 320 mm)</td>
<td>Approx. 6 in (150 mm) NOTE: Return cable is of smaller diameter</td>
</tr>
<tr>
<td>Weight in Air</td>
<td>13 lbs/ft – 34 lbs/ft (20 kg/m – 51 kg/m)</td>
<td>Up to approx. 85 lbs/ft (125 kg/m)</td>
<td>Approx. 40 lbs/ft (60 kg/m) for entire bundle</td>
</tr>
<tr>
<td>Minimum Bend Radius</td>
<td>~ 6 ft (2.0 m)</td>
<td>~ 15 ft (5.0 m)</td>
<td>Varies</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>
</tbody>
</table>
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HVDC Cable ‘slices’
Neptune project on the left, Basslink (Tasmania) on the right

<table>
<thead>
<tr>
<th>Parameter</th>
<th>HVAC</th>
<th>HVDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable Cost</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Electrical Losses</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Practical Maximum Length</td>
<td>~100 km</td>
<td>Theoretically unlimited, current longest submarine cable is about 600 km</td>
</tr>
<tr>
<td>System reliability</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>OSP/Convertor platform cost</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Max power per cable</td>
<td>~400 MW</td>
<td>Currently Western Link; transmits 2,200 MW</td>
</tr>
<tr>
<td>Onshore footprint</td>
<td>Medium</td>
<td>Large</td>
</tr>
</tbody>
</table>
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So how are submarine cables protected from external aggression?

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

What drives the specified cable burial depth?

- Requirements from Federal and state agencies (e.g., USACE in federally maintained shipping channels, states such as New Jersey have a burial depth requirement in their waters etc.)
- 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.
- Site and region-specific risk factors and soil conditions.
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.
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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.
What goes into a CBRA?

- Seabed Bathymetry
- Sediment Mobility
- Seabed Geology
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What goes into a CBRA?

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

- **Shipping Activity**
  (2019 AIS Data, Marine Cadastre)

- **Analysis of fishing types & commercial vessel types encountered**
### CBRA Output

| KP  | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 |
|-----|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|      | 3 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

### Depth Of Lowering recommendations

| KP  | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 |
|-----|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|      | 3 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Risk Assessment**

- **Landing Vessels**
  - Offshore Wind Submarine Cabling
  
- **CBRA Output**
  - Risk Assessment
  
- **Depth Of Lowering recommendations**
  - Further information on the risk assessment and the specific criteria for depth lowering is provided in the context of the document.
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.
**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.
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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
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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
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**Post Lay Burial**

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

**ROV Deepocean’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
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
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Other Cable Protection

Articulated Split Pipe

Uraduct

Cable Protection Systems
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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.
Any Questions?

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NYSERDA have commissioned a submarine cabling informational report. The initial draft will be released imminently. Please contact Morgan Brunbauer for further details.

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