Lessons Learned Abroad: Cable Best Practices as Examined in London Array and Walney

Howard Kidorf
What do Wind, Wave and Tidal all have in common ...

Submarine Cables

Telecom
- Cables have been laid at sea for 160 years

Offshore Oil/Gas Industry
- Pipelines, umbilicals and cables laid at sea for 30-40 years

Installation Techniques Similar in Both Industries
- Ploughs, jetting, cable handling equipment
- Marine survey requirements (bathymetry, seabed hazard survey, geotechnical data etc)

Specialist Installers
- Skills transfer from submarine telecoms and oil/gas to develop offshore energy
- There is a large pool of experienced personnel with 20-30 years of practical experience

Lessons learned in many fields are important in alternative offshore energy
Example: Telecoms

OVERVIEW
• Historically telecom cables landed at suitable sandy beaches
• Landings chosen for ease of installation, not point of presence
• Shortest route off the shelf into deepwater
• Over time systems grouped together in shared Terminal Stations

BENEFITS
• Reusable landings, terminals and infrastructure
• Small diameter cables, easy to bury
• Small footprint size – narrow corridor
• Locations published on Charts and commercial databases
• Well known and proven routes

First undersea faults were found in telecom cables
Offshore Wind Farm Cables

Many cable-related aspects of projects:

- Desktop study
- **Design: Route Engineering**
  - Planning & Risk Assessment
  - Survey Data
  - Cable & Pipeline Crossings
  - Burial
- Permitting
- Installation
  - Vendor selection
  - Quality Control
- Spares planning
- Etc.

80% of insurance claims in European offshore windfarms
Design: Overview

- Foundation technology
- Economic length of cables
- Security and maintenance of cable over its lifetime
- Installation techniques required
- Seabed type expected (burial or surface lay?)
- Export strategy: multiple?
- Environmental issues
- Terrestrial Point Of Presence
- New Or Existing Landing Point?
- Landing Point Suitability
- Landing Point Capacity
- Natural Processes
- Manmade Activities
- Interaction With 3rd Party Infrastructure
- (Pre-) Front End Engineering Study (FEED)
Lessons Learned: Cable Routing

• Risk assessment is vital to find route
• Investment in planning will yield significant benefits
• Shortest route from A to B is not quarantined to be technically suitable or most cost effective
Why Bury Cables?

- Subsea cables have been laid since the 1850s (telegraphs, coaxial, fiber-optic, umbilical and power)
- Routinely buried since the 1980s providing extra protection
- Fault rates fell significantly after burial was introduced
- In shallow water (less than 1000m)
  - Before 1980’s – 2 to 6 faults per 1000km per year recorded
  - After 1980’s – 0.5 to 2 faults per 1000km per year recorded
- In deep water (deeper than 1000m)
  - Surface laid cable 0.05 to 0.2 faults / 1000km / year

Burial Assessment

CHALLENGE: Mapping seabed hazards on the cable route, assessing risks and choosing the right tools for cable installation

• Multiple surveys may need to be conducted, no “one size fits all” solution
• Burial Protection Index – derive burial depth based on potential threat AND sediment strength
• Sediment analysis required for route for selection of the correct burial tool and suitable burial depth to protect the cable.
Burial Protection Index

**BPI = 0** Assumes that the cable is surface laid

**BPI = 1** Depth of burial consistent with protecting a cable from normal fishing gear only.

**BPI = 2** Depth of burial will give protection from vessels with anchors up to approximately 2 tonnes. This may be adequate for normal fishing activity, but would not be adequate for larger ships (e.g. tankers, large container ships)

**BPI = 3** Depth of burial sufficient to protect from anchors of all but the largest ships. Suitable for anchorages with adjustments made to suit known ship/anchor sizes.

Cable route needs to be analysed for risk AND sediment characteristics to determine a suitable burial depth

Some Lessons Learned

• Export cable installation attempted without consideration of limited weather window
• Incorrect specification for installation equipment
• Double handling of cable (cable memory)
• Inexperienced installation crews using poor procedures
Conclusions
Offshore wind farm cable design requires a multi-disciplined approach

- Obtain the right data at the right time
  - DTS, Survey, etc.
- Resist the urge to draw a box around cable planning and say “we are done”
- Learn from past experiences
- Design with the future in mind
London Array

- 175 Turbines in Phase 1
- 2 offshore substations
- 210 km of 33 kV array cables
  - Each 0.65 to 1.20 km long
- 4 x 150 kV export cables: 220 km
  - €100M = $136M
  - Nexans export cables
Walney Wind Farm

- Irish Sea
- 102 Turbines in 2 phases
- 2 offshore substations
- 33 kV Array cables
- 2 export cables
  - 44km and 43 km
- 15 m radius rock dump for scour
Connections

J TUBES
- External metal conduit
- “J” shaped end near seabed level
- Diver fed cable end
- Older wind farms & substations

SUBSEA CONNECTORS
- Internal to monopile
- Plugged in using coupling
- Diverless installation
- Quicker installation
Export Cables: Considerations

PROJECT FACTORS
- Plan for multiple parallel cable routes
- Survey a wide corridor to allow engineering flexibility
- Turbine and Substation configurations
- Orientation of subsea connection points

LEGISLATION AND REGULATION FACTORS
- Permitted corridors
- Environmentally Sensitive Areas

3RD PARTY FACTORS
- Accommodating other marine users and seabed stakeholders
Survey Techniques for Cable Routes

• Marine Geophysics
  – Multibeam Echo Sounder – seabed modelling
  – Side Scan Sonar – seabed imagery, hazards
  – Sub Bottom Profiler – sediment thickness
  – Magnetometer – metallic objects (UXO etc)

• Marine Geotechnics
  – Coring – Sediment composition
  – Boreholes – drilling for foundations study
  – Cone Penetrometer Testing – Sediment type and soil strength
  – Lab Testing – provides data on sediment characteristics
Array Cables

CONSTRUCTION

- Cable layout around each turbine
- Order of Installation (phases of development)
- Establishment of a “cable free zone” for jack-up rigs
- Cable repair, recovery or replacement
- Managing hazards from construction, spud can holes
Seabed Hazards

2 categories of marine hazards:

- **Natural Hazards** all water depths: seismic activity, faults, pockmarks, depressions, sediment mobility, sandwaves, megaripples, scour, rock outcrop etc.

- **Manmade Hazards** typically shallow water (vessel activity, fishing, anchoring, dredging, wrecks, debris/dumping)

**NEED TO MAP THESE HAZARDS**
Installation Techniques

- **Ploughing**: Towed by vessel or barge with anchor spread.
- **Jetting Sled**: Towed by vessel or barge with jetting tool.
- **ROV**: Free swimming solution with jetting/cutting tools.
- **Vertical Injector**: Blade used to liquify soil laying cable at specified depth.
- **Rock Dumping**: Retrospective cable burial solution for surface laid cables.
- **Mattressing**: Post lay cable protection, used over pipelines etc.
- **Articulated Pipe**: Post lay cable armour protection.
- **Plastic Armour**: Used in subsea connections.
Tools for Cable Design

CHALLENGE: Interpreting the various survey datasets to generate a risk minimised cable route

Geographical Information System

- Electronic chart based interface
- Data is imported in configurable layers
- Historical databases – FEED study, Nautical Charts
- Survey data input - bathymetry and seabed features

- Engineering tool for the cable route design engineer
- Cable design using a mapping interface
DESIGN: Competence

UK Health & Safety Executive (HSE)
Construction (Design & Maintenance) CDM Reg. 2007
Approved Code of Practice (ACOP) Appendix 4

RESPONSIBILITY LEVEL: Designer

Designers will need to:
- Eliminate hazards where feasible
- Reduce risks from those hazards that cannot be eliminated
- Provide information on residual risks if they are significant

The following are conducted:
- Risk assessments using survey, construction and design data
- Risk assessments of the proposed installation methods
- Liaison with CDM Coordinator
Cable & Pipeline Crossings

Engineering cables over existing subsea plant

• Situation of cable/pipeline (surface laid or buried?)
• Status (OOS or Active) Clear it or protect it?
• Optimal Crossing angle: 60-90° for cables; 90° for pipelines
• Crossing protection (mattressing, uraduct/polyspace)
• Safe working distances
• Interaction of export & array cables
• Databases: UK Deal, Geocable, Kingfisher, survey data
Power Cable Landing Points

WHAT IS TECHNICALLY POSSIBLE?

- 7 Subsea power cables landing in Mexico – Cozumel Island
- Installed into rocky foreshore
- Steep approach slopes
- Environmentally sensitive area
- 80mm diameter (34.5Kv)
- Laid parallel, typical separation 20m
- Environmentally sensitive – reefs
- Strong ocean currents
Sediment Analysis

Purpose: Categorising the expected sediment conditions on the cable route for selection of the correct burial tool and determining suitable burial depth to protect the cable.

<table>
<thead>
<tr>
<th>Sediment Type</th>
<th>Description</th>
<th>Undrained Shear Strength (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Very Soft</td>
<td>&lt;20</td>
</tr>
<tr>
<td>II</td>
<td>Soft</td>
<td>20 – 40</td>
</tr>
<tr>
<td>III</td>
<td>Firm</td>
<td>40-75</td>
</tr>
<tr>
<td>IV</td>
<td>Stiff</td>
<td>75 – 150</td>
</tr>
<tr>
<td>V</td>
<td>Very Stiff</td>
<td>150 – 300</td>
</tr>
<tr>
<td>VI</td>
<td>Hard</td>
<td>&gt; 300</td>
</tr>
</tbody>
</table>
Array Cables: UK
Overview

- ROUND 1 - typically small, generally simple linear arrays
- ROUND 2 - more turbines, complex array cable layouts
- ROUND 3 - increased complexity, more seabed variability
Case Study: Oil/Gas Industry

OVERVIEW

- Concentration of oil/gas activity in the Southern North Sea
- Shallow water - coincident with gas deposits
- Numerous pipelines
- Concentration at 4 main UK landings

- Mature Industry
- New platforms and pipelines unlikely
- Decommissioning will occur in next 20 years
- New industry may develop
  - carbon storage
  - Waste disposal
Burial Protection Index

<table>
<thead>
<tr>
<th>SOIL TYPE</th>
<th>BPI 0</th>
<th>BPI 1</th>
<th>BPI 2</th>
<th>BPI 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>COARSE SANDS</td>
<td>0m</td>
<td>1m</td>
<td>2m</td>
<td>3m</td>
</tr>
<tr>
<td>FINE SANDS</td>
<td>0m</td>
<td>0.5m</td>
<td>1m</td>
<td>1.5m</td>
</tr>
<tr>
<td>MOBILE SEDS</td>
<td>0m</td>
<td>0.5m + sed ht</td>
<td>1m + sed ht</td>
<td>1.5m + sed ht</td>
</tr>
<tr>
<td>CLAY I/II</td>
<td>0m</td>
<td>2.5m</td>
<td>3m</td>
<td>5m</td>
</tr>
<tr>
<td>CLAY III</td>
<td>0m</td>
<td>0.8m</td>
<td>1.5m</td>
<td>2m</td>
</tr>
<tr>
<td>CLAY IV</td>
<td>0m</td>
<td>0.5m</td>
<td>1m</td>
<td>1.5m</td>
</tr>
<tr>
<td>CLAY V</td>
<td>0m</td>
<td>0.5m</td>
<td>0.5m estim</td>
<td>1m estim</td>
</tr>
</tbody>
</table>

Cable route needs to be analysed for risk AND sediment characteristics to determine a suitable burial depth.
# Installation

## Equipment: Pros & Cons

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<thead>
<tr>
<th>Technique</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ploughing</strong></td>
<td>Long track record</td>
<td>Launch and recovery</td>
</tr>
<tr>
<td></td>
<td>Good for harder soils</td>
<td>Limited ops near offshore structures/complex terrain</td>
</tr>
<tr>
<td></td>
<td>Can also be fitted with jetting/vibrating tools</td>
<td>Inaccuracy over shorter distances</td>
</tr>
<tr>
<td></td>
<td>Good availability, cost</td>
<td></td>
</tr>
<tr>
<td><strong>Pre Cut Trench Plough</strong></td>
<td>Multi pass</td>
<td>No simultaneous lay/burial</td>
</tr>
<tr>
<td></td>
<td>Good for harder soils</td>
<td>As above for ploughing</td>
</tr>
<tr>
<td><strong>Trenching ROV</strong></td>
<td>Multi pass</td>
<td>Need experienced crew</td>
</tr>
<tr>
<td></td>
<td>Good for hard soils (cutting)</td>
<td>Can be expensive</td>
</tr>
<tr>
<td></td>
<td>Goes close to structures</td>
<td>Availability</td>
</tr>
<tr>
<td><strong>Jetting ROV / Sled</strong></td>
<td>Multi pass</td>
<td>Not good for hard soils</td>
</tr>
<tr>
<td></td>
<td>Goes close to structures</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flexibility, launch/recovery</td>
<td></td>
</tr>
</tbody>
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# Installation

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<tr>
<th>Technique</th>
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</tr>
</thead>
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<tr>
<td>Vertical Injector</td>
<td>Good track record</td>
<td>Launch and recovery</td>
</tr>
<tr>
<td></td>
<td>Good in unconsolidated soils</td>
<td>Limited ops near offshore structures/complex terrain</td>
</tr>
<tr>
<td></td>
<td>Good for deeper burial in mobile sediments</td>
<td>Inaccuracy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Availability</td>
</tr>
<tr>
<td>Rock Dumping</td>
<td>Accuracy</td>
<td>High cost</td>
</tr>
<tr>
<td></td>
<td>High protection levels</td>
<td>Availability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ops &amp; Maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2nd vessel required?</td>
</tr>
<tr>
<td>Artificial Cable Protection</td>
<td>Accuracy</td>
<td>Possible High cost</td>
</tr>
<tr>
<td>Mattresses</td>
<td></td>
<td>Diver Intervention</td>
</tr>
<tr>
<td>Articulated Pipe Uraduct</td>
<td>Accuracy, certain protection levels</td>
<td>Possible additional vessel</td>
</tr>
<tr>
<td></td>
<td>Good close to structures</td>
<td>Time consuming to deploy</td>
</tr>
</tbody>
</table>
Offshore Energy & Renewables

- Export & Array Cable Route Engineering
- Cable Planning & De-confliction
- Client Representation for Survey & Installation
- Contractor/Supplier Selection & Management
- Asset Assessment for Due Diligence Studies
- Desk Top Studies for Future Windfarms
Marine Consultancy & Management

- Cable Route Risk Assessment
- Cable Burial Assessment
- Marine Operations Planning & Procurement
- Documentation Control
- Pipeline & Cable Crossings
- Stakeholder Notification Management
Submarine Cables

- System Feasibility & Desk Top Studies
- System Route Design
- Installation Planning & Project Management
- Route Clearance Operations
- Cable Burial Verification Surveys
Provision of Skilled Offshore Personnel

• Extensive Database of Qualified Personnel
  —Client/Purchaser Representatives
  —Surveyors, Geophysicists & Hydrographers
  —Marine Crew/Back Deck Teams
  —ROV/Plough Pilots/Supervisors/Techs
  —Divers
  —Cable Officers & Engineers, Testers & Jointers

• Full 24 hr Response Management
• Travel & Visa Support
• Comprehensively Insured Personnel
Track Record

- Galloper
- West of Duddon Sands
- Baltic 2
- Sakhalin III Kirinskoye
- Gwynt-Y-Mor
- Ormonde and Walney
- London Array
- Dogger Bank
- Hohe See
- Humber
- Teesside
- Dan Tysk

- BARD 1 ROV
- North Delta I & II
- Arkona
- Arklow Bank
- Lid & Lincs
- Scroby Sands
- Robin Rigg
- BRITNED ROV
- Rhyl Flats
- Sheringham Shoal
- Greater Gabbard