TenneT Offshore

Lessons learned from HVDC submarine cable installation from a TSO perspective

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Agenda

- Overview of TenneT's Offshore Activities
- initial Route Survey
- Cable Installation
- Vessel and Equipment
- Burial Tools
- Weather Limitations
- Burial Assessment Study (BAS)
- Reasonable Endeavour Criteria for Cable Burial
- Challenges
- Projects
- Summary

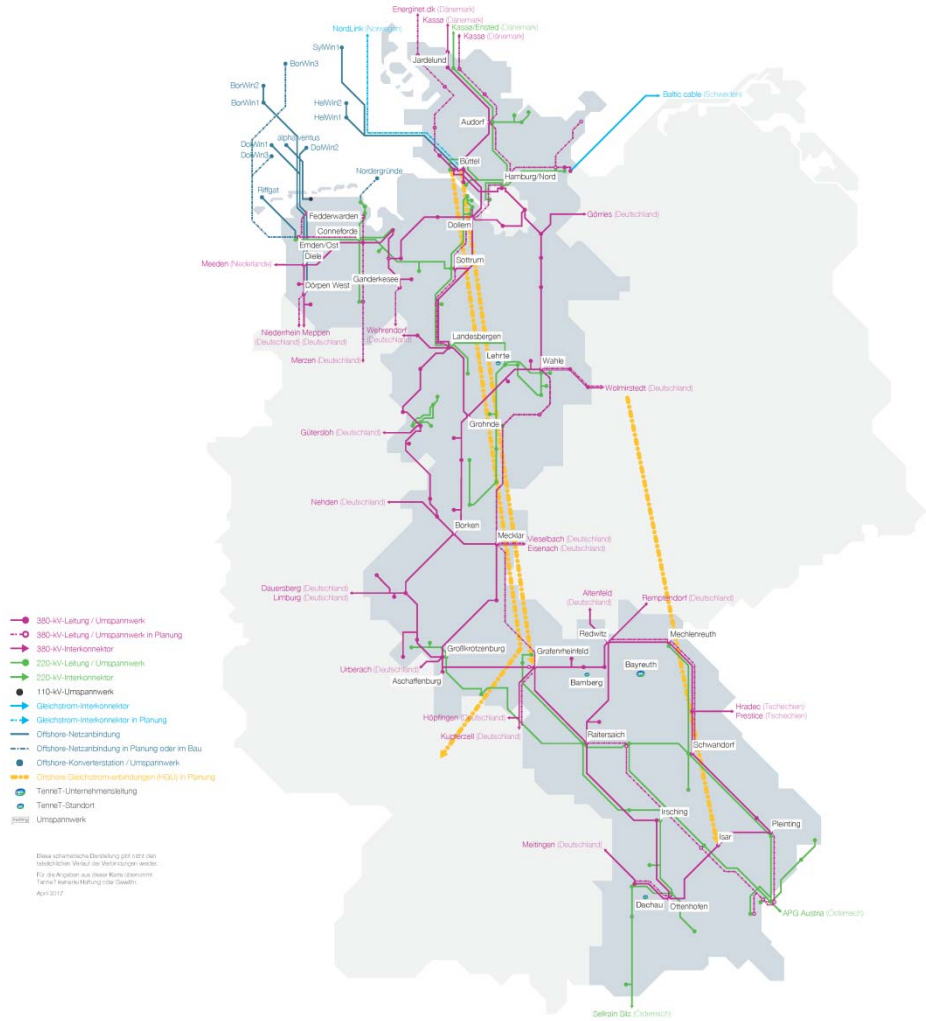
TenneT Offshore

TenneT – The Company

- We supply 41 million end users with electricity
- Operation, maintenance and further development of (extra high-voltage power grids in parts of Germany and the Netherlands
- Statutory mandate for grid expansion and safe operation on- and offshore

TenneT

- More than **22,000 km** total grid length
- Grid availability **99.9999 %**
- Over **3,000** employees
- turnover of **EUR 3.2 billion**



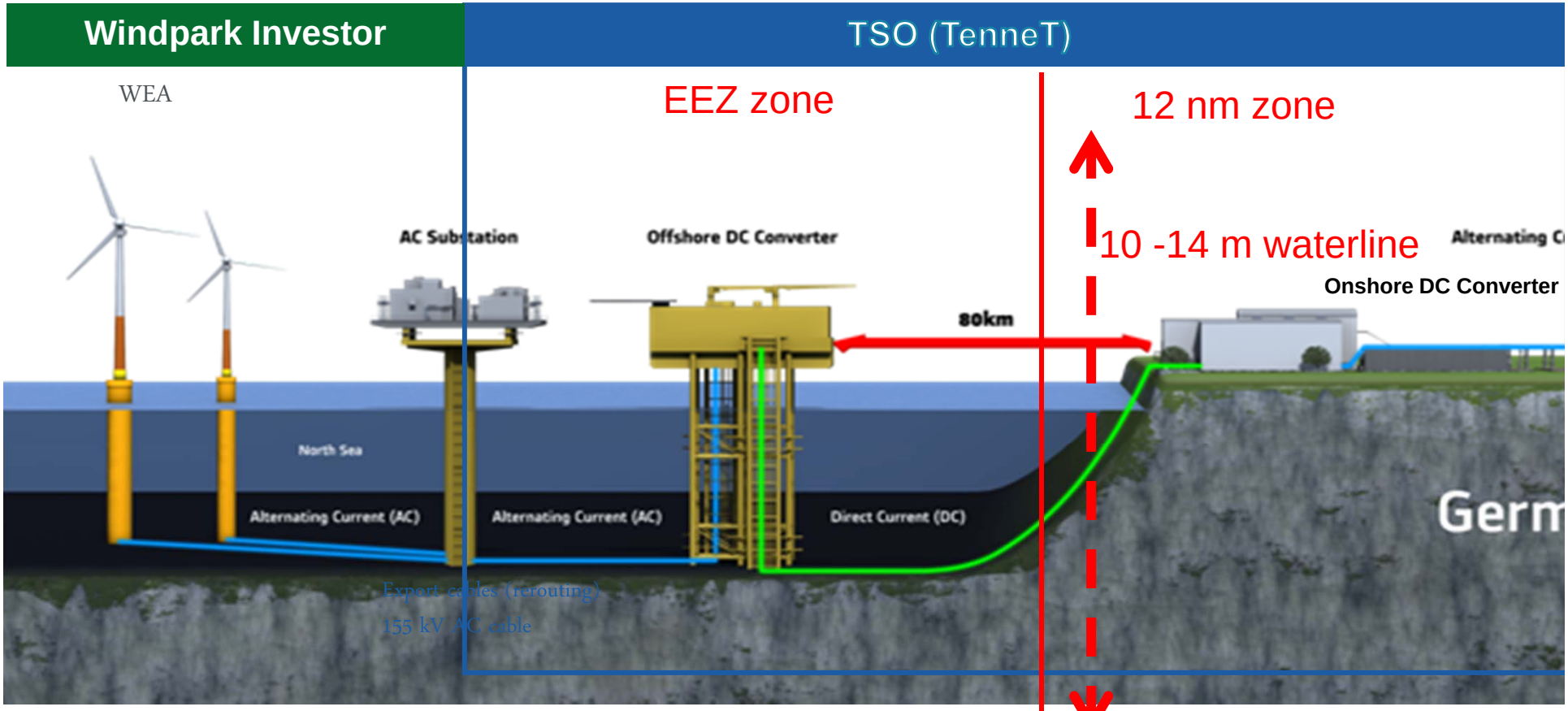
TenneT electrifies the North Sea

Status quo und and targets

- There are currently 15 offshore wind farms (OWF) with 953 wind mills in the German section of the North Sea with a calculated capacity of 4,410 MW connected to the grid.
  (State: July2017 / source: WindGuard)

- Per direction of the German Federal Government 6.5 GW offshore wind capacity are to be constructed until 2020. TenneT already commissioned 5.2 GW of transmission capacity and will achieve the targets for the German part of the North Sea! Until 2019 TenneT aim at 7.1 GW transmission capacity.

Connection Concept to the Offshore Energy



Authorities:
BSH – Federal Maritime and Hydrographic Agency
BfN – Federal Agency for Nature Protection
GDWS – Federal Shipping Agency

Authorities:
NLSTBV –
Lower Saxony Authority

Initial Survey

Work steps of a Cable Route Survey (CRS) and route definition

Before start of survey activities

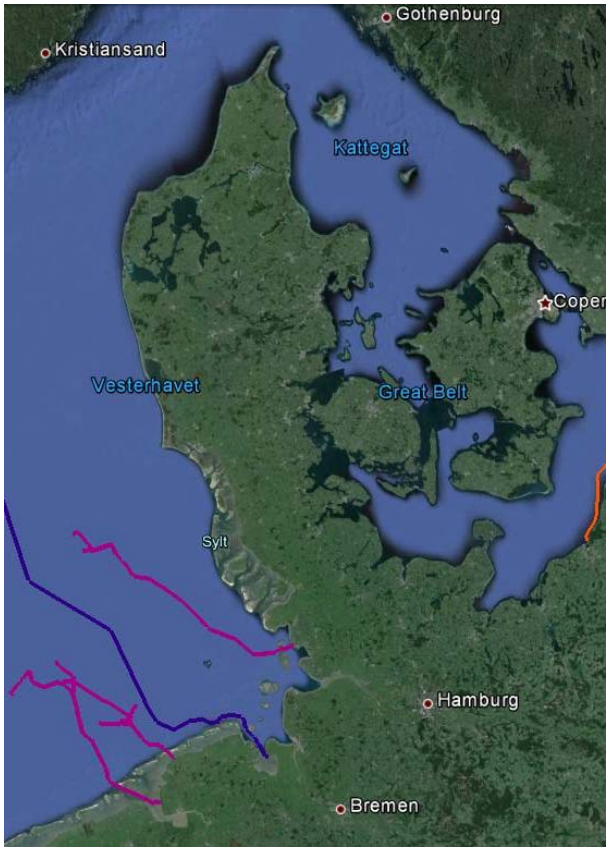
- **Desk Top Study**

Survey activities according to industrial standards, IHO recommendations along a proposed cable route (offshore, near-shore, landing site (BMH))

- **Bathymetric survey**
- **Geophysical survey**
- **Geotechnical survey**
- **Environmental survey**
- **Object detection and UXO survey**
- **Cable and pipeline crossing survey**

Final product out of survey results

- **Survey report / charts /GIS data**
- **Burial Assessment Study (to be done by Contractor)**



Survey Vessel Equipment, for one vessel operation

- Surface and underwater positioning
- Multibeam Echosounder (MBES)
- Sidescan Sonar (SSS)
- Sub Bottom Profiler (SBP)
- Magnetometer/Gradiometer
- Data processing and visualisation

- Precise alignment of survey sensors within the vessel reference system
- Provision of redundancy main sensors
- All survey data are collated in parallel and allow for combined interpretation of multiple sensor / discipline information (high level of data integrity)
- Initial processing on board (prompt QC)
- Cost reduction due to single mobilisation / demobilisation and transit time
- Additional survey time reduced to a minimum due to flexibility in equipment utilisation

Typical Survey Vessel

Permanent equipped survey vessel with standard survey sensors installed;

include data processing capability on-board

24/7 operational

Underwater Positioning Technology

Two technologies available in principal:

- USBL (Ultra Short Base Line)

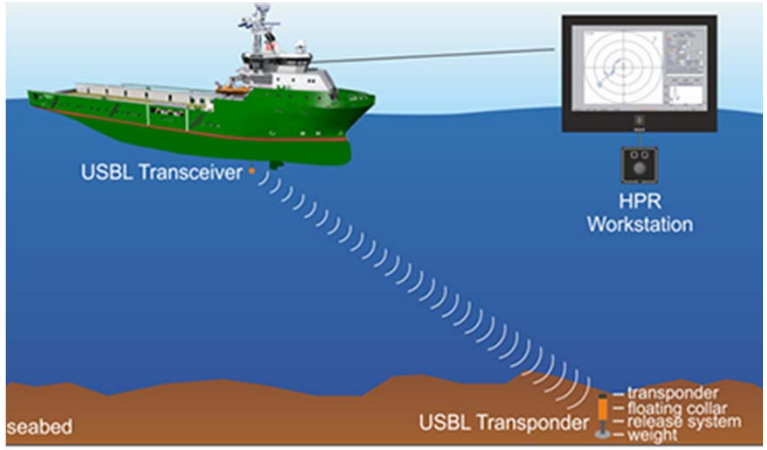
This method allows for horizontal positioning within ±1-2m accuracy for towed systems.

With stationary systems (e.g. landed geotechnical equipment) the horizontal positioning can be expected at ±1m accuracy (long time reading = improved statistic)

Complete system includes auxiliary sensors:
Surface positioning equipment
Heading sensor
Motion sensor
Sound velocity probe

- LBL (Long Base Line)

Extensive installation work required in survey area, mostly used for positioning in deep water



Quelle: F.C. ROV-PILOTING ApS

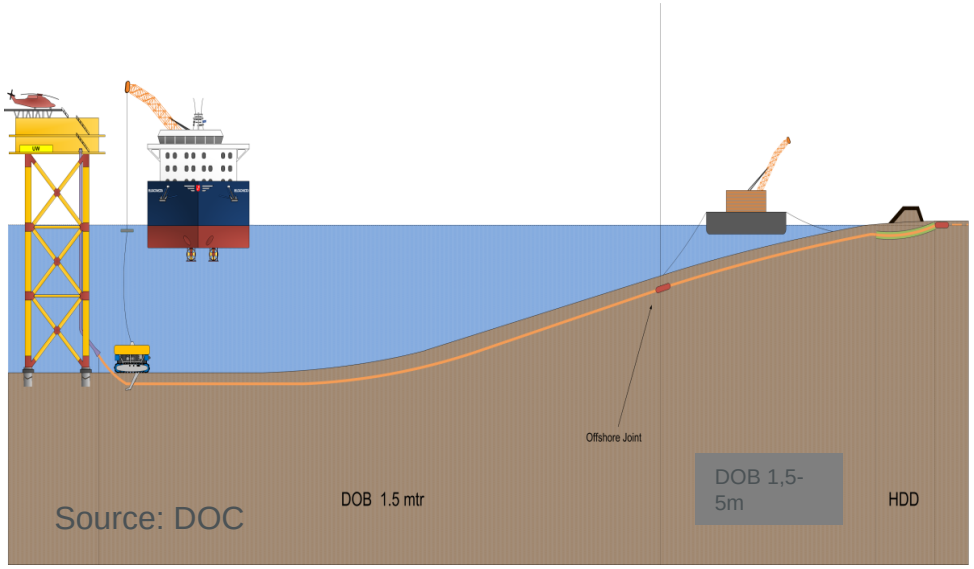
Cable Strategies

Definitions

- **SLB - Simultaneous Lay and Burial:** Laying and burying of the Cables in one operation with one Burial tool
- **PLB - Post Lay Burial:**
  First, laying the Cables on the seabed,
  Second, burying the Cables with a different vessel together with a Burial tool

Requirements:

- Cable parameters
- Vessel units, Availability
- Decks layout
- Weather conditions
- Building approach
- Seabed conditions
- Water depth



Trenching - Devices

- **Simultaneous Lay & Burial**
  - SLB with Plough
  - SLB with Hydro Plough (Jetting)
  - SLB with Chain Cutter
  - SLB with Vertical Injector

- **Post Lay Burial**
  - PLB with Jetting ROV (Remoted operating vehicle)
  - PLB Mass Flow Excavation (later deburial)
  - PLB Jetting Lances (later deburial)

Review of Buried Cables (EEZ)

Total length of TenneT cables buried in the German EEZ from 2009 until today:

- approximately 1000km
  - ~ 300km in PLB Methode
  - ~ 700km in SLB Methode

Cable Lay Vessel

Nexans Skagerak, Source: Marine Traffic

Prysmian Cable Enterprise Source: Prysmian

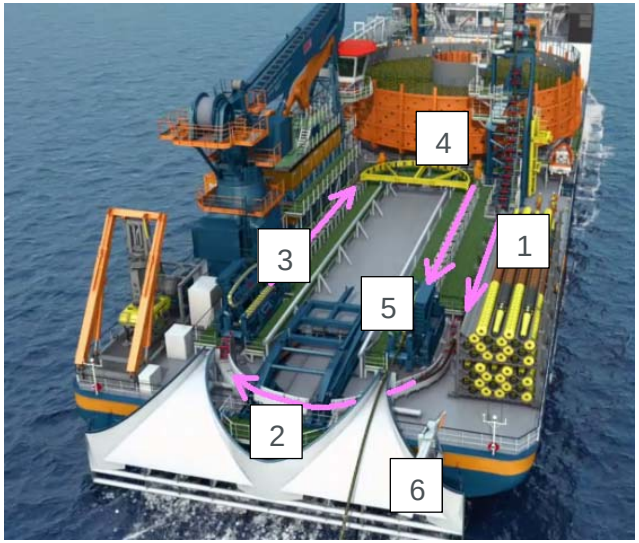
NKT Victoria, Source: NKT

Van Oord Nexus, Source: Van Oord

Cable Routing concept

The cable routing concept relatively new, with a summary below for cable laying

1. Cable from the gooseneck is routed into the space between the vessel deck and under the working platform.
2. Cable is diverted under the over boarding chute(s), towards the port side tensioner.
3. Cable from portside tensioner is then routed towards the quadrant, across support tables used for installation of cable protection systems (2nd end).
4. The subsea quadrant, acts as an accumulator for excess cable during laying.
5. Past the subsea quadrant, the cable heads towards the starboard tensioner, across support tables used for installation of cable protection systems (1st end).
6. The cable is then overboarded using the starboard chute for standard lay, and both chutes, when the quadrant being deployed subsea.



Nearshore Cable Lay Vessels

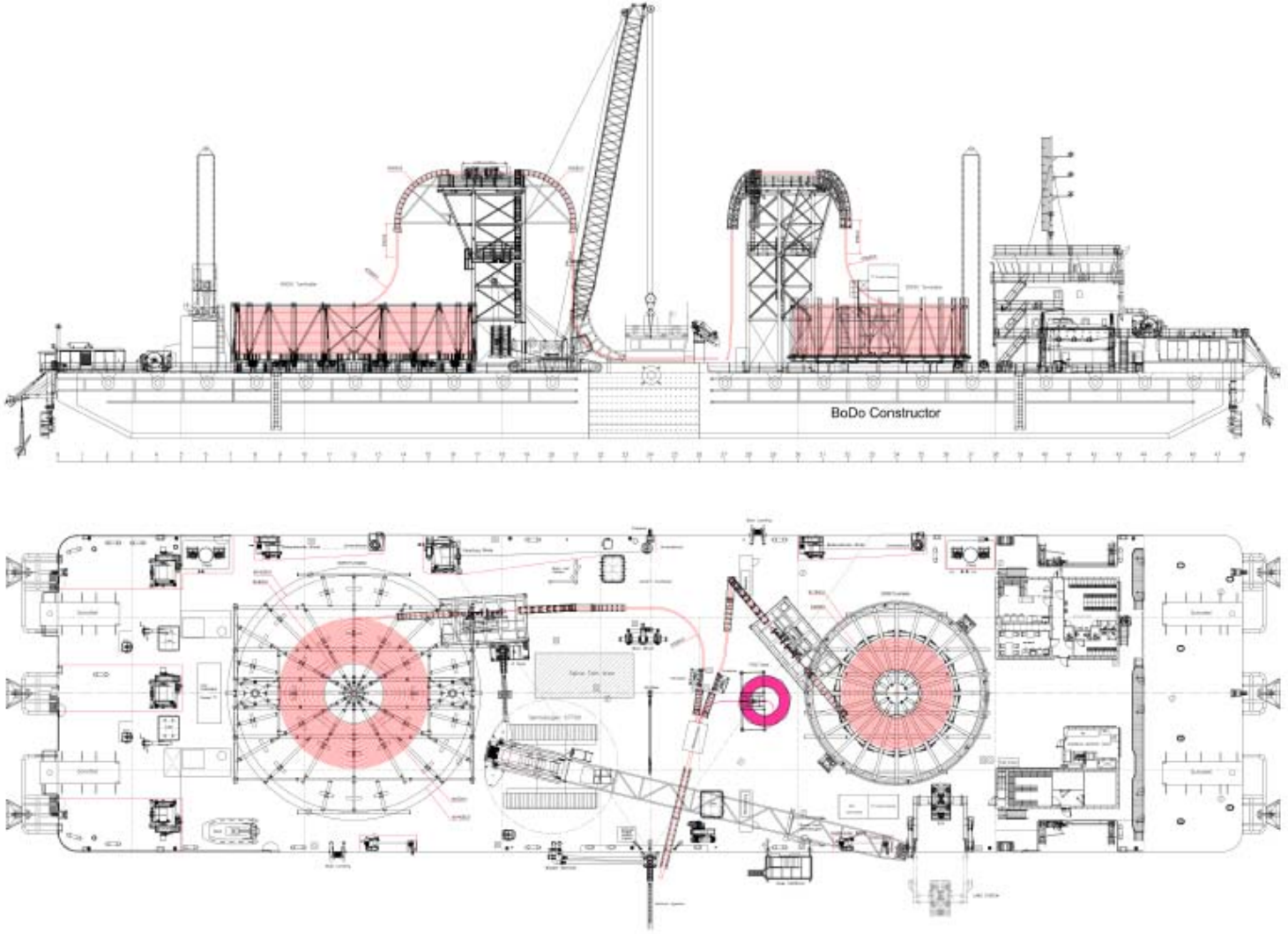
Bohlen & Doyen, Transpooling of cable from CLB „Bodo Installer“ to CLB „Bodo Connector“…

…to avoid joints and to safe installation time

Installation barge with special designed Vibration Sword

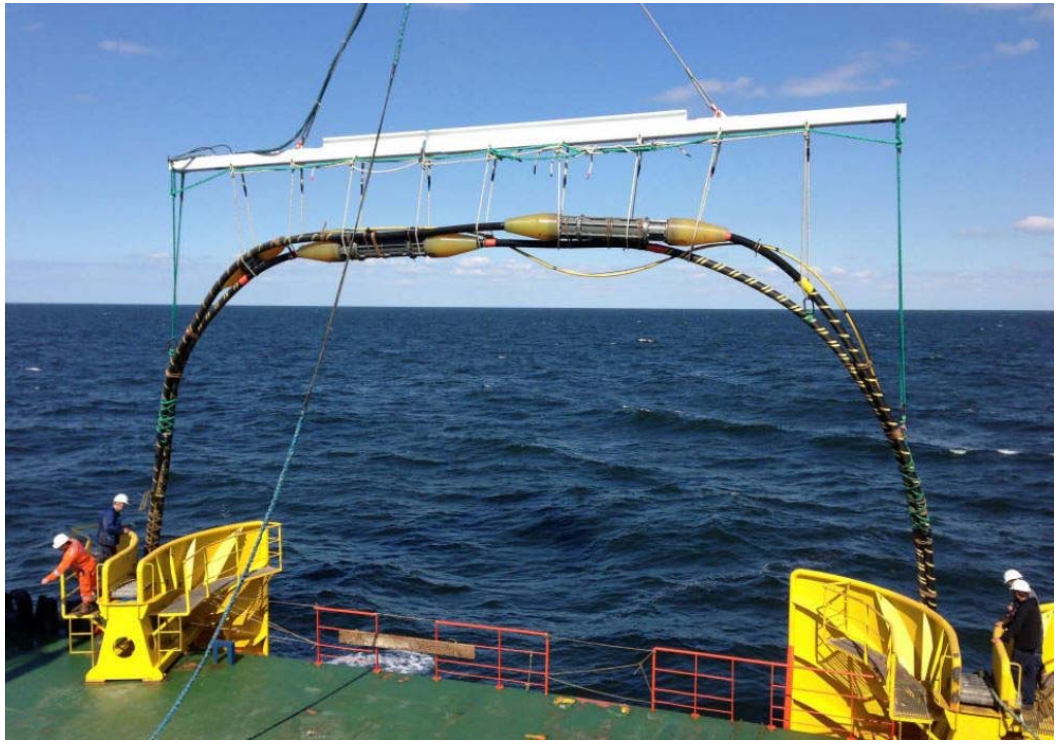
Anchor handling with very shallow draft anchor-ponton

Typical Deck Layout of Cable Lay Barge



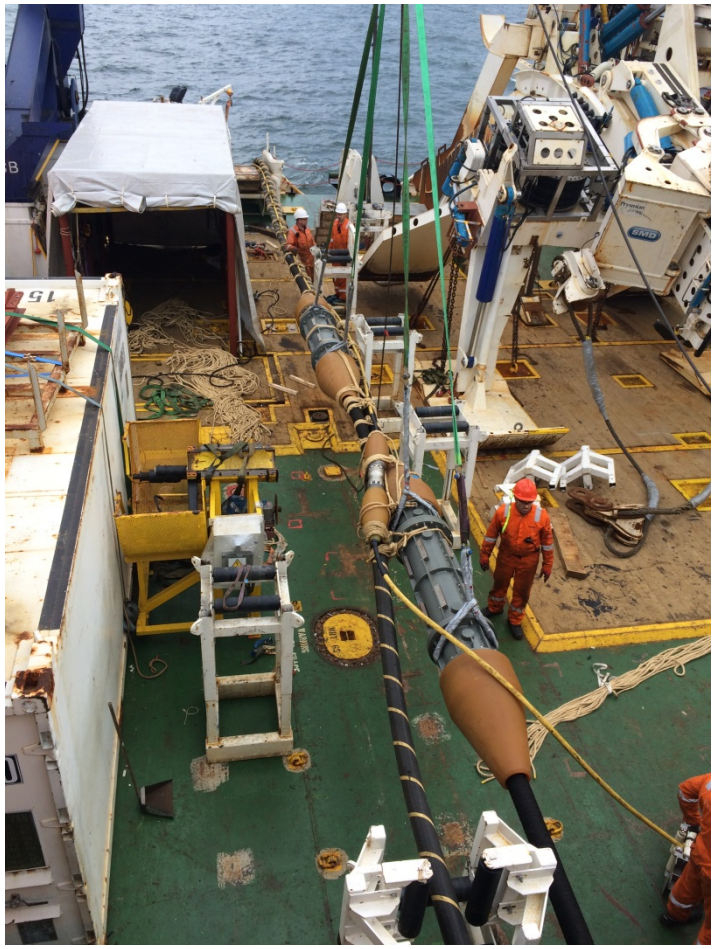
Installation Equipment

Cable Bundling Machine DC Cables



Joint Deployment frame

Installation Equipment



Jointing HVDC Cable

Tenchener

Ship units in general

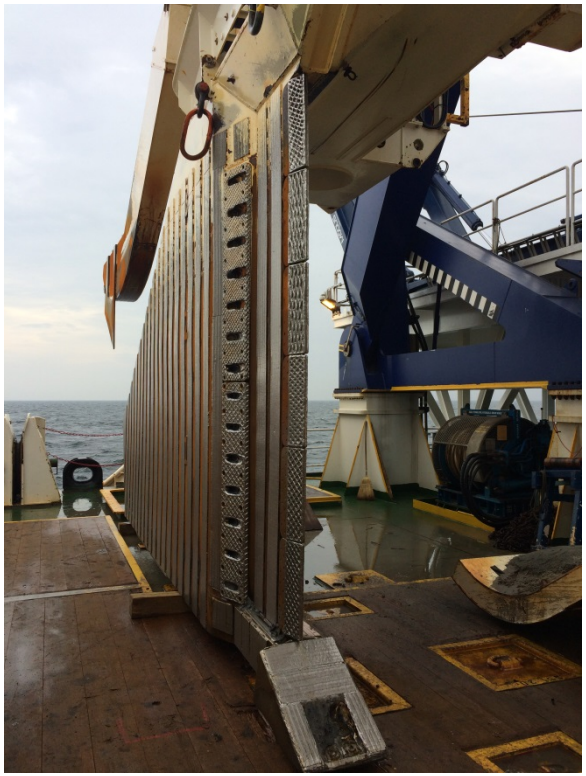
Cable installation unit

- CLV (with or without Burial device)
- PLB Trenching vessel (with Trenching tool)
- CLB (Barge with tug boats)
- Tug boats, anchor Handling tugs
- Guard Vessels
- CTV Crew Vessel
- Installation Support Vessel

General selection of ships and devices

- Cable system lengths, joints, weight
- Cable type, coilable, HVDC / HVAC, turntable
- Water depth, beaching conditions
- Cable corridor, distance to parallel systems/crossings, other constructions
- Distance to harbours
- Seabed conditions → Surveys Burial Assessment Study (BAS)
- Weather Conditions, Limitations
- Environmental requirements (2K criteria, Biotopes)

Cable installation tools: SLB



Heavy Duty plough, Source: Prysmian

Hydro Plough, Source: Prysmian

Vertical Injector, Source: Global Marine

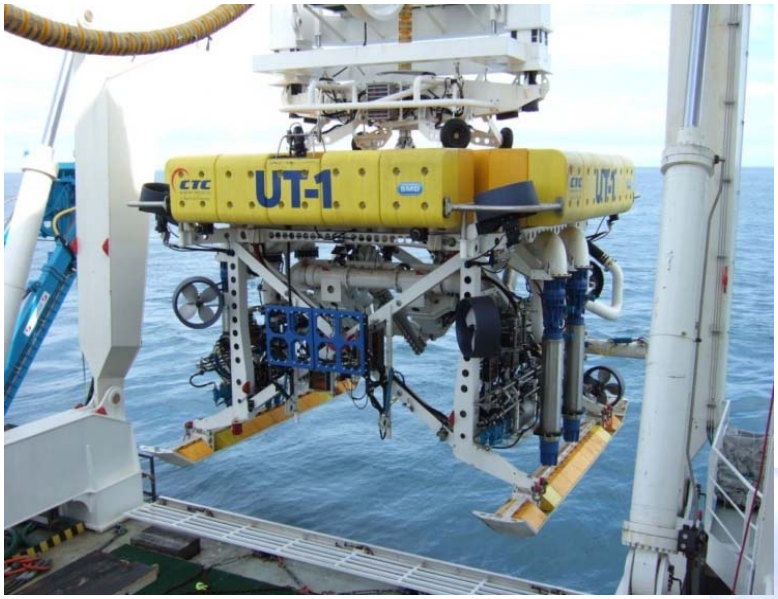
Cable installation tools: SLB

Chain Cutter I Trencher, Source: Canyon

Ocean Trencher, Source: Ocean.com

T1 Trencher Source: Deep Ocean

Cable installation tools: PLB



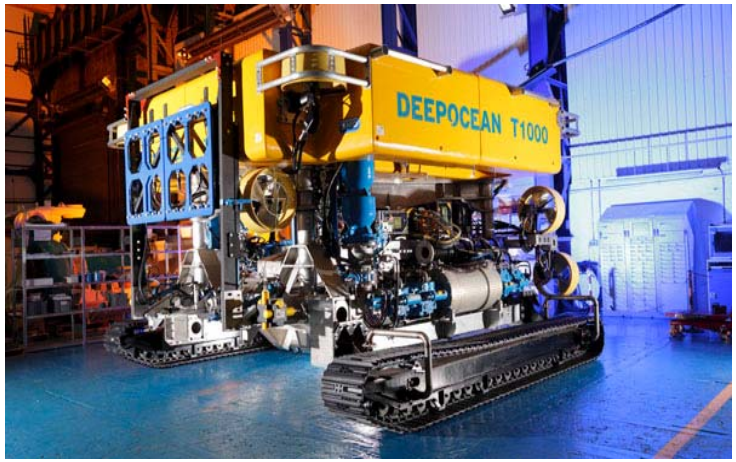
Trenching ROV, Source: Deep Ocean

Free Flying TROV

Trenching ROV T 1200, Source: Helix

Tracked TROV

Cable installation tools: PLB & Pre Plough



Trenching ROV T 1000, Source: Deep Ocean

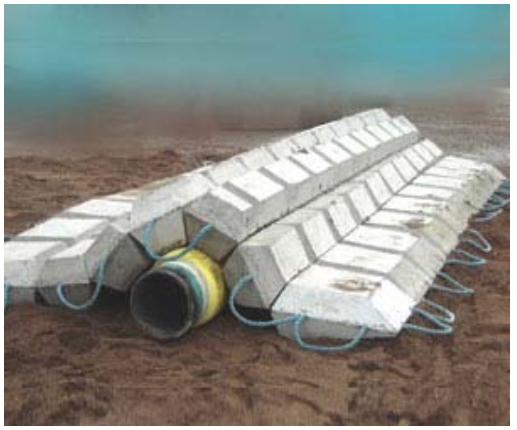
Scar Pflug, Source: Ecosse

Mass Flow Excevator, Source: Rotech

other Protection measures

Alternative Protection activities in case of non-achievement of required burial depth

- Rock placement – very efficient
- Exclusion Zone – very difficult to receive Permission
- Cable Awareness, Publication – this is definitely a must
- Concrete Matrasses - little suitable
- Split Pipes – Cable ends, Crossings (Protection against Rock placement)



Concrete / Geo Matrasses
Source: subseaprotecion systems

Crossing before Rock placement

split pipes- Source: Vos Protect

TenneT's weather limitation, Cable laying

Seekabelverlegungsprozess	Signifikante Wellenhöhe H_s	Wind-geschwindigkeit[1] Vw
Wattkabelverlegung und Anlandung (trockenfallende Bereiche)	1,0 m	10,7 m/s (≡max(5 Bft.))
Küstennahe Kabelverlegung (bis ca. 10m Tiefenlinie)	1,5 m	13,8 m/s (≡max(6 Bft.))
Küstenferne Kabelverlegung (ab ca. 10m Tiefenlinie)	3,0 m	13,8 m/s (≡max(6 Bft.))
Kabeleinzug in eine Plattform	1,5 m	10,7 m/s (≡max(5 Bft.))
Verkehrssicherung	8,0 m	20,7 m/s (≡max(8 Bft.))
UXO Untersuchung, Identifikation und Räumung	1,5 m	10,7 m/s (≡max(5 Bft.))

Tabelle 1: Seekabelverlegungsprozesse und ihre Wetterlimitierungen.

- commercial limitations based on agreed schedule
- it's contractor risk in case vessel goes on Standby below limitation figures
- customer pays standby rates if actual values are above limitation figures

TenneT's Burial Assessment Study (BAS)

Descriptive terms for confidence levels

L	Low confidence, the DL specification is unlikely to be achieved for the majority of the section and alternative protection methods should be considered.
M	Moderate confidence, the confidence of achieving the DL specification is high for the majority of the section, although there will be areas, some significant where this should not be guaranteed.
H	High confidence, the DL specification is anticipated to be achieved, with a very limited risk of not achieving specification in some localised areas.
N/A	No trenching (e.g. crossing location).

BAS Matrix

Shallow Soils		Trenching Assessment					
Seabed Sediments	Description	Target DL (m)	TRENCHER	NO OF PASSES	1ST PASS SPEED (m/hr)	2ND PASS SPEED (m/hr)	LOWERING CONFIDENCE
		1.5	T1200/T1500	1	200-250	NR	H
Shelly or silty fine to medium SAND over clayey SILT Organic CLAY at 1m DL	HN_0034: 0-0.35m: Silty GYTTJA soft to stiff 0.35-1.00m: clayey GYTTJA 1.00-4.00m: Silty GYTTJA SN2014_09_VC_80: 0-0.40m: Medium dense grey slightly sandy, very clayey SILT, fine sand 0.40-1.15m: Medium dense organic slightly sandy very clayey SILT (M), fine sand, 1.15-2.20m: Medium dense slightly organic sandy very clayey SILT, fine sand. 2.20-3.50m: Medium dense organic sandy very clayey SILT, fine sand. 3.50-4.90m: Medium dense slightly organic sandy very clayey SILT, fine sand. HN_0036: 0-4.00m: Silty GYTTJA, soft	1.5	T1200/T1500	1	200-250	NR	H
	HN_0037: 0-0.30m:fine SAND, silty, loose 0.30-1.40m: silty GYTTJA, soft 1.40-3.20m: sandy GYTTJA 3.20-4.00m: silty GYTTJA						

TenneT's Reasonable Endeavour Criteria for Cable Burying

example Jetting ROV

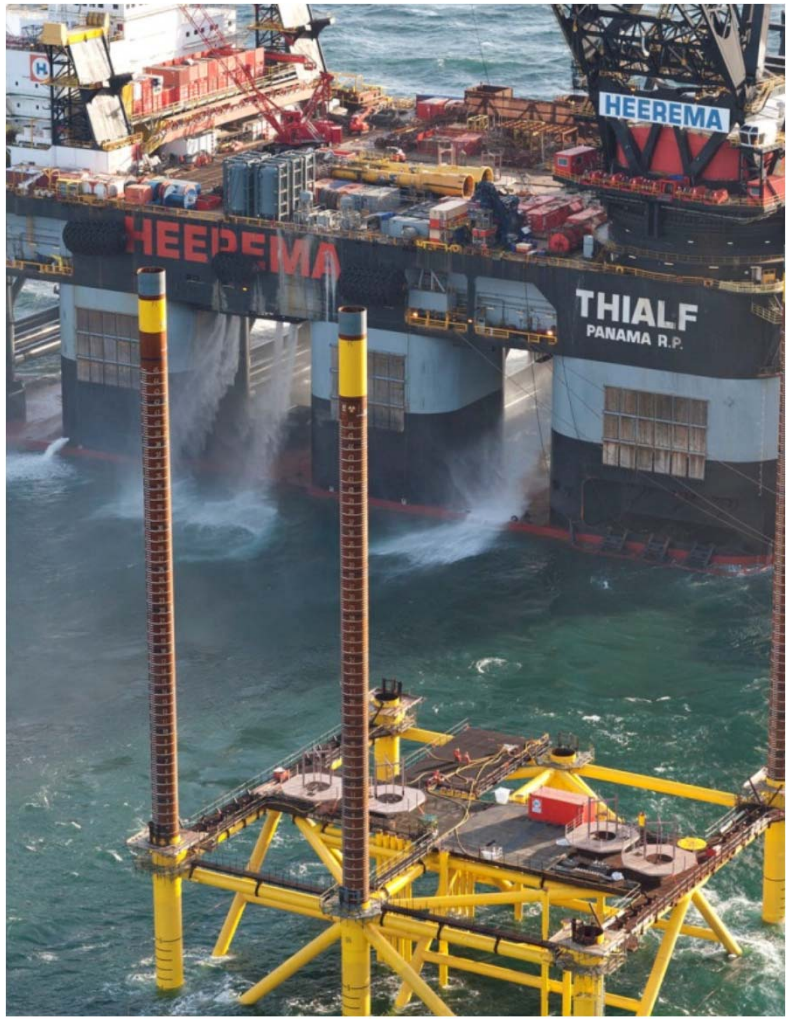
- If the burial speed of the jetting ROV is reduced to lower than the progress rate specified, the jetting swords of the ROV may be raised by 20 cm, when ..
- averaging 3.00m/min in the latest 15 minutes of continuous burial operations for target burial depth of 1.5m or shallower
- If after raising the jetting swords depth and, despite best efforts, progress rate is still not restored after the specified period, the Contractor may repeat the process until the specified burial speed is restored.
- If the burial speed drops below the specified progress rate at a trench depth of 50 cm, as a result of debris or impenetrable materials, the area shall be deemed not suitable for burial operation by the jetting ROV.

Challenge Offshore

Challenge Offshore

Technology

- TenneT is the first company in the world to build HVDC grid connections for offshore wind power
- Limited experience worldwide with the operation of HVDC grid connections for offshore wind farms
- Complex technology must be able to withstand the harsh conditions of the North Sea for 30 years.



Challenge Offshore

Safety

- This working environment poses numerous risks
- Emergency responses take a long time because of the long distance from the coast
- All TenneT offshore personnel has completed a wide range of training, including that of a special first-aider
- TenneT contracted the development of safety gear, which meets the requirements to work offshore and with high voltage power.

Challenge Offshore

Ordnance finds

- It has been estimated that 1,3 million tons of ordnance are still lost in the North Sea
- Ordnance areas are clearly marked on maps, but actually the ordnance contaminated areas have spread all across the sea because of ocean currents.
- The protection of man and environment must always be of highest priority
- When the Riffgat cable was laid, 30 tons of ordnance were recovered and cleared

Challenge Offshore

Environmental Protection

TenneT has implemented various compensation measures

- Spiekeroog, dismantling of old feeds
- Ostheller at Norderney
- Grohdepolder at Norderney
- Leybucht – centre plate
- Renaturation of dunes at Norderney

TenneT is working closely with nature conservation organisations and authorities, e.g. with the National Park Wadden Sea of Lower Saxony administration or the *Ökowerk* foundation.

Our Offshore Projects

alpha ventus
BorWin1
BorWin2
BorWin3
DolWin1
DolWin2
DolWin3
DolWin6
HelWin1
HelWin2
Nordergründe
Riffgat
SylWin1

BorWin1 - First HVDC Connection

Cable length (off-/onshore)	Techno-logy	Output (MW)	Feed-in point	Operatio-nal
200 (125/75)	DC	400	Diele	2010

- World's first DC connection of an offshore wind farm
- More than 1000 m of horizontal drilling under the Ems

DolWin 2 - gravity based Foundation

Cable length (off-/onshore)	Techno-logy	Output (MW)	Feed-in point	Operatio-nal
135 (45/90)	DC	916	Dörpen/ West	2016

- Fabrication of the converter platform in Dubai/Norway
- First ever use of a gravity based foundation

Summery

- Optimization of the **Initial Survey** with the aim to deliver all needed results concerning seabed conditions.
- Based on the results of the Initial Survey the contractor must prove by a **BAS** (Burial Assessment Study) that the chosen Burial tool is able to fulfil all burial requirements along whole route.
- There is **no universal tool** on the market available, which is able to fulfil all requirements for a cable laying project.
- **Combined Installation Methods** of laying campaigns need to be considered
- **Weather Criteria** are used for commercial Limitation
- Tenderers are not willing to give a “certain guaranty” related to Burial depth. From there, **Reasonable Endeavour Criteria** needs to be implemented, even its not in line with Authorities requirements
- **Nearshore Cable installation** requires **well prepared Installation Procedures** with respect to local conditions (seabed, depth, traffic, etc.) , environmental conditions (location, wind, waves, current, National Park Requirements)

Thank you very much for your attention!