ARINET

PLUMETT

www.plumettaz.com

VISION & PERFORMANCE

The Aspects of the High Voltage Cable Installation

Willem Griffioen

Grzegorz Kowalczyk

The Aspects of Designing and Installing the High Voltage Cable Lines

Contents

- Introduction
  - Cable (unarmoured) in duct
  - Cable in duct installation techniques
- Cable Installation Equipment
- Water Push-Pull Projects
- Examples FreeFloating
- Trials for Offshore Windparks
- Pulling Force Calculation Software
- Conclusions

Introduction, Cable in Duct

- Cable in duct instead of armoured cable
  - Cables can be removed / replaced (without digging)
  - Better mechanical protection (free space)
    - Well known fact in Telecommunications
  - Save on cable costs
  - Reduced AC losses

Introduction, Cable in Duct

- Cable in duct instead of armoured cable: land
  - Ducts can be laid in short sections (e.g. 100 m), easy to connect
  - No need to keep long trenches open for long time
  - Reduced disturbance neighbourhood
  - Ability to remove or replace cable without opening trench
  - Extremely long cable lenghts can be installed
  - Option to flow cable lengths to desired location

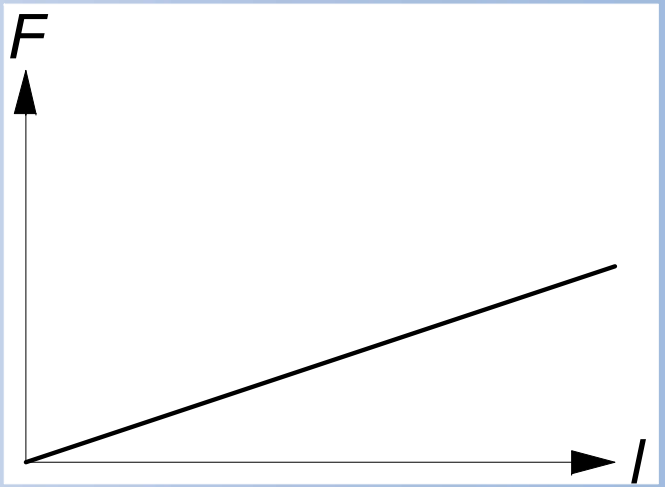
Introduction, Cable in Duct

- Cable in duct instead of armoured cable: sea
  - Duct laying instead of cable laying
    - No preferred torsion direction for duct →
    - Reduced risk for kinking duct
    - And easy to repair (before cable is in)
  - Option to obtain route info by intelligent pigging
  - Cable installation VERY simple and NO risk
  - Extremely long cable lenghts (with joints) can be installed, off-shore and from shore
  - Option to flow cable lengths to desired location

Introduction, Force Build-Up

- **Build up installation force**

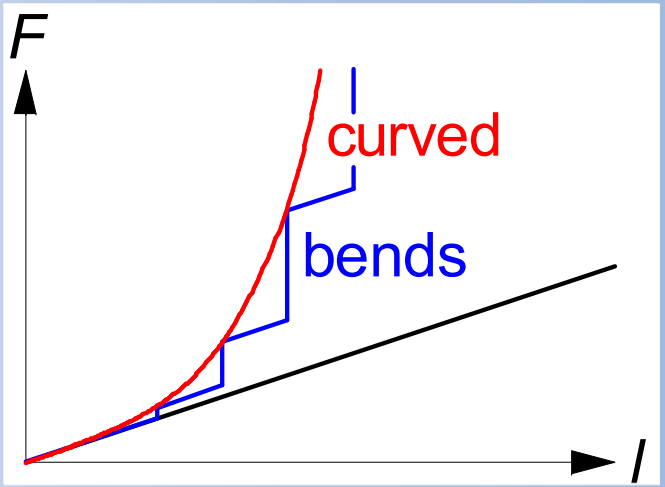
1. **Gravity (linear)**



Introduction, Force Build-Up

- **Build up installation force**

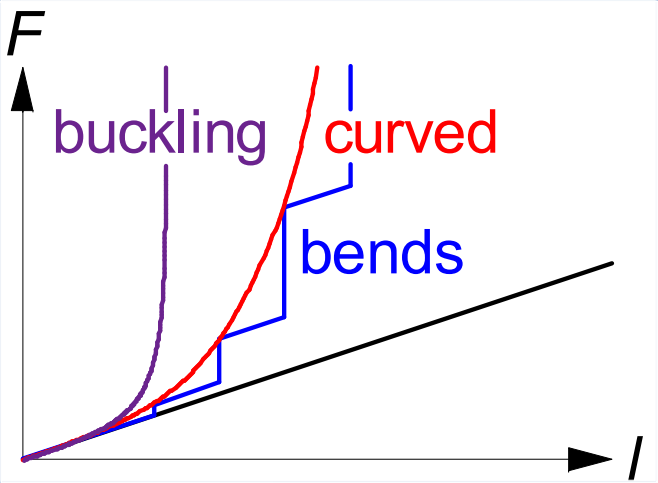
1. **Gravity (linear)**
2. **Cable pullforce (exponential)**



Introduction, Force Build-Up

- **Build up installation force**

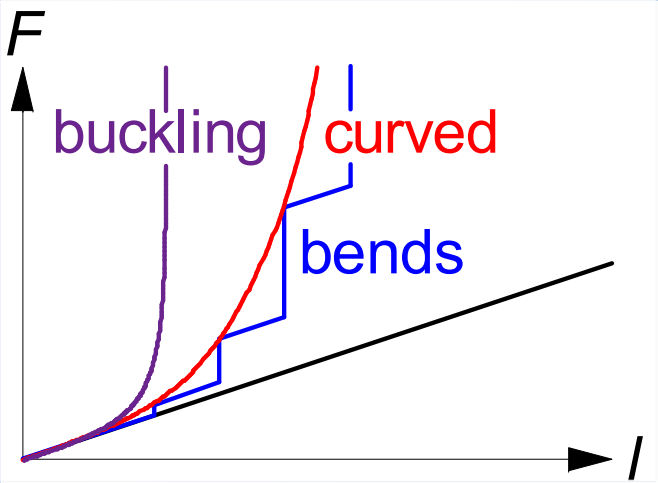
1. **Gravity (linear)**
2. **Cable pullforce (exponential)**
3. **Cable pushforce (asymptotic)**



Introduction, Force Build-Up

- **Build up installation force**

1. **Gravity (linear)**
2. **Cable pullforce (exponential)**
3. **Cable pushforce (asymptotic)**
4. **Cable stiffness in bends**

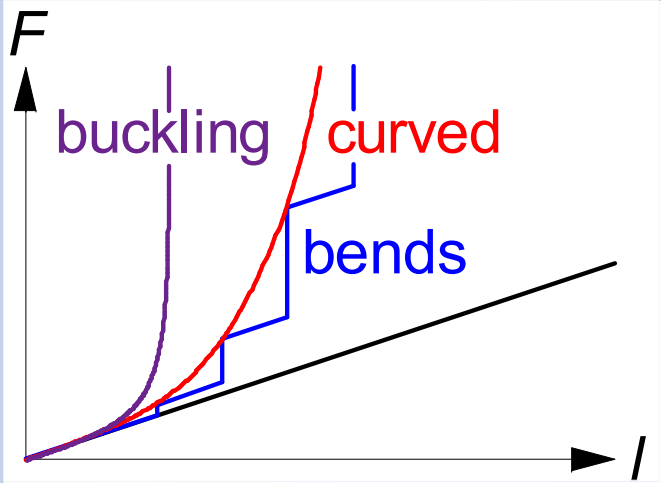


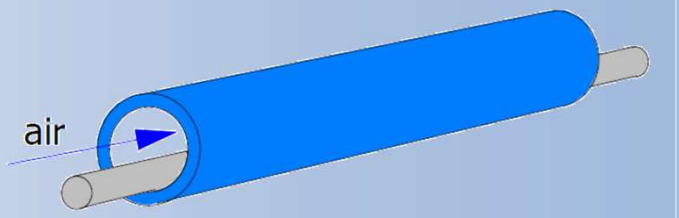
Introduction, Force Build-Up

- **Build up installation force**

1. Gravity (linear)
2. Cable pullforce (exponential)
3. Cable pushforce (asymptotic)
4. Cable stiffness in bends

- **Clever installation methods**
  - Jetting (limits 2. and 3.)



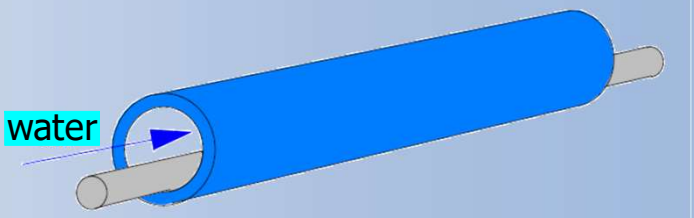


Introduction, Force Build-Up

- **Build up installation force**

1. Gravity (linear)
2. Cable pullforce (exponential)
3. Cable pushforce (asymptotic)
4. Cable stiffness in bends

- **Clever installation methods**
  - Jetting (limits 2. and 3.)
  - Floating (also limits 1.)

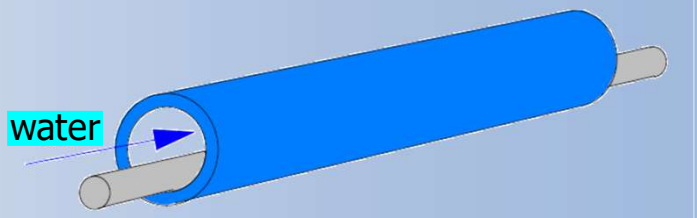


Introduction, Force Build-Up

- **Build up installation force**

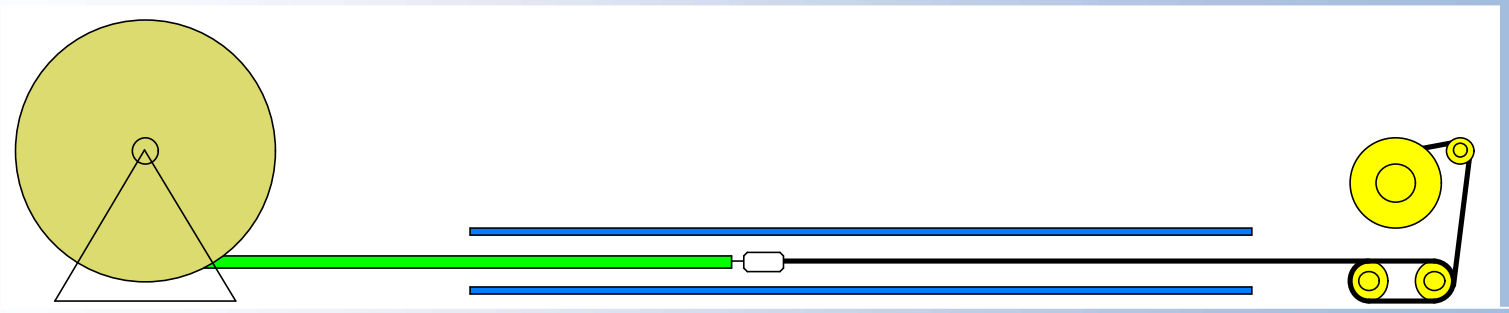
1. Gravity (linear)
2. Cable pullforce (exponential)
3. Cable pushforce (asymptotic)
4. Cable stiffness in bends

- **Clever installation methods**
  - Jetting (limits 2. and 3.)
  - Floating (also limits 1.)
- **Note: effect 4. still left**



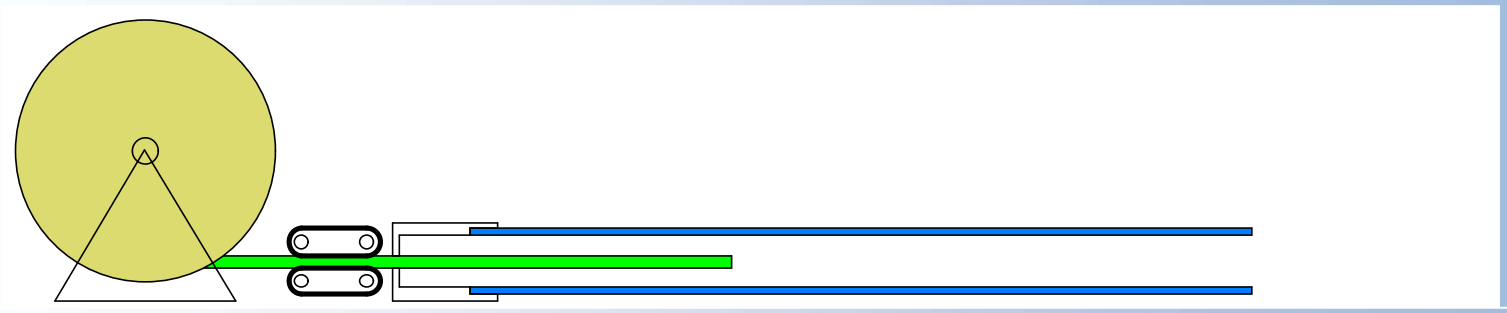
Introduction, Installation Method

- **Techniques to install cables into ducts:**
  - **Winch pulling**



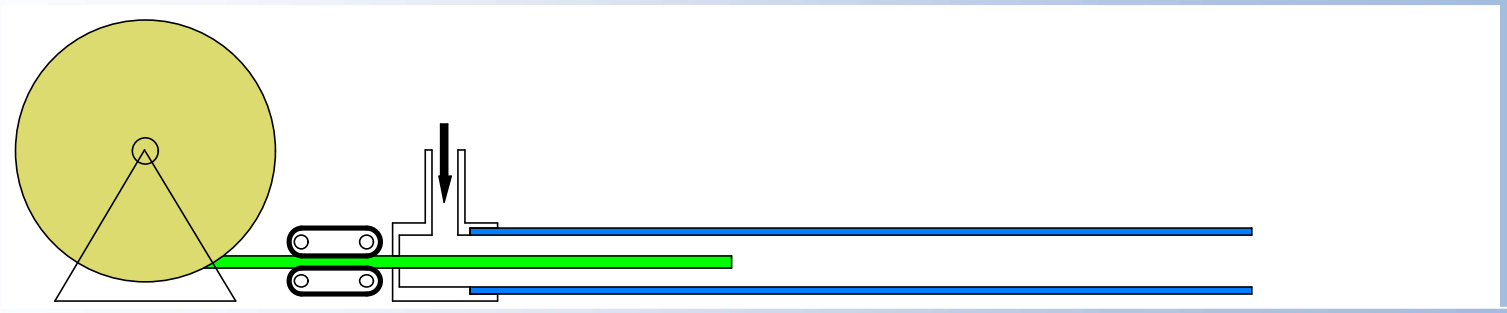
Introduction, Installation Method

- **Techniques to install cables into ducts:**
  - **Winch pulling**
  - **Pushing (rodding)**



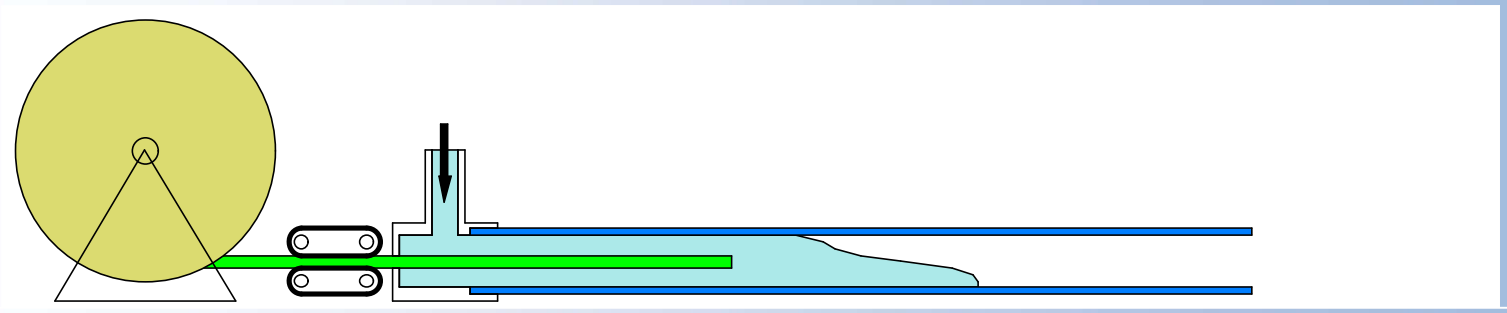
Introduction, Installation Method

- **Techniques to install cables into ducts:**
  - Winch pulling
  - Pushing (rodding)
  - Jetting (blowing)



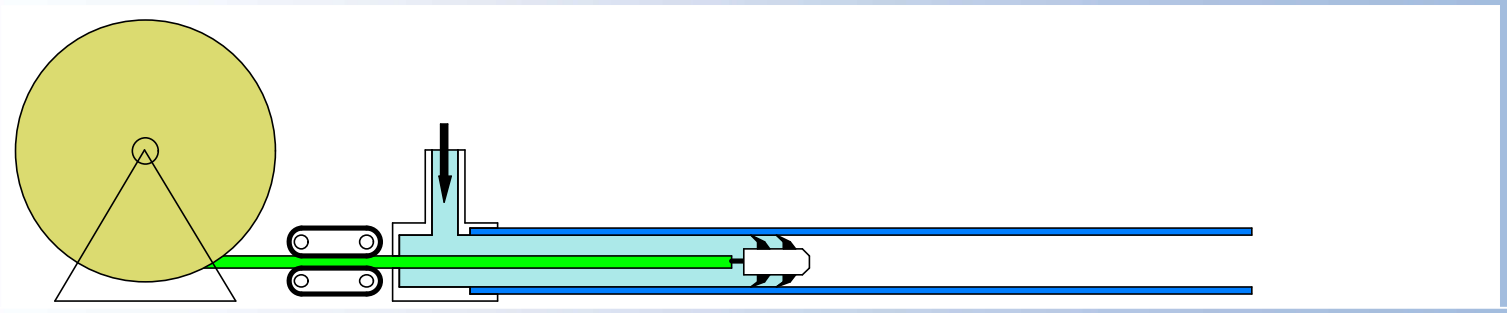
Introduction, Installation Method

- **Techniques to install cables into ducts:**
  - Winch pulling
  - Pushing (rodding)
  - Jetting (blowing)
  - Floating



Introduction, Installation Method

- **Techniques to install cables into ducts:**
  - Winch pulling
  - Pushing (rodding)
  - Jetting (blowing)
  - Floating
  - Water Push-Pull



Introduction, Installation Method

- **Techniques to install cables into ducts:**
  - Winch pulling
  - Pushing (rodding)
  - Jetting (blowing)
  - Floating
  - Water Push-Pull
  - FreeFloating

Introduction, Installation Method

- **Techniques to install cables into ducts:**
  - Winch pulling
  - Pushing (rodding)
  - Jetting (blowing)
  - Floating
  - Water Push-Pull
  - FreeFloating

WATUCAB
(WAter TUbe CABle)

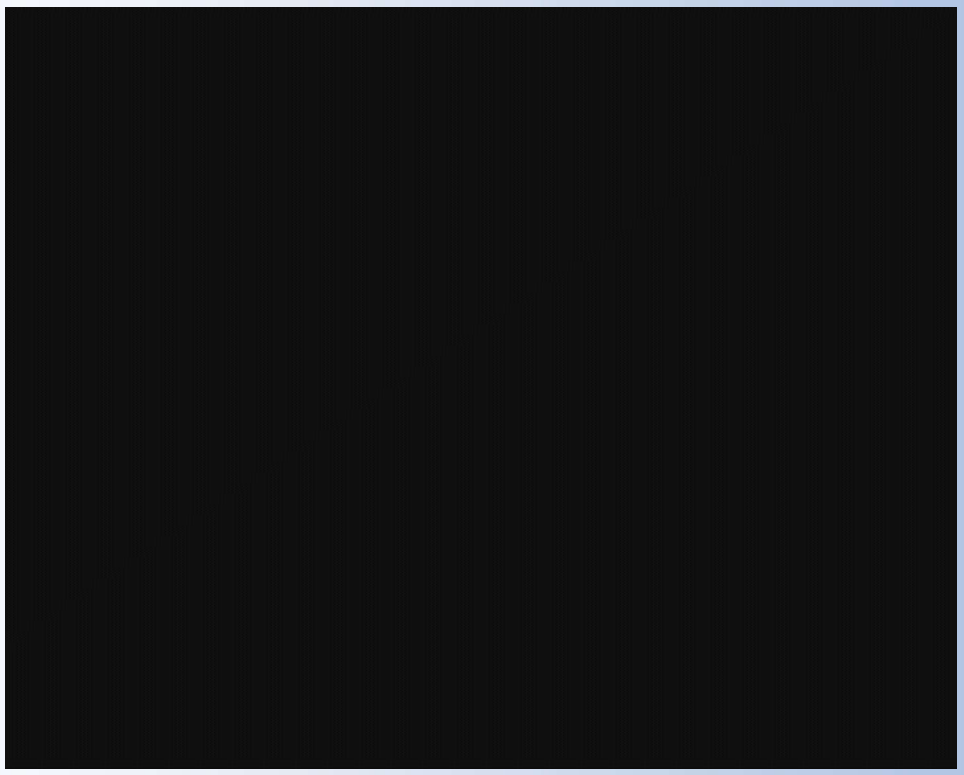
Introduction, Floating

- EXTREMELY long lengths (density matching)
  - 10 km (already), 20 km, 50 km, 100 km .. ?
- Waterflow smaller than airflow
  - Smaller pumps and/or bigger pipes
  - Lower water (cable) speed
- Water is safer
- Needs water supply and drain
- Hydrostatic pressure (every 10 m up = +1 bar)
  - Not relevant for Offshore

Introduction, Water Push-Pull

- Floating also possible with pig at cable end
- Becomes effectively water push-pull
- Exponential force increase returns
- Installation lengths still large, depends on bends
  - For Cu-core cables comparable to winch pulling
  - Winner for Al-core cables. Over 3 km reached
  - Less force, less cable wear, sharper bends possible
  - Always winner with winch backup
- Needs less water flow, any size of duct possible

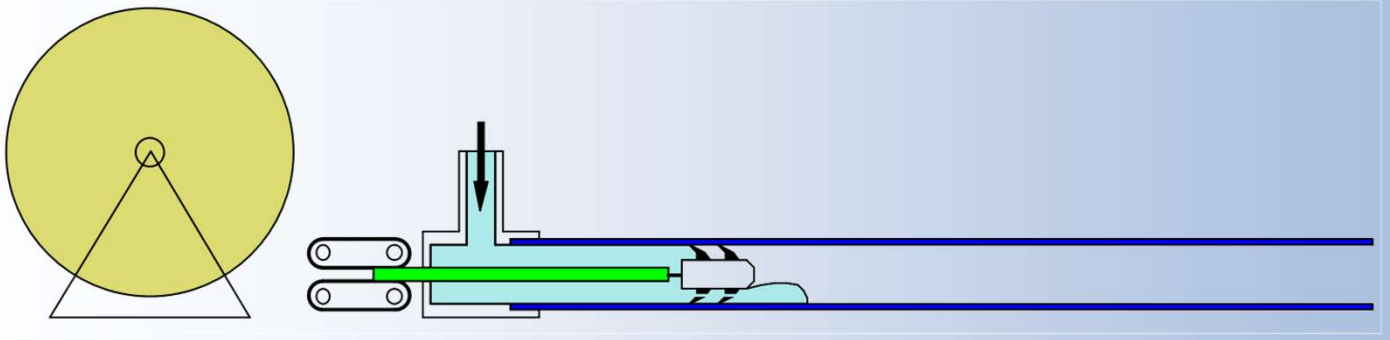
Introduction, Water Push-Pull



Introduction, FreeFloating

Install first length

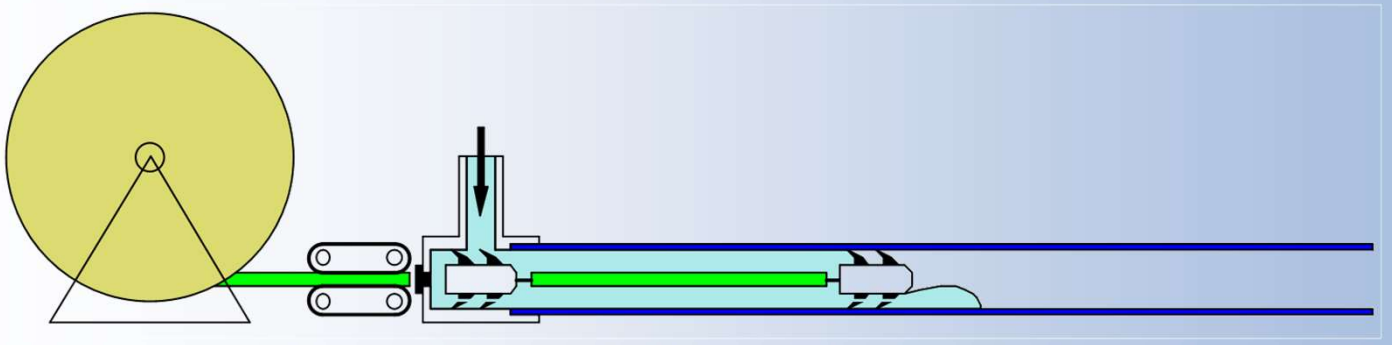
- “Traditional” Water Push-Pull with Pig installation
  (tricks to insert cable completely)



Introduction, FreeFloating

FreeFloating

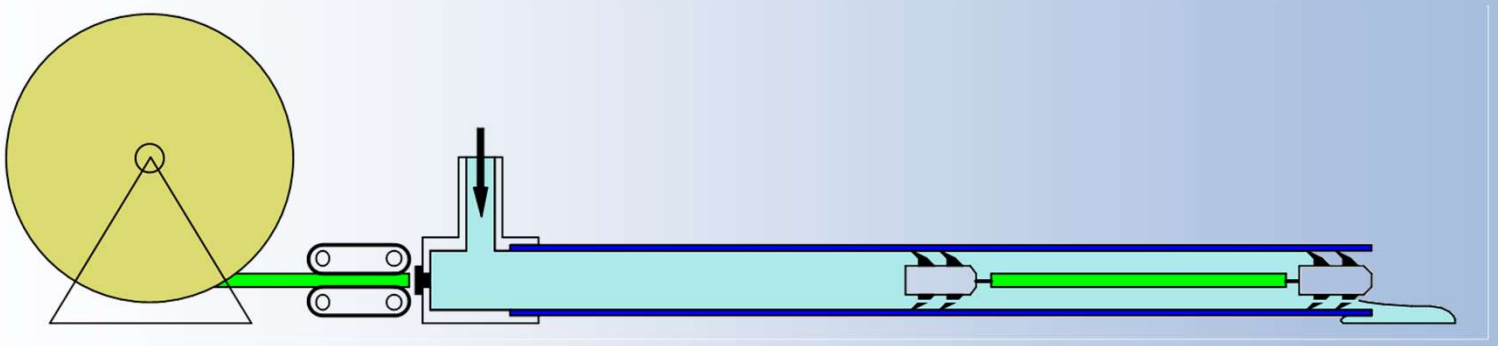
- Finish length 1 and mount rear pig
- Close and flow further
  (2nd cable placed in equipment in meantime)



Introduction, FreeFloating

FreeFloating

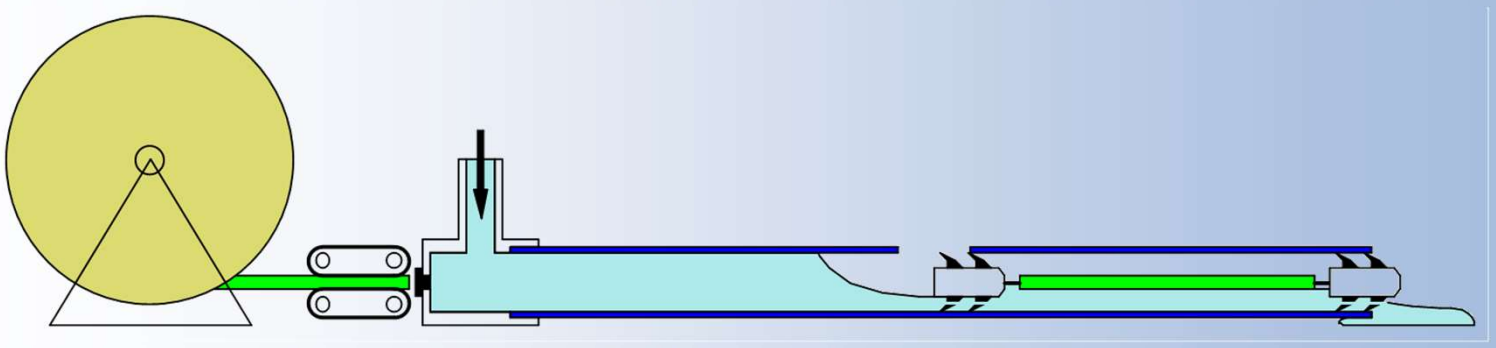
- Continue until end position



Introduction, FreeFloating

After arrival first length

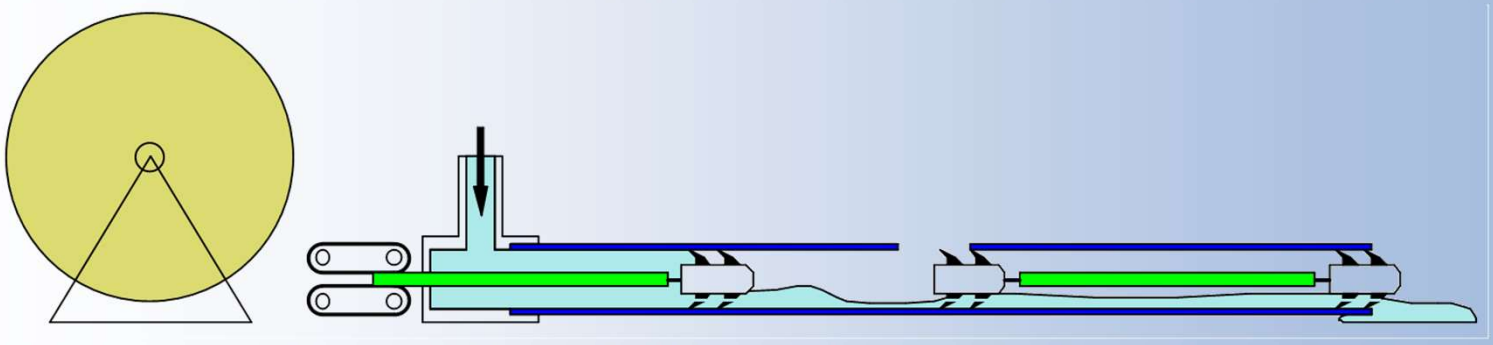
- Open duct at rear end length 1



Introduction, FreeFloating

Install second length

- Repeat with length 2, etcetera
- Operation at 1 location
- No need to go to hard-to-reach places



Introduction, FreeFloating

It really works!

Introduction, FreeFloating

- FreeFloating and Water Push-Pull length equal
  - 3 km possible for most Al-core cables
- Brings the cable to any desired location
  - Almost no limit, 100 km away no problem
- Also to places not accessible by cable drum
- FreeFloating can be used advantageously
  - when cable launching platforms are difficult to access (or not accessible at all)
  - when working at cable launching platform is expensive

Cable Installation Equipment

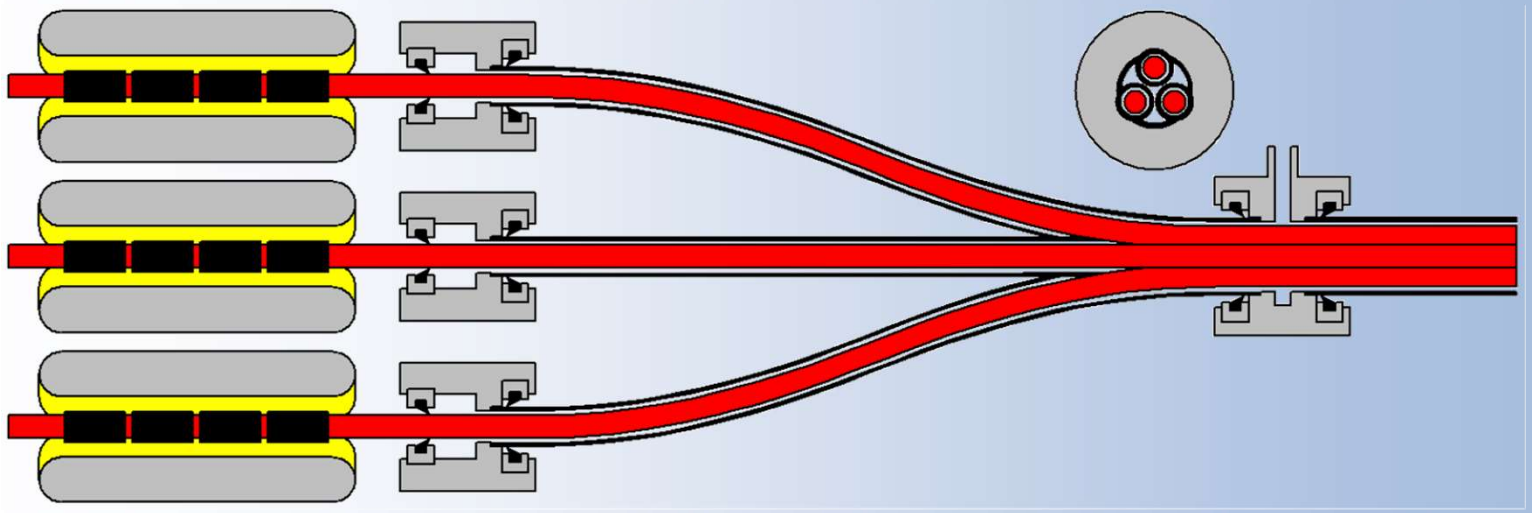
- **Single core cables**

Cable Installation Equipment

- **Stranded 3-core cables**

Cable Installation Equipment

- **Bundle of 3 parallel cables**



Water Push-Pull Projects

- **Water Push-Pull France**
  - HV cable lengths up to 3.3 km

Water Push-Pull Projects

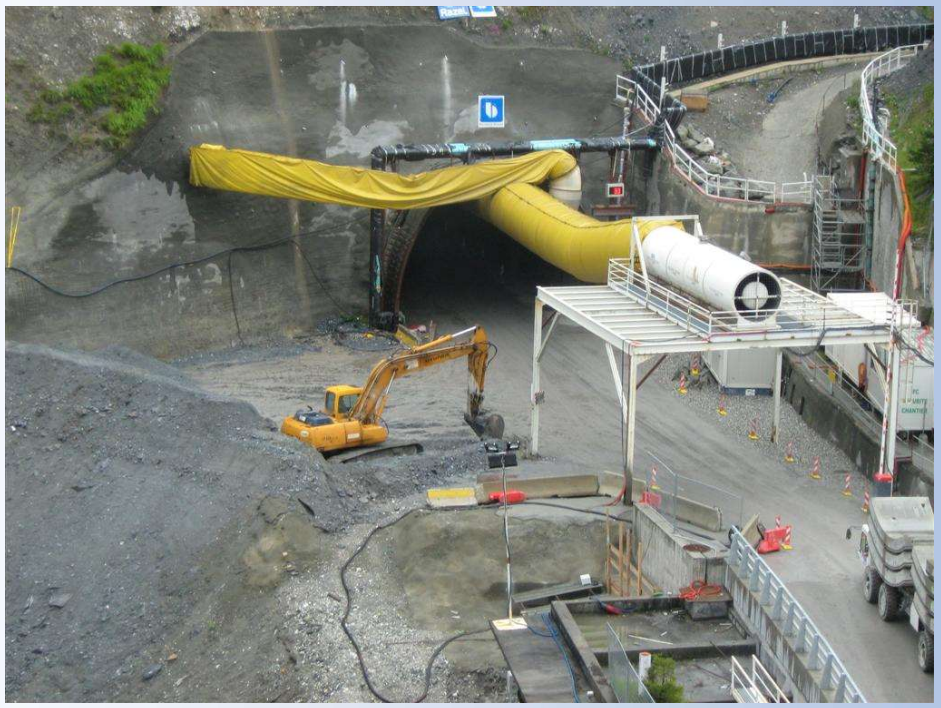
- **Water Push-Pull Austria**
  - Heavy HV cable (copper, lead)
  - High-friction jacket (graphite)
  - Cable lengths around 1 km

Water Push-Pull Projects

- Other projects
  - HV cable water push-pull in corrugated HDPE duct: Sweden
  - HV cable water push/pull in preparation:
    - United Kingdom: crossing national park by FreeFloating
    - Switzerland: 3 parallel cables in steel duct
    - Japan: 3 stranded cables in corrugated HDPE duct
  - HV cable Floating trials: Denmark
  - LV cable Floating (up to 10 km): France

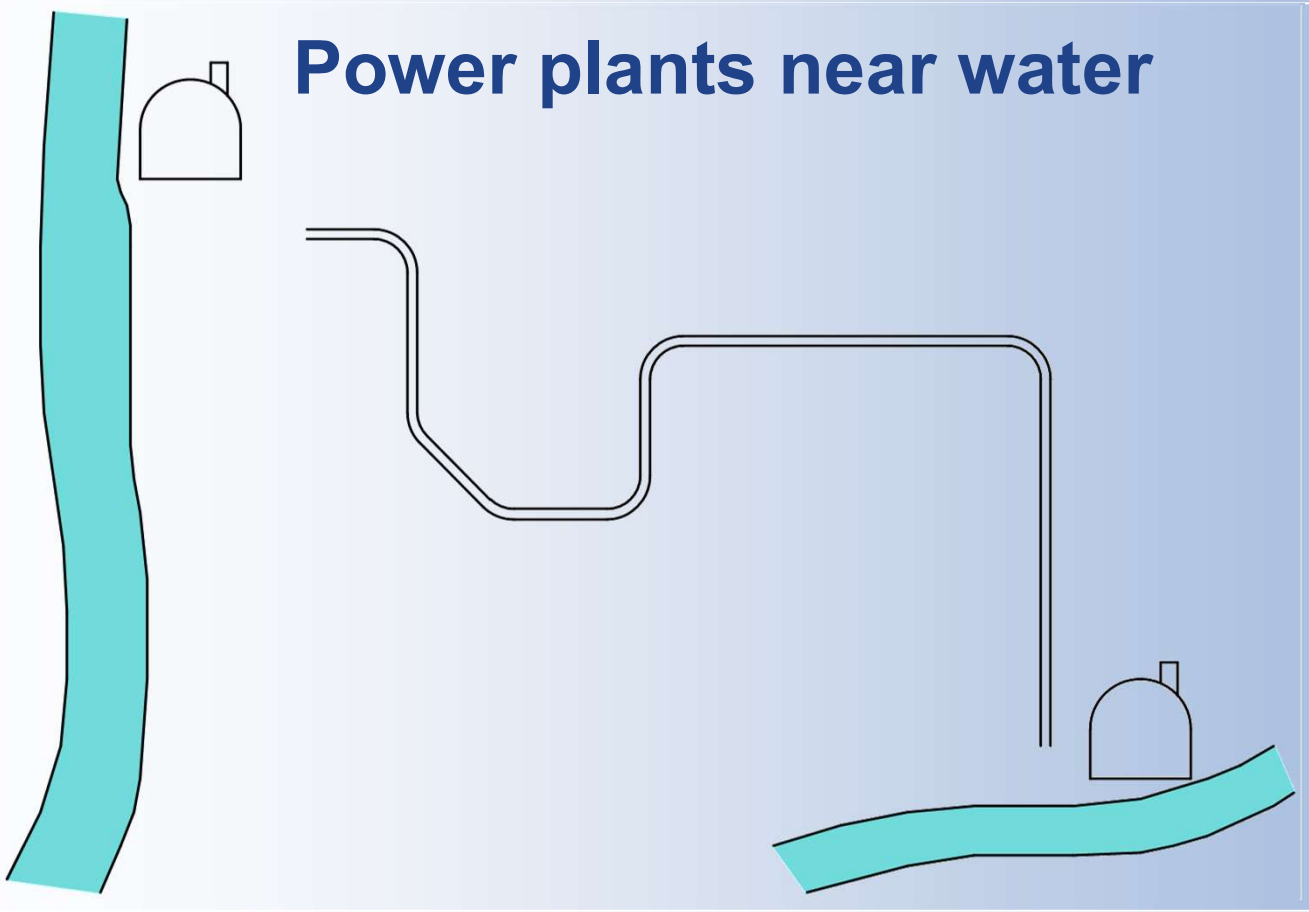
Examples FF: tunnels

- Not allowed to work with drum in tunnel



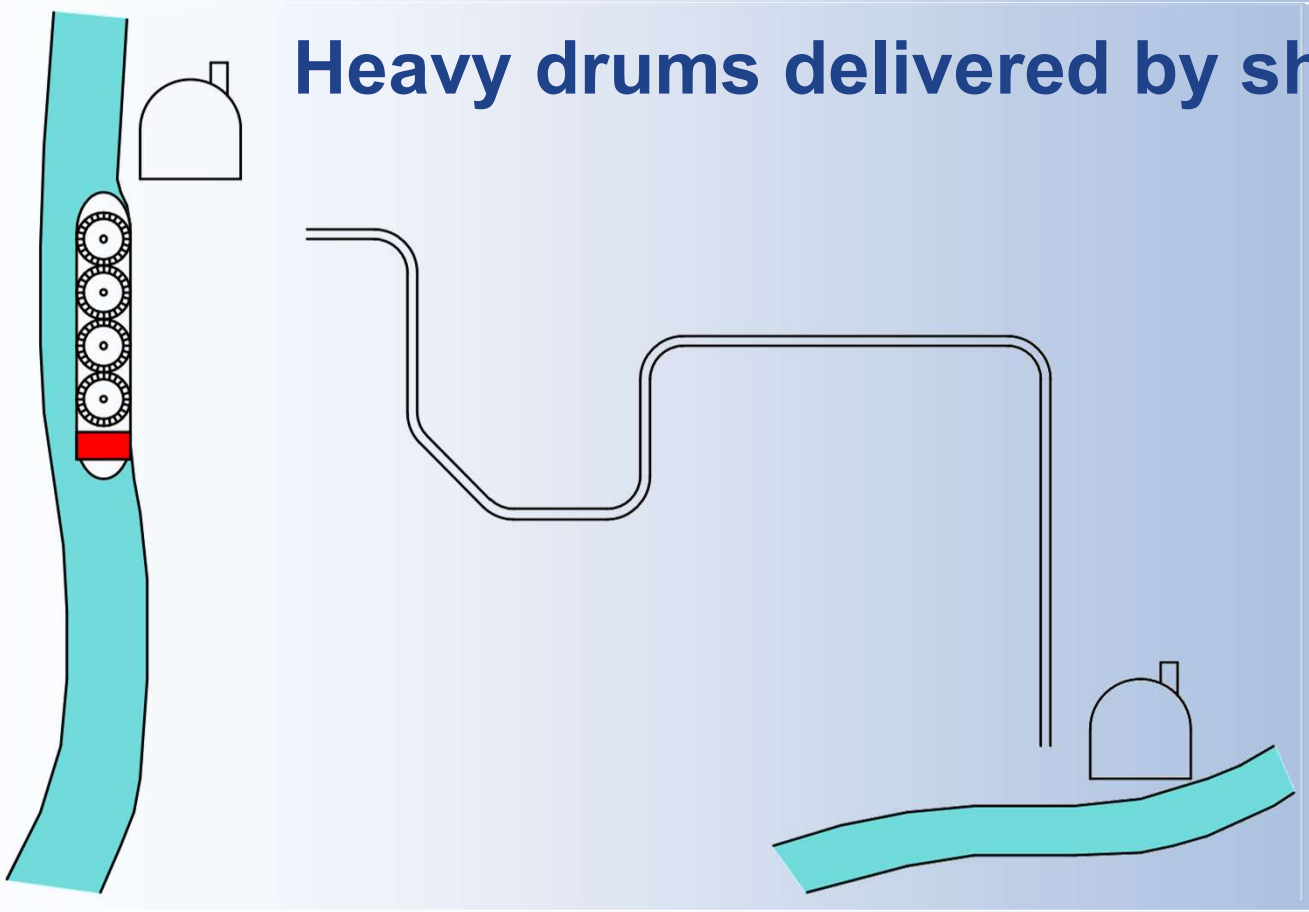
Examples FF: 400 kV cables

Power plants near water



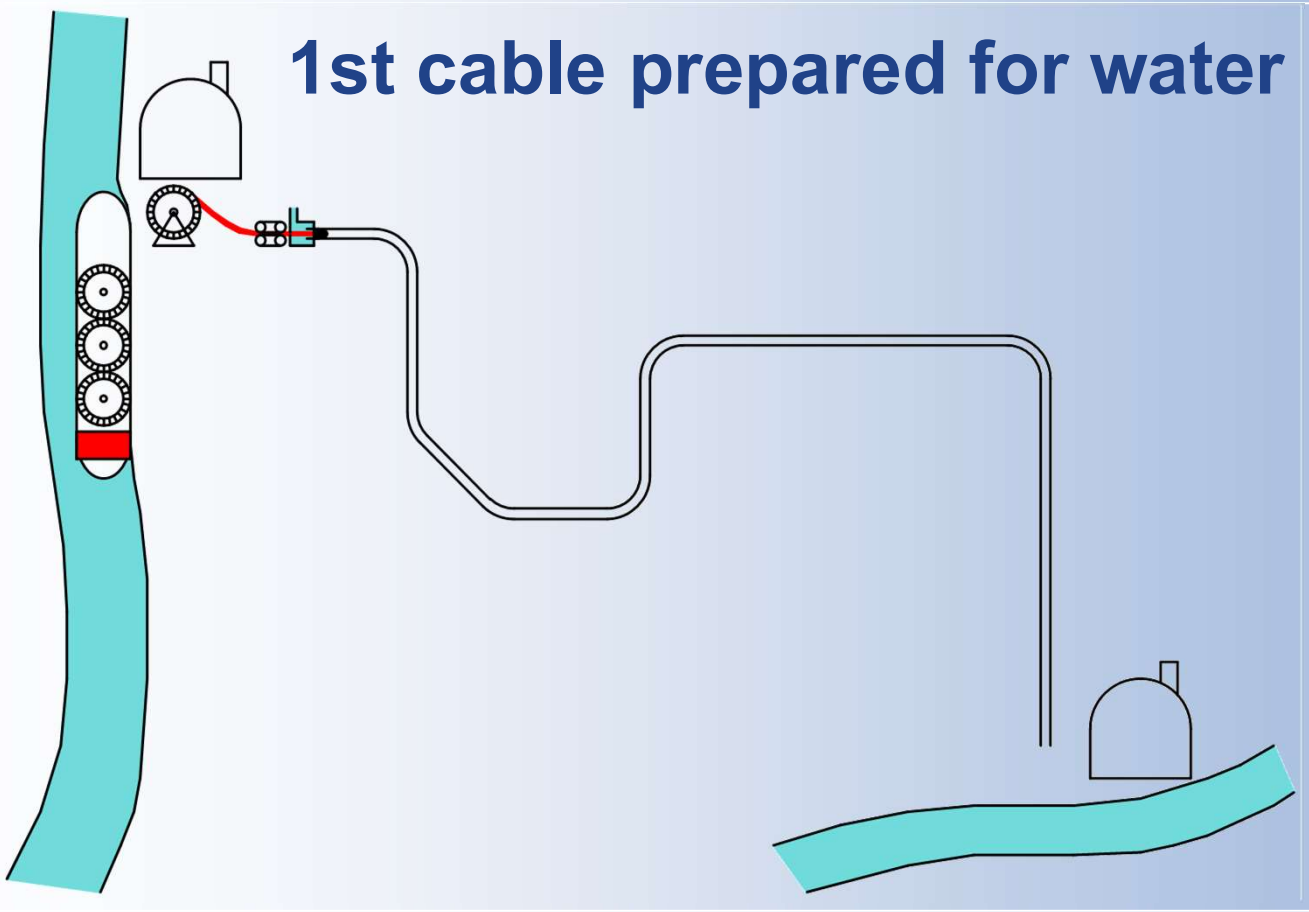
Examples FF: 400 kV cables

Heavy drums delivered by ship



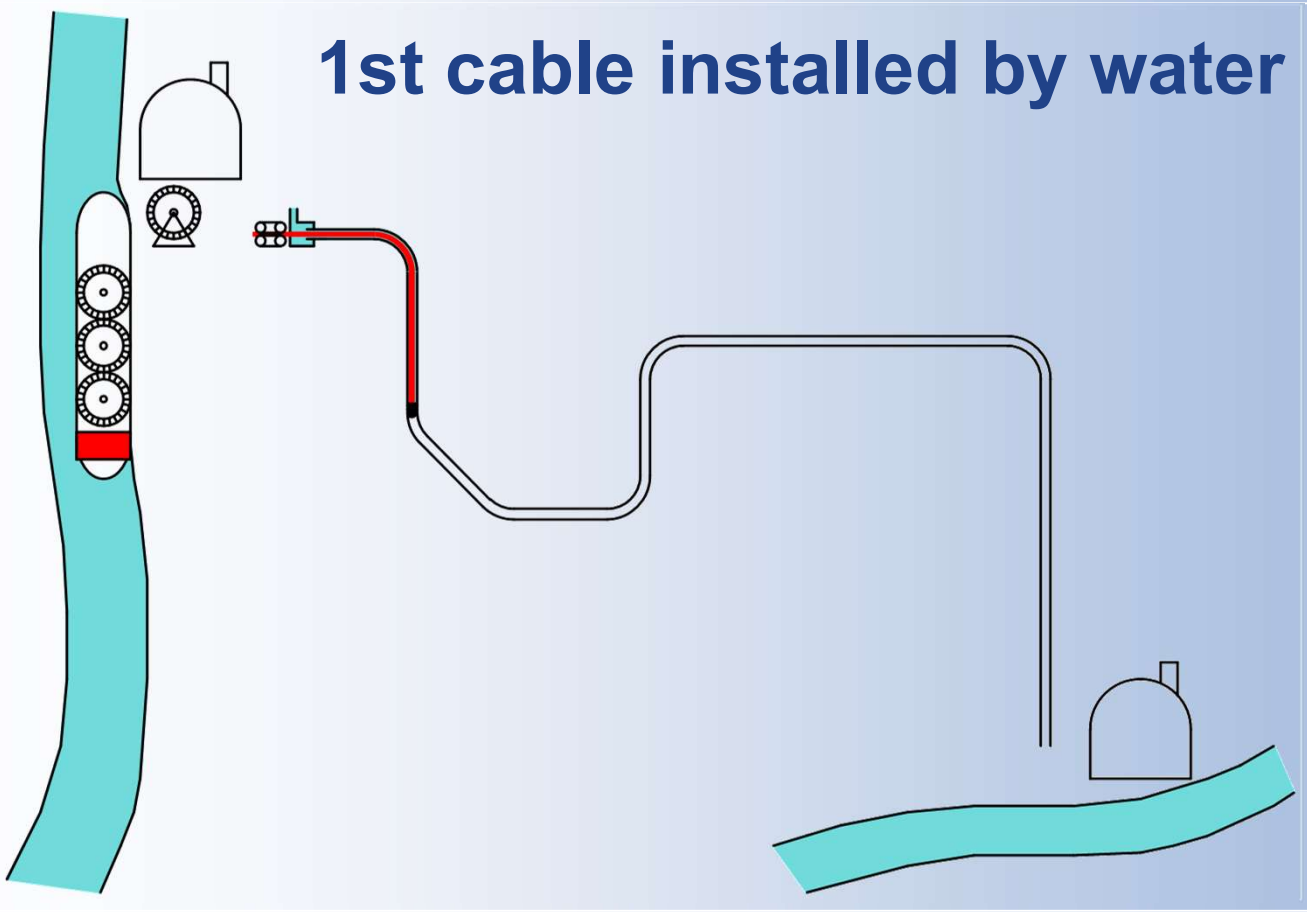
Examples FF: 400 kV cables

1st cable prepared for water push-pull with pig

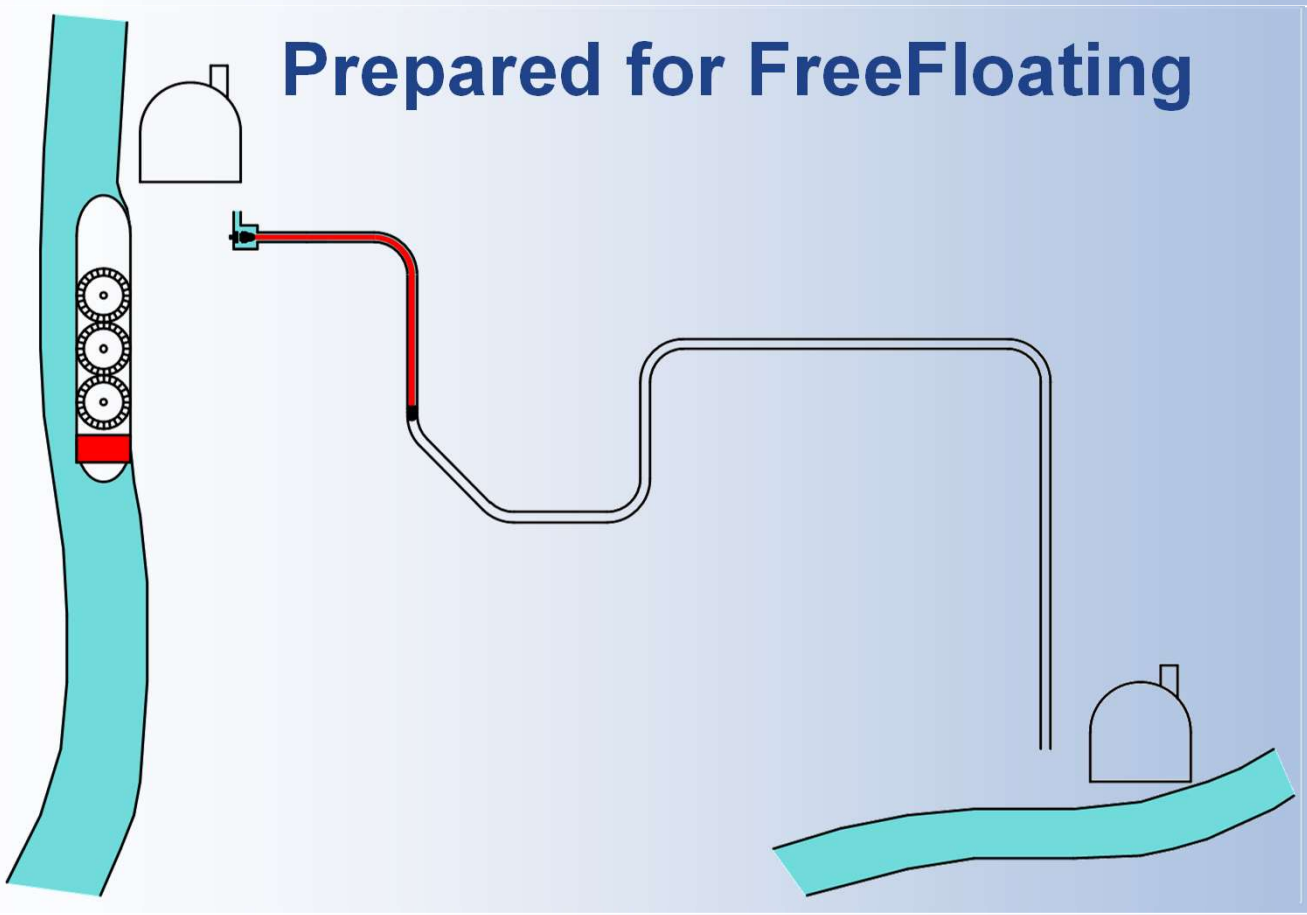


Examples FF: 400 kV cables

1st cable installed by water push-pull with pig

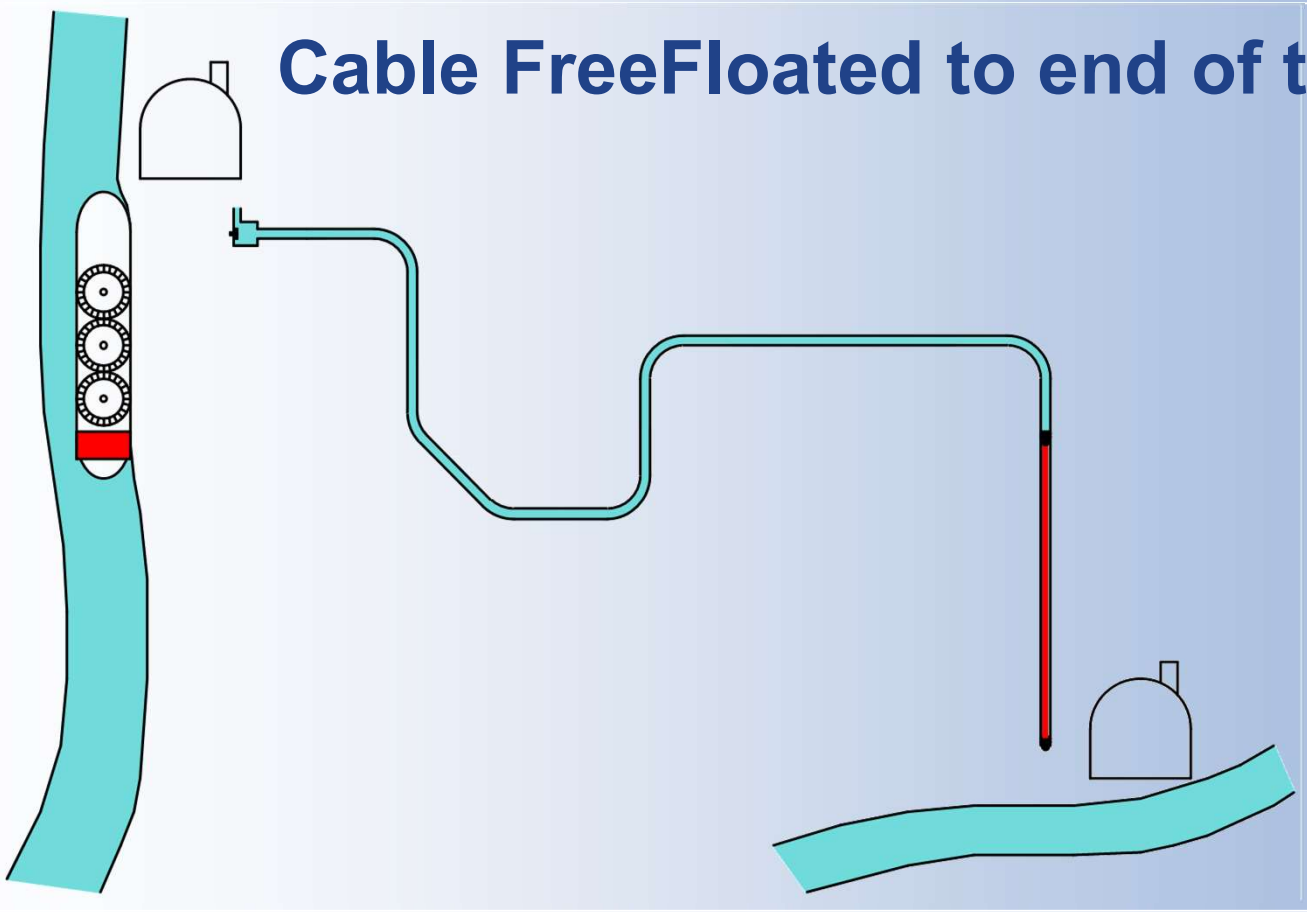


Examples FF: 400 kV cables



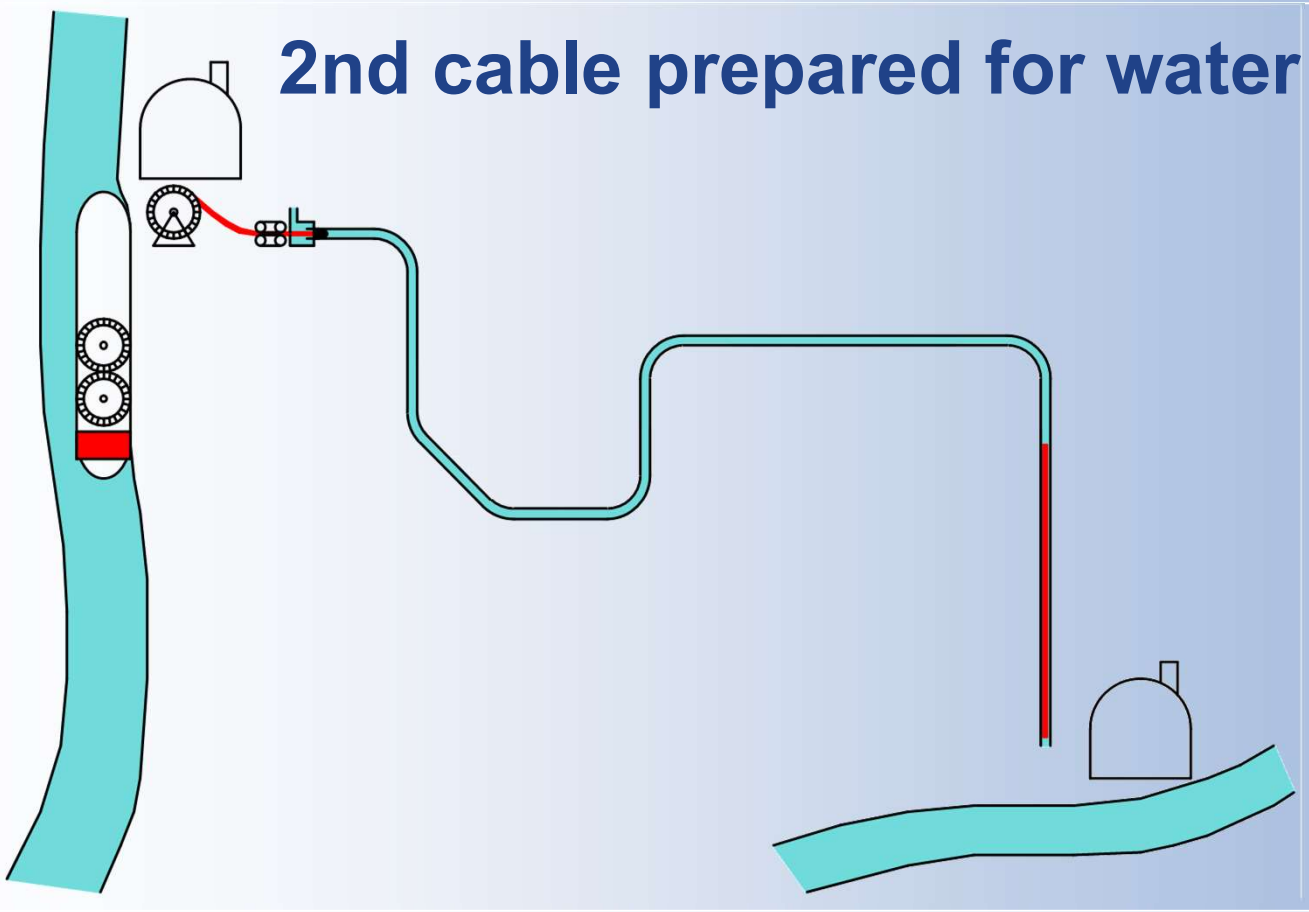
Examples FF: 400 kV cables

Cable FreeFloated to end of trajectory



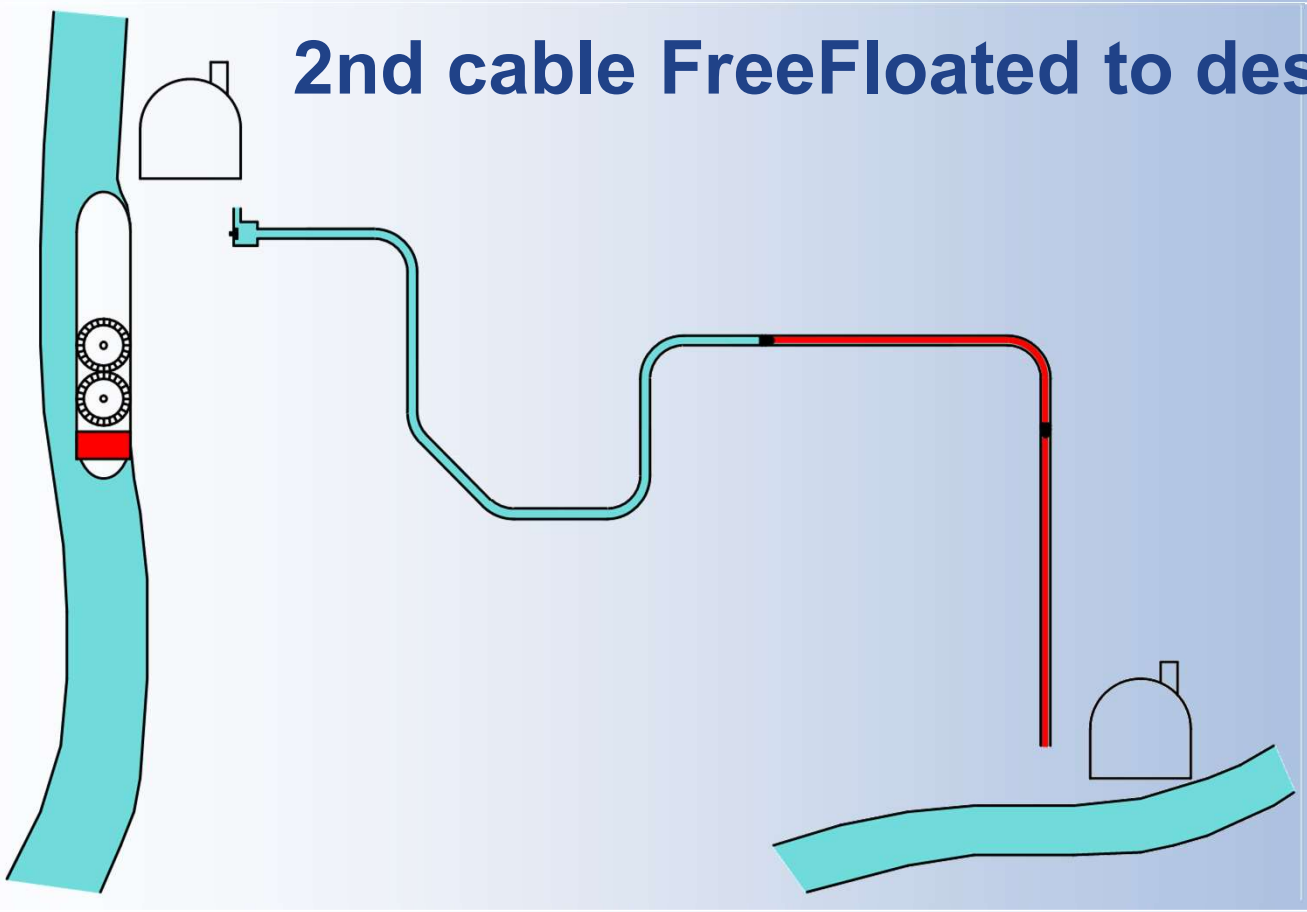
Examples FF: 400 kV cables

2nd cable prepared for water push-pull with pig

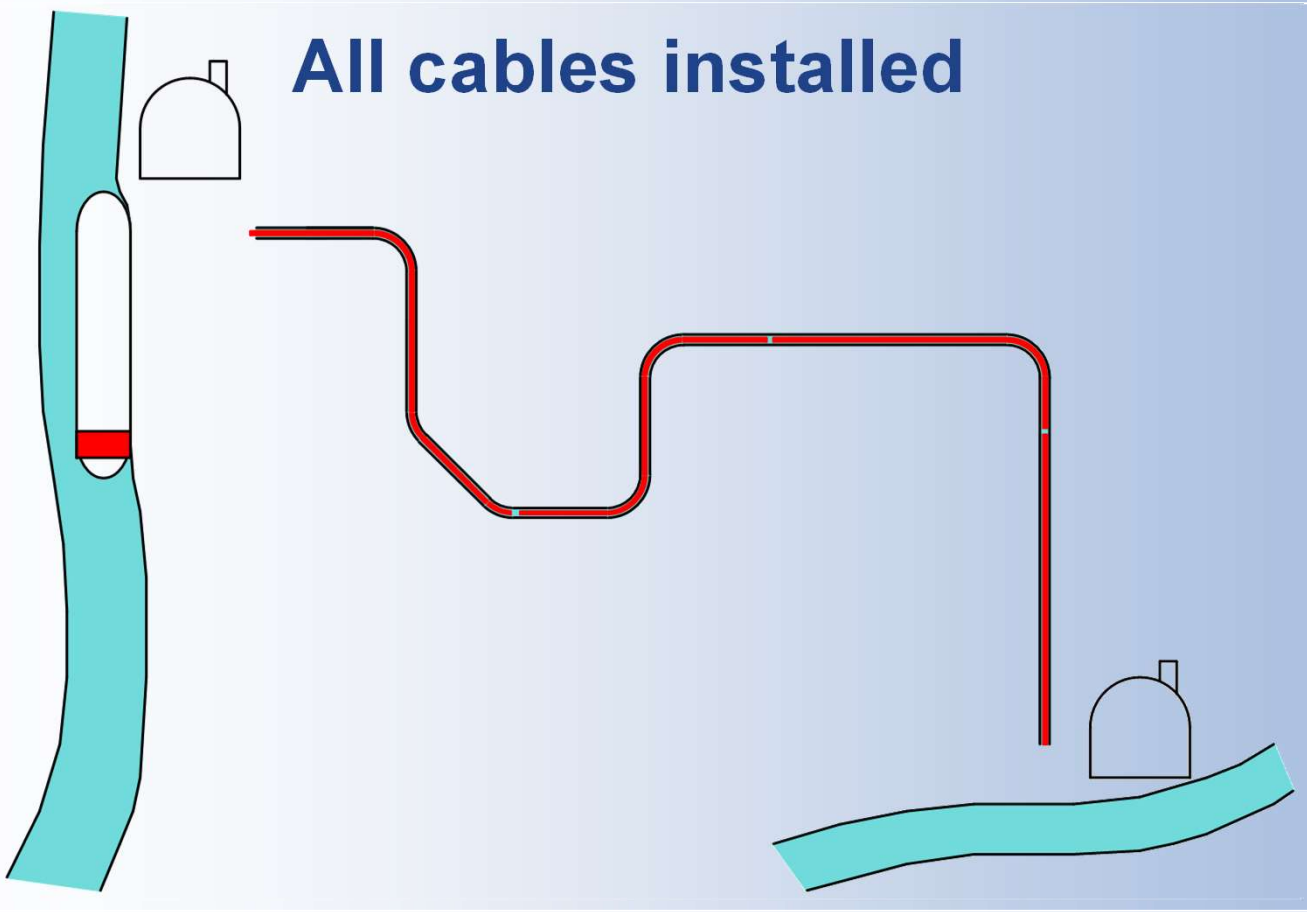


Examples FF: 400 kV cables

2nd cable FreeFloated to destination



Examples FF: 400 kV cables

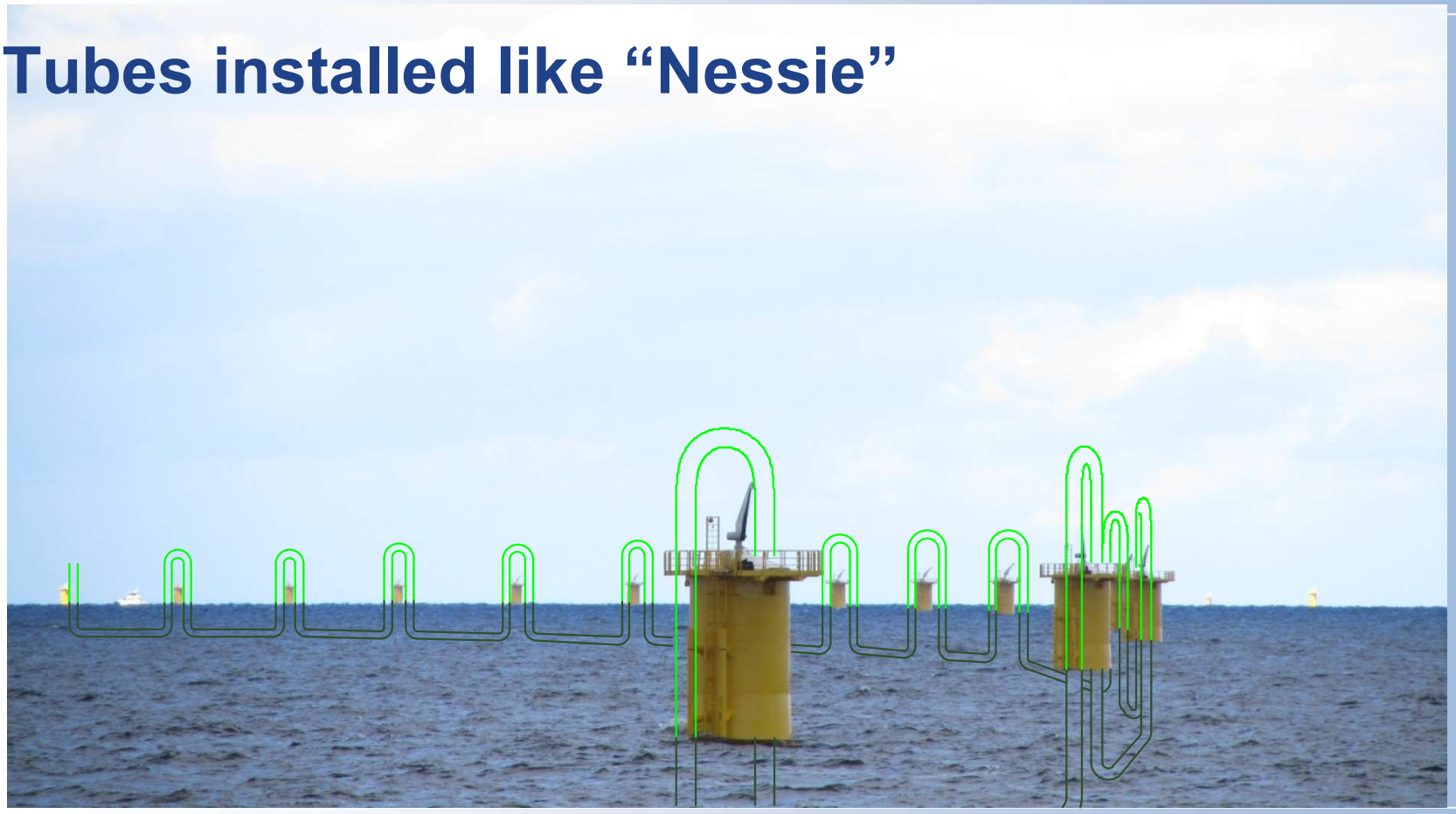


Examples FF: Offshore Windparks

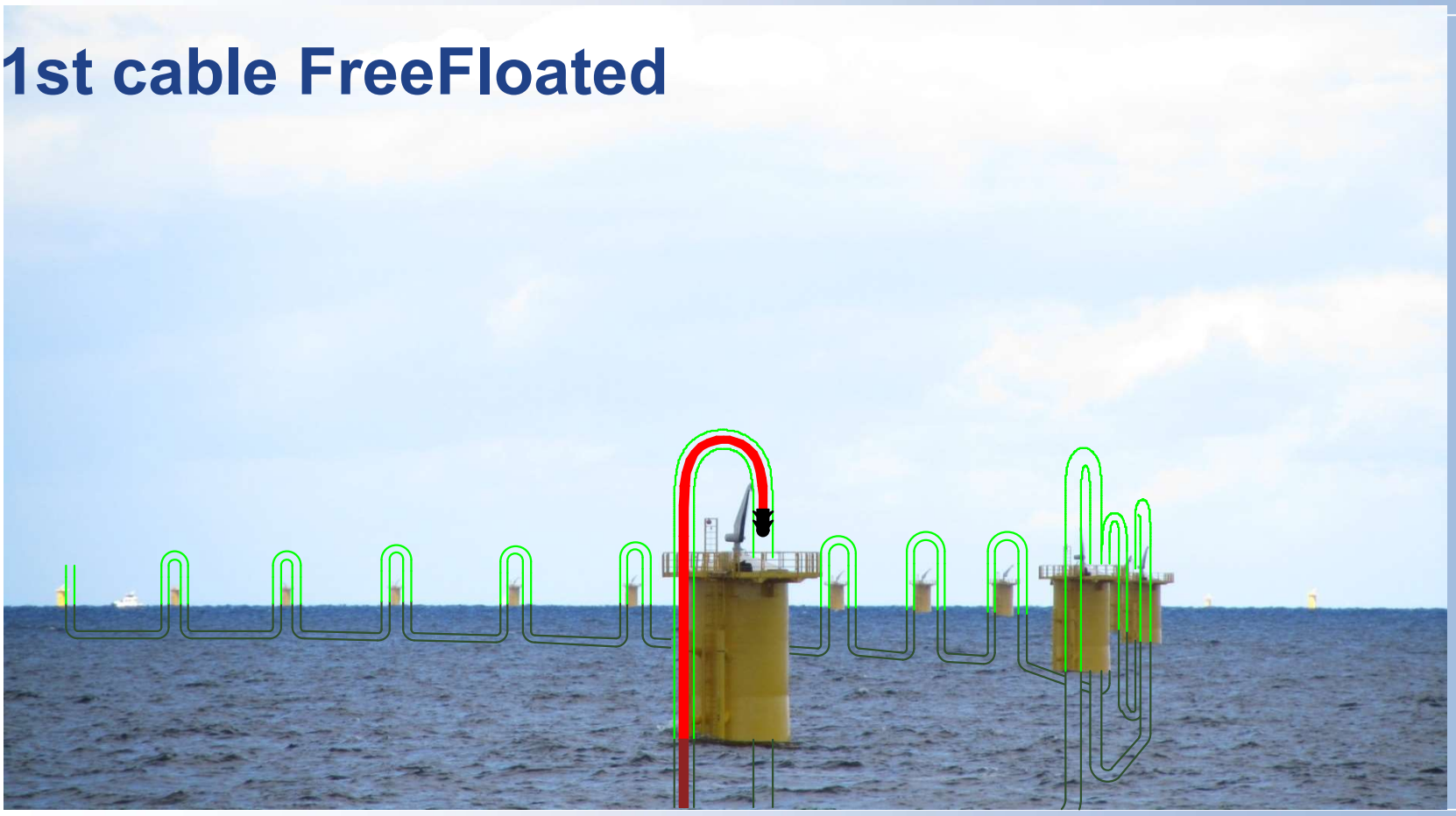
Transition Pieces (TPs): feet of wind turbines

Examples FF: Offshore Windparks

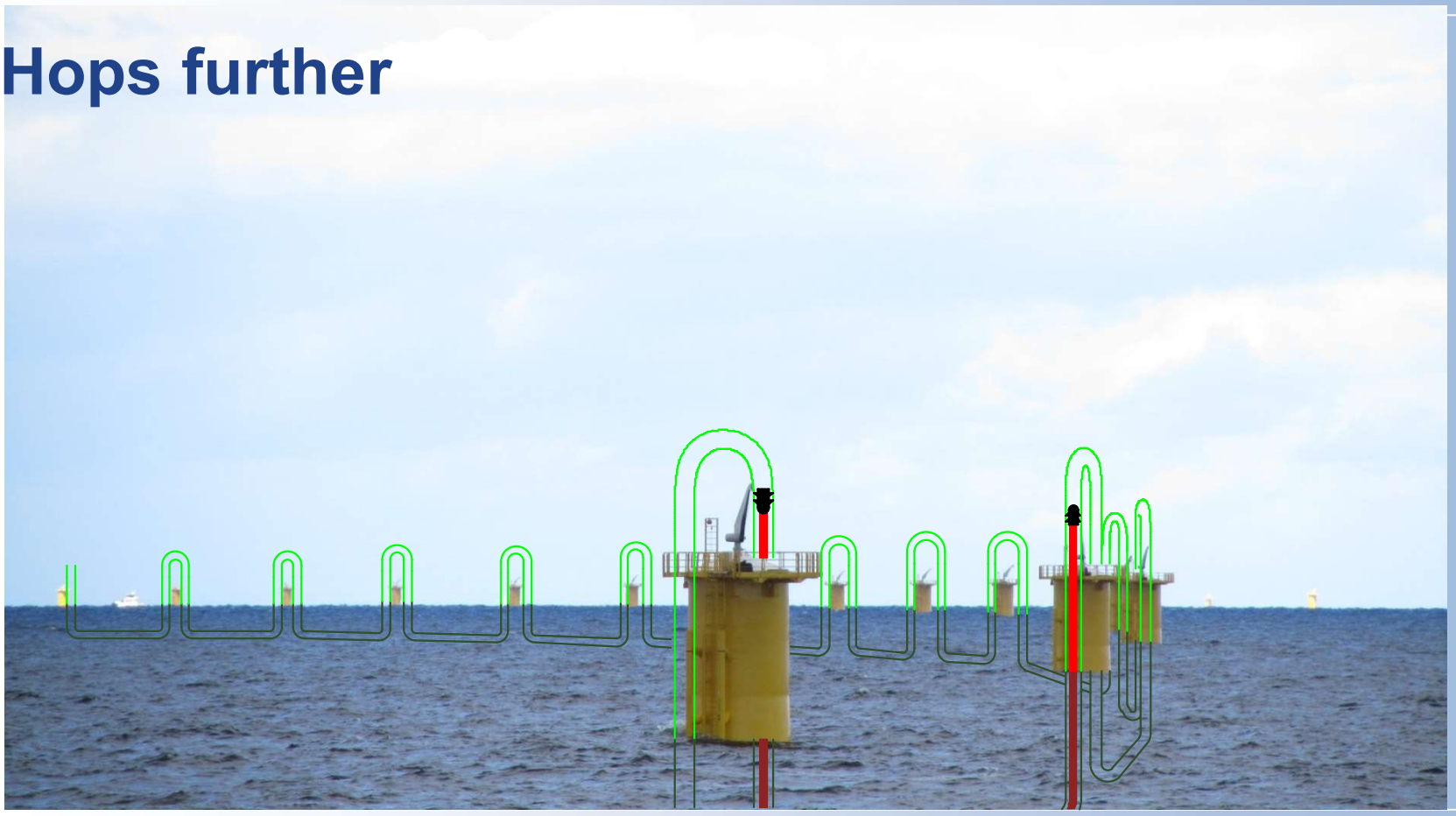
Tubes installed like “Nessie”



Examples FF: Offshore Windparks



Examples FF: Offshore Windparks



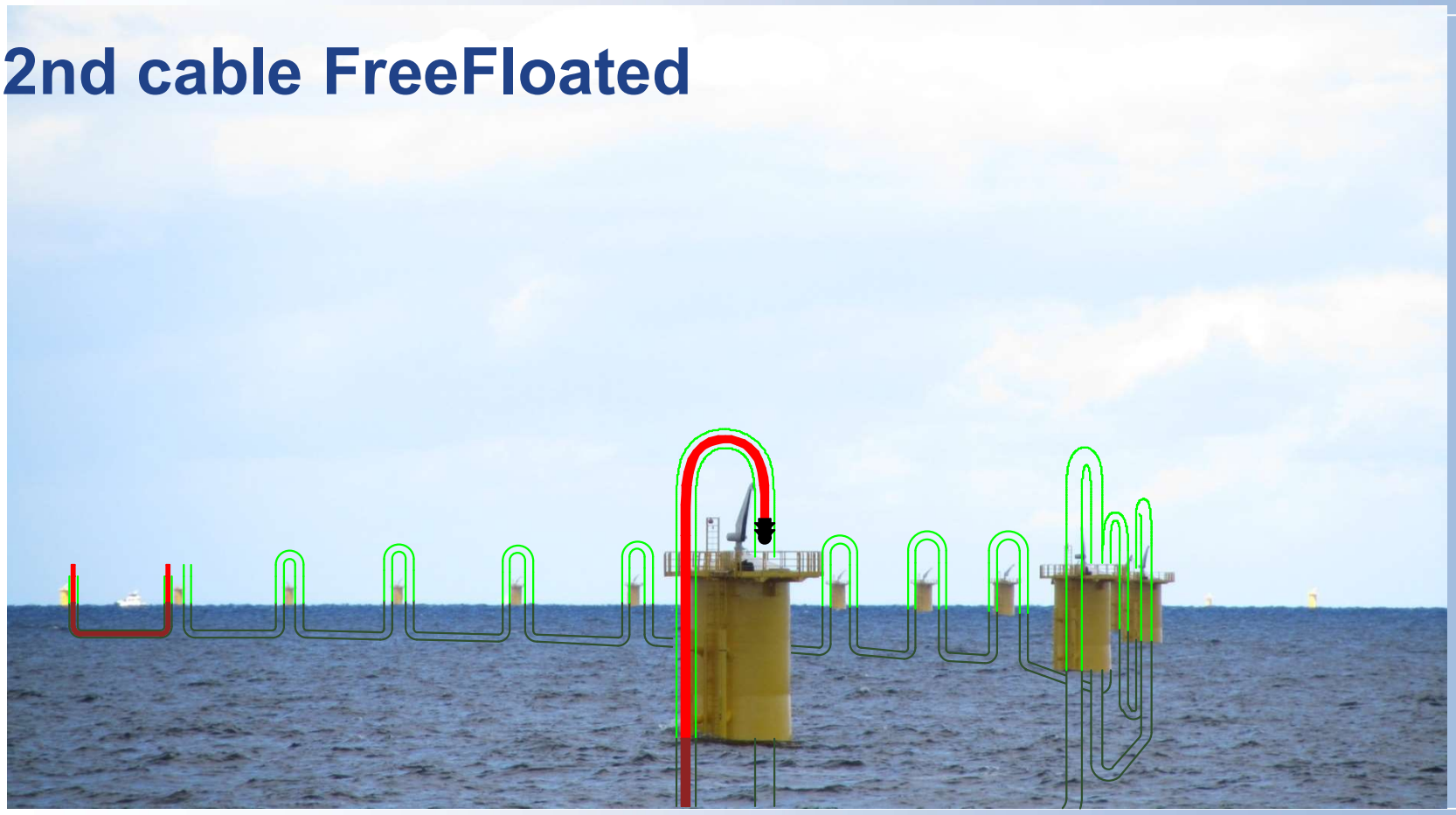
Examples FF: Offshore Windparks

And further ...

Examples FF: Offshore Windparks

Examples FF: Offshore Windparks

2nd cable FreeFloated

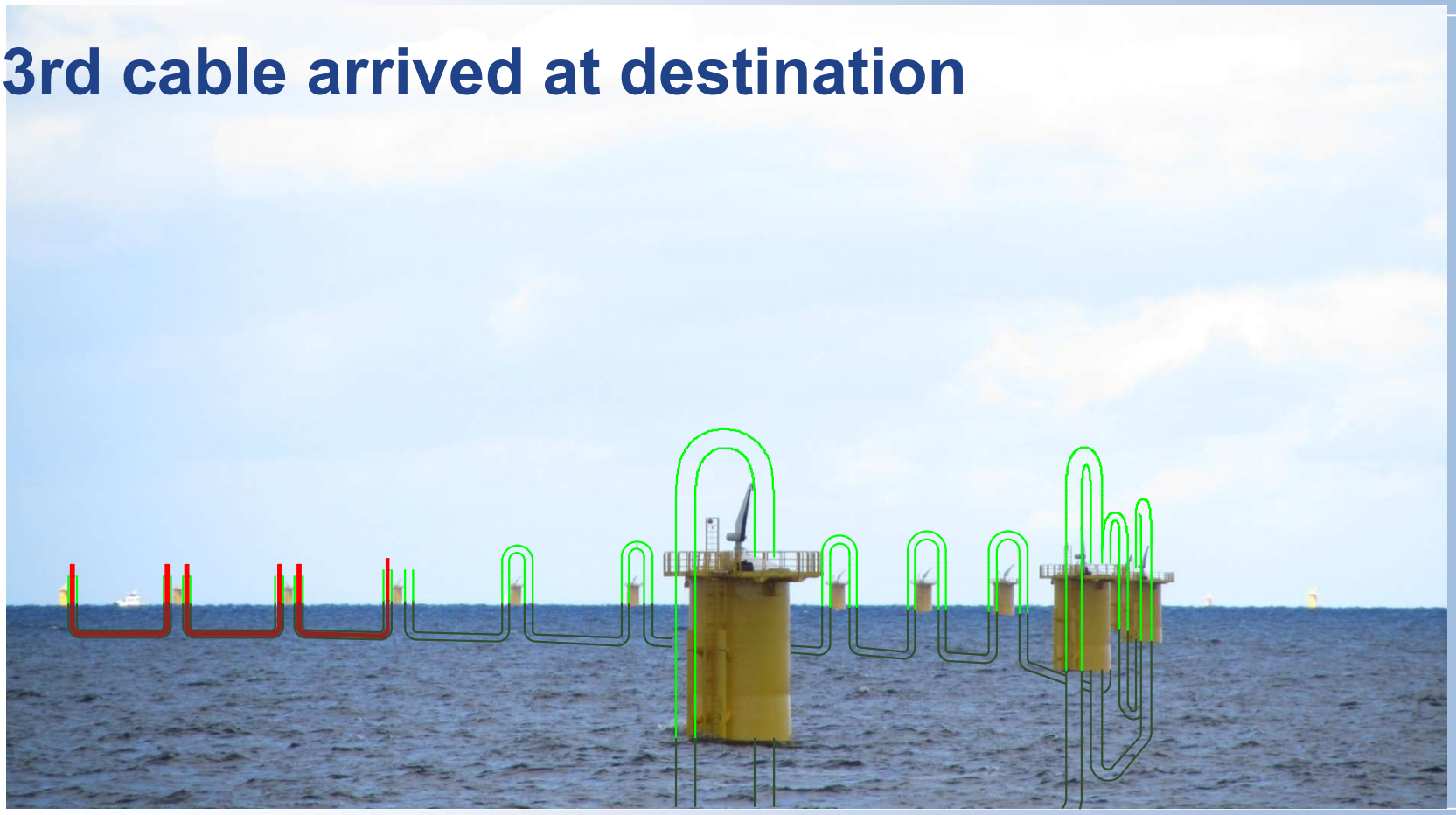


Examples FF: Offshore Windparks

2nd cable arrived at destination

Examples FF: Offshore Windparks

3rd cable arrived at destination



Examples FF: Offshore Windparks

All cables installed

Examples FF: Offshore Windparks

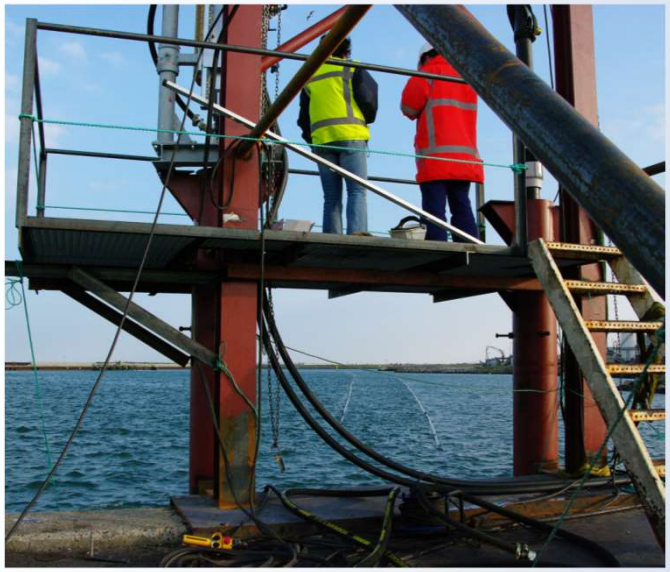
Energy supply can start

Trials for Offshore Windparks

- **Land trial, 1 km, with end loops**
  - Cable 82mm 3x300mm^2 in 125/102mm duct, WaterPushPull
  - Cable 60mm 1x630mm^2 in 90/80mm duct, Floated

Trials for Offshore Windparks

- Harbour trial, 680 m loop
  - Cable 82mm 3x300mm^2 in 125/102mm duct
  - Water Push-Pull and Floating!



Trials for Offshore Windparks

- Harbour trial, 680 m loop

Pulling Force Calculation Software

- Software calculates force build-up for all effects:
  - Gravity (corrected for buoyancy, when applicable)
  - Capstan (under pulling and pushing forces)
  - Buckling (under pushing forces)
  - Stiffness cable in bends and undulations
- For all installation methods:
  - Pulling (winch), Pushing (rodding)
  - Jetting, Floating, Water Push-Pull, FreeFloating
  - Also for multiple cables

Pulling Force Calculation Software

- **Parameters:**
  - Cable (diameter, weight, stiffness)
  - Duct (diameter, COF, winding amplitude and period)
  - Equipment (push or pull force, pressure, capacity)
  - Trajectory (slopes, bends, with angle and radius)
- **Example (225 kV cable):**
  - Cable (137.6 mm, 34 and 18.9 kgf/m, 25000 Nm2)
  - Duct (280/225 mm, 0.12, 150 mm, 50 m)
  - Trajectory (bend radius 30xOD = 8.4 m)
  - Equipment (14000 N push, 8 bar water)

Pulling Force Calculation Software, Example

- Curves and slopes (details of part trajectory)

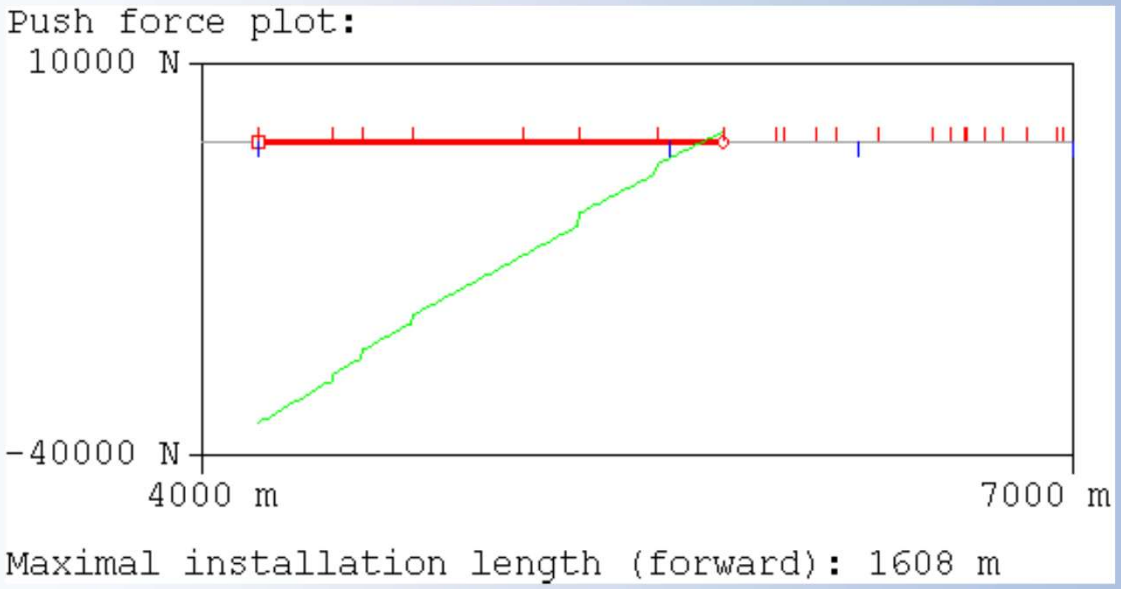
Curves on (m): (radius(m)/angle(deg) in parenthesis)

9(8.40/24)	125(8.40/13)	242(8.40/ 8)	648(8.40/30)	680(8.40/36)	739(8.40/12)
1351(8.40/16)	1589(8.40/18)	1601(8.40/34)	1612(8.40/29)	1702(8.40/13)	1773(8.40/11)
1850(8.40/ 6)	1971(8.40/12)	2103(8.40/31)	2258(8.40/26)	2265(8.40/26)	2277(8.40/26)
2284(8.40/31)	2527(8.40/ 1)	2656(8.40/16)	2744(8.40/12)	2794(8.40/12)	2941(8.40/ 6)
3047(8.40/37)	3113(8.40/ 1)	3174(8.40/37)	3262(8.40/30)	3488(8.40/92)	3534(8.40/35)
3571(8.40/63)	3601(8.40/38)	3653(8.40/ 9)	3709(8.40/23)	3727(8.40/25)	3775(8.40/11)
3822(8.40/11)	3923(8.40/11)	3950(8.40/10)	4196(8.40/ 3)	4454(8.40/ 9)	4558(8.40/11)
4726(8.40/11)	5111(8.40/ 1)	5302(8.40/19)	5572(8.40/15)	5804(8.40/21)	5982(8.40/44)
6011(8.40/51)	6116(8.40/45)	6187(8.40/17)	6334(8.40/ 7)	6517(8.40/46)	6580(8.40/ 9)
6627(8.40/21)	6635(8.40/36)	6699(8.40/12)	6761(8.40/29)	6843(8.40/41)	6947(8.40/15)
6971(8.40/64)	7021(8.40/52)	7039(8.40/24)	7089(8.40/21)	7142(8.40/93)	7207(8.40/90)
7405(8.40/20)	7705(8.40/15)	7747(8.40/58)	7756(8.40/45)	7927(8.40/ 5)	8192(8.40/ 9)
8429(8.40/12)	8477(8.40/10)	8660(8.40/26)	8723(8.40/36)	8805(8.40/18)	8971(8.40/61)
9023(8.40/95)	9087(8.40/ 1)	9185(8.40/25)	9357(8.40/ 4)	9635(8.40/18)	9690(8.40/20)
9853(8.40/ 4)	10015(8.40/37)	10023(8.40/37)	10115(8.40/60)		

Slope	from (m)	to (m)	incl. (deg)	end height (m)	Slope	from (m)	to (m)	incl. (deg)	end height (m)
1	0	691	-2.07	-25	8	5612	6263	-0.53	-113
2	691	1601	0.06	-24	9	6263	7021	-4.39	-171
3	1601	2527	-1.73	-52	10	7021	7766	-0.47	-177
4	2527	3113	-4.49	-98	11	7766	8477	-0.32	-181
5	3113	3822	-1.62	-118	12	8477	9185	-0.32	-185
6	3822	4196	3.21	-97	13	9185	10146	-0.48	-193
7	4196	5612	-0.40	-107	14	10146	20000	0.00	---

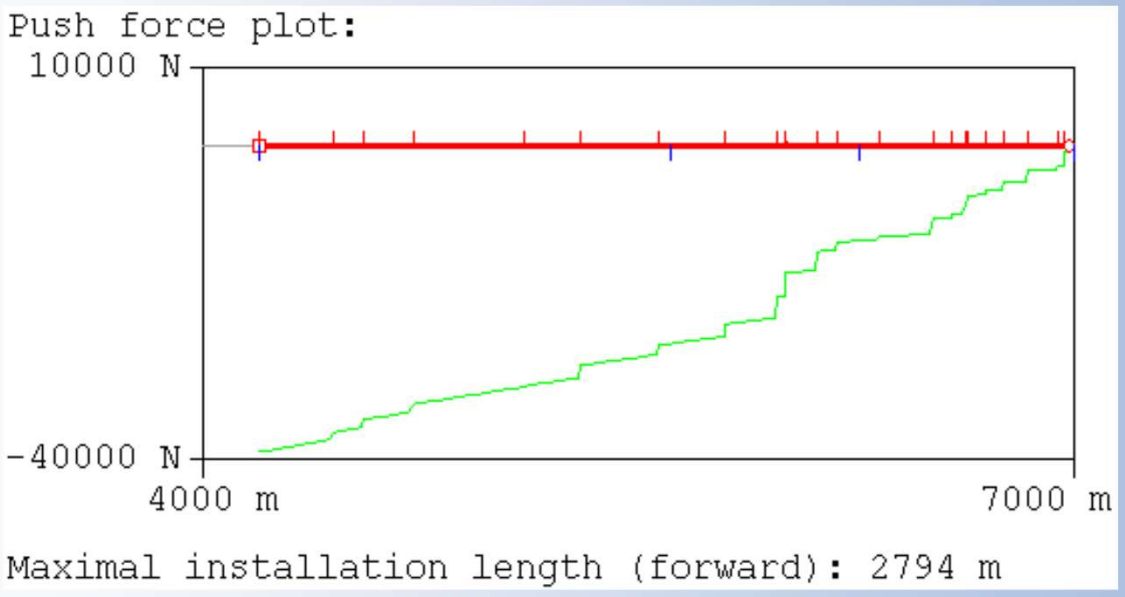
Pulling Force Calculation Software, Example

Water Push-Pull Cu-core Cable (34 kgf/m)



Pulling Force Calculation Software, Example

Water Push-Pull Al-core Cable (18.9 kgf/m)



Conclusions

- Cable in duct instead of armoured cable
- Advantages for both land and offshore
- Different cable installation techniques presented
- Water Push-Pull and Floating
  - Less forces, less wear of cable (allows sharper bends)
  - Long lengths possible (especially Al-core cable)
  - Operation from one side, less installation steps
  - More versatility

Conclusions

- Several land projects done
- Trials for Offshore Windpark performed
- Extremely long cable lengths possible
  - 10 km already, but much longer possible (100 km?)
- Option of FreeFloating
  - 100 km no problem
- Software to calculate force build-up

PLUMETT

www.plumettaz.com

VISION & PERFORMANCE

Thanks for your attention