INSULATED CONDUCTORS COMMITTEE

Established 1947

Fall 2016 meeting, Scottsdale, AZ

Subcommittee C

www.plumettaz.com

New Techniques to Install High Voltage Cables into Ducts

Willem Griffioen

Plumettaz SA

Route de la Gribannaz 7, 1880 Bex, Switzerland

VISION & PERFORMANCE

Contents

- Introduction
- The new techniques
- Cable configurations
- Water Push-Pull projects
- Other Projects
- Examples Free-Floating
- Pulling force calculation software
- Conclusions

Introduction

- Cable in duct vs armoured cable
- How to install a cable into a duct?
- Several methods
- New methods presented
- But first shortly a bit theory

Cable in duct vs armored cable

- 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

Cable in duct vs armored cable

- 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

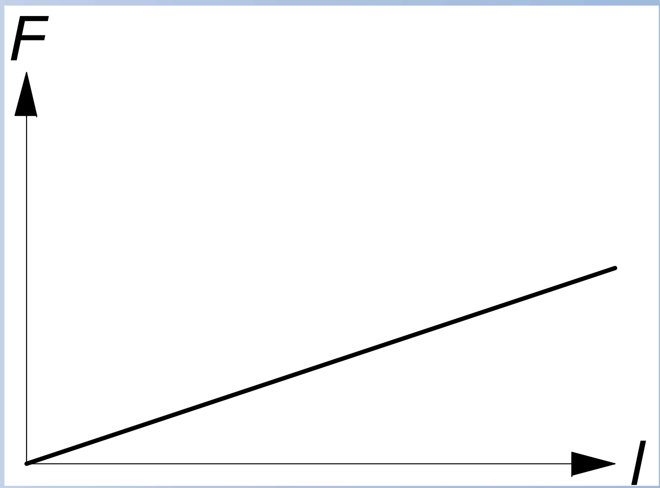
Cable in duct vs armored cable

- 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**

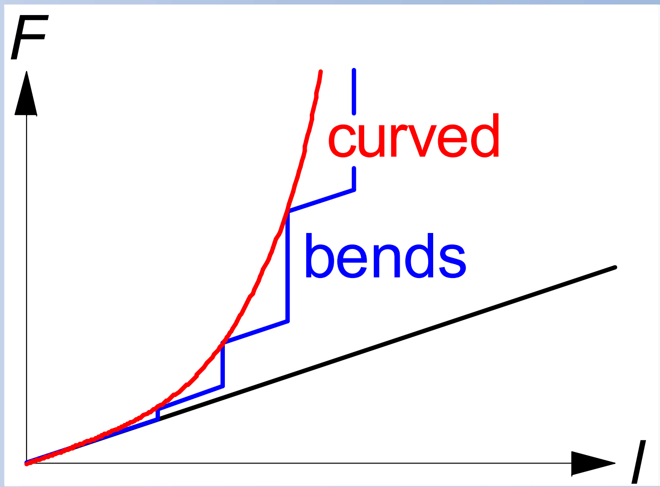
1. **Gravity (linear)**



Introduction, Force Build-Up

- **Build up installation force**

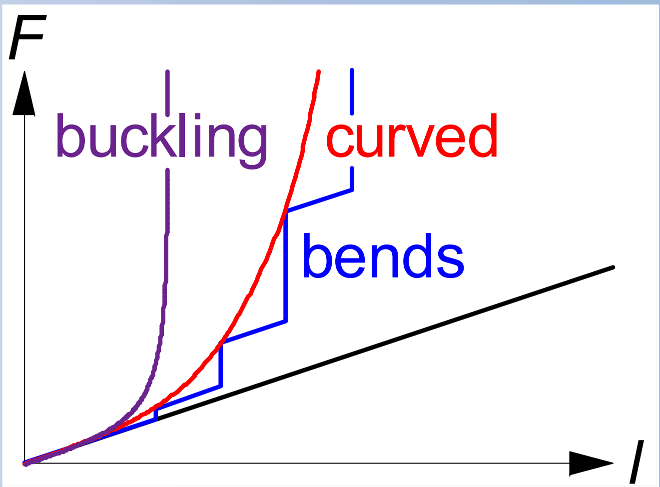
1. **Gravity (linear)**
2. **Cable pullforce (exponential)**



Introduction, Force Build-Up

- **Build up installation force**

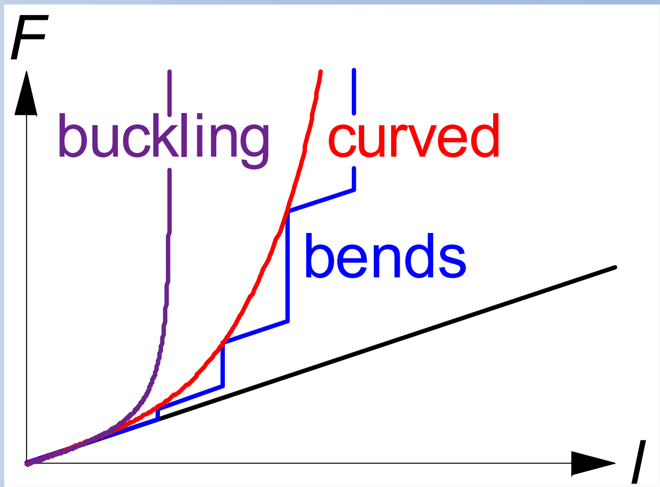
1. **Gravity (linear)**
2. **Cable pullforce (exponential)**
3. **Cable pushforce (asymptotic)**



Introduction, Force Build-Up

- Build up installation force

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

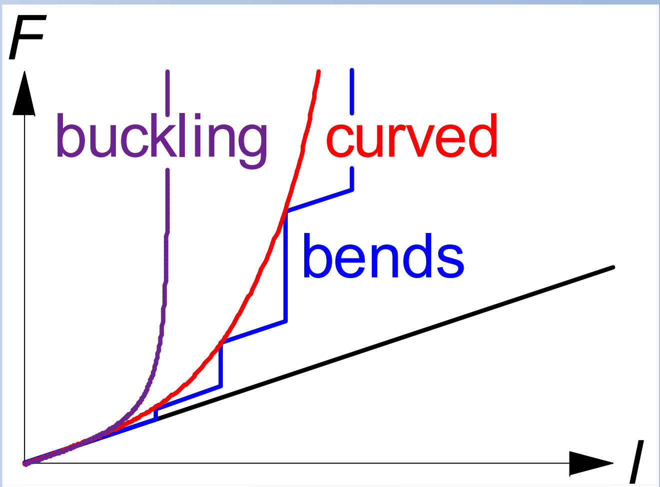


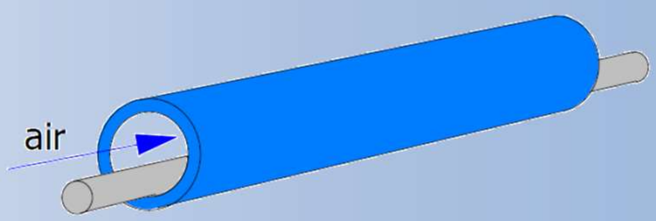
Introduction, Force Build-Up

- **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.)**



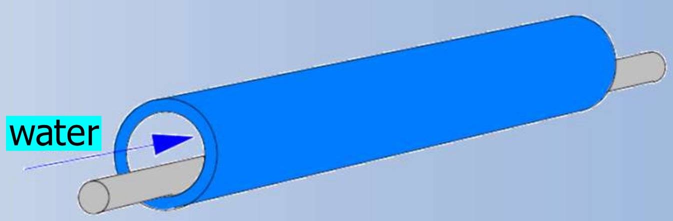


Introduction, Force Build-Up

- Build up installation force

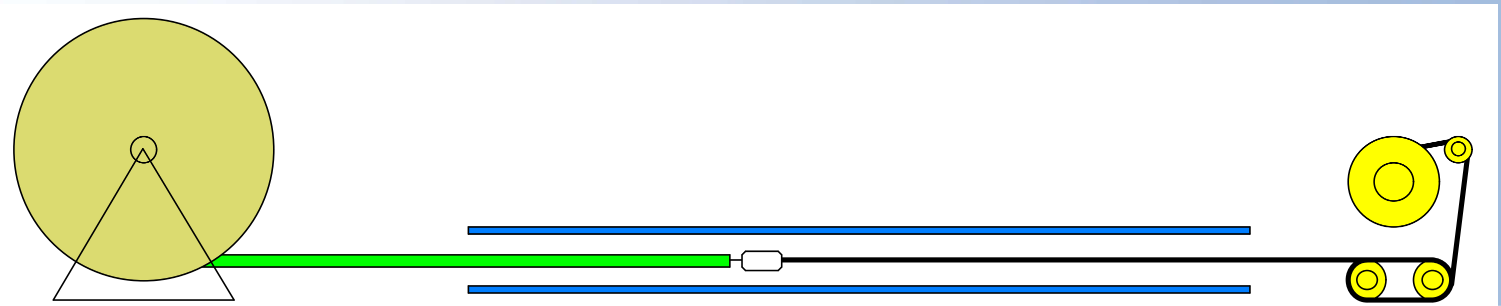
1. Gravity (linear)
2. Cable pullforce (exponential)
3. Cable pushforce (asymptotic)
4. Cable stiffness in bends

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



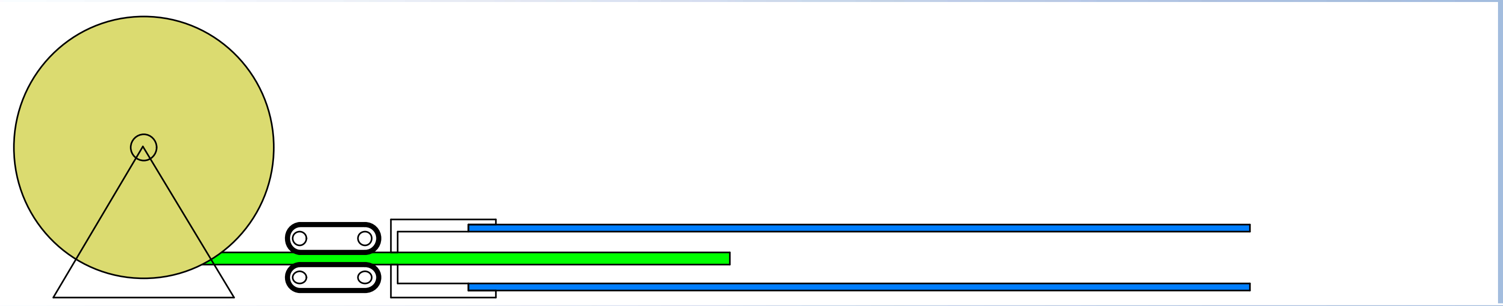
Introduction, Installation Method

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



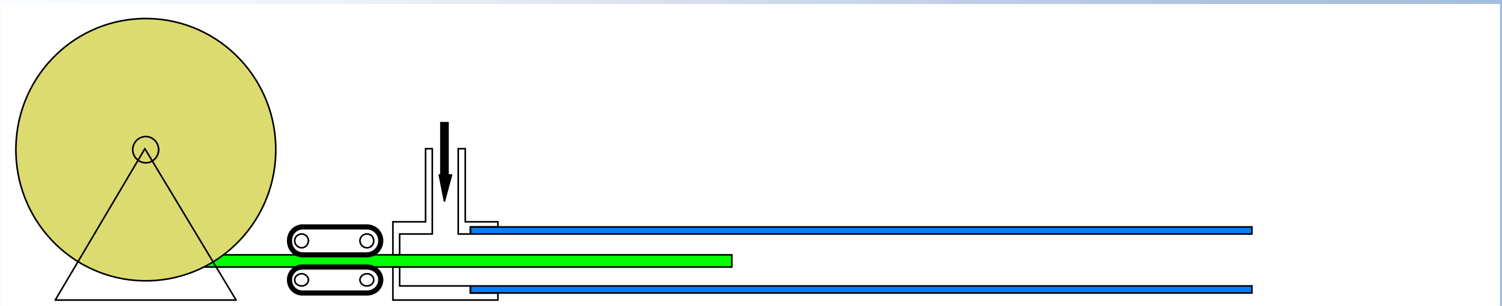
Introduction, Installation Method

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



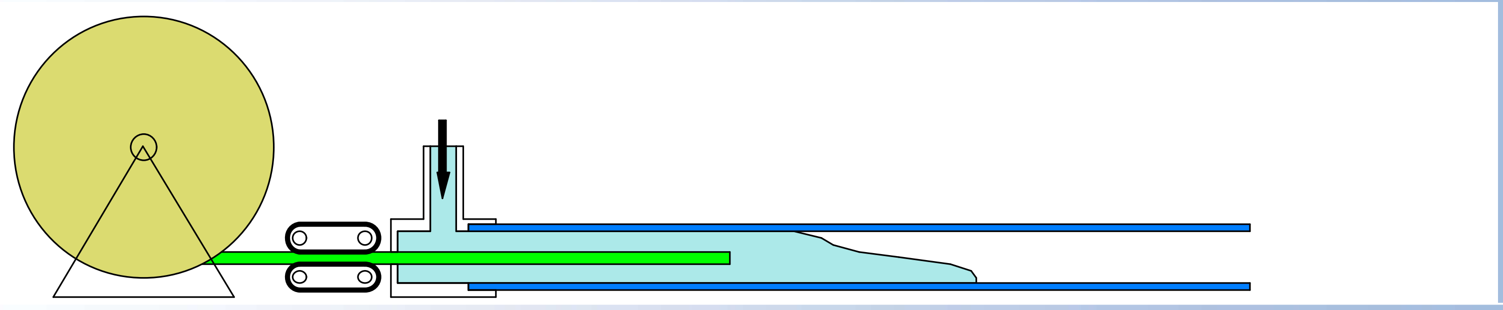
Introduction, Installation Method

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



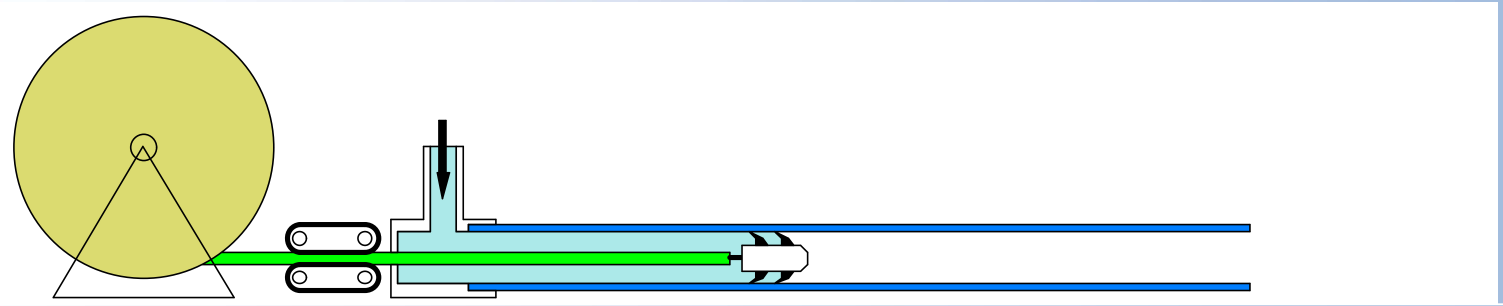
Introduction, Installation Method

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



Introduction, Installation Method

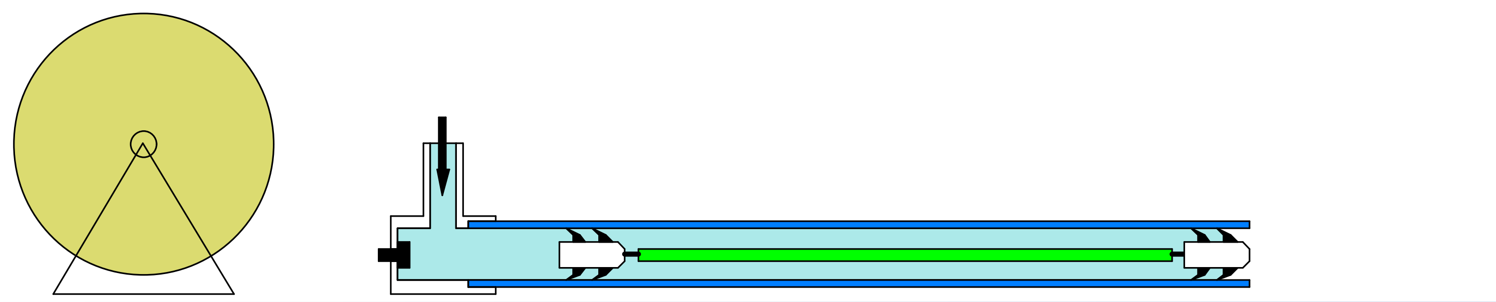
- Techniques to install cables into ducts:
  - Winch pulling
  - Pushing (rodding)
  - Jetting (blowing)
  - Floating
  - Water Push-Pull



Introduction, Installation Method

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

the new techniques



Introduction, Floating

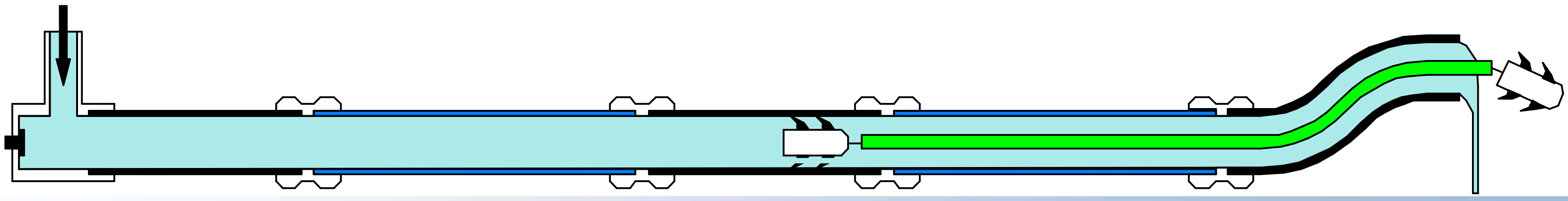
- EXTREMELY long lengths (density matching)
  - 10 km (already), 20 km, 50 km, 100 km .. ?
- Waterflow smaller than airflow
  - Smaller pumps and/or bigger pipes
  - Lower water (cable) speed
- Water is safer
- Needs water supply and drain
- Hydrostatic pressure (every 10 m up = +1 bar)
  - Not relevant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

Introduction, Water Push-Pulling

- 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

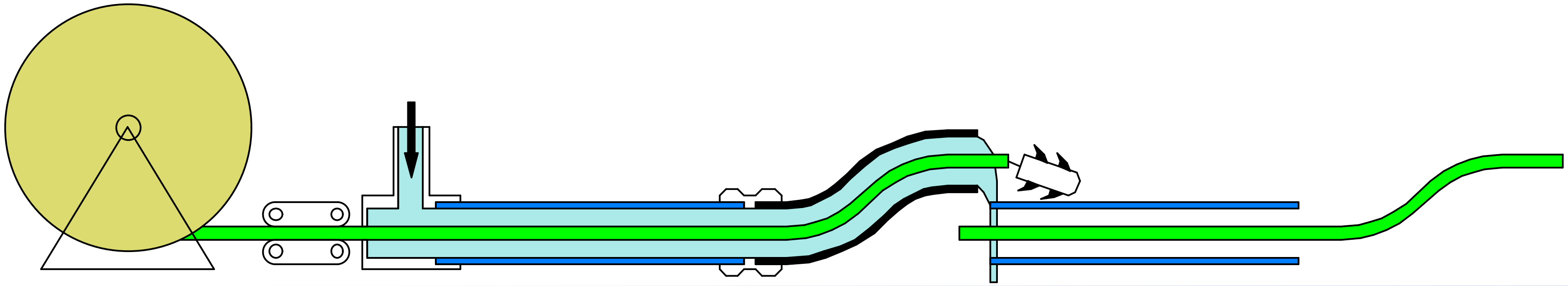
Introduction, FreeFloating

- Install cable 1 by Water Push-Pulling
- When cable 1 is in, mount rear pig
- Close, with duct rear extension
- Flow further to desired location
- Duct front extension for cable overlength



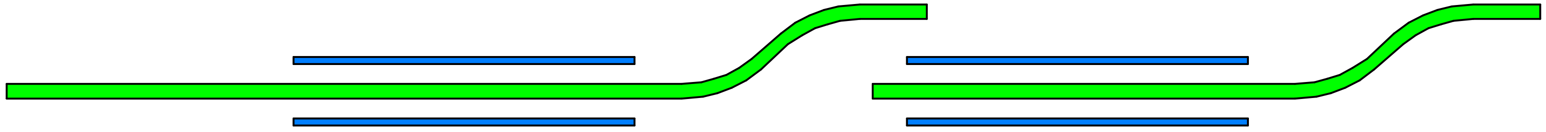
Introduction, FreeFloating

- Remove duct connection and front extension
- Remove pigs
- Place new front (bypass) duct extension
- Install cable 2 with Water Push-Pulling



Introduction, FreeFloating

- Remove duct extension and equipment
- All cables installed
- Can be repeated for multiple sections
- FreeFloating length matches WaterPushPulling
- Hard to reach (launch) places can be avoided



Introduction, FreeFloating

It really works!

The New Techniques

- No winch rope to install
- Labour + equipment one side of duct
- No synchronization problems
- Low forces, water cooling, less (no) wear
- Long lengths (extremely!)
- Option of FreeFloating (one launch location)

Cable Configurations

- **Single core cables**

Cable Configurations

- **Stranded 3-core cables**

Cable Configurations

- **Bundle of 3 parallel cables**

Water Push-Pull Projects

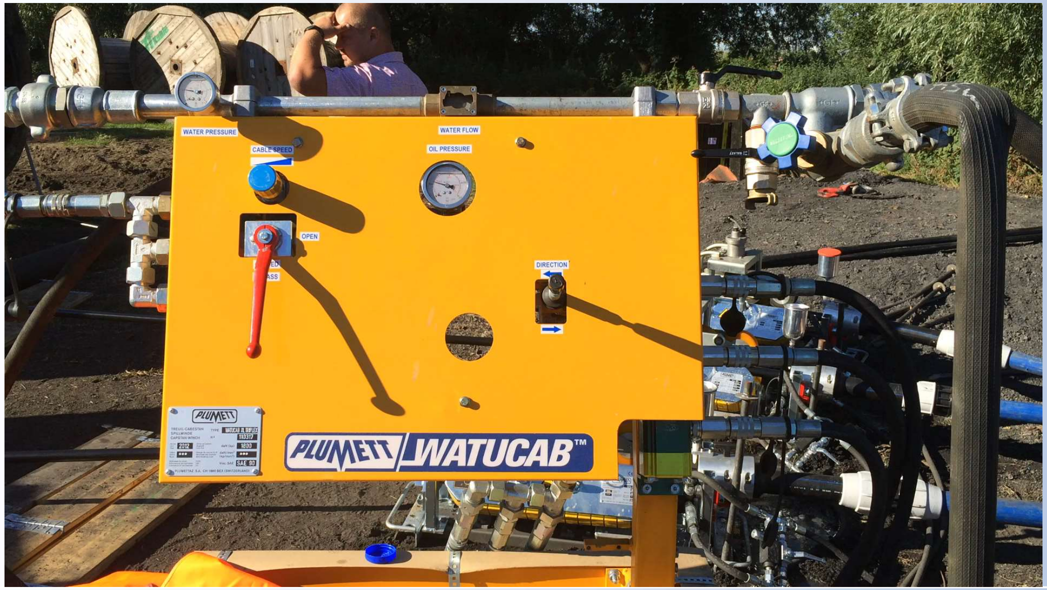
- Water Push-Pull France
  - HV cable lengths up to 3.3 km

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

- **Trefoil Water Push-Pull Poland**
  - **Bundle of 3 parallel cables (3×240 mm^2 AL)**
  - **200/164 mm HDPE duct, 1100 m long**



Other projects

- **Harbour Floating harbour trial (Denmark)**
  - 3×300 mm^2 AL offshore windpark array cable 36 kV
  - 125/102 mm duct, 680 m with 180° loop

Other projects

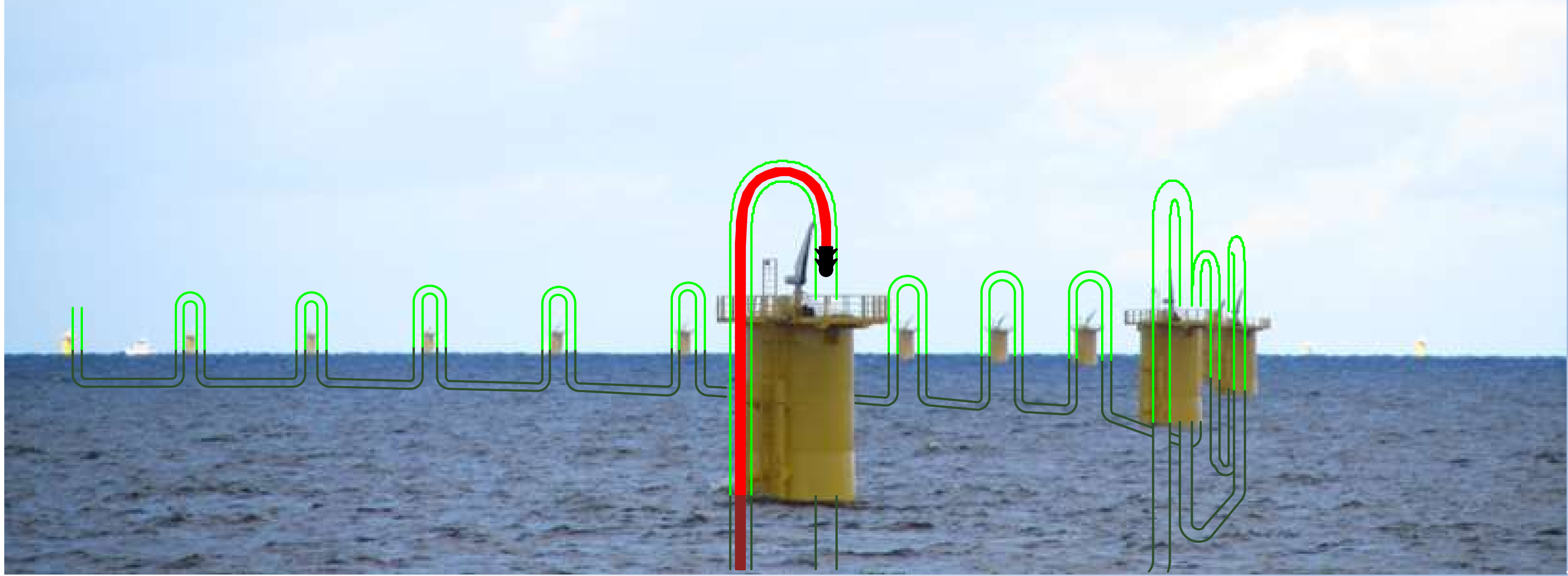
- Other projects
  - HV cable water push-pull in corrugated HDPE duct: Sweden
  - LV cable Floating (up to 10 km): France
  - HV cable water push/pull in preparation:
    - Denmark: Windpark, installation from sea and from land, including FreeFloating
    - UK, PL (done) and CH: 3 cables in single duct
    - Japan: 3 stranded cables in corrugated HDPE duct
    - UK: Water Push-Pull and FreeFloating single core cables

Example FF: Offshore Windparks

Transition Pieces (TPs): feet of wind turbines

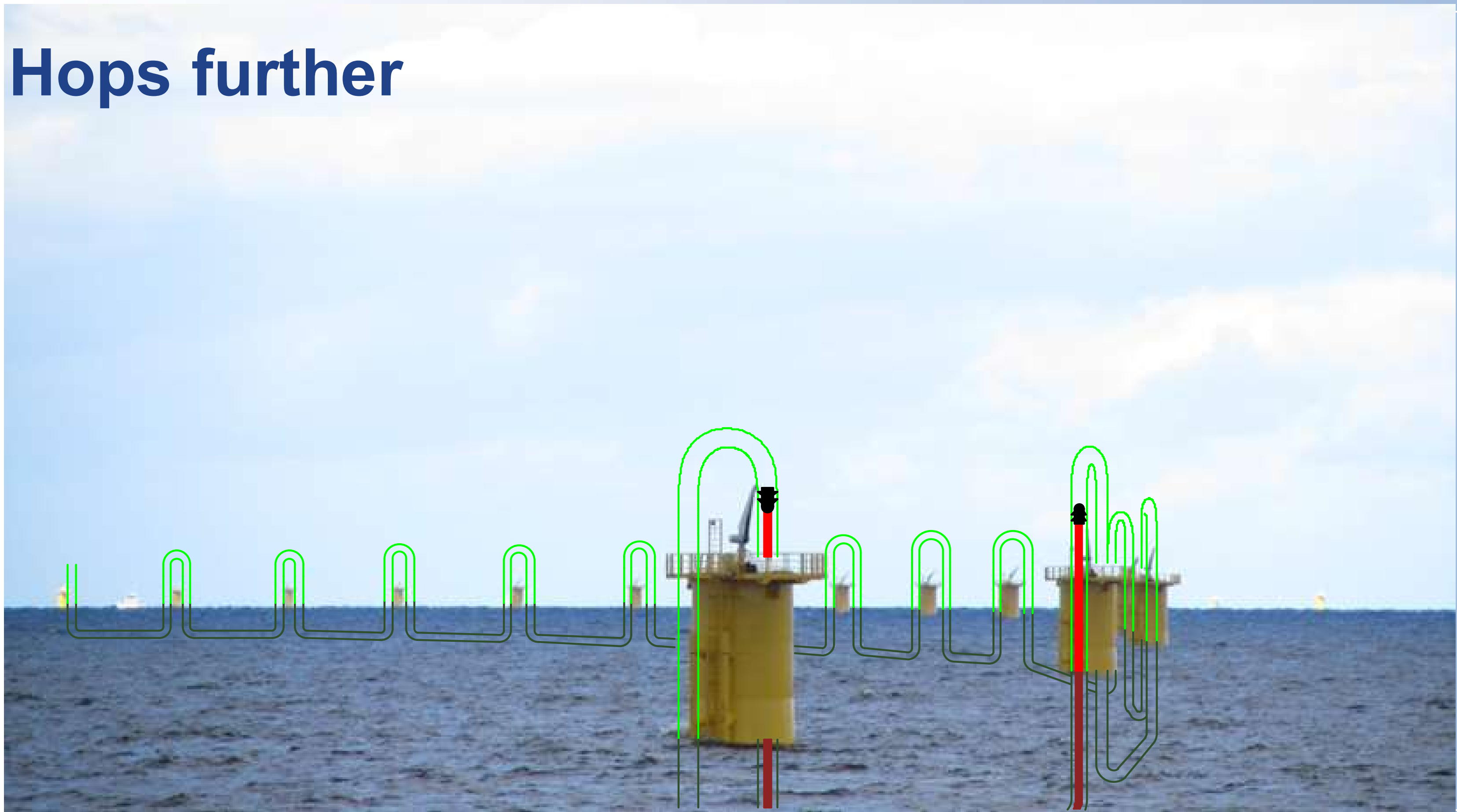
Tubes installed like “Nessie”

1st cable FreeFloated



Example FF: Offshore Windparks

Hops further



Example FF: Offshore Windparks

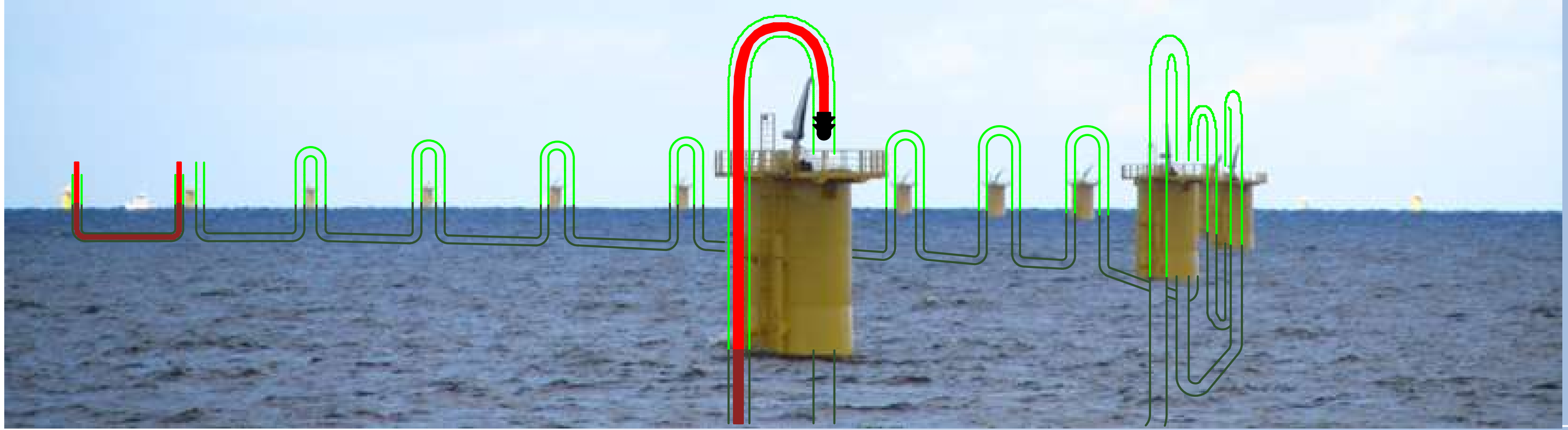
And further ...

Example FF: Offshore Windparks

1st cable arrived at destination

Example FF: Offshore Windparks

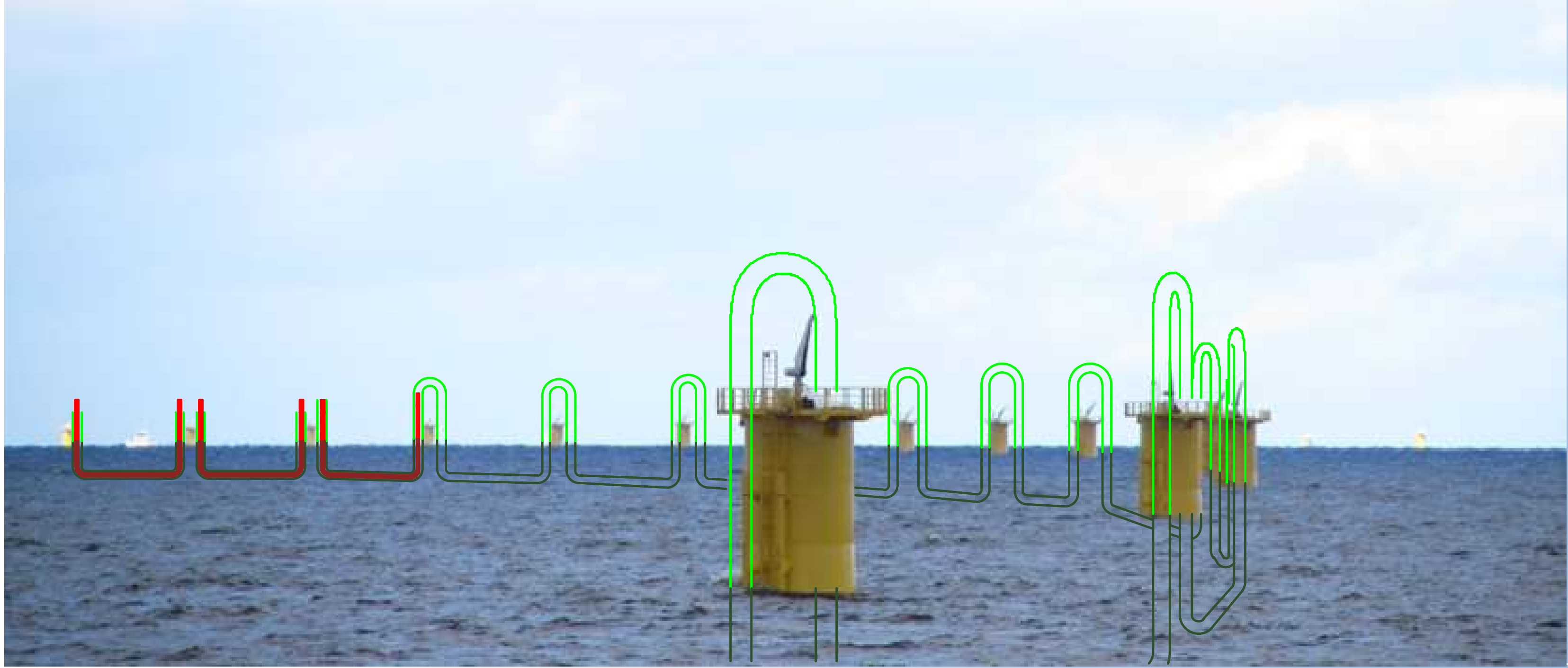
2nd cable FreeFloated



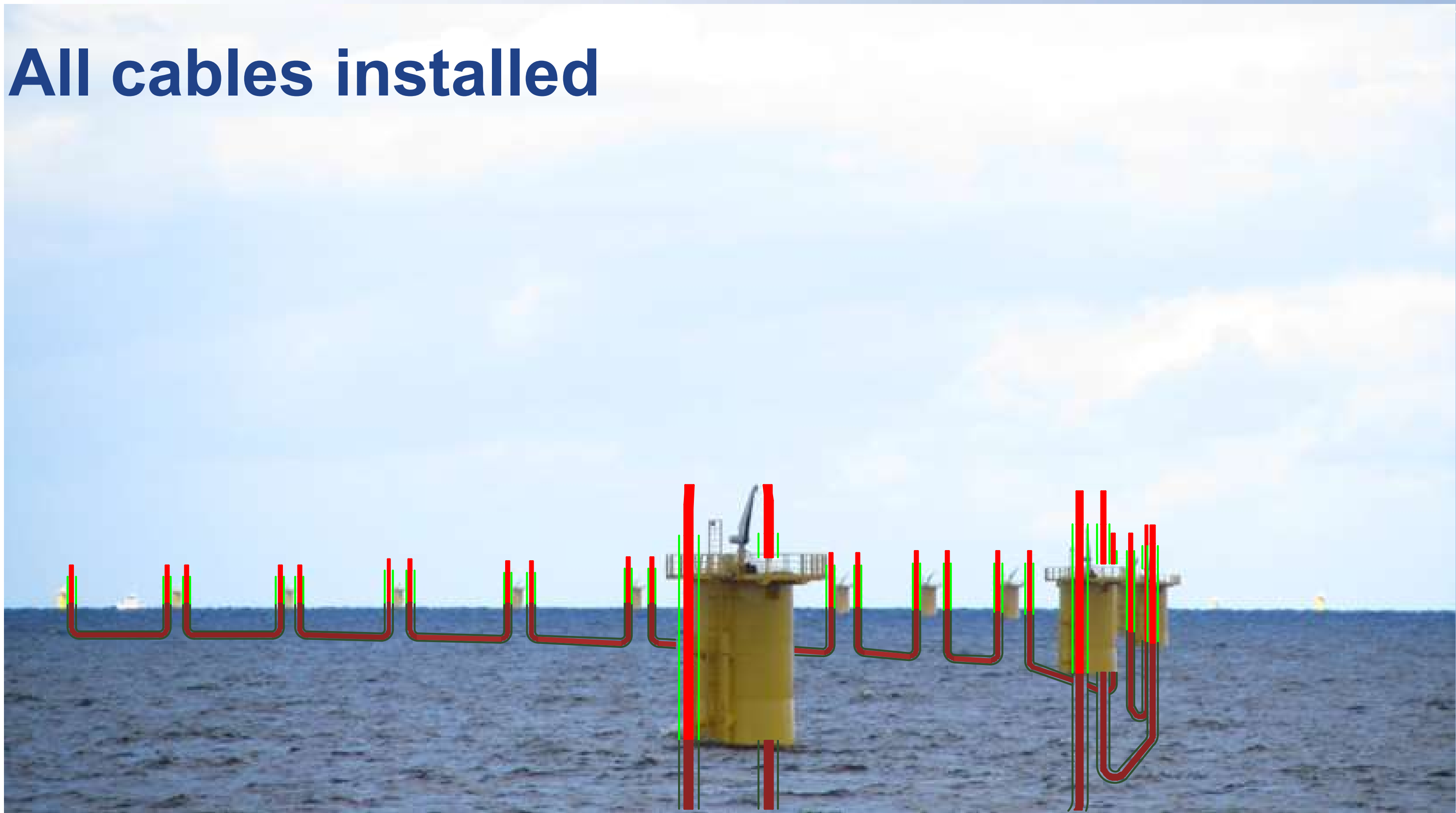
Example FF: Offshore Windparks

2nd cable arrived at destination

3rd cable arrived at destination



Example FF: Offshore Windparks



Example FF: Offshore Windparks

Energy supply can start

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 (380 kV cable):
  - Cable (145 mm, 38 (Cu) or 24 (Al) kg/m, 30000 Nm^2)
  - Duct (250/230 mm, 0.15, 225 mm, 50 m)
  - Trajectory (bend radius 30xOD = 7.5 m)
  - Equipment (18000 N push, 6.4 bar water, 40000 N pull)

Pulling Force Calculation Software

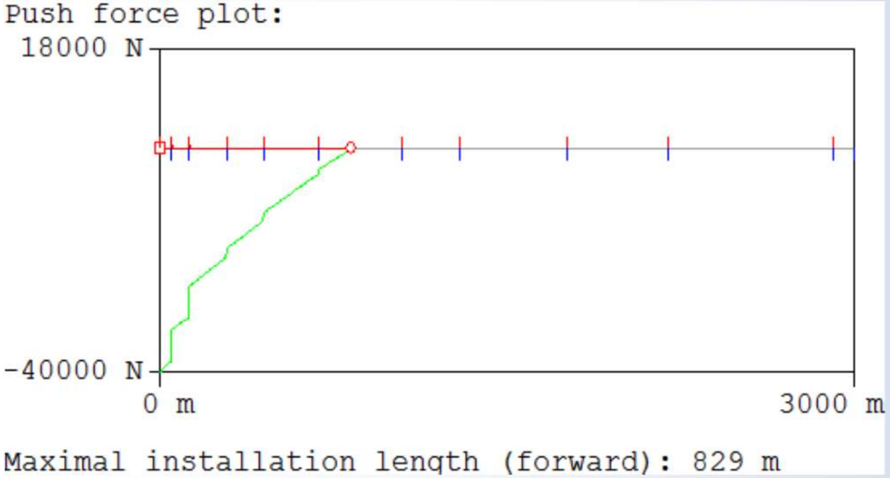
- **Trajectory**

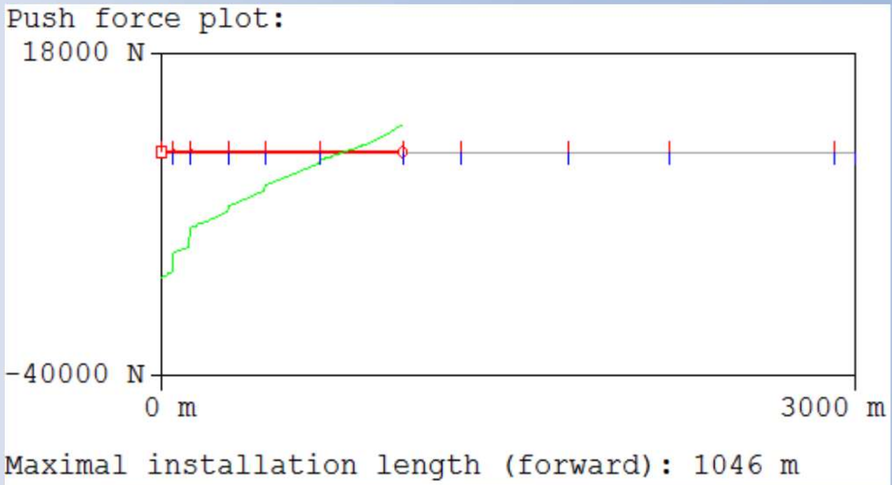
Curves on (m): (radius(m)/angle(deg) in parenthesis)
0(7.50/ 0) 53(7.50/80) 126(7.50/94) 289(7.50/23) 450(7.50/23) 689(7.50/14)
1046(7.50/38) 1298(7.50/28) 1759(7.50/41) 2200(7.50/ 0) 2907(7.50/31)

Slope	from (m)	to (m)	incl. (deg)	end height (m)	Slope	from (m)	to (m)	incl. (deg)	end height (m)
1	0	53	0.00	0	7	1046	1298	0.45	12
2	53	126	-0.78	-1	8	1298	1759	0.00	12
3	126	289	1.05	2	9	1759	2200	0.00	12
4	289	450	1.07	5	10	2200	2907	0.49	18
5	450	689	0.96	9	11	2907	20000	0.00	---
6	689	1046	0.16	10					

Pulling Force Calculation Software

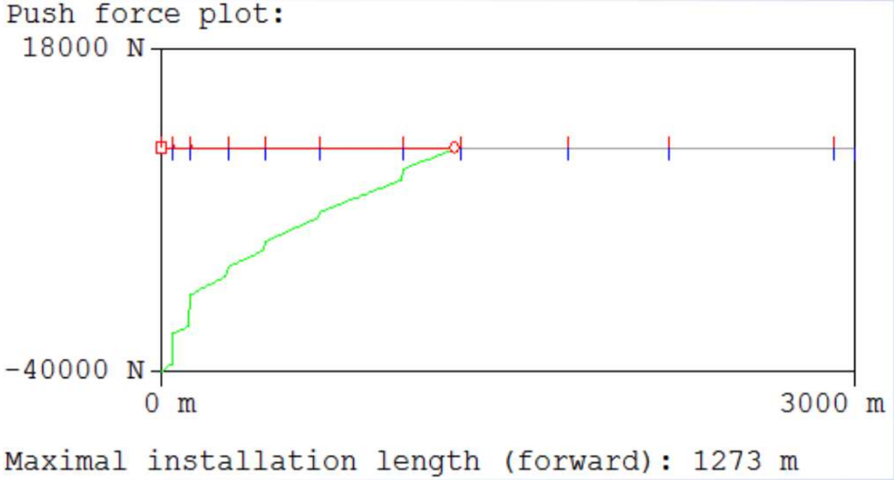
- Copper cable
  - Winch pulling 829 m   WaterPushPulling 1046 m

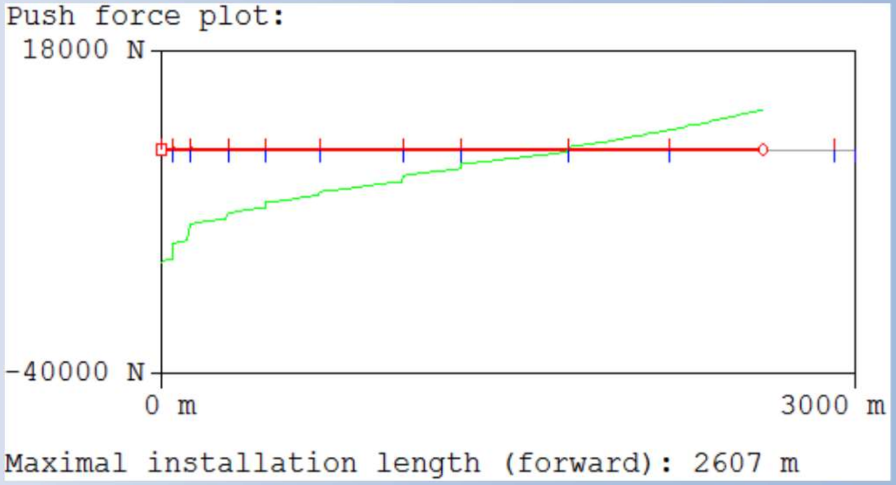




Pulling Force Calculation Software

- Aluminum cable
  - Winch pulling 1273 m   WaterPushPulling 2607 m!





Conclusions

- Cable-in-duct installation techniques presented
- Water Push-Pull and (Free)Floating
  - Less forces, less wear of cable
  - Long lengths possible (especially Al-core cable)
  - Operation from one side, less installation steps
  - More versatility (FreeFloating)
- Several land projects and trials done
- Other land and offshore projects in preparation
- Software that takes all effects into account

PLUMETT

www.plumettaz.com

Thanks for your attention

VISION & PERFORMANCE