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SEERC

Deep Water Power Cable Systems? Indeed!

2-06

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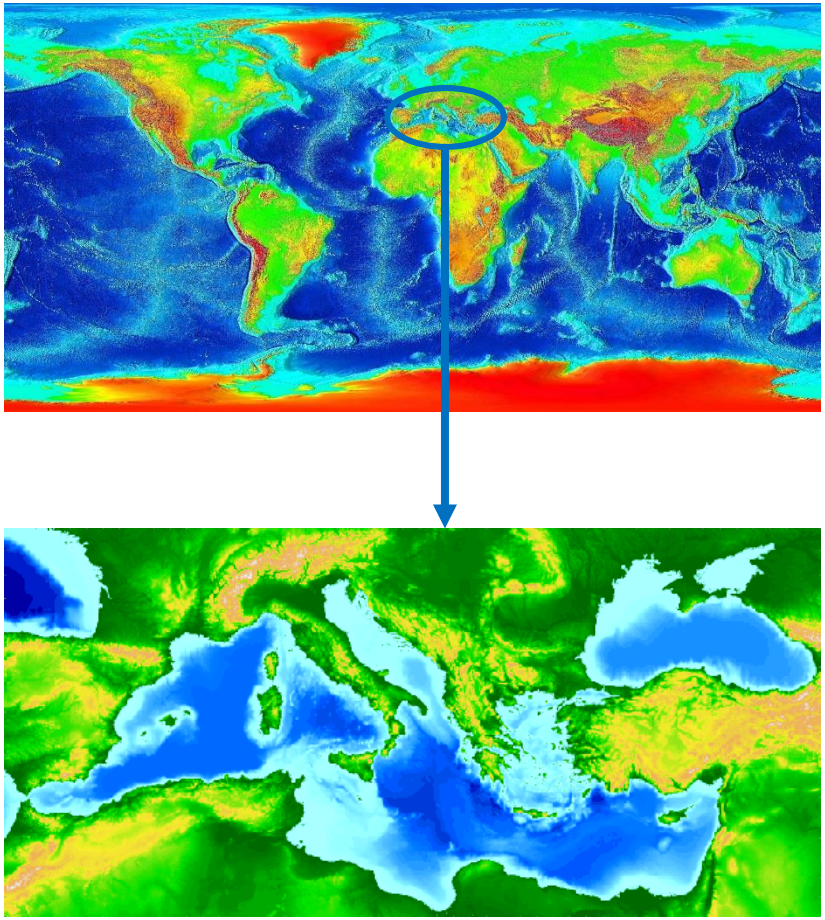
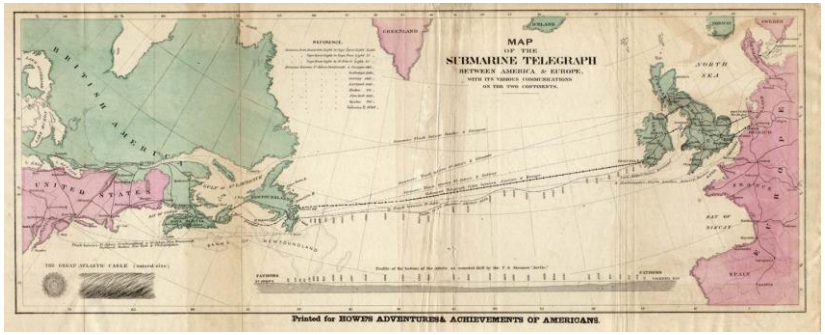
Ocean and sea depths



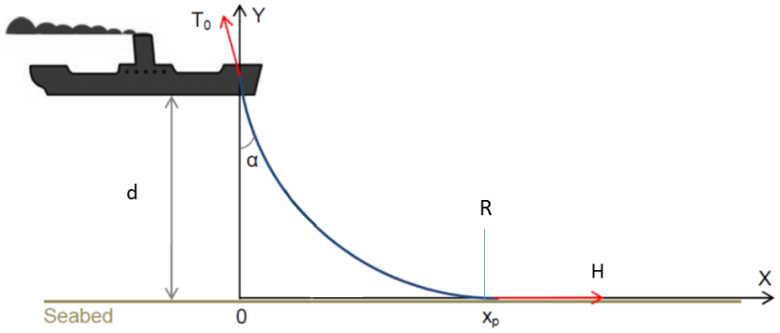
- The average ocean depth is nearly 3,700 meters
- Maximum of 10,994 m (some state 11,034 m) Mariana trench close to Japan and Philippines
- Mediterranean: average depth of 1500 m and deepest 5267 m (Calypso Deep in Ionian Sea)

Transatlantic Telecom cable



- 1858 first message sent
- That early already – so what's the difficulty?
- 550 kg/**km** (!) ≈ 0.5 kg/m
- Power cable ≈ 50 kg/m
- Tension ca. 100 x larger!

Laying a cable



- Catenary length

$$L_0 = d \cdot \sqrt{\left(1 + 2 \cdot \frac{H}{w \cdot d}\right)}$$

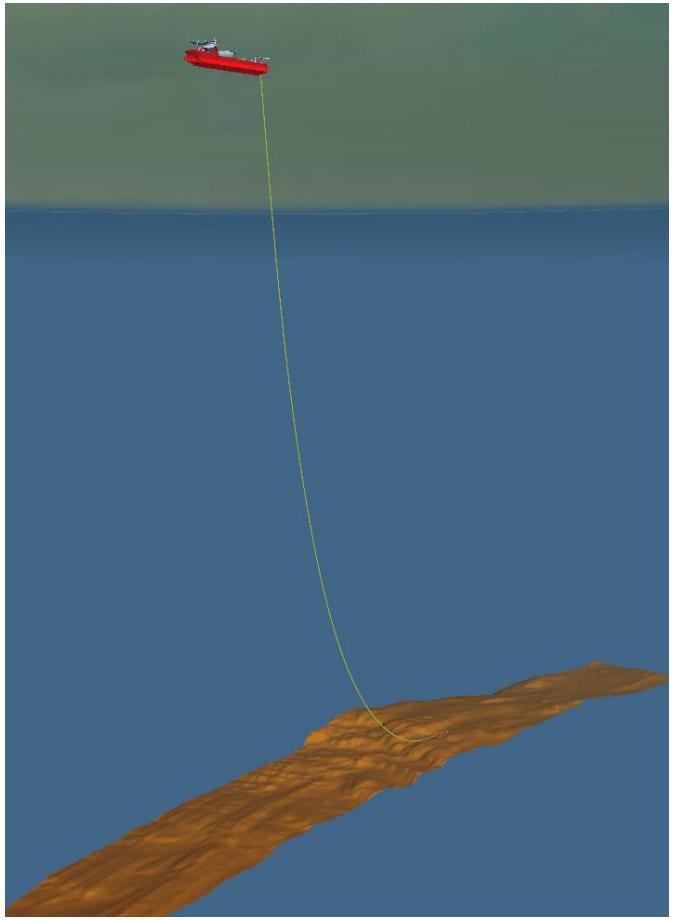
- Tension

$$T_E = w \cdot d + H + D$$

weight

depth

Calculating the dynamic tension



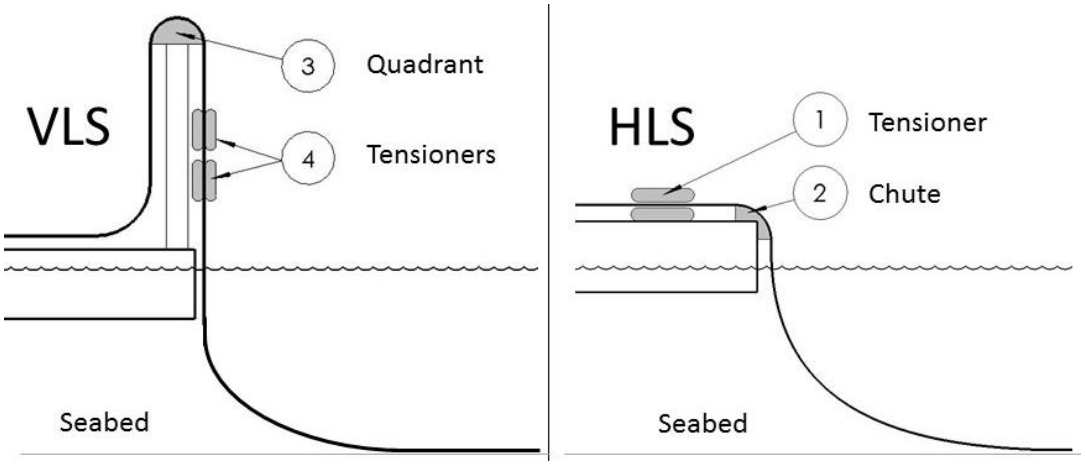
- Using special purpose software
- Or using the equations in TB623
  - $D = \sqrt{D_I^2 + D_D^2}$
  - D_I stands for inertia force
  - D_D stands for drag force

Requirements and challenges

- Tension, side-wall pressure and squeeze forces
- Hydrostatic pressure
- Longitudinal water penetration
- Recovery force

Squeeze force

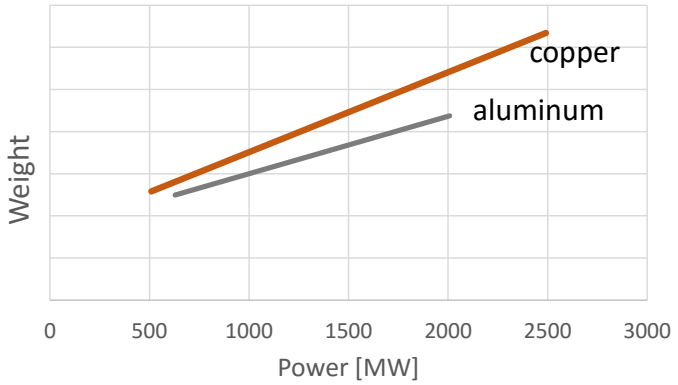
Sidewall pressure



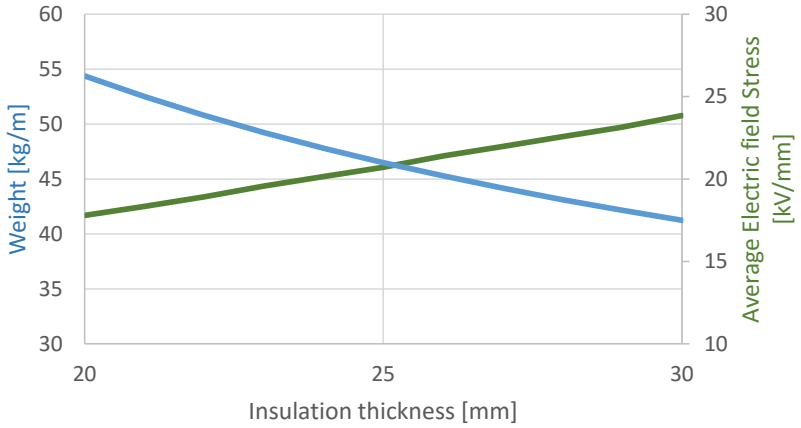
Cable design rules

Larger weight → Larger tension → Smaller depth

- Aluminium vs Copper
  - For same power: lower weight. But lower maximum power



- Insulation thickness
  - Increased electric stress
  - Lower weight



Cable design rules

- More armour makes cable more stiff (*EA*)

$$EA = E_A A_A \cdot \cos^3(\alpha_A) + E_C A_c$$

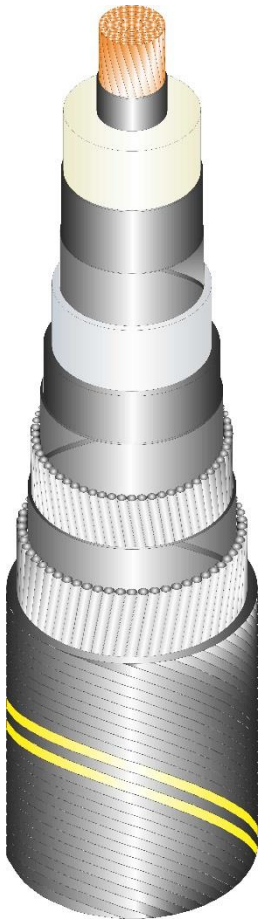
$$\varepsilon = \frac{T}{EA},$$

  - Less strain on conductor (ε)

- But larger weight
  - Increases the tension

$$T_E = w \cdot d + H + D$$

- Gain?



Extruded and MI DC cable

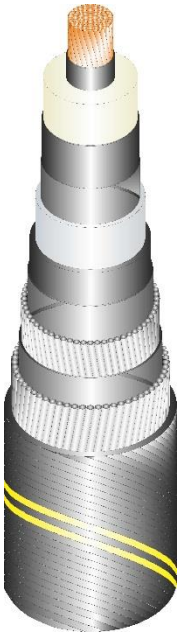
U = 525 kV

P = 1200 MW (pair)

A = 1000 mm^2 Aluminium

W = 49 kg/m

EA = 705 MN



U = 525 kV

P = 1200 MW (pair)

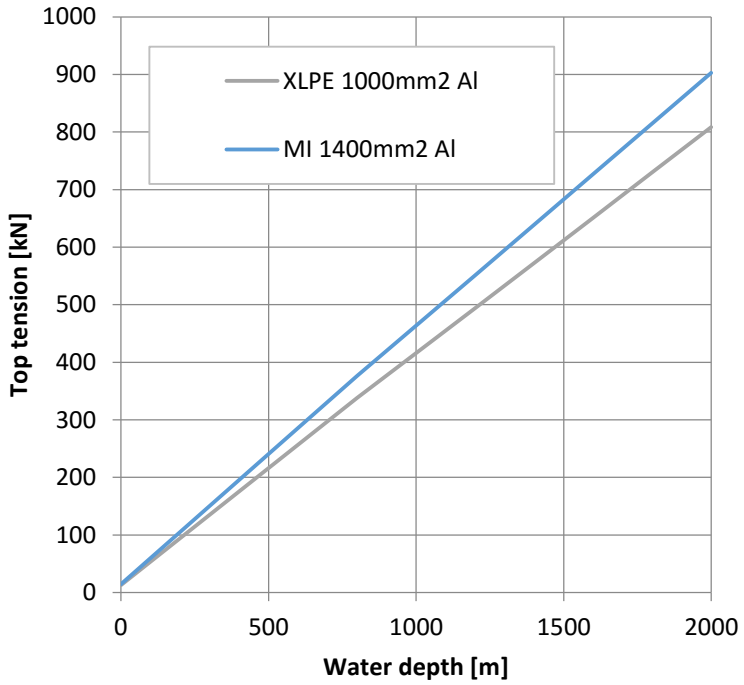
A = 1400 mm2 Aluminium

W = 52 kg/m

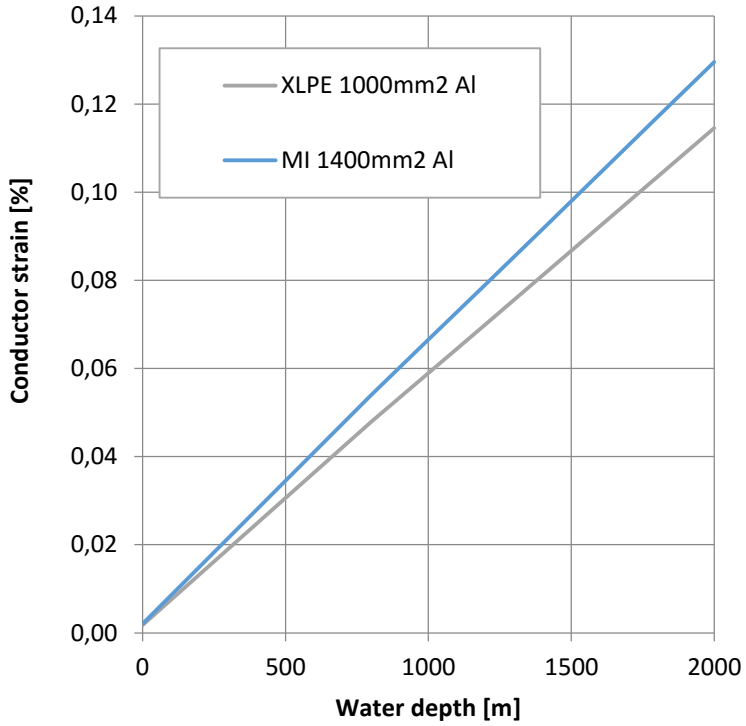
EA = 697 MN

The Comparison

Top tension

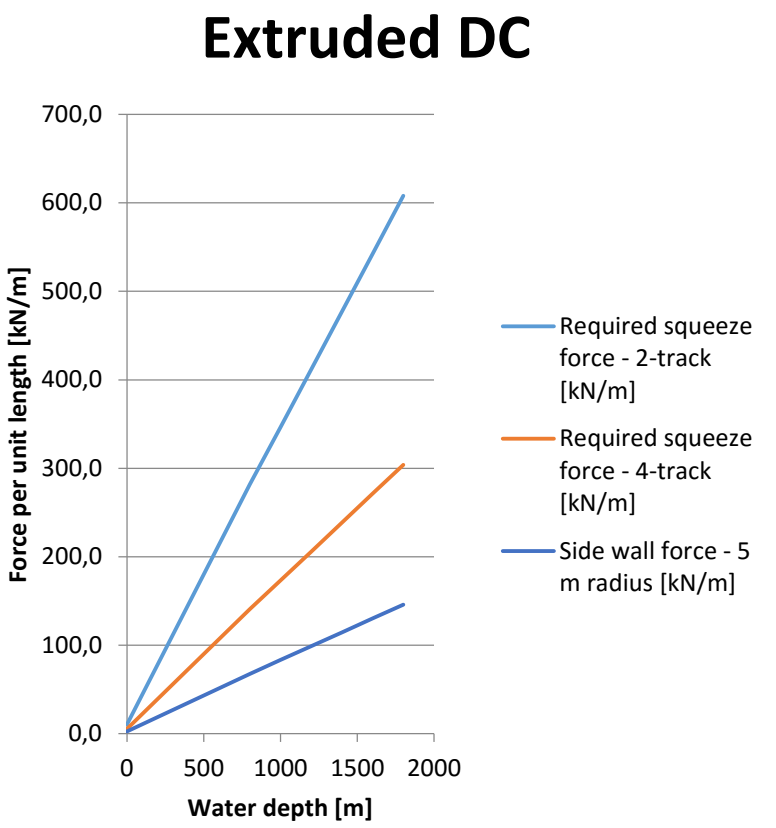


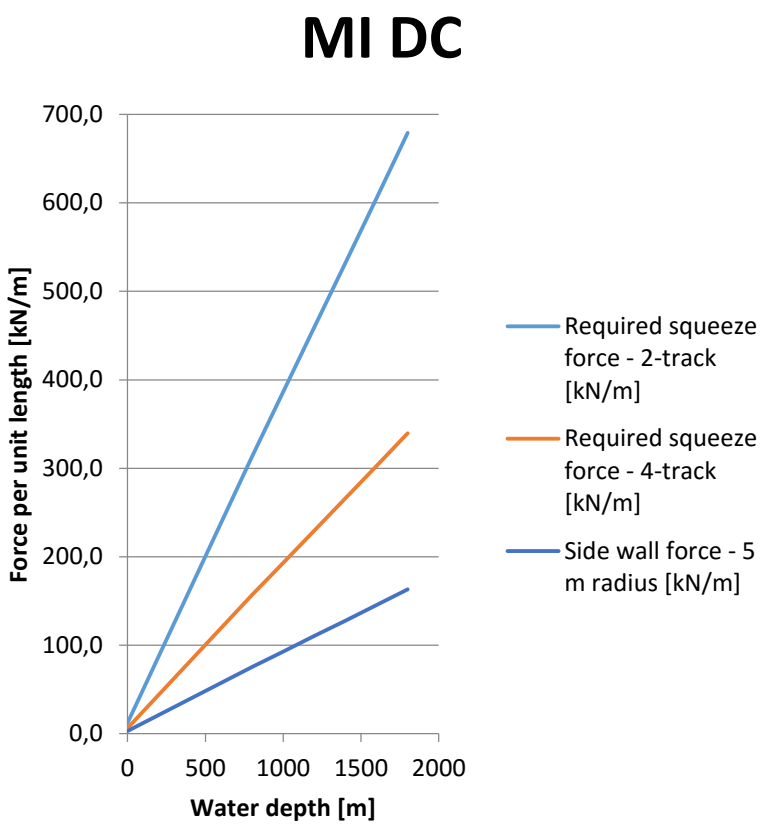
Conductor strain



Quite similar top tension and conductor strain

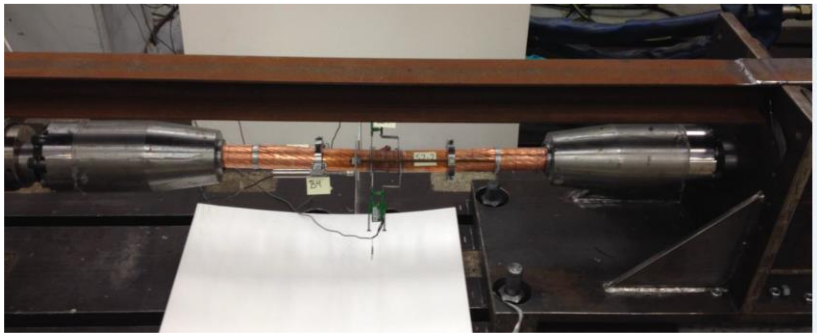
The Comparison





Quite similar squeeze and side wall forces

Tensile test on conductor joints

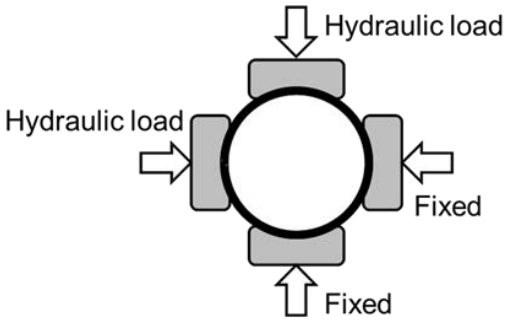


- Conductor joints for deep sea applications are welded
- Heat Affected Zone
- Some annealing → reducing yield stress and tensile strength

- The test result show that Mediterranean depths can be reached

Squeeze test

- Cable tensioned..
- ..and squeezed
- With optical fibre – no significant attenuation
- Electrical test
- Tested at > 500 kN/m



Conductor water penetration test

- Tests up to at least 200 Bar have been performed
- Large cross sections
- With good results

- Mediterranean depths can be reached

Conclusion

- XLPE and MI cables are both suitable for deep water installation
  - Similar top tension, conductor strains, squeeze and side wall forces
- Vertical Laying Systems suitable for extreme depths
  - Avoid Side Wall Pressure
  - Lower recovery force