WHEN TRUST MATTERS

Feasibility of Ultra-long Cable-based HVDC Links

"*How does the use insulated cables instead of overhead lines affect the assumption that HVDC has no practical limit on transmission distance*?"

Cornelis A. Plet, Narasimha R. Boyalla, Cory Liu - ACDC Global 2025, Birmingham

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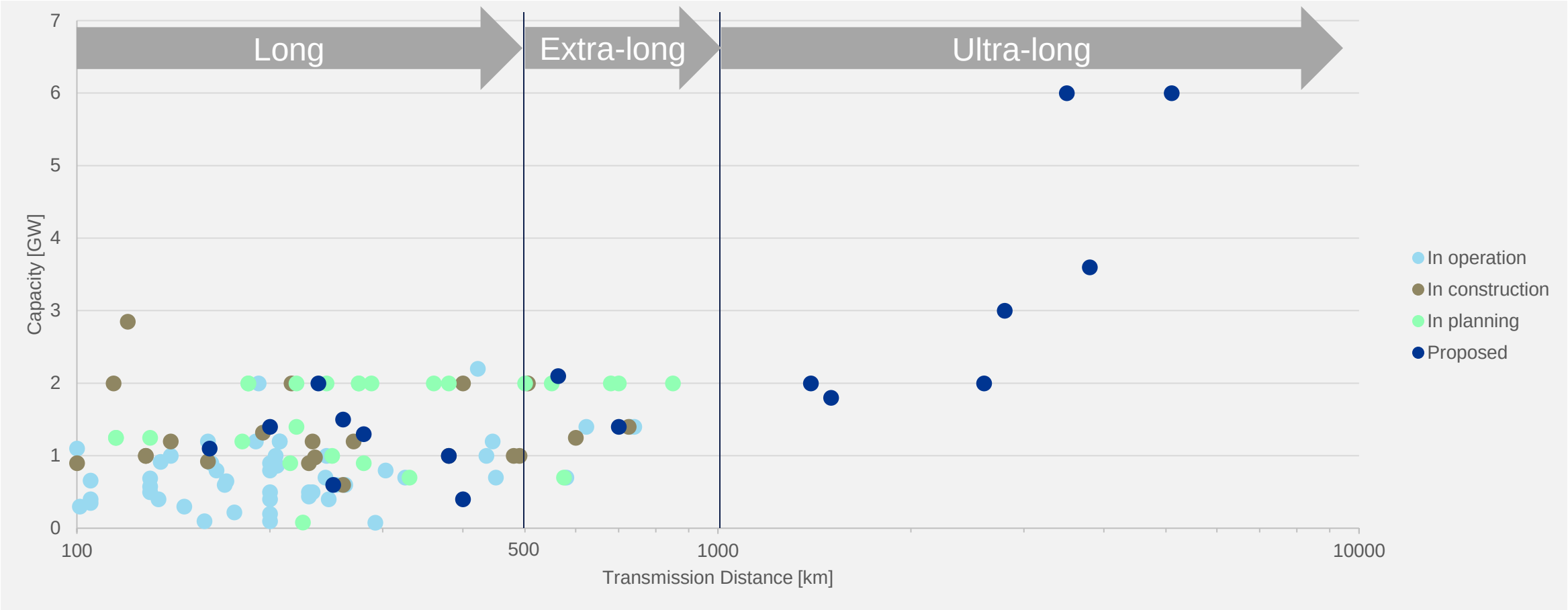
Courtesy of TenneT

The emergence of a new class of HVDC systems




ASC
NATO-L
BSSC
Xlinks
Green
Vein
OSOWOG
AAPowerLink
TasLink
Extra-long (500 – 1000 km)
Ultra-long (>1000 km)

What limits the maximum transmission distance and capacity of HVDC systems?

Overhead lines

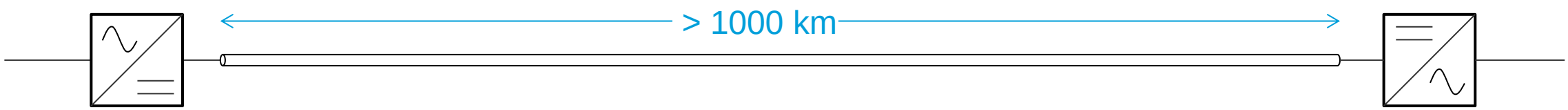
- Voltage rating can be increased relatively easy by increasing insulator length
  - 1100 kV systems in operation in China
- Current rating can be increased relatively easily by adding more conductors in a bundle

Insulated power cables have limited ratings:

- Limited voltage rating due to maximum produceable insulation thickness and material insulation strength
- Limited current rating due to maximum produceable conductor diameter and material operating temperature

Courtesy of TenneT

What factors are affected by increasing cable length?



- Impact on HVDC system design
  - Increasing cable voltage drop
    - Limit imposed by transformer tap range
    - Limit imposed by transformer tap changer speed
  - Increasing pre-insertion resistor rating
  - Converter control
  - Potential excessive overvoltages in cables?
- Impact on cable monitoring
- Increasing losses
- Decreasing availability
  - Topology
  - Increasing failure rate
  - Increasing repair time
    - Fault locating
    - Impact on testing
- Increasing manufacturing time
- Impact on procurement

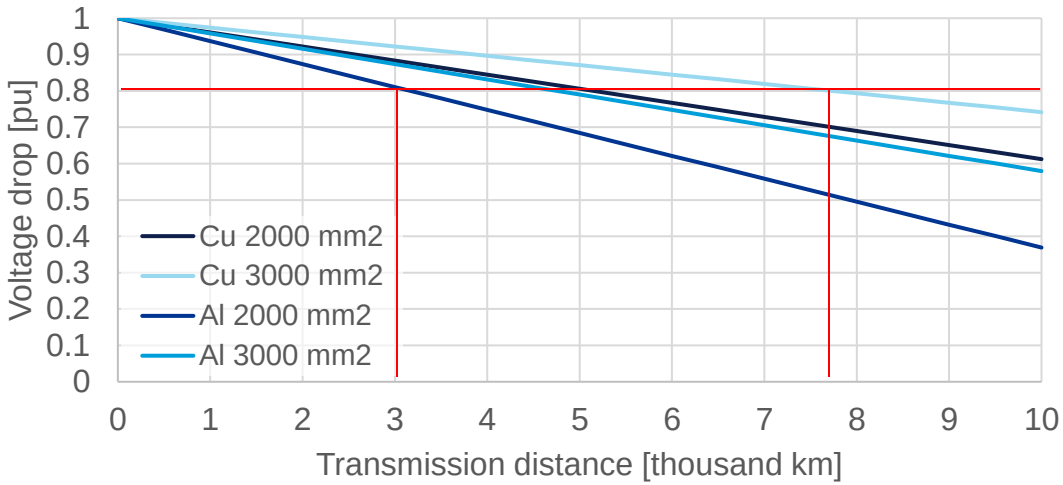
DC voltage drop increases with cable length and impacts interface transformer tap changer design

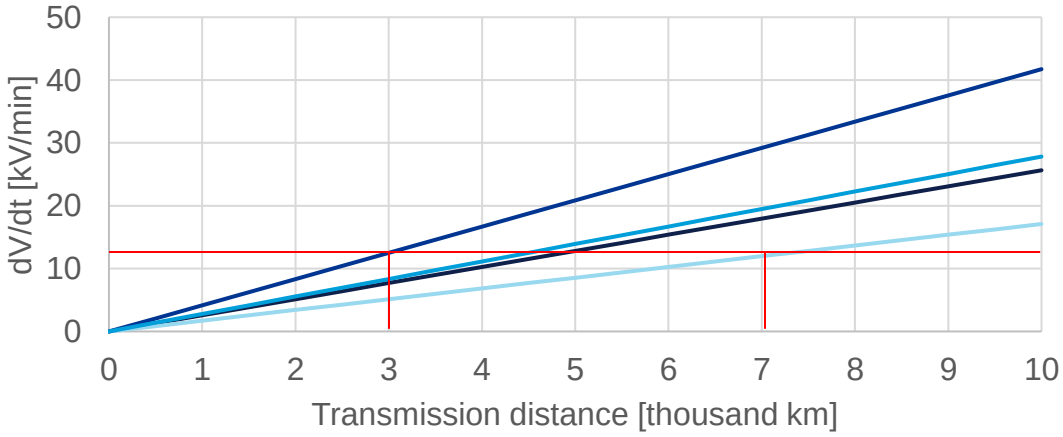
Steady state:

- Requires larger tap range on interface transformers
- Maximum tap range of commercially available transformers is 40%
- This equates to ~20% of DC voltage drop
- Depending on cable conductor type for a 500 kV system, this happens at 3000 ~ 7500 km

Dynamic:

- Variable loading leads to dv/dt which increases with cable length
- If dv/dt exceeds tap changer speed, additional control considerations such as ramp rate limits are needed

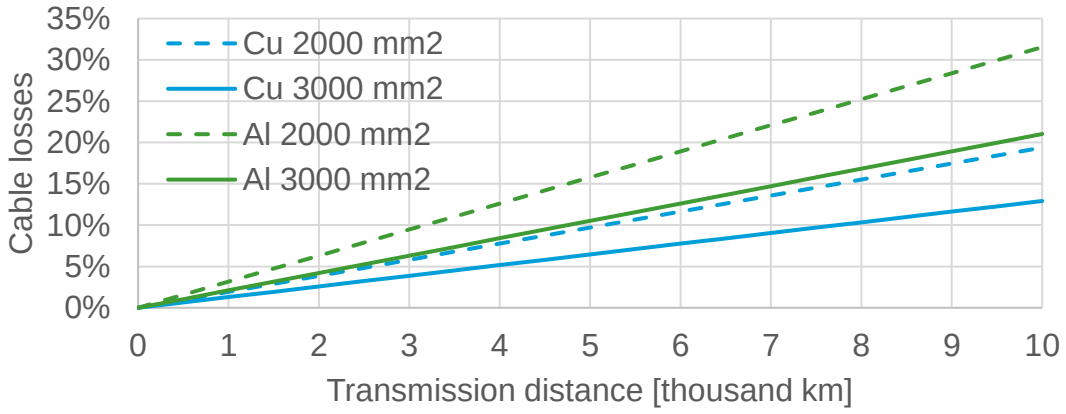




Performance decreases with cable length

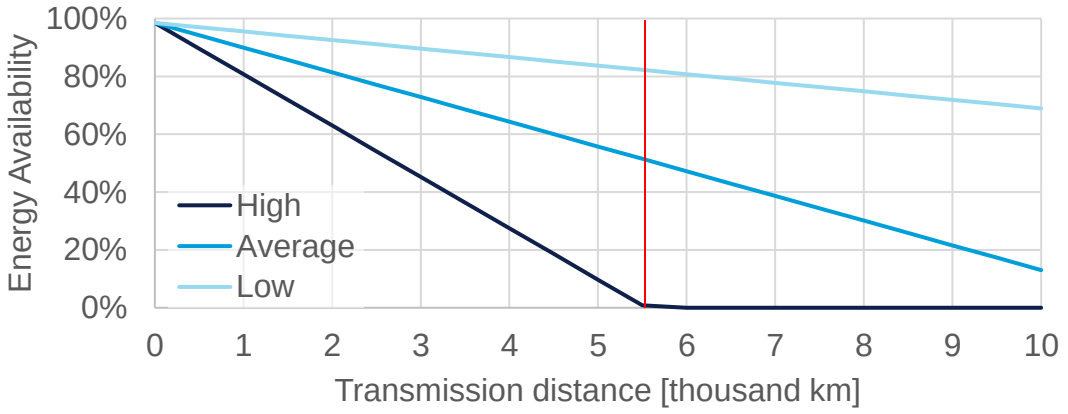
Increased cable losses

- Can be substantial at longer distances e.g. 5 – 13% at 4000 km
- Strongly depends on conductor size and material
- Must be appropriately modelled in business case



Decreased energy availability

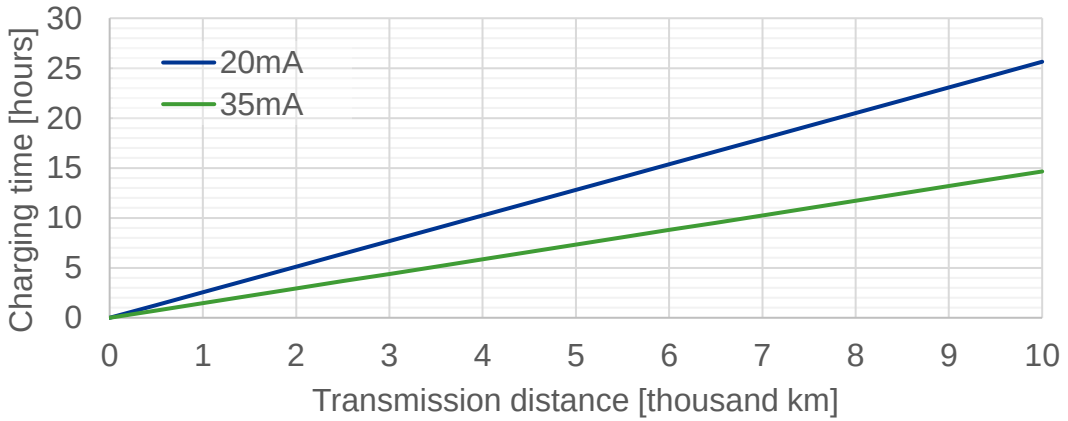
- Longer cables mean higher failure rates, longer repair times and thus higher annual outage times
- Worst case values used by OFGEM result in 0% availability at 5500 km length
- May become prohibitive at shorter lengths
- Must be appropriately modelled in business case



Testing & production time

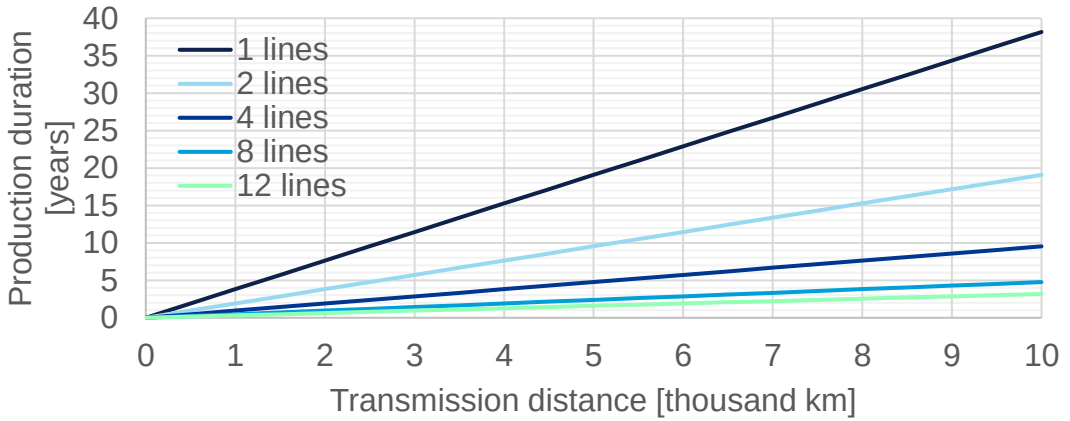
Cable testing time

- Longer cable lengths lead to higher cable capacitance
- Longer charging times for DC cable testing after installation or after repair
- Can be done with existing DC test sources within reasonable time



Production time

- Assuming extrusion speed of 1 min/m
- Production time of ultra-long cables runs into multiple years, even with multiple extrusion lines
- Most likely, multiple vendors are needed to complete production in reasonable project time
- Additional technology qualification required



Conclusion: Worthy of further consideration

- Ultra-long cable based HVDC systems of more than 1000 km length are being proposed
- No fundamental red flags from an HVDC system design perspective
- After 3000 km, the DC voltage drop across the cable can exceed capabilities of commercially available tap changers
- Choice of cable conductor type is of key importance in determining feasible length
- Economic impact of HVDC system performance must be adequately modelled in feasibility study
  - Losses become substantial but are very predictable
  - Energy unavailability can be become prohibitive, will require intentional cable protection, and cable QA/QC
- Cable production will require more extrusion lines than most factories/vendors offer to complete within reasonable project time.
  - Multi-vendor solutions and increased qualification requirements

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