Electricity Infrastructure Workshop
Is 380 kV Underground Cable an option?

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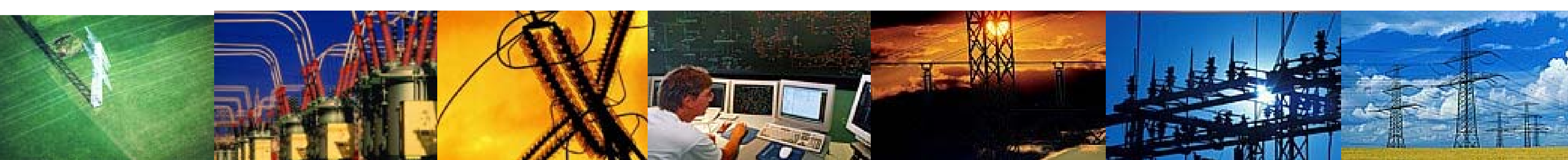


Introduction

- Communication of the European Commission of January 10th 2007:

  “Priority Interconnection Action Plan”

  Under the heading “Urgent action needed” , the Commission points out:

  “Amounts invested in cross-border infrastructure in Europe appear dramatically low. Only € 200 million yearly is invested in electricity grids with as a main driver, the increase of cross-border transmission capacity”. This only represents 5 % of transmission investment…….”

- The TSO presentations given this morning clearly pointed to the main problem relating to transmission investment, and particularly cross-border investment: the difficulty to obtain the necessary planning consents and authorisations.

- Financing difficulties in a stable and attractive regulated framework should not be, and up to now, are not the main obstacle - except in some cases, which are situated at the periphery of the European system.

- So, to what extent is underground cable (UGC) a solution to the problem ?

HV UGC Technologies

- Extruded Cable System
  - XLPE: Cross-linked Polyethylene cables are currently available up to 400 kV AC.
- Oil Filled Cables
  - With diminishing market share in new AC cable markets
- Gas-Insulated Transmission Systems and High-Temperature superconductor technology
  - Relatively immature technology for EHV transmission and currently have limited application

Madrid Airport: 13 km of 400 kV cables

Technical aspects of HV UGC

Some basic engineering issues need to be highlighted regarding 400 kV AC cables:

1. 400 kV cables are inherently huge capacitors; the capacitive charging current imposes a constraint on the effective application of cables in AC transmission systems
2. The strong capacitive behavior causes voltage deviations, especially in unloaded situations (e.g. when switching), which limits manageable application to relatively short distances.
3. The integration of these characteristics in the existing grid may lead to transient overvoltages and resonance effects, jeopardizing the system reliability.

Capacitive charging of 400 kV UGC

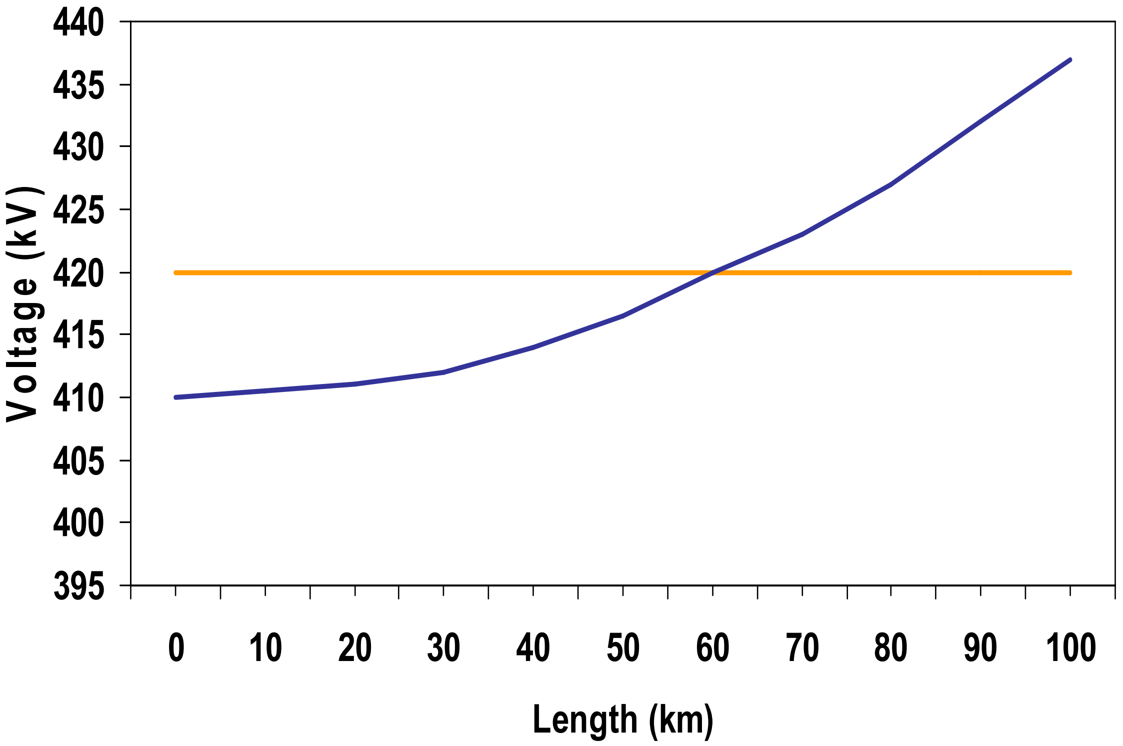
- Typical capacitive charge of a 400 kV UGC:
  - 20 MVAR per kilometer,
  - versus typically 0,5 MVAR/km for OHL
- This means for a 40 km section:
  - Capacitive charge of 40*20 = 800 MVAR
- When considering lengths > 40 km:
  - Capacitive load becomes prohibitive and significantly reduces available transmission capacity.

Voltage control with 400 kV UGC

Voltage at the end of an unloaded 380kV cable, as a function of its length

The figure clearly illustrates that the open-end voltage reaches unacceptable values for distances exceeding 40km.

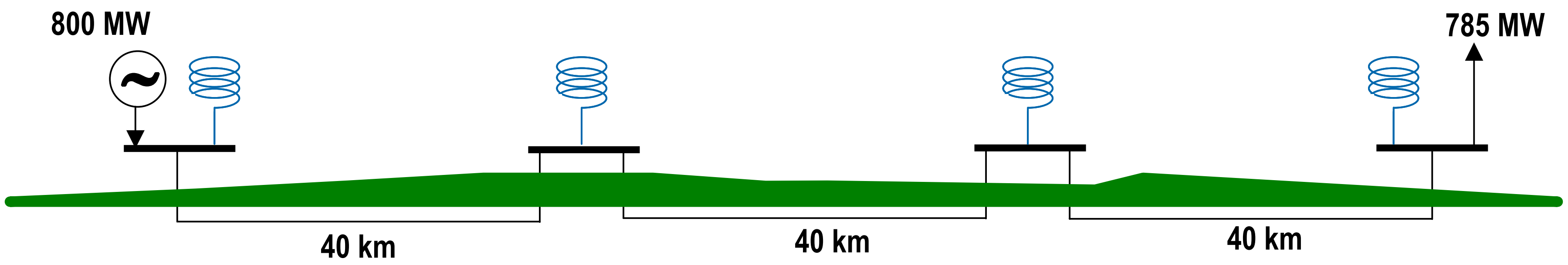
The sending end voltage of 410 kV actually may occur in substations.



HV UGC for longer distances ?

For a distance of (say) 120 km, the following compensated and purely theoretical solution could be put forward:

- Max length of cable sections = 40 km



Studies have indicated that such a scheme would cause severe transient overvoltages, seriously jeopardizing the grid reliability.

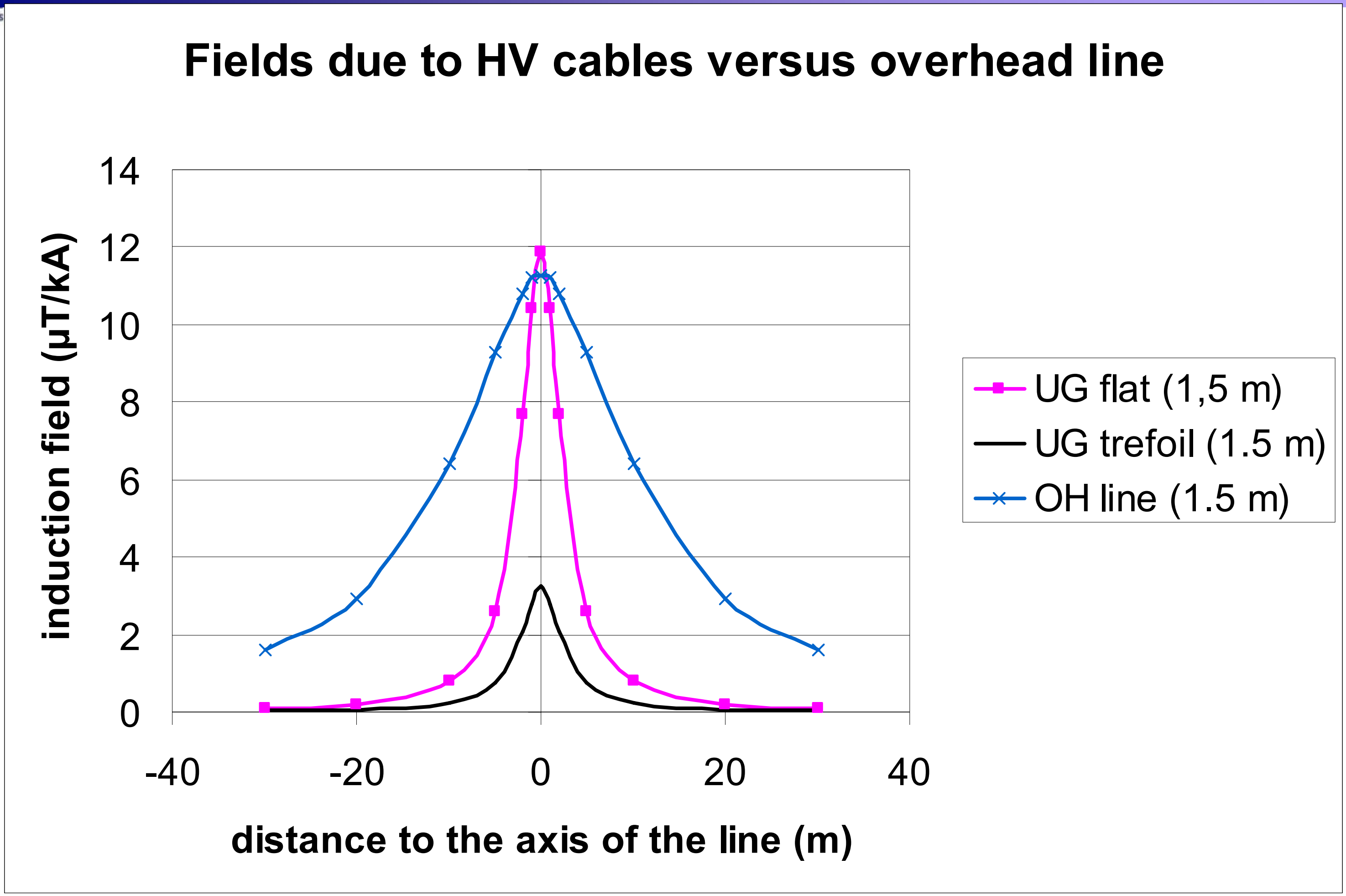
➔ **The remaining underground options for distances > 40 km are:**

- **High Voltage Direct Current (HVDC)**
- **Lower voltages (e.g. 220 kV), with cable capacities of 400 - 500 MVA**

Other aspects of HV UGC

- **Routing:**
  - The route must be kept free of construction or rooted trees above and along the cable route, right-of-way width proportional to capacity : 1.5 to 2 m per 1000 MVA.
  - Tunneling solutions may be necessary, e.g. in mountainous areas or in cities.
- **Operations and maintenance:**
  - Even though fault rate is lower for UGC than overhead lines (OHL), it is more difficult to locate a fault along the cable
  - Repair time for UGC is longer (more than 20 x) if compared to OHL and this causes longer period of outages, with repercussion to cross-border flows and Security of Supply
  - Decommissioning of UGC is more difficult and expensive
- **Costs:**
  - Typically, overall cost will be higher by a factor 8 to 15 for same capacity, depending on local situation and system constraints, and even > 15 in cases with tunneling.
- **Electro magnetic fields (EMF)**

EMF



Typical field levels at 1.5 m above ground for a 400 kV overhead line compared with a 400 kV underground cable

Conclusion

- 400 kV AC UGC is a valuable but costly solution.

  For technical reasons, its use is limited to particular situations, and most cost effectively considered as providing the **"missing link"** in optimum overhead route planning, with lengths to max 40 km (depending on local system conditions and constraints, this max limit may have to be be lowered).

- For longer distances and loads exceeding 400 - 500 MW, HVDC is the remaining underground option.
  - May be the natural choice in specific cases like sea crossings, large offshore non synchronous grids;
  - for onshore:
    - if justified by economic benefit vs impact on environmental and visual amenity.

      or
    - as last resort for improving security of supply.

⇨ TSOs are ready to explore and implement all viable options, provided they are supported by a stable and attractive regulatory framework, based on sound economic principles or energy policy.

THANK YOU

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