Study Committee C1

POWER SYSTEM DEVELOPMENT AND ECONOMICS

Paper C1-ID10807-2022

Determining optimal technical solutions for new EHV transmission lines (OHL/UGC) in an early project stage

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Motivation

Source: elia, Belgium

- Increasing application of AC underground cables (UGC) in European extra high voltage (EHV) transmission grid
- Different technical behaviour of UGC than overhead lines → emergence/amplification of technical phenomena
- What are the most limiting technical hurdles to UGC integration? Is there a maximum cable hosting capacity?

Method/Approach

Identifying technical hurdles

- <u>Reactive power</u>: critical, but manageable
- <u>Voltage stability</u>: critical, but manageable
- <u>Temporary overloading</u>: critical for planning
- <u>Resonance</u>: most critical
- <u>Switching phenomenon</u>: not critical

KPIs: Key Performance Indicators

KPI defined for
- reactive power management
- resonance phenomena
- temporary overload management

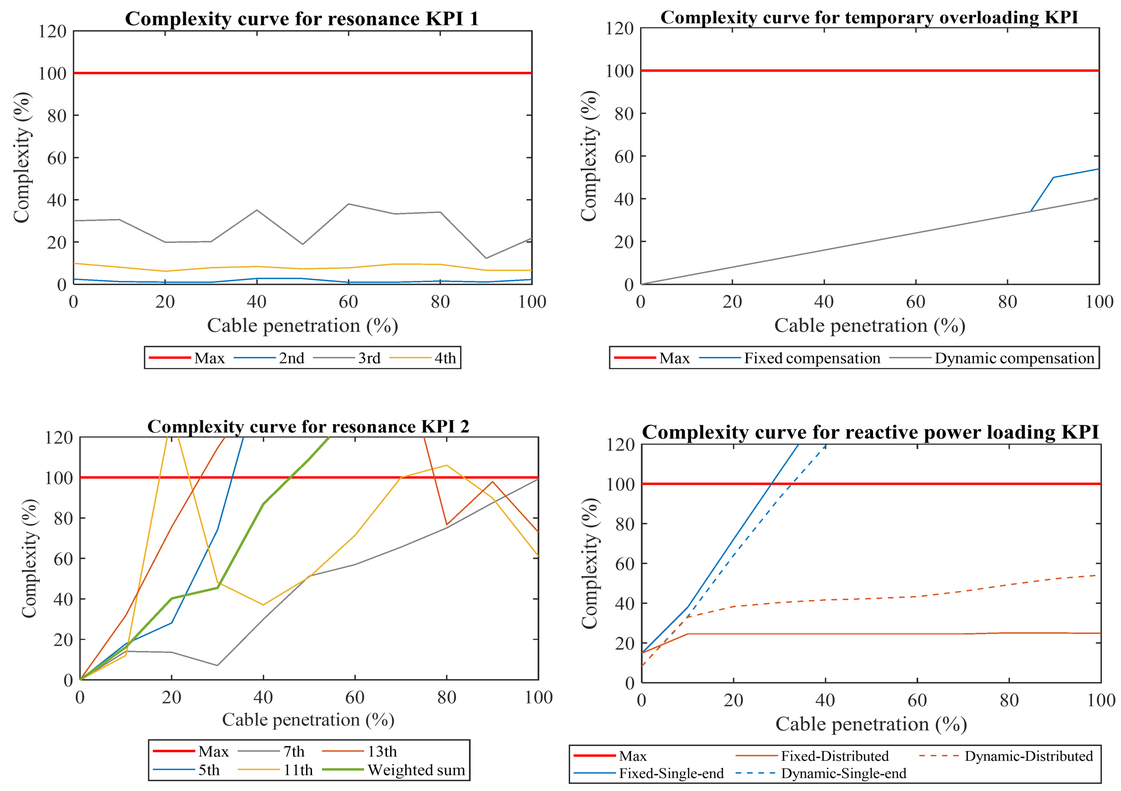
Cable Hosting Capacity (CHC)

CHC as function of complexity

$$Complexity = \sum_i w_i * KPI_i$$

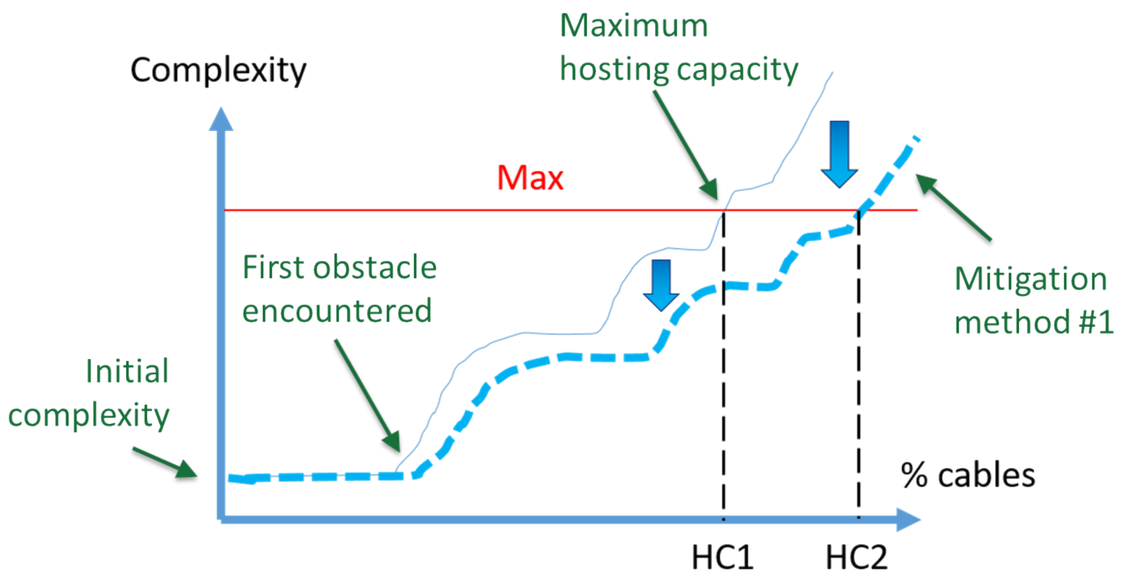
where i = KPI index, w_i = weighting factor of i^{th} KPI

Case Study and Discussion: Cable Hosting Capacity of EHV Grid



- Reactive power management KPIs based on steady-state voltages and reactive power flows
- Different types of compensation (fixed/dynamic) and schemes investigated
- Increased complexity with non-distributed compensation
- Temporary overload management KPI does not limit UGC length
- Resonance KPI 1 based on harmonic self-impedance; KPI 2 based on harmonic background amplification
- Resonance KPI 2 limits UGC to 45% of total length

Cable Hosting Capacity (CHC)



Conclusion

- Proposed methodology is a systematic and holistic approach to determine cable hosting capacity
- Reactive power management not limiting but trade-off between cost and operational efficiency
- Temporary overloading – no significant impact on the grid
- Risks due to resonances challenging to quantify; cable length limited due to harmonic spread
- Practically, methodology useful to identify a safe amount of cables for different locations/grid

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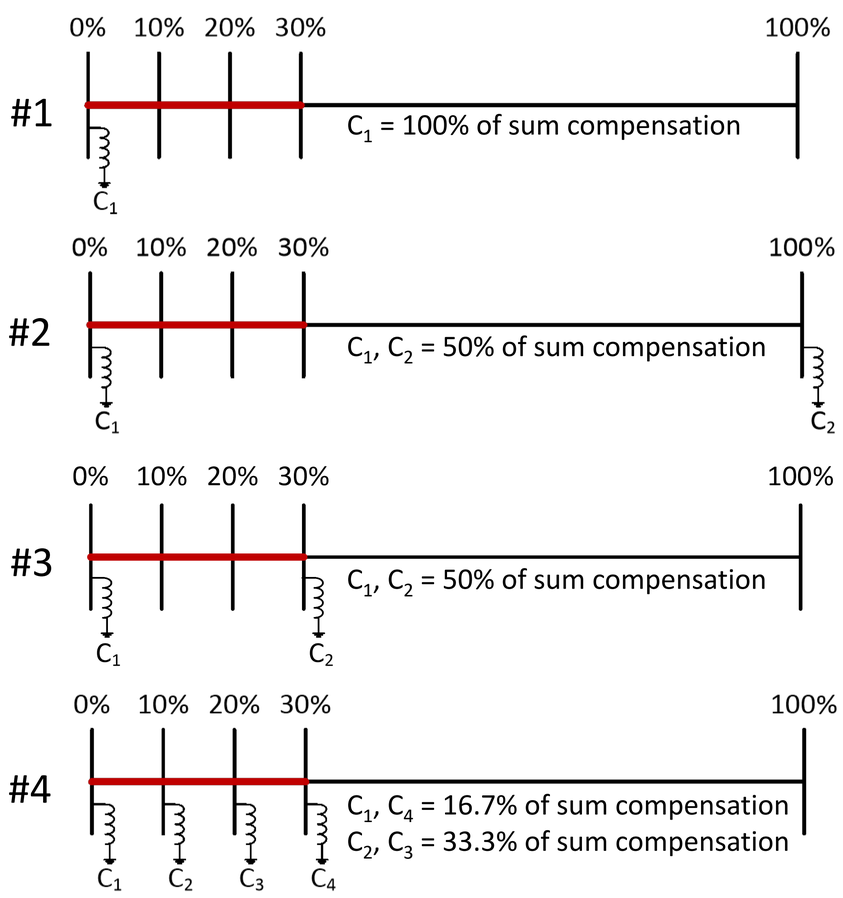
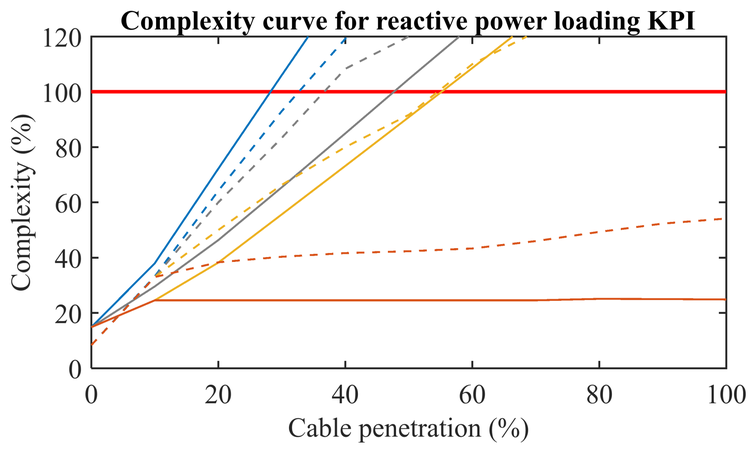
Reactive Power Compensation

- Fixed and dynamic compensation, 4 different schemes

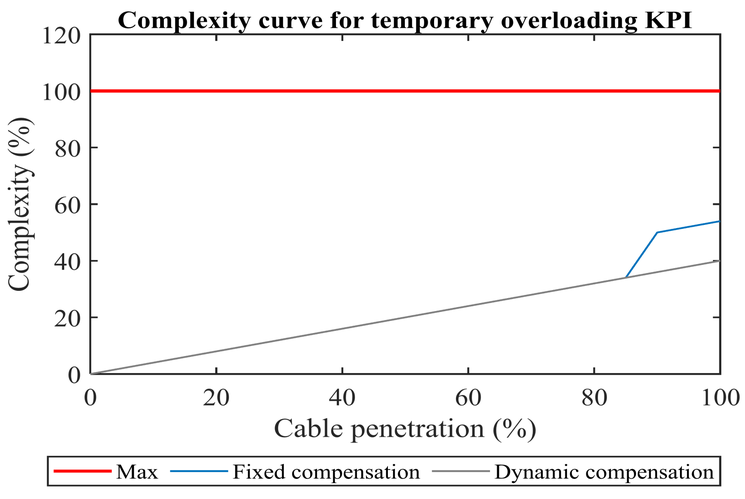


Reactive Power KPI



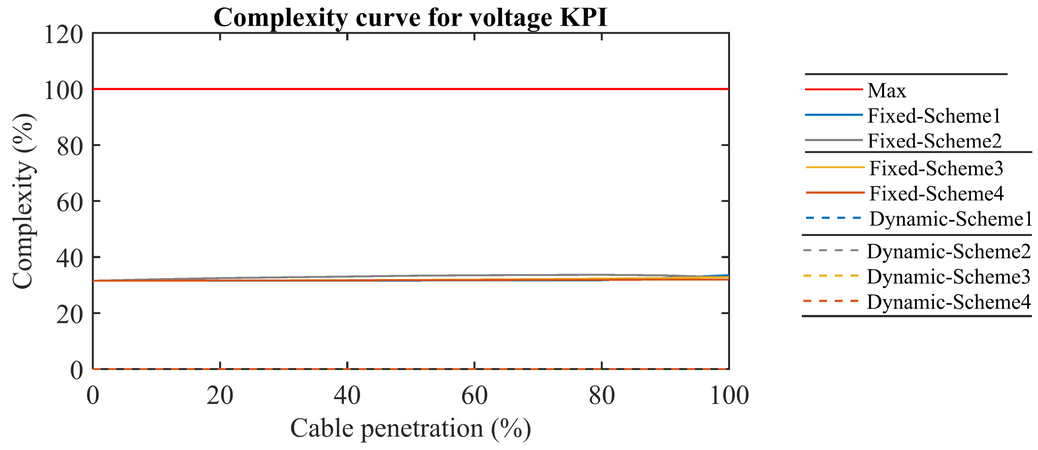
- 100% complexity: 95th percentile of reactive power >30 % of total line rating

Temporary Overloading KPI



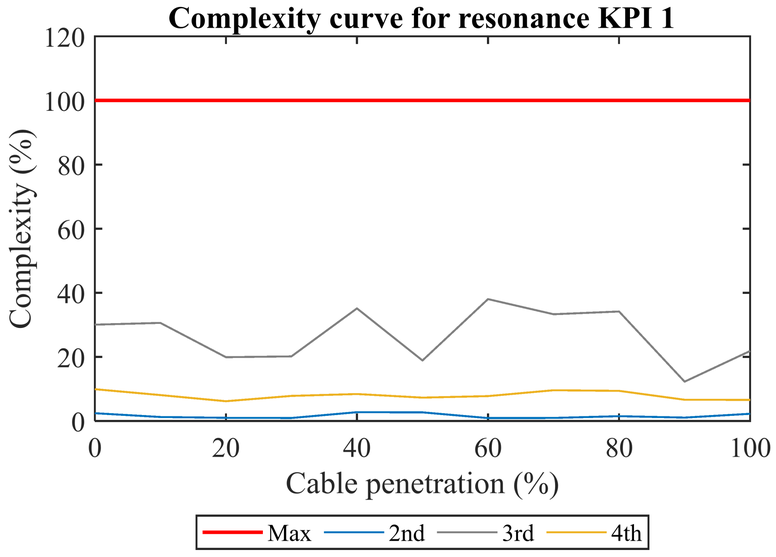
- Max. / Average active power line loading in n-1 situations
- Temporary overload limit: 120% nominal line rating

Voltage KPI



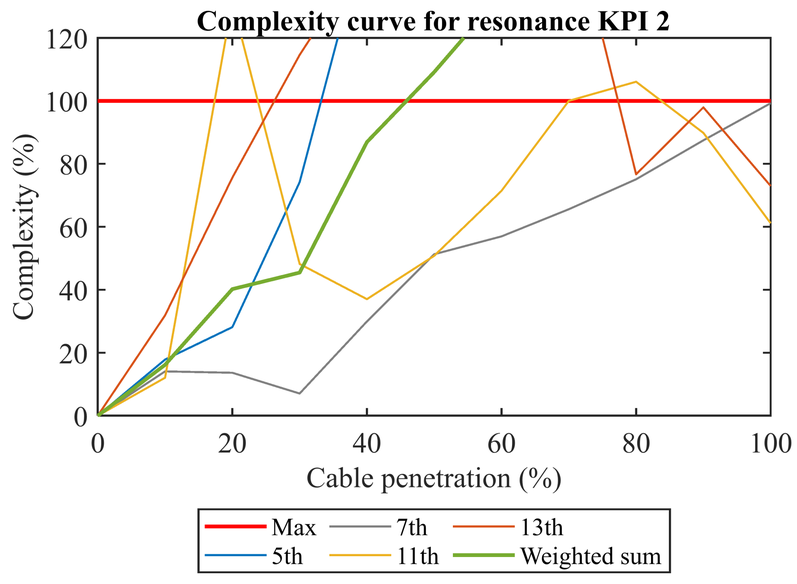
- Limits: 0.9 – 1.1 pu of nominal voltage
- $CC_{voltage} = 0.1(U_{min} + U_{median} + U_{max}) + 0.7U_{limit}$

Resonance KPI 1



- High self-impedance 2nd, 3rd, 4th harmonic range at any substation
- Limits: 400 Ω, 600 Ω, 2500 Ω for 100 Hz, 150 Hz, 200 Hz (from literature)

Resonance KPI 2



- High background harmonic amplification for 5th, 7th, 11th and 13th harmonic at any substation
- Limit: 2 pu gain from original harmonic waveform

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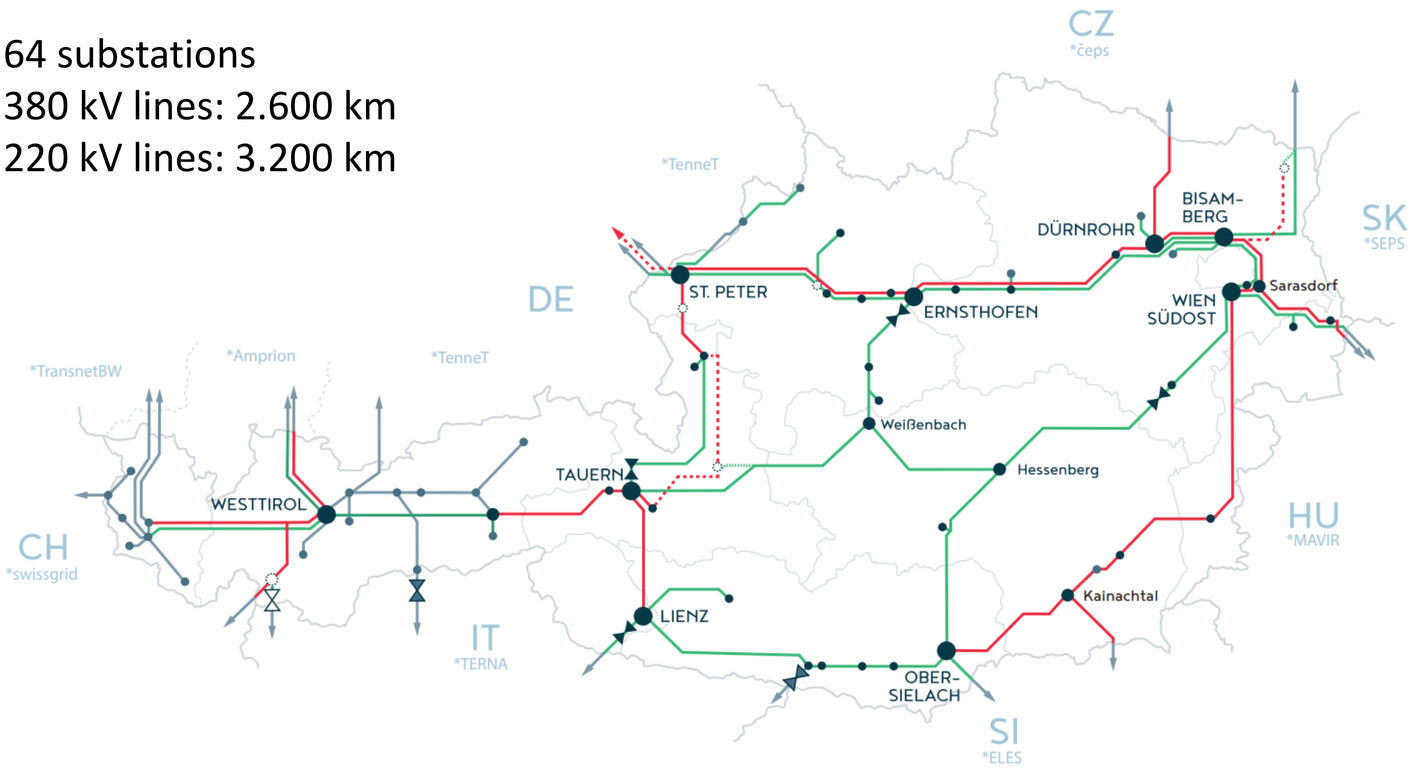
Test Grid / Study Case

- Derived from Austrian transmission system

  64 substations
  380 kV lines: 2.600 km
  220 kV lines: 3.200 km



- Study Case: cable application in 4 lines
- Different load scenarios