



Research of conversion of HVAC overhead transmission lines to HVDC and obstacles in the conversion process

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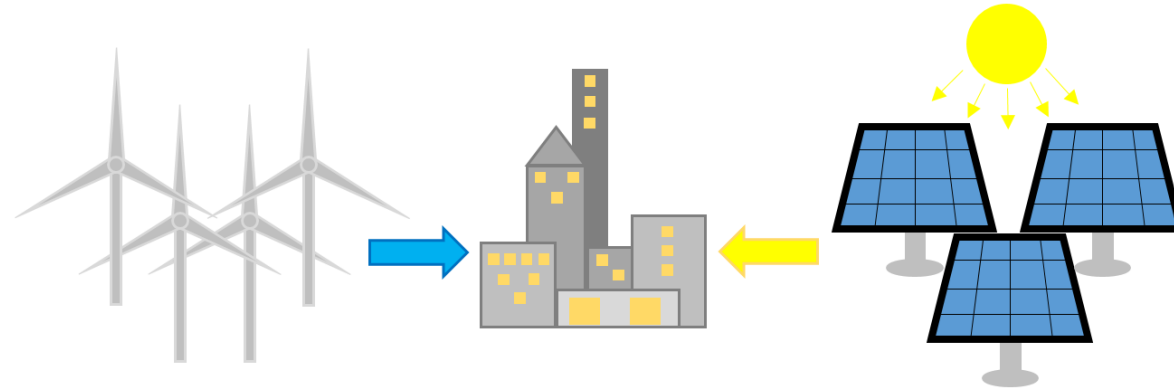
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Agenda

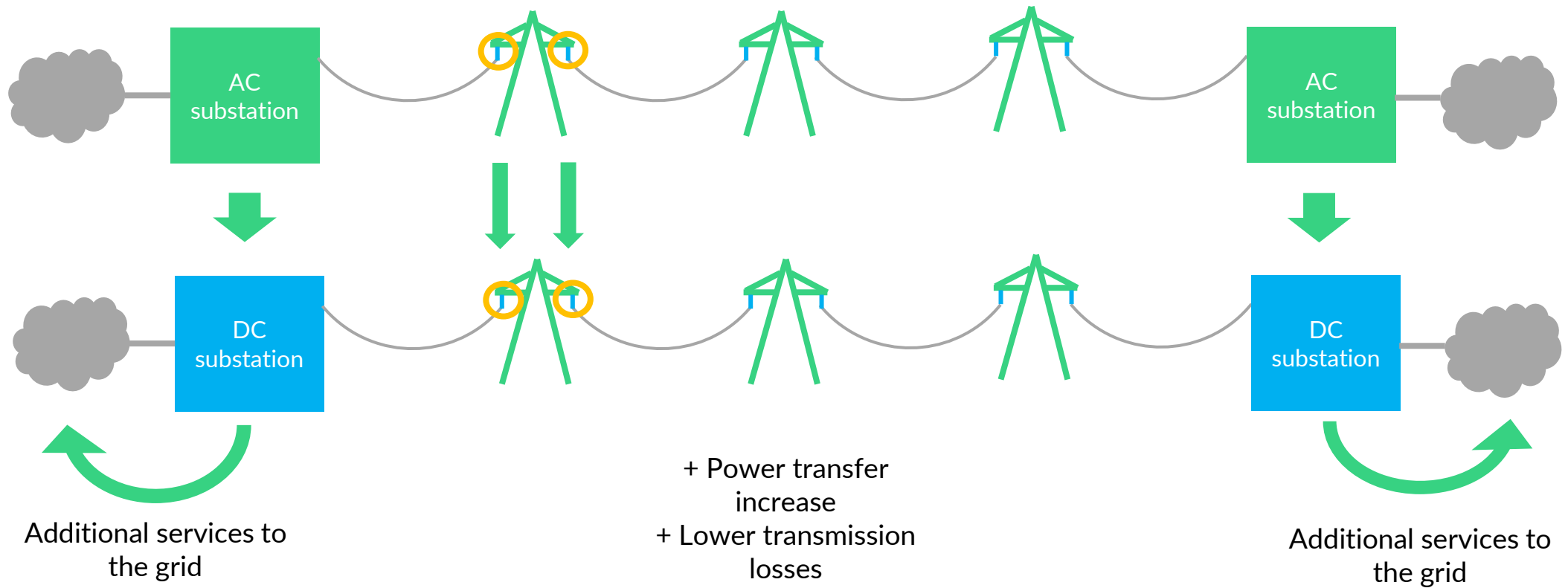
- The problem
- A possible solution
- The power increase achievable
- Summary of the benefits
- Challenges of upgrading OHL from AC to DC
- A real-world project

The Problem

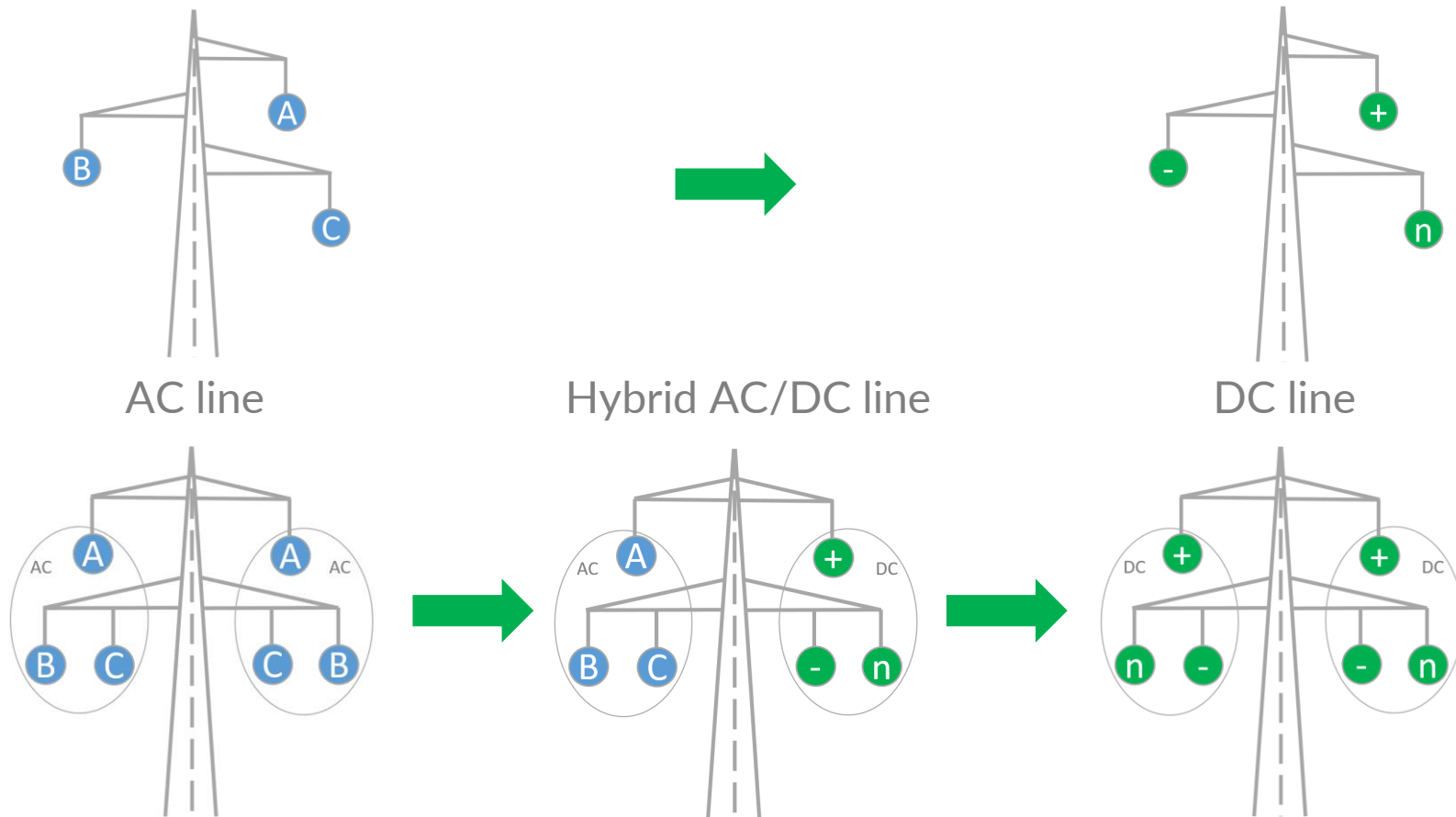


- Flexibility → priority
 - Existing AC lines capacity cannot be fully utilized due to different transmission stability concerns
 - AC lines are usually enhanced by:
 - FACTS devices
 - Upgrading existing corridors
 - Creating new corridors
- Not enough to keep up with the grid development

A possible solution - Upgrading OHL from AC to DC

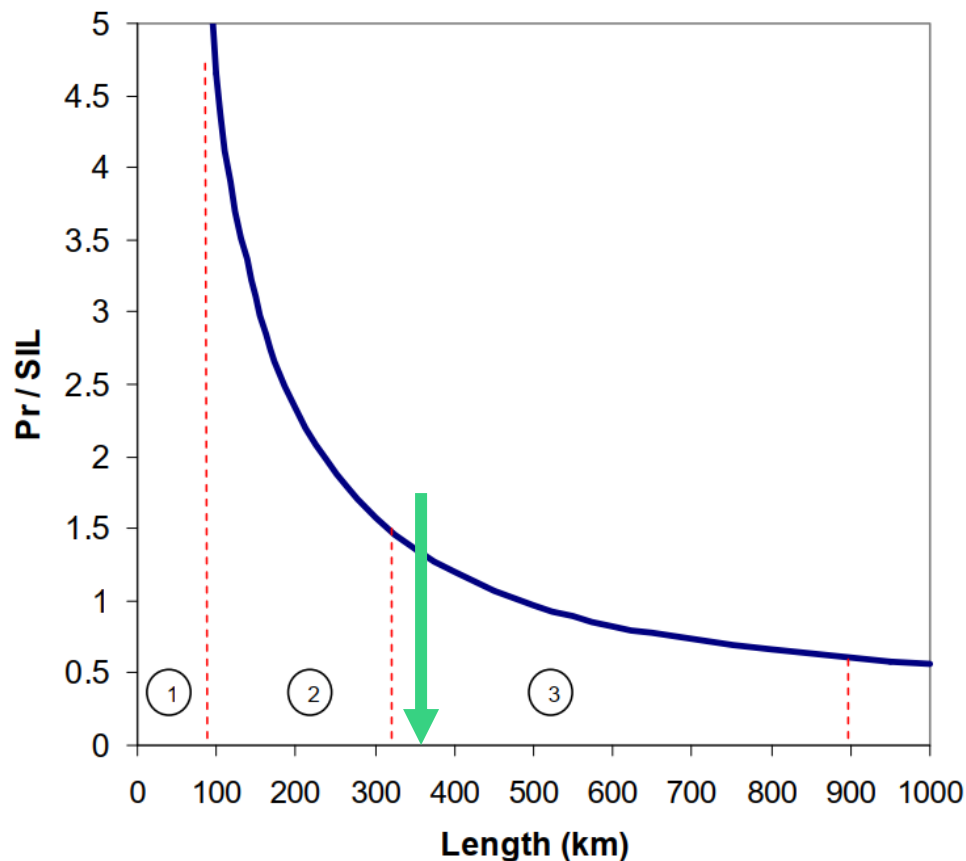


A possible solution - Upgrading OHL from AC to DC



- Advanced power flow, protection and stability control features
- Faster timeframe for projects, compared to building a new line
- An increase in power transfer, utilizing the same ROW
- Increased public acceptance

Possible Power Increase – AC vs DC – 340 km, 400kV, 1GW example



- 1 – Thermal Range 0 – 80 km
- 2 – Voltage drop limit 80 – 320 km (5 %)
- 3 – Small signal angle stability (steady state) ≥ 320 km - a stability margin of 30% relating to a power angle of 44°

$$\frac{P_{DC}}{P_{AC}} = \frac{2 \cdot U_{DC} \cdot I_{DC}}{\frac{U_{AC}}{\sqrt{3}} \cdot 3 \cdot I_{AC}} \approx 1,15 \frac{U_{DC}}{U_{AC}}$$



Conversion to 400kV DC:

$$\frac{1000 \cdot 1,15}{1000 \cdot 0,7} = \frac{1150}{700} = 1,64$$

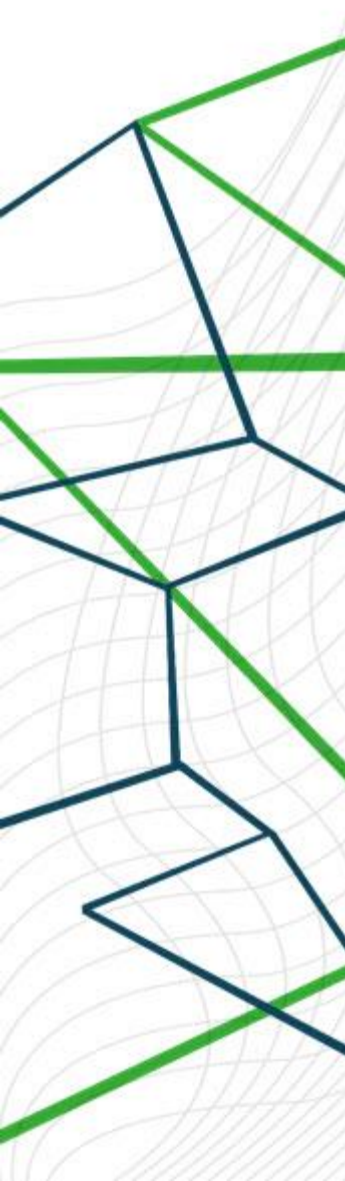
64% capacity increase

Voltage uprating to 500kV:

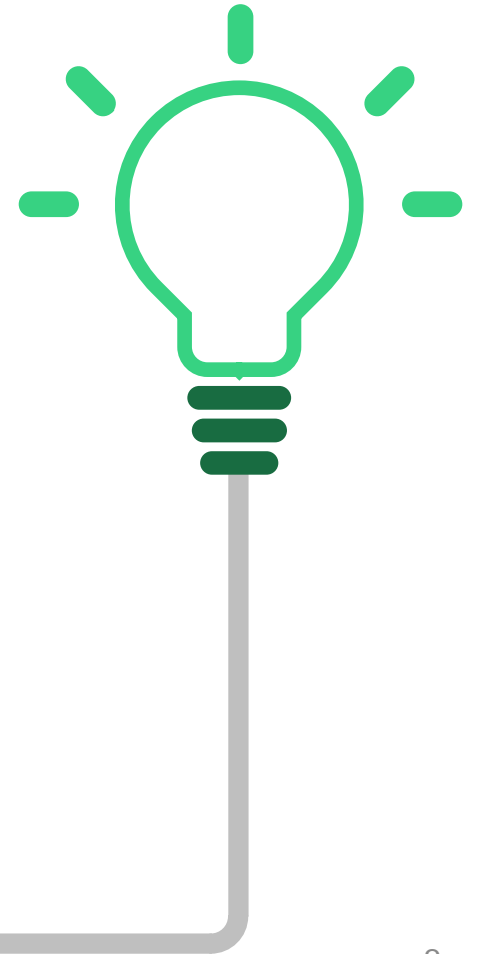
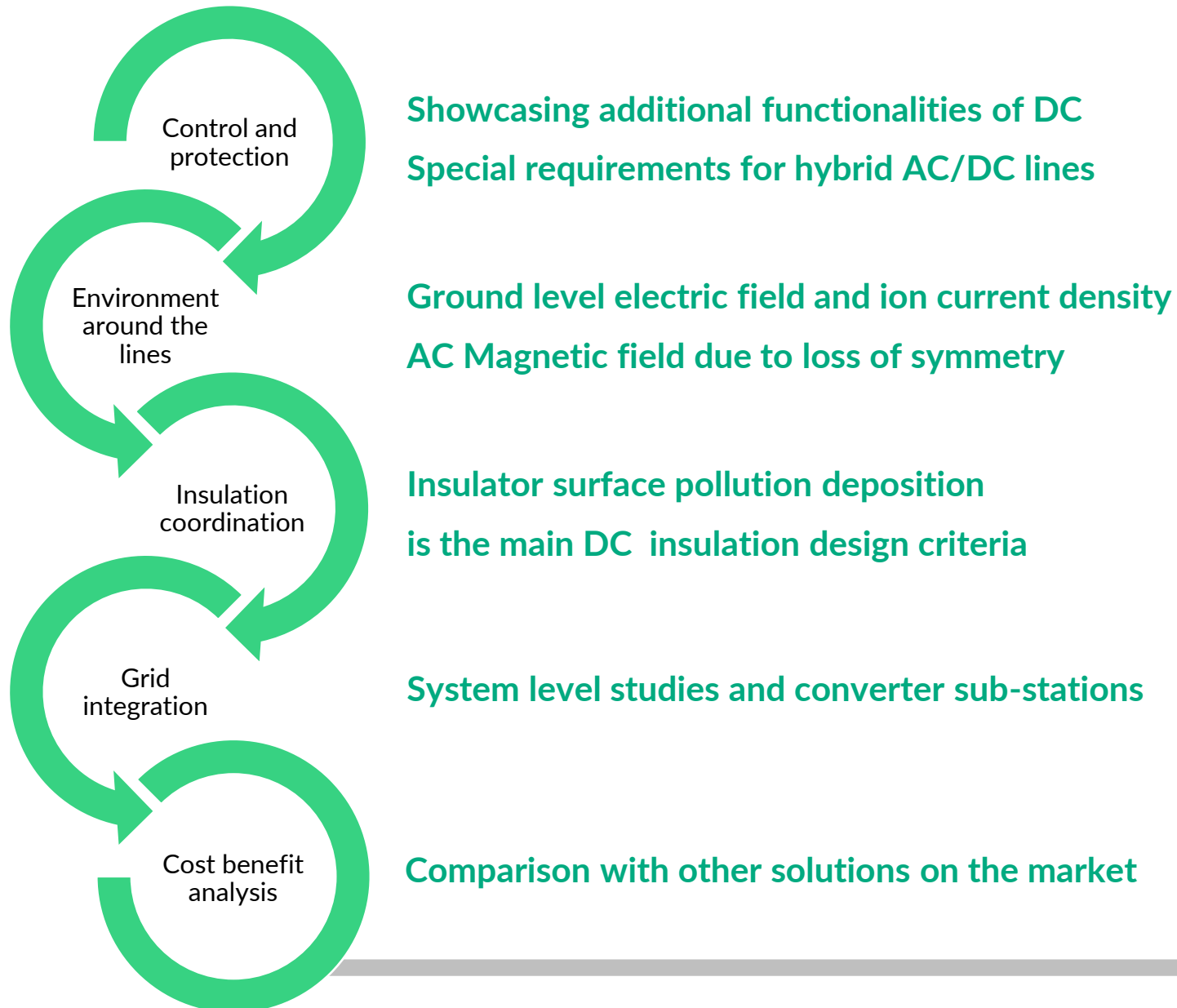
$$\frac{1000 \cdot 1,4375}{1000 \cdot 0,7} = \frac{1437,5}{700} = 2,05$$

105% capacity increase

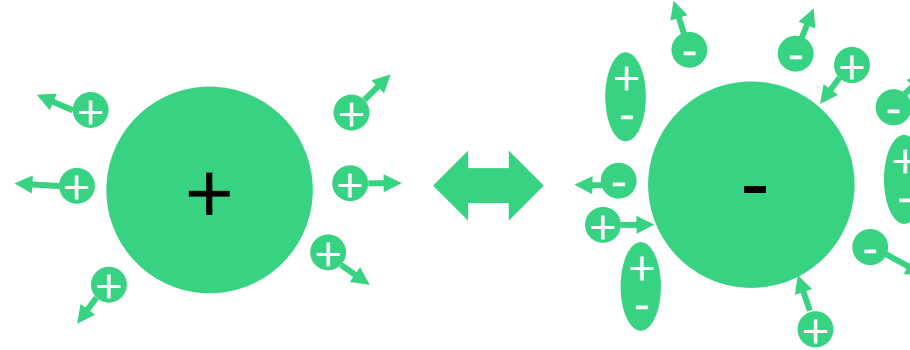
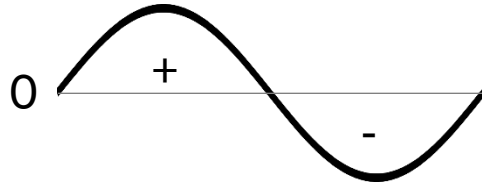
Summary of the benefits

- 
- ✚ Support in the integration of renewable energy resources
 - ✚ Shorter timeframe for the project and lower implementation costs
 - ✚ Improvement of the system stability & reliability
 - ✚ Improved control of power flow (independent P & Q control)
 - ✚ Transfer capacity increase
 - ✚ Lower lifetime transmission operational losses

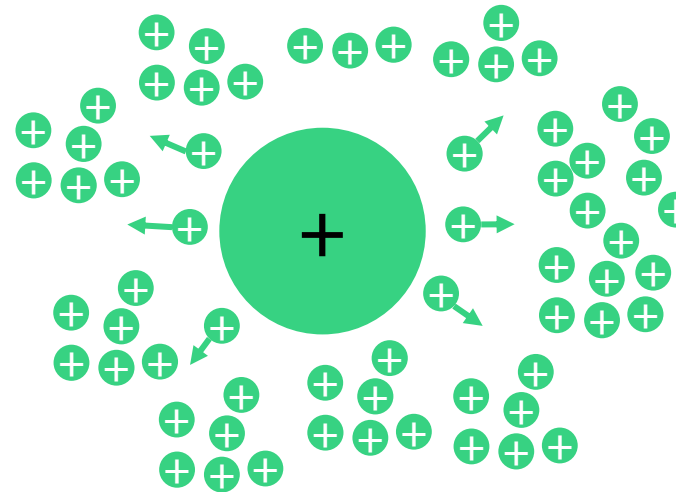
Challenges of the upgrade



Difference between AC and DC electrical field



Laplace
 $\Delta\phi = 0$



Poisson
$$\Delta\phi = \frac{\rho^+ - \rho^-}{\epsilon}$$

AC vs DC insulator dimensioning process

AC insulator
design process

Temporary
overvoltage

Slow-front
overvoltage

Fast-front
overvoltage

Pollution is
satisfied

DC insulator
design process

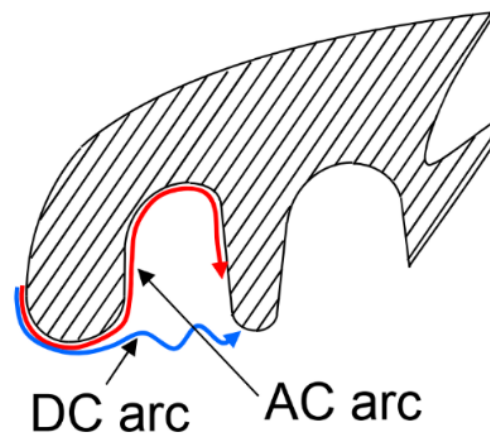
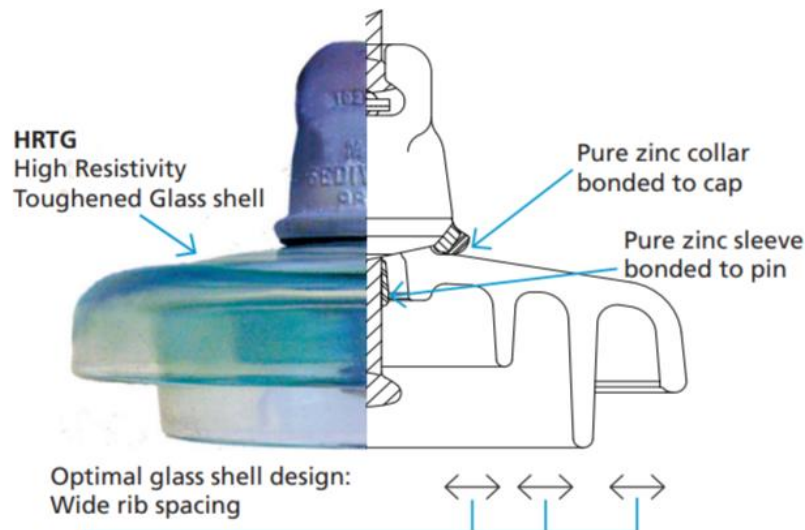
Overvoltages
rather low

Pollution
performance
is dominant

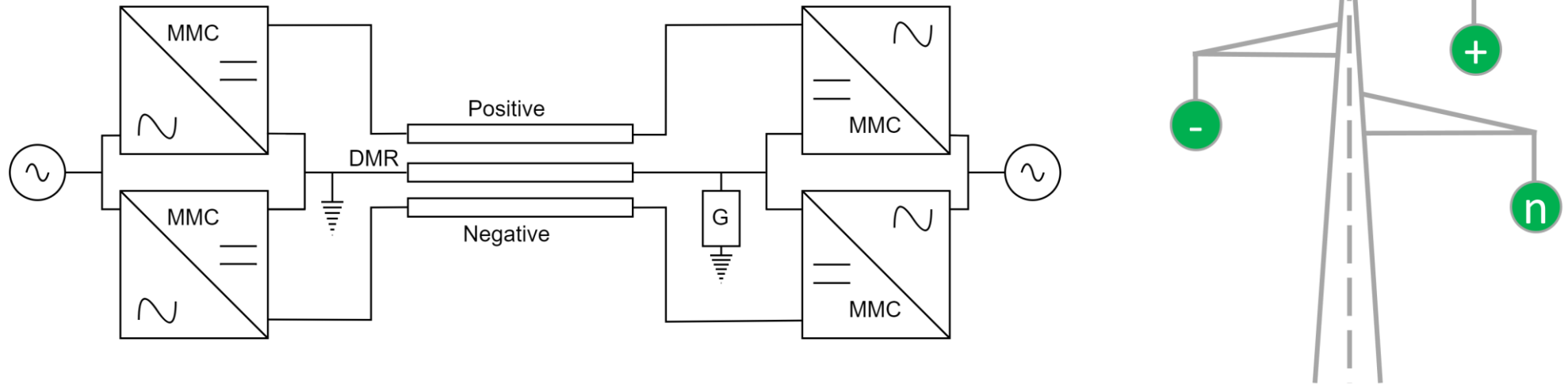
More pollution is attracted to insulators energized with DC

Required creepage distance is often considerably higher for DC than AC

Very limited measurements of DC pollution are available

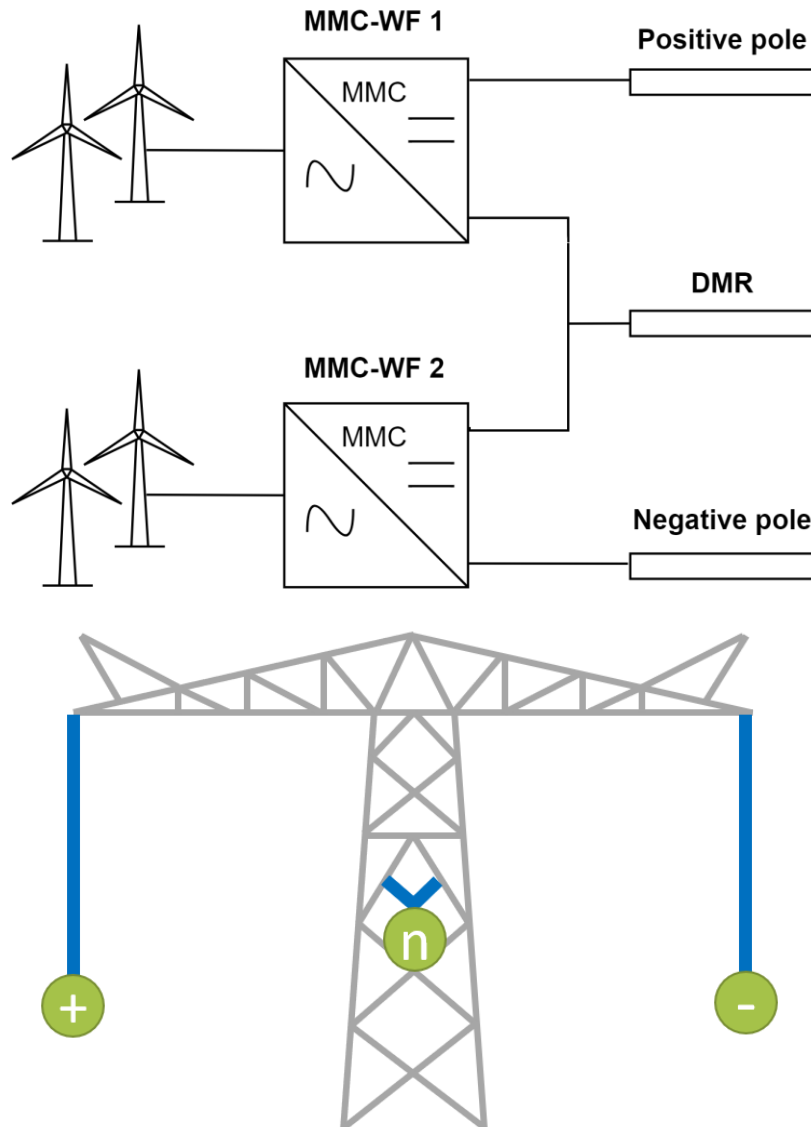


Configuration of poles - Bipolar configuration with dedicated metallic return (DMR)



- Suitable for the conversion → translating 3 phases to 2 poles & DMR without additional cost
- Following the latest regulations in EU → DMR is mandatory
- High power availability and flexibility (50% power redundancy)
 - Better N-1
- Ideal for lines that need to be highly reliable with large power ratings

Research on the DMR – How to ensure independent pole operation and DMR reliability?

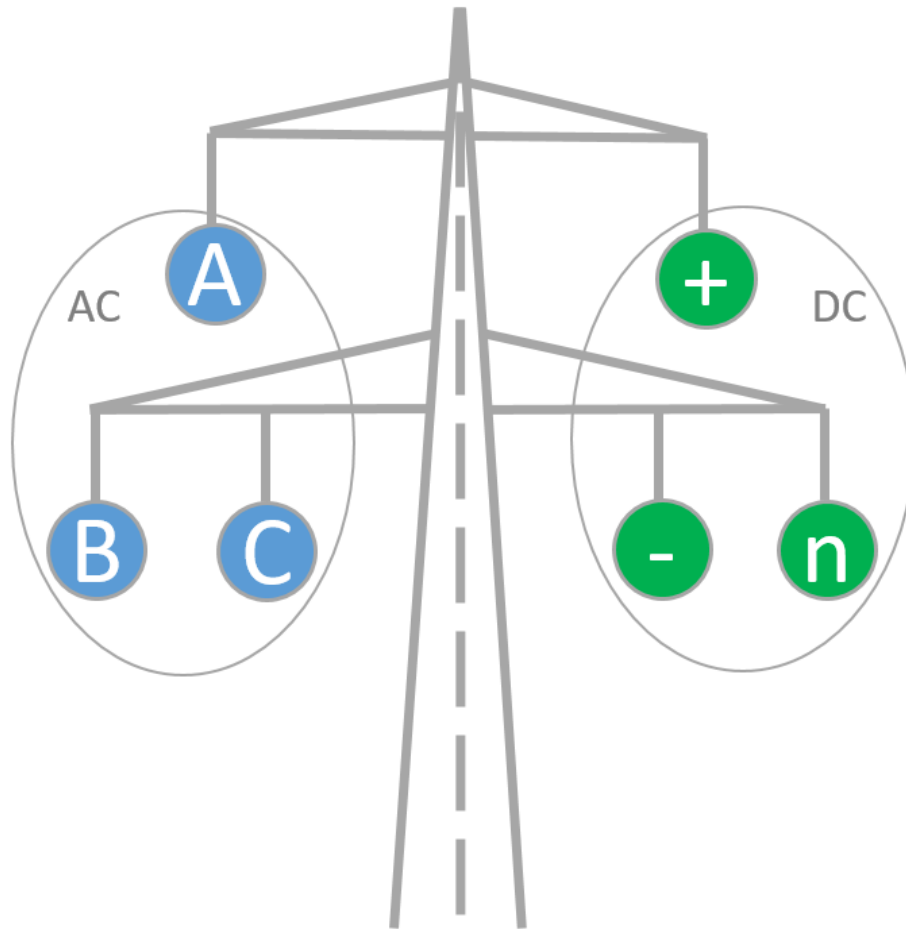


- What happens in case of an unbalanced operation?
- Do faults along DMR extinguish?
- How to design the insulation on the DMR?

If you want to know more:

D. Hart, R. Courtellemont, A. Xemard, A. Bertinato, "Implications of faults on insulation coordination of dedicated metallic return on bipolar HVDC overhead transmission lines", Electric Power Systems Research, Volume 218, 2023.

Hybrid OHL research topics



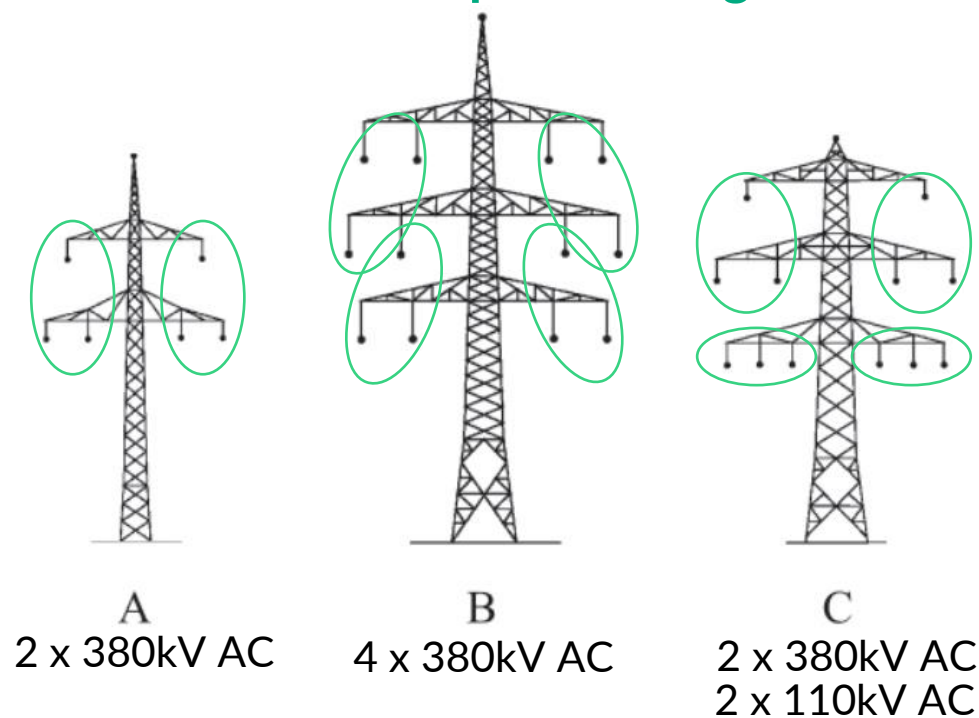
- **Mutual coupling in steady state and fault state**
 - Impacts on control and protection
 - Impacts on AC transformers
- **Fault extinction on the DC side**
- **Is the insulation performance of the AC side impacted by the DC component?**
- **How does the DMR behave with the AC component?**



Existing projects of upgrading

Only existing project – Amprion's Ultranet project

- One 380 kV AC circuit is transformed to 380 kV DC
- 2 GW over 340 km
- Will become multi terminal
 - Ultranet connected to A North DC links in the Rhineland.
- Insulators are changed using live line work
- Full bridge MMC converter & Bipolar configuration with DMR



Possible application in Croatia- High-power corridor to the South-North



Peak load of Croatia – 3 GW

Thank you for your attention!

