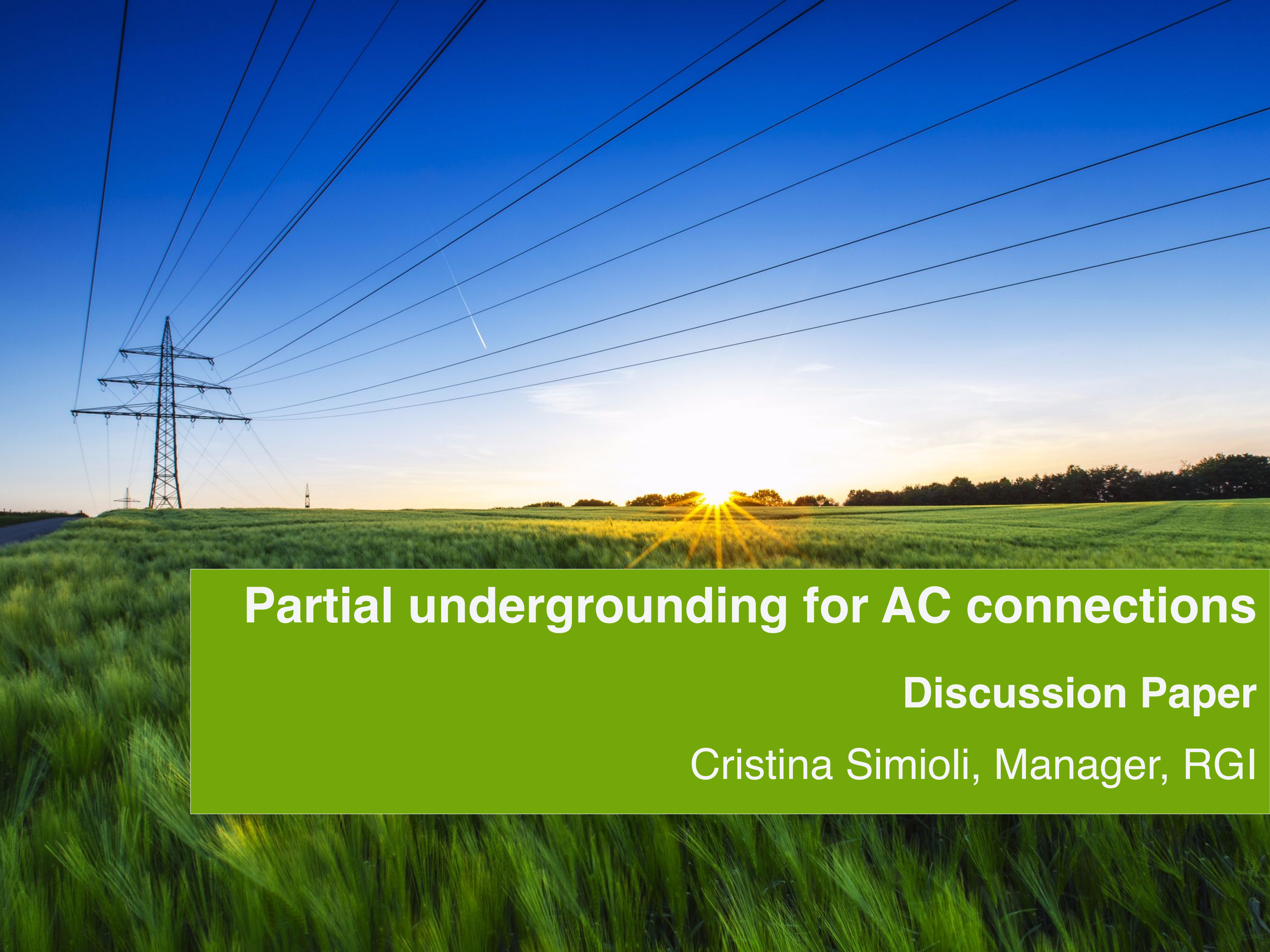

Partial undergrounding for AC connections

Discussion Paper

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Outline

1. Why RGI did this discussion paper?
2. Scope
3. State of the art
    1. Technology
    2. Partial underground system
    3. Installation methods
    4. Legislative and regulatory frameworks
4. Environmental and social aspects
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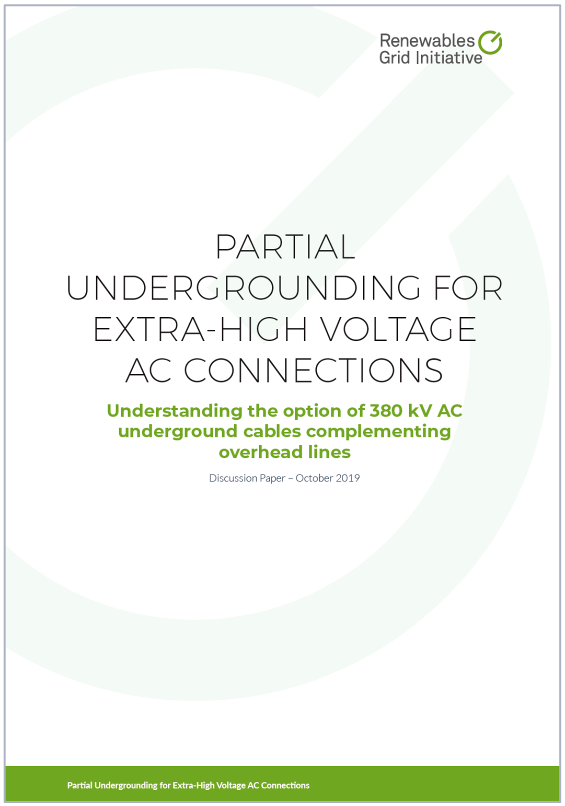
Why RGI did this discussion paper?

"Is it possible to use underground cables instead of overhead lines? When?"

- In the context of the energy transition, there is an urgent need to develop the necessary grid infrastructure to allow the integration of larger shares of renewables.
- The question of which technology should be chosen for a new power line is often raised in debates about new transmission grid projects.
- Pylons are not very popular and there is a raising demand for underground cables.

Scope - Understanding


Renewables Grid Initiative

PARTIAL UNDERGROUNDING FOR EXTRA-HIGH VOLTAGE AC CONNECTIONS

Understanding the option of 380 kV AC underground cables complementing overhead lines

Discussion Paper – October 2019

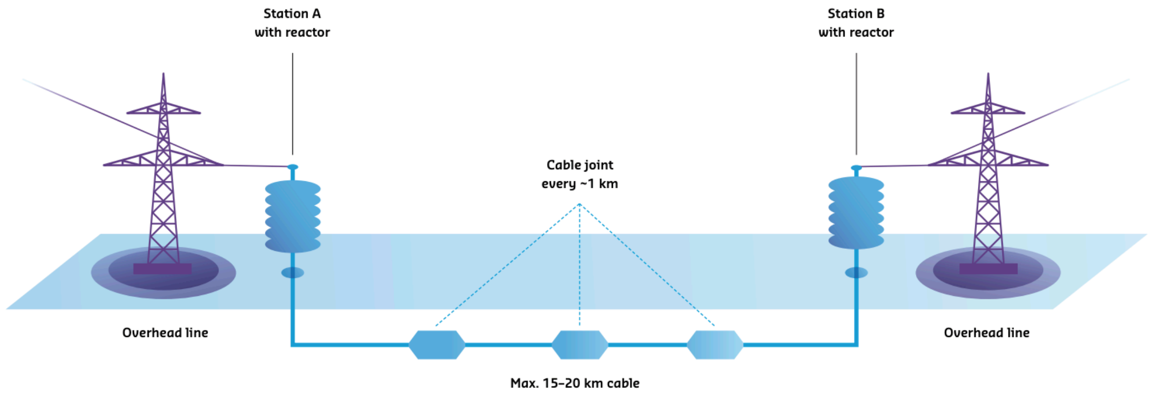
Partial Undergrounding for Extra-High Voltage AC Connections

- Alternating current (AC)
- Extra-high voltage (EHV)
  - 380 kv AC
- Underground cables (UC) complementing overhead lines (OHL)
- Dimensions considered
  - Technological
  - Legislative & Regulatory
  - Systemic
  - Environmental and social
  - Financial

Technology

- EHV cross-linked polyethylene (XLPE) power cables are today the core technology used in EHV AC UC sections and have been in service in Europe for almost 25 years.
- EHV AC UC make up less than 2% of the EHV AC land transmission systems in western Europe.

Partial undergrounding system



- Cables are usually delivered in lengths of between approximately 700 to 1000 m, this is due to transportation limits for the weight and size of the cable drum.

- They are connected together by pre-manufactured **joints** which require careful on-site assembly to be cautiously executed by qualified staff.

- Cable sections are linked to OHLs via **transition stations**
  - whose size and layout are determined by the transmission capacity and the additional equipment installed. In some cases, they require a reasonably large plot of a land which can create a visual impact.

Installation methods

The method used (open or closed burial techniques) depends upon a range of factors and each has advantages and disadvanges:

- surface disruption for the general public/impact on the immediate surroundings (e.g. traffic, noise, vibration, dust)
- environmental impacts (soil, wetland, peatbogs, etc.)
- installation time
- fault localisation and repair
- costs

Legislative and regulatory frameworks

- European TSOs work within different legal environments and regulatory frameworks which, with few exceptions, provide limited clarity on the decision between OHL and UC.
- The default technology has been traditionally OHL, mainly for costs and operational reasons.
- Regulatory frameworks can also prescribe or incentivise the deployment of technological innovation.
- The choice to utilise underground cables can be influenced by political considerations and priorities.

System performance aspects (1)

- Maintaining the availability and reliability of the grid is of paramount importance.
- A larger number of longer UC sections at high-voltage level changes the behaviour of the system.
- There are technical limits to AC undergrounding due to the different electrical characteristics of cables and overhead lines resulting in
  - in some cases no cabling is acceptable
  - in some cases the total length of cabling of a circuit is limited
  - in some cases the total length of cabling in a region is limited
- There is no general rule of thumb how long a cable section within a circuit or region may be, but the maximum length of UC sections has to be evaluated on a case by case basis.

System performance aspects (2)

- REACTIVE POWER COMPENSATION
  - Carefully evaluated to avoid frequency shifts (resonance and resonant phenomena).
  - High voltage peaks may lead to disruption of industrial consumers and even to outages/damages of high voltage equipment
  - Size and costs considerations
- FAULTS
  - UC sections are less likely to suffer a failure compared to OHL
  - longer fault localization and repair
  - transition stations between UC sections and OHL can be equipped with additional differential protection units that allow for selective and precise fault localisation, either in the cable or in the OHL. These additional units require
    - a more comprehensive design of the transition stations and, therefore, increase the total costs of the installation of a cable section. On the other hand, they reduce the time needed for fault identification and repair.
- RESTORATION
  - in power lines that are of special importance to restore the electric system, there might be restrictions as to whether cabling sections are permissible.

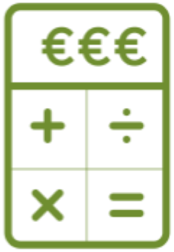
Environmental aspects

- Soil of UC sections is a major consideration, especially regarding agriculture and nature protection.
  - Focu on: soil degradation, contamination, hydrology, thermal effects (during construction and operation)
- In comparison to OHLs, the construction and operation of UC sections can pose an increased risk to wetlands and peatbogs which can be sensitive to the construction of trenches.
- UC sections are the only fail-safe way of eliminating bird collision risk during operation.
  - Focus on: ground nesting bird species during construction
- In areas of high visual amenity and visibility, UC sections can be used to minimise the visual impact during the operation phase.
  - Focus on: heritage assets, archeological areas, transition stations

Social aspects

- Underground cables can be an option when lines must enter densely populated urban areas.
- The intensity of the magnetic field is higher directly over the cable due to the proximity of the cable to the surface and falls away rapidly at a distance from the source.
- Building underground lines might lead to higher acceptance with some parts of the public, but it is unlikely to be the solution for all issues of local acceptance.
  - stakeholders assess the advantages and disadvantages of technological options in different ways (e.g. affected landowners, land users and adjacent residents at the OHL section of the project)

Costs



- The capital build costs vary greatly, depending on terrain (installation), route length and power capacity.
- Civil engineering costs for all methods of cable installation are considerable compared to those of an overhead line.
- Underground cables are always more expensive when compared to equivalent overhead lines.
- The financial aspect is important as the costs of grid development are charged to the electricity consumer via grid fees.

Recommendations

TSOs, technical institutions, NRAs, legislators and industry to work together

Technical safety and secure system operation	• Promote further research on UC sections impact on the system
Legal and regulatory frameworks/Public Participation	• Provide clarity and promote transparency and stakeholder engagement through legislative and regulatory frameworks
Environmental impacts	• Consolidate environmental impact monitoring/research programmes
Financial aspects	• Collect, consolidate and connect projects (allowing comparability, when possible)

Thank you!

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