RGI Cable Workshop "Understanding Underground Cables"

13 and 14 February in Spreitenbach, Switzerland
A workshop kindly hosted by Swissgrid

During the 1.5 day workshop, more than 70 participants from industry, TSOs, NGOs, academia and politics discussed most urgent challenges around the question under which conditions extra-high voltage transmission grids could be built underground. During the first day, a series of presentations demonstrated the current knowledge about undergrounding covering technology, environmental impacts, costs and policy approaches. The second day was used to discuss how to move ahead to solve main challenges. Workshop participants generally agreed that with current technology, partial undergrounding can be the most feasible approach rather than wholly overhead or underground solutions. At the same time, in many countries regulatory and policy frameworks are not yet prepared to support this option. Furthermore, the necessity to proactively share further insights on relevant cable projects became obvious. Swissgrid stated its interest to develop a platform for such a purpose and suggested to define common criteria for studies to be able to compare and mutually profit from the experiences gathered in new projects. RGI will support this process.

Technology

"Whether and to what extent an underground solution is technically feasible can only be determined via case-by-case analyses"

The current state-of-the art technology are so-called extra high voltage cross linked polyethylene (XLPE) cables which consist of a copper conductor and an XLPE insulation. Different shielding system can be added to protect the cables against water or to minimise magnetic fields. Normally, the cables are laid directly in the soil, surrounded only by a sand blending. Most of the original soil is refilled after the cable is embedded. Cable tunnels are possible as well, but are a more expensive solution most likely to be used when it is impossible to lay cables directly in the ground or use overhead lines because of existing built development or the natural environment. Different pieces of cables are combined with joints which form the most challenging points in the system. Thus, they need to be carefully installed by qualified experts. While it is possible to manufacture long pieces of cable that do not need joints, longer cables are so heavy and big that the transport of sections of more than 1,000 metres length are unmanageable on land due to bridges, tunnels, etc. There is no general answer to the question of how many kilometres of underground cables are technically feasible in a specific case. Compensation may be required depending on system specifications. Therefore partial undergrounding solutions will have to be assessed carefully on a case-by-case basis.
Since every cable is produced based on the project specification, it is recommended by manufacturers that TSOs retain additional stock for any possible future repairs. The fact that cables are tailor-made means also that the repetition factor from one project to another is rather small. TSOs that currently operate extra high voltage cables report that outage times in case of failure are longer than expected. This is often linked to the unavailability of construction expert teams for the specific cable type. Some workshop participants suggested that a standardisation of cables would thus bring a lot of advantages and in the end would even save costs.

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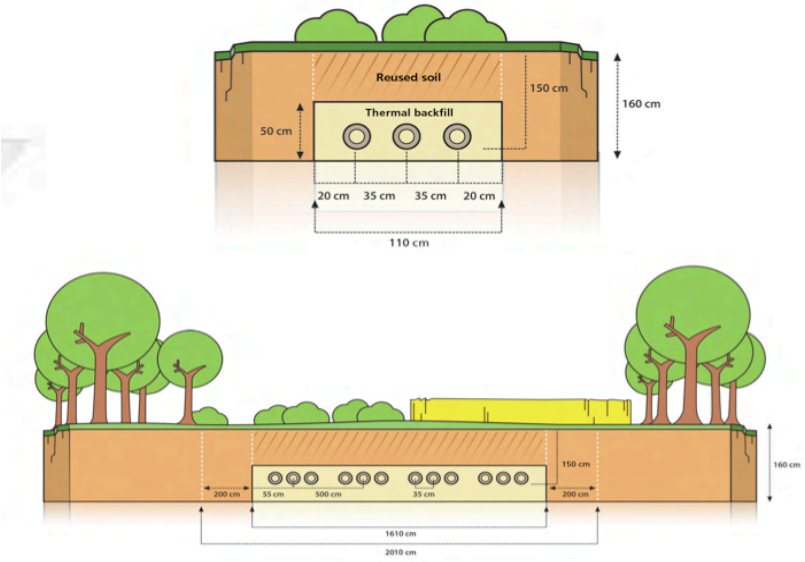
Good practice: In the Randstad project in the Netherlands, TenneT is currently building 20km of 380 kV underground cables in two sections of 10km each. The circuit length consists of 240km single cable, 120 terminators and 228 joints, 2 series- and 11 compensation reactors. Before the decision to build some parts underground, TenneT had developed a risk profile, based on experiences e.g. in Japan. Besides this project, TenneT and Europacable intend to create a joint evaluation programme for partial undergrounding. A working group together with experts from TenneT, the universities of Hannover and Delft and Europacable will be established and a scientific research programme for cable pilot projects developed.

Illustration: typical build-up of cable installations



Source: Europacable

Open questions/concerns:

- Technical stability of the system if partial underground solutions are inserted – concern that the overall system could become more vulnerable if more underground sections are added
- Differing opinions whether technological standards are probable in the near future and whether they would benefits
- Availability of experts to install and repair cable joints

More information:

- Joint paper of Entso-E and Europacable: "Feasibility and technical aspects of partial undergrounding of extra high voltage power transmission lines", available online: http://ec.europa.eu/energy/infrastructure/studies/doc/2010_high_voltage_power_transmission_lines.pdf

Environment

"The environmental impacts of overhead lines and underground cables differ substantially"

Participating environmental NGOs stated that the technological question of a line is subordinate to the question whether a new line is needed at all. In case of a proven need, the decision between underground cables and overhead lines should be guided by the following questions: will the proposed line cross a protected area?; what kind of protected area is affected?; how are flora and fauna impacted?

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Both overhead lines and underground cables have impacts on the environment. However, the species affected and the phase of occurrence differ. The major impacts of overhead lines occur during the operation phase, mainly related to the collision of specific bird species and the visible impacts on landscape. On the contrary, underground cables cause impacts on the environment mostly during their construction. Beetles, amphibians, reptiles and bats, as well as ferns and seed plants can then be affected by underground cables. Moreover, construction works can cause soil compaction which can have considerable negative impacts on biodiversity. A permanent environmental monitoring of the construction works is thus indispensible. From an environmental point of view, wetlands, swamps and bogs should be avoided when planning underground cables as these may suffer severe or irreparable harm. Moreover, hydrological considerations should be made during the planning phase to avoid sensitive water flows. Archaeology may need to be taken into account in route planning, and also the possibility of encountering archaeological sites can prolong the construction phase.
There are minor restrictions on land-use after the construction: agriculture and farming are possible on top of the cable trench. Deep rooting plants and vineyards have to be avoided to prevent any harm to the cable caused by roots.
The greatest chance to avoid environmental impacts of underground cables is their early consideration. Strategic environmental assessment during the primary planning phase is by some considered to be crucial for this.

Overview: impacts of underground cables on flora and fauna:

Phase	Threat	Ferns	Seed plants	Mollusca	Dragonflies	Beetles	Butterflies	Fish	Amphibians	Reptiles	Bats	Mammals	Rest- and breeding Birds
Con-struction	1 Killing	x	x	x		x			x	x	x	x	x
	2 Disturbance			x		x			x	x	x	x	x
	3 Propagation		-	-	-	x	-		-	-	x	x	x
	4 Destruction	x	x										
Plant/ Operation	1 Killing												
	2 Disturbance								-	-		-	-
	3 Propagation												
	4 Destruction												

Source: OECOS

Many people who are affected by new power lines have concerns about the impact electro- and magnetic fields (EMF) can have on their health. Both overhead lines and underground cables produce EMF. Underground cables have magnetic fields right above them, but the value decreases faster when moving away from the cable. If required, underground cables can be shielded to further reduce EMF at the surface.

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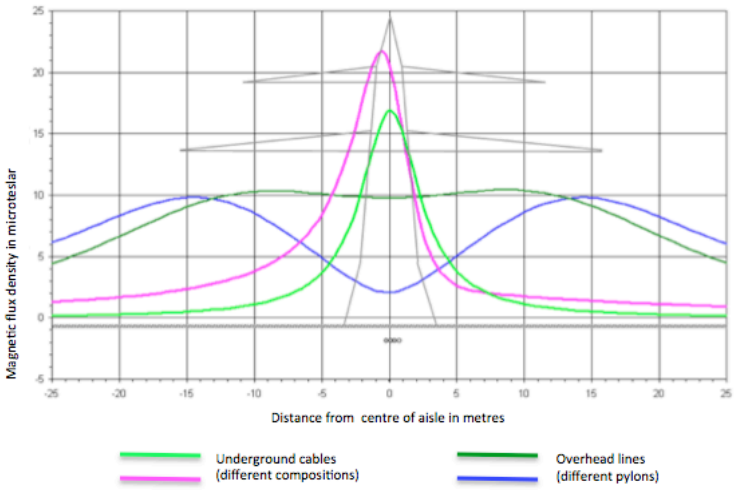
Overview: magnetic field density of overhead lines and underground cables:



Source: Dr. H.-Peter Neitzke, ECOLOG-Institut, Hannover

Open questions/ concerns:

- Disagreement whether overall, overhead lines are the more favourable solution for biodiversity (creation of green corridors)
- Experience and studies on long-term effects of underground cables are scarce

More information:

- Study on the ecological impacts of 380kV underground cables and hvdc underground cables, commissioned by the German Ministry of Environment, available online: http://www.gbv.de/dms/clausthal/E_BOOKS/2012/2012EB137.pdf (in German)

Costs

"Purely considering investment costs will neither help the discussion nor the decision-making process. Cost considerations should cover a life cycle analysis."

Investment costs for underground solutions are higher than for overhead lines. One cost driver is the price of raw materials, mainly copper and the insulation materials. Moreover, the installation costs are key for varying cost levels: Depending on soil conditions, cost incurred for civil works can make up to 60% of installation costs. Hence, clarity about the exact cost level of a specific underground project can only be obtained based on thorough studies of the local environment, making early estimations of undergrounding costs for a specific project difficult.
According to one commentator, investment costs for undergrounding are in average about 5 – 10 times higher than for overhead lines. However, this cost multiple only applies to the undergrounded section. When considering the entire project, of which only sections may be undergrounded, lower cost multiples are possible. Combining different infrastructures (e.g. underground electricity cables with road tunnels) could further decrease the costs.
There are other factors which are more difficult to determine, such as the costs of visual amenity or other externalities. While there are studies on the depreciation of houses in the proximity of cables or the costs of delaying the construction of energy infrastructure, they only

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cover single issues. Discussions on how to factor in the cost of not being able to build a line in time are ongoing.
It will thus not serve the decision between underground cables and overhead lines if simple price tags or ratios of investment costs are used. It is rather useful to consider the full life cycle.

Studies: A study conducted by the consultancy firm BET on behalf of the Federal Ministry of Environment considers the benefits of an accelerated grid extension in comparison to the cost increase of underground cables in Germany. The costs of not building the line consist of costs to control energy, costs for redispatch, and the compensation for cut renewables feed-in. The study concludes that if one year can be saved in the realisation of the project due to partial undergrounding, higher investment costs can be neutralised.
A study conducted in the UK compares the costs of different technologies, including overhead and underground cables. The study considers building and life-time costs, but does not include social and environmental costs.

Good practice: In the UK, a fund has been established by the regulator Ofgem. With 500 million pounds, existing overhead lines in National Parks or other designated scenic areas can be put underground in the UK in the coming years. National Grid is currently developing a procedure to determine the most precious and valuable landscapes where the money should be spent, and how stakeholder views can be included.

Open questions/concerns:
- Potential of partial undergrounding to speed up realisation of the project and thus to save money
- Regulator's legal obligation to minimise investment costs prevents undergrounding solutions
- Societal costs vs. societal benefits of undergrounding
- Who should bear the costs? Regional vs. national increase of net tariffs or extra costs to be covered by tax payers

More information:
- Electricity Transmission Costing Study, commissioned by National Grid and Department of Energy & Climate Change UK, available online: http://renewables-grid.eu/uploads/media/Electricity_Transmission_Costing_Study_Parsons_Brinckerhoff.pdf
- Study "Expansion of electricity grids with cable or overhead under special consideration of renewables infeed", commissioned by the German Ministry of Environment, available online: http://renewables-grid.eu/uploads/media/Netzausbau_Studie_IZES.pdf (in German)

Policy, Project Planning and Regulation

"Underground cables are an additional tool in our box"

The legislative frameworks and planning practices which determine how the decision between underground cables and overhead lines is made, vary from country to country. In countries where the regulatory regime has a strong focus on cost efficiency underground solutions are often not used. In other countries, investment costs are weight also against other factors (such as social costs), making the regime more technology neutral. Most TSOs favour the legal possibility to discuss partial undergrounding options since more tools offer more chances to reach a consensus with involved stakeholders. However, this may of course by no means go on the cost of system stability. There was a general consensus that considering the option of partial underground solutions should be done from the beginning of each project. Participants of the workshop agreed that the

process behind the technology decision should be as transparent as possible. Some participants stated they would favour clear criteria on when to consider or choose undergrounding. Others said the needed transparency could mainly be achieved by very clear decision-making procedures where criteria were not possible. In the end, the policy discussion group agreed that a clear and transparent process would base its discussion on an extensive set of factors to consider but without offering "default" solutions

Good practice: The concrete design of this decision-making procedure can vary. During the workshop, two models were discussed: a) the Swiss model and b) the UK model.

a) Upon the recommendation of the Parliament, the Swiss government started a process to develop a set of criteria to choose between different siting alternatives, including a potential option for undergrounding. A working group was established which included representatives from relevant government departments, NGOS, and cantons to ensure that all interests were considered adequately in the process. The criteria are categorized in four pillars: spatial development, technical aspects, conservation of environment, and economic efficiency. A specific weight for each criteria is set beforehand by the competent authorities. For specific projects, different corridors will be considered separately and points will be allocated for each category. However, the highest amount of points will not automatically lead to the decision for one corridor. This system should rather help to balance out different arguments and make the decision more transparent.
b) The TSO National Grid conducted a public consultation to find out more on the opinion of the public on undergrounding policy. The results led to the development of a new approach to the design and routeing of new power lines. While previously, only under certain circumstances (e.g. proximity to areas with high landscape value), undergrounding was considered as an option, it is now to be considered for all projects and to be chosen or ruled out via a discussion process with relevant stakeholders and local experts. In other words it is a process not a policy. As in Switzerland, spatial development, technical aspects, conservation of environment, and economic efficiency have to be taken into consideration. There is however no grading system applied.
c) Some countries package the approach towards undergrounding of extra high voltage lines with the consideration of the lower voltage system. In Denmark, a master plan for undergrounding high voltage lines (132KV/ 150kV) and the reduction of the visual impact of existing 400kV overhead lines was adopted in 2009. In France, the government decided to underground at least 30% of new high voltage lines (63kV / 90kV) and not to increase the total length of overhead lines.

Open questions/ concerns:

- How to install regulatory regimes that do not focus solely on cost-efficiency but allow adding undergrounding to the toolbox

More information:

- National Grid: "Our approach to the design and routeing of new electricity transmission lines", online available: http://www.nationalgrid.com/NR/rdonlyres/E9F96A2A-C987-403F-AE7D-BDA07821F2C8/55465/OurApproach.pdf

If you have questions, comments or relevant information, please contact us: Antina Sander, antina@renewables-grid.eu

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