Renewables Grid Initiative

The prospects of undergrounding power lines

5 and 6 July 2017, Raesfeld, Germany

Workshop summary

Day 1

1. Welcome by Klaus Kleinekorte (CEO of Amprion) and Antonella Battaglini (CEO of RGI)

Both CEOs shared their expectations for the workshop:

Dr. Klaus Kleinekorte stated that underground cabling still involved many challenges; thus, pioneers that test cabling in their projects were currently needed. The German law foresees a number of pilot projects, including the Amprion project close to Raesfeld. Amprion is proud to be a frontrunner, test new technology, share their experience and discuss lessons learned. They are happy to engage in more cable projects if that means that acceptance will be significantly higher, but Kleinekorte also pointed out that there were still weak points connected to the technology as almost all cable manufactures relied on the same suppliers. He concluded that gaining and exchanging experiences is needed before next steps were taken.

Antonella Battaglini expected to learn a lot during the event and to find the courage to set up a taskforce that would deliver high-level principles or guidelines connected to undergrounding. We should not forget that undergrounding comes with impacts, which is why we needed to learn how to deal with them, make sure we always made the right choice for each single situation, and not see undergrounding as the silver bullet. This would only come with experience and with experience came the courage to lead. In closing, Antonella called on TSOs and other industry actors to become the leaders of the energy transition and manage the changes ahead.

2. Overview: upcoming cable projects in Europe and their different technological, policy and stakeholder approaches

2.1 Volker Wendt I Europacable: Underground cables in Europe

Dr. Volker Wendt gave an introductory overview of where Europe stands in terms of underground power lines. He began by saying there has been remarkable progress since 2013 when RGI held its last underground cable workshop. “We have moved away from theory to having leading TSOs implement and successfully operate underground projects”, Wendt said. He continued by stressing that underground cable technology was mature and fully available. Full undergrounding is possible for DC projects, but not possible for AC projects – here partial undergrounding of up to 25 km complementing overhead lines is the available technology option. Because the workshop focused on AC projects, he went on to mainly look at those projects. From 1996 to 2015 some 4,691 km total AC land cables have been installed. As projects are now being rolled out, it is important to stress that there is no standard solution, every project is different and the Amprion project in Raesfeld that the workshop is centred around is the first project of its kind in Germany.

Wendt also emphasised the importance of impact and acceptance of underground cables, since according to Europacable’s calculations almost 50 per cent of Europe’s key future transmission infrastructure will be build underground (incl. subsea). Wendt underlined that we needed to distinguish between construction and operation when talking about environmental impacts. While undergrounding always meant a significant environmental intrusion during construction, vegetation could re-establish itself quickly if properly cared for. During operation of up to 40 years, there will be no limit to agriculture or raising cattle, with the only exemption of deep-rooting trees above the cable trench.

To facilitate acceptance all current projects needed to be monitored carefully in order to learn from them, exchange the experiences and address concerns that are being raised early on, Wendt suggested. He especially stressed the need for a clearer policy framework that allowed for the creation of appropriate compensation schemes, which would be able to address most of the opposition’s concerns that are currently being raised.

He closed by saying that we could not take it for granted that electricity is always readily available, meaning that if projects were delayed society would have to face the repercussions of that. Consequently, we needed a concise legislative framework that allowed project developers to consider undergrounding as an option from the very outset of a planning procedure.

2.2 Andrew Carryer I Renewables Grid Initiative: Legal frameworks, criteria and stakeholder perceptions for undergrounding

The presentation looked to provide an overview of a piece of research done by RGI on the current situation of undergrounding in countries in which RGI has a TSO member. Nine countries were included in the review.

What underground projects are planned?

Projects can naturally be broken down into two groups, longer distance DC and shorter distance AC. Most countries interviewed had several DC projects planned; most were landing points for marine interconnectors or cross-border interconnectors. Italy and Germany had the most projects in the pipeline with ~750Km and ~1650Km respectively (mostly the large north-south routes). Most countries had between one to three shorter distance AC projects planned. All were under 20Km in length, most were in urban areas and were sections of larger overhead projects.

Current legal frameworks

Most countries take a "neutral" approach to undergrounding, basing the decision on the information and plans provided by the TSO judged against objective criteria. France and Germany have a positive consideration of the technology, defining it as preferable in certain situations. Norway was the only country looked at that has a negative consideration of the technology, based largely on cost considerations. Criteria employed by TSOs and regulators when deciding upon undergrounding include cost, technical considerations, environmental considerations, heritage and proximity.

Stakeholder perceptions

It was shown that, generally, undergrounding could improve stakeholder acceptance, especially with regards to those adjacent to the line. However, the scale of the works required and the impact on the soil can make the process less popular amongst landowners and farmers especially. Others commented that many stakeholders would be against any type of infrastructure planned in their proximity, irrespective of technology type. This shows that underground cabling is not a "silver bullet" in terms of nature protection and public acceptance but rather shifts environmental protection priorities and changes the dynamics of stakeholder engagement.

Future change in legal frameworks and concluding thoughts

It was found that there existed both a desire for legal and regulatory clarity from TSOs on when undergrounding is appropriate, but also the concern that any changes in legislation can have severe impact upon the project planning process of ongoing projects.

2.3 Discussion with the audience

The discussion following the two initial presentations focused on how to protect and not delay on-going permitting procedures – possibly with the help of adding the option of undergrounding to any project technology discussion early on. Audience members voiced concern over undergrounding being the silver bullet that speeds up processes, when in reality TSOs now often have to deal with farmers who have a strong lobby behind them, opposing underground projects. The discussion moved towards agreement that if both options, overhead lines and underground cables can be considered for every project from the start, this creates more options. The right choice under the particular project circumstances can then help shorten processes. And, while a call for changes in the regulatory framework might come to early,

because legal changes might result in no permits being granted at all for a certain amount of time, a set of guidelines that are taken into account by regulators when making decisions could be helpful. A perceivable first step could be to create a platform for all players to agree on guidelines. The second step would then be to look at what that means on national level, as regulations can differ a lot across Europe.

3. New regulation: mainstreaming undergrounding in Germany?

3.1 Heinrich Laun and Oliver Smith I Bürgerdialog Stromnetz

Heinrich Laun from the German Bürgerdialog Stromnetz (Citizen Dialogue Power Grid), a project financed by the German Ministry for Economy and Energy (BMWi), presented Germany's unique legislative situation in Europe with regard to undergrounding as well as his perception of stakeholder reactions to the new 2015 underground law. The first law that affected undergrounding in Germany was the 2009 Power Grid Expansion Act (EnLAG), which foresaw four AC pilot projects for partial undergrounding in order to gain practical experience in construction, operation and maintenance of underground AC power cables. The Amprion project in Raesfeld is one of these pilots. In 2015, the underground cable act came into force, which gave priority to undergrounding over overhead lines for all DC electricity highways. Since then the use of overhead lines for DC projects has only been allowed in exceptional cases (if undergrounding would violate the federal nature conservation act, if a new line could easily be bundled with an existing one or if the assessment of an overhead line has been requested by affected regional authorities).

The Bürgerdialog Stromnetz (BDS) has been established by the BMWi to create a new culture of public dialogue on the topic of grids. They aim to de-emotionalise the debate by promoting a common understanding with regard to why grid development is necessary to properly integrate renewables into the system. BDS has offices in regions that are affected by grid development and employs experts that can give the interested public an overview about the energy transition, the current grid development, administrative procedures for planning and approval, public participation options, technical options / alternatives, as well as health and nature protection. They see themselves as an intermediary organisation that also provides mediation and conflict resolution, a role they are accepted in because they are perceived as authentic and without agenda. Being a more independent player than TSOs, they can talk about the need for grids without having to push specific projects. In the course of the discussion, 50Hertz attested to these statements and added that they had noticed an acceptance benefit with BDS being part of the discussion and actively invite them to join info markets and round tables with stakeholders.

On stakeholder reactions that the BDS has come across since the underground cable act, Laun said that not all, but large parts of the population seem satisfied with legislative changes. There was, however, a new kind of strong opposition. Farmers, forest and land owners were afraid of the effects of cables on soil and agricultural land, feared that environmental groups focusing on soil protection shared. The main issues that arose in relation to this new opposition were related to questions of

financial compensation. Many people were now demanding yearly financial compensation because a cable was much more invasive and took up more land than an overhead line. For the general public, concerns regarding health and electromagnetic fields seemed to be decreasing with the promise of undergrounding whereas questions related to rising project, and thus electricity bill costs, were coming up more frequently.

4. Three case studies on technical, environmental and acceptance aspects of underground cables

4.1 Case study Germany: Raesfeld – presented by Gerald Kaendler and Dr. Jan Brüggmann I Amprion

The Raesfeld cable is part of a 150 km 380 kV power line built in north western Germany which should be completed in 2021. It is an AC line with three underground sections, the Raesfeld one of which is already in test mode since mid 2016.

Part of the motivation for this pilot project was Amprion's wish to find out if undergrounding was really the "silver bullet" with regard to acceptability that some claim it is. To be able to evaluate this as good as possible Amprion started an extensive dialogue with the community and local stakeholders in Raesfeld and set up a visitors' centre with comprehensive information on the project.

More than a decade ago, Amprion also started a soil evaluation project to find out more about the impact of undergrounding on the surrounding soil. The research indicates low impact on soil and harvest and has resulted in an intricate soil protection plan for the construction phase. To re-establishing the soil structure exactly as it was before, the soil was taken out layer by layer and stored in separate piles. It was put back the same way to create conditions under which the soil can naturally console again. As a result of the soil protection approach, the two cable trenches of the project had to be opened at different times, so that the area above the respective other trench could serve as a storage area. Amprion continues to further monitor the impact on soil and harvest now that the cable is in operation.

Technical challenges of the projects were mainly related to how unique the project still is. Every obstacle, such as a street or a river is different and has to be crossed using an individually designed technical solution.

Overall, the construction of this project was six times more expensive than an overhead lines would have been, the construction site was very large and permitting took long, but Amprion presumes that this will go quicker in the future as there is also a learning curve for regulators. The pilot also provides valuable information for Amprion and its peers for future projects.

4.2 Case study Belgium: Stevin – presented by Jeroen Mentens I Elia

The Stevin project involves the laying of a double 380-kV high-voltage line between Zomergem and Zeebrugge in Belgium to connect offshore wind farms to the country's main grid. 45 km of Stevin are build overhead,10 km of it underground. The

underground parts run through a Natura2000 bird protection area, which is why an overhead line was not possible. The only other option would have been to build an overhead line above a village, which Elia did not opt for.

To make sure that birds were affected as little as possible, Elia worked with an agency for bird protection to be informed about migration and breeding times and tailor their construction periods around these times, if feasible. Similar to Amprion they also split the soil in as many layers as possible – from two to seven layers depending on the area – and made it a priority not to remove wet soil. However, because the area that the cable is laid in gets a lot of rain and has a lot of drainage, it was not always possible to put the soil back without impact on its condition and the drainage system. Elia intends to repair these damage and has agreed with affected farmers individually on the best point in time to do so.

Logistically, Elia always opened 800 to 900 meters of the trenches at one time and then used the areas above the unopened parts of the projects corridor to store the soil. Overall the construction site was always around 3 km in length at one time.

To further advance acceptability of Stevin, Elia kept informed about local circumstances and made sure that construction in the area of an annual horse riding contest was finished and grass was sown in time for the contest to take place as usual. However, Elia decided not to create compensation schemes for affected farmers, aside from compensating for negative effects, because they wanted to avoid having a cable on one's land turning into a profitable business.

4.3 Case study Netherlands: Randstad – Sjouke Bootsma I TenneT

Randstad is a 380 kV connection between the Rotterdam and Amsterdam areas, thus connecting two of the most densely populated areas in Western Europe and passing by the large Schiphol airport. The project is 58 km long of which 9.3 km are underground (in four sections). The whole project was build below sea level, which added to its complexity.

As could be expected with a setup as difficult as this, TenneT had to deal with a lot of objections, many of which had to be settled in court. They started a dialogue with the public, which resulted in the use of a new pylon design, the use of cables at complex spatial bottlenecks and corridor modifications. This entire process took eight years.

Once they decided to underground parts of the project, TenneT also started a research project on the behaviour and risks of 380 kV cabling in a meshed grid together with technical universities. The main reason behind this was that undergrounding parts of a project always means more complexity for the system, which creates more liability. In times of rising undergrounding demand TenneT intends to gain as much knowledge as possible, but also make their experiences available to others. The provisional conclusions are that the amount of 380 kV cables that can be integrated into existing overhead lines needs a case-by-case-study, that the maximum length of an AC underground cable piece is 1 km and that the maximum number of underground cables between two substations is three.

Out of their research TenneT has now developed a tool box approach during which they analyse a set of criteria (human environment, nature/ecology, landscape) to determine project feasibility, likelihood of permit and identify points of attention. They further examine the points of attention to find out if any bottlenecks exist. If bottlenecks exist, the toolbox is applied. It contains solutions like optimisation of overhead routes, applying other technical measure or undergrounding. The solution that best serves the circumstances is then applied. Similarly to Amprion, TenneT does not treat undergrounding as the silver bullet, but has already started to apply the toolbox solution that Amprion would like to be recognised by regulatory authorities in Germany (and elsewhere).

4.4 Discussion

The discussion after the presentation of the three pilot projects sought clarification on the topic of heat impact on soil and then mainly revolved around the issues of cost and acceptance. On the former, both Amprion and Elia confirmed that they measure the temperature impact around cables and substations and that the weather has a much bigger influence on soil temperature than the heat emitted from the cable. Jeroen Mentens (Elia) also explained that they simulate the temperature impact before construction to make sure that cables are laid at a distance that prevents the soil from heating up too much. Measurements on the Stevin project have shown that there is a maximum impact of 1.5 degrees on the top soil layers.

Cost

Participants discussed whether there is a chance of costs for undergrounding significantly decreasing in the future, especially considering that the projects discussed were pilot projects that hopefully brought TSOs further along on the learning curve. Gerald Kaendler (Amprion) argued that their pilot project in Raesfeld was build under conditions that posed very little obstacles and that it will be hard to find similarly good conditions again – which rather means that costs might even increase for future projects because they might have to cross more roads, pipelines etc. In any case, half the costs of an underground project were construction costs, which were very hard to bring down. Sjouke Bootsma (TenneT) countered that he does expect cost reductions in the future and that one should not only look at the costs incurred, but also consider the social costs that might have occurred if one had not been able to build the line in time.

On questions of acceptance and fairness

An audience member brought up the issue of felt unfairness for communities getting on overhead line versus those getting an underground cable. The presenters responded that there were very clear rules in which cases it was allowed to underground. In Germany, for example, you cannot underground AC if you are not within 400 meters of a community. In the Netherlands, the Ministry of Economics makes the final technology decision and for the Stevin project there was a clear decision to only underground 10 km, so it was clear from the beginning that not all communities could get an underground cable. The difficult question that many TSOs

still have to deal with, though, is how to treat single farms and houses and whether one should underground for those.

5. World café

5.1 Technology

The world café sessions on the lessons learned regarding the technological challenges of underground cables addressed the following points:

Systems differ

To determine the feasibility and length of AC underground cables, it is important to evaluate each system individually. Each connection and their role for system security is different. Islands have very often stronger constraints than well interconnected countries.

Knowledge exchange is important

Since experience regarding AC HV underground cables is scarce, knowledge exchange across Europe (or even worldwide) is key. Cigré is a useful platform for such an exchange on technological details. Committees on different aspects can be initiated by any member, results are available for all members as well.

Consider that the system is currently in transition

Participants agreed that the system is currently undergoing a massive change. Grid management therefore needs to adapt to a change of generation and consumption patterns, which needs innovative approaches. Undergrounding certain distances will add new challenges to a system in transition. This needs to be taken into account when planning new cables ("don't change everything at once"). Testing how the system behaves with the first pilot projects in operation will give further insights that need to be evaluated and considered for further planning.

Don't just look at operation

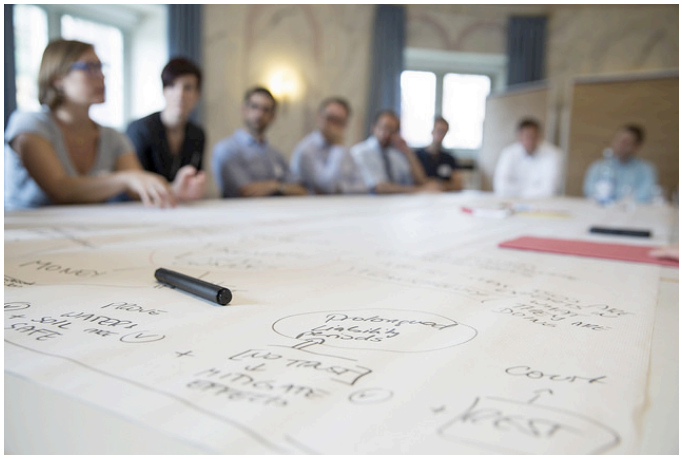
Knowledge exchange is not only important for the planning and operation of underground cable, but also regarding laying methods, long-term operation and dismantling. It is important to share information about innovative and less intrusive methods.

You need to clearly communicate about technology

Physical constraints need to be clearly communicated to decision-makers, so that they can develop a regulatory and political framework that allows for enough innovation and testing without serious threats to system security. Participants agreed that this needs a dedicated person who can translate technical details into a language that is understood by laymen.

5.2 Public participation

Opposition of farmers



In the first part of the discussion participants focused on exchanging experiences related to the new strong opposition against undergrounding, farmers and landowners. It was said that they could broadly be divided into four groups: 1. Those who are worried about their land losing economic value. They are usually very rational in their arguments and a solution in the form of payments to compensate for their losses can often be found. 2. Those who are extremely worried about long-term impacts on soil and hydrology can often be satisfied by explaining the existing research to them and bringing them together with agricultural experts involved in that research. 3. A third group is described as more emotional and less trusting. To make sure they are also on board it is highly important to put efforts into building trust and creating a transparent process that leaves room for their own decisions. In Belgium, for example, farmers could choose at what point in time they wanted to have their drainage repaired. TSOs could believably convey that they were fine with prolonged liability periods in order to lessen the farmers concerns and also ready to mitigate all effects, if possible, which created a lot of trust in the end. 4. The fourth group of landowners could not be won over by any efforts of this kind and often kept being strongly opposed. Those cases had to be settled in court.

A toolbox to allow for choices and value creation

The second part of the discussion looked more towards wishes for the future in order to be able to plan more widely accepted projects. There was a general call towards the TSOs to engage with stakeholders even earlier and consult NGOs as soon as they know which points they want to connect in order to make sure that NGOs can actually support the plans and will not have to oppose. After that the conversation developed into a brainstorming on how grids can create additional value, whether they are build overhead or underground. One option can for example be to think about the development of smart pylons that can also serve as a forest fire warning system or to charge electric bikes along biking trails. If the benefits that the technology used can bring to a region or community is always thought through at the beginning of a new grid project, the decision on going over or under ground can be made much easier. Of course, this decision should always be reached in direct dialogue with stakeholders and citizens who can be expected to be much more open to a grid project if it actually creates additional local value. This toolbox of options can however only be made available during consultations if there is regulatory approval of the related costs – something that participants around the table were united in calling for.

5.3 Environmental impacts

Known environmental risks

Participants in the groups talked about environmental risks that are currently known from real world experiences and the experience of undergrounding from other sectors. Impacts during construction included disturbance on the soil fauna. Including earthworms, microorganisms and the risk of spreading invasive species into the exposed soil. Introducing invasive weed species was also seen as a risk that needs to be mitigated for. The environmental impacts caused by the extensive construction works ware also discussed, including the impact upon ground nesting birds and smaller mammal species.

Impacts from the operation phase focused on issues of hydrology. Included potential impacts on water permeation and the cutting of watercourse important for certain species and farming activity. A special risk was identified for wetland and peat land habitats where the hydrological conditions are fundamental.

The work currently being done to mitigate

Many things are being done to mitigate the identified risks. Such actions discussed included

- The correct re-layering of soil to maintain quality and drainage conditions
- Proper soil storage to maintain topsoil quality and reduce the risk of invasive species
- Time the works sensitively: Both in terms of the daily scheduling of the works to reduce environmental disturbance and the seasonal timing to reduce impacts on certain bird species
- Extensive environmental monitoring being done at the pilot sites (including at Raesfeld) to understand potential impacts of EMF, impacts upon soil ecology. Work being done in partnership with universities

What needs to happen to improve practices and increase knowledge

It was agreed that we need to improve our collective knowledge of the potential environmental risks. This would include more research and the proper collection and ordering of the information which is already out there.

Day 2

The second workshop day started with excursions to the cable construction site close to Raesfeld and the visitors' centre exhibition. This was followed by a round of reflection and wrap-up discussion on the way forward.

Panel wrap-up discussion and workshop outcomes

Panellists: Gerald Kaendler (Amprion), Jeroen Mentens (Elia), Alice Collier (RSPB), Dr. Volker Waschk (NKT Cables), Antonella Battaglini (RGI)

The final panel reflected once more on the myth of undergrounding as the silver bullet and agreed that the most important thing is not to underground all grid projects, but to use the best technology under the given circumstances, to choose this technology in cooperation with local stakeholders, and in the best case also create additional local social or natural value. In order to be able to build the best projects possible, one needs to be able to choose from a number of different options, not only when it comes to the corridor, but also when the engagement strategy, the visual aspects and especially technology aspects. This means that undergrounding should always be part of the toolkit available to TSOs (which in many European countries is currently not the case). But to understand when to best pull this option out of the toolkit, we still need to learn a lot about the technology and its impacts. It was suggested during the panel discussion, but also during previous discussion rounds already, to develop principles and guidelines that foster a common understanding of nature and environment impacts of underground cables, the acceptability of cables and the values of people in a given context, as well as remaining technological challenges. These guidelines should not only be used for industry, but also as a tool in engagement processes to explain and discuss the decision-making process with stakeholders.

From this, a proposal to set up a task force was made that would explore the idea of setting up a knowledge base, hosted by RGI. Such a knowledge base would collate the information from the environmental assessments of the undergrounding projects that have already been completed across Europe, as well as collating the information from various post project environmental monitoring activities being done by research organisations on the completed projects. In addition, it would aim to collect innovative technical solutions (including TSOs' wishes to the cable industry) and gather evaluation outcomes of stakeholder engagement processes to develop a better

sense of what stakeholders and citizens most value in connection with a new project and whether the value creation angle is a fruitful one.

Such a task force would include TSOs, NGOs and industry participants and could develop an effective way of standardising the information on issues such as high-risk habitats and species, the impacts on different soil and crop types as well as effective stakeholder cooperation and intelligent technical solutions. Such a platform of data would increase transparency and knowledge and allow for an informed decision to be made on the comparative impacts of undergrounding vs overhead lines, and ultimately hopefully also influence regulatory decision-making and the legal framework. This exercise would ideally also contribute to a much more strategic and early long-term vision and make sure that all projects are contributing in the most sustainable way to this long-term vision.

The next steps will be to develop the right guiding questions for this task force. The following participants agreed to contribute to the task force: Alice Collier (RSPB), Gerald Kaendler (Amprion), Sjouke Bootsma (TenneT), Dr. Volker Wendt (Europacable). It will be moderated by the RGI Secretariat.