Scottish & Southern Electricity Networks

TRANSMISSION

The challenges with undergrounding at 400kV

Introduction

SSEN Transmission's Pathway to 2030 projects form part of a major upgrade of the electricity transmission system across Great Britain (GB) that is required to help deliver UK and Scottish Government climate change and energy security targets. This includes the requirement to develop three new major onshore overhead electricity transmission lines across the north of Scotland. This paper explores some of the technical and engineering, operational, environmental and economic challenges associated with underground cabling which need to be carefully considered in the development, delivery and ongoing operation of electricity transmission infrastructure, alongside wider network development and operational considerations.

All references to 400kV throughout this paper assume a double 400kV circuit and the challenges presented are specific to the undergrounding of this technology and capacity.

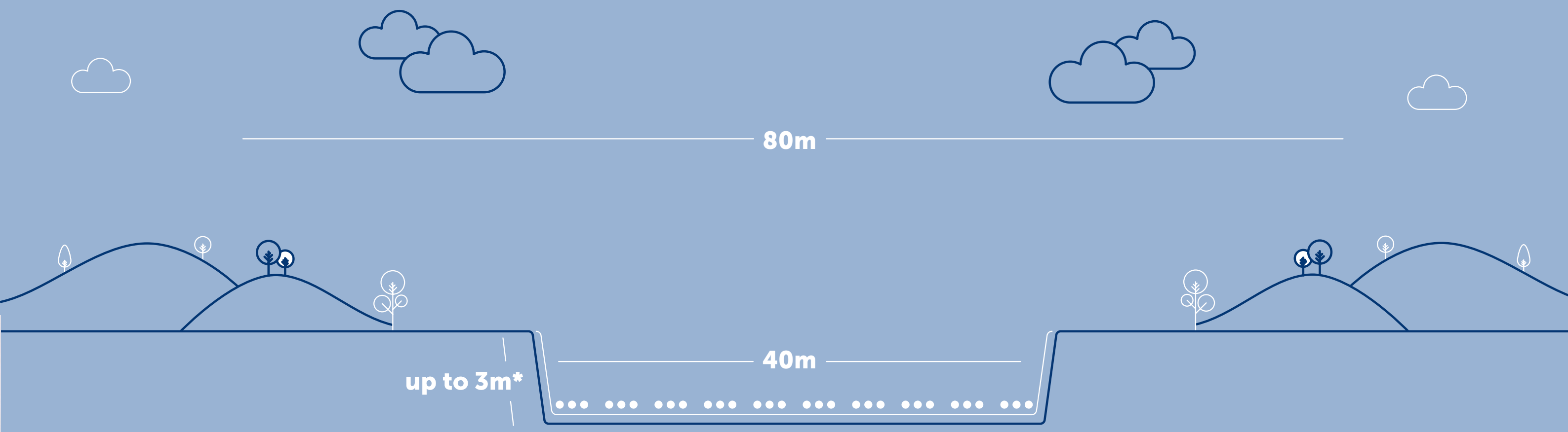
Engineering considerations

Undergrounding engineering requirements

Underground transmission circuits at 400kV for SSEN Transmission's Pathway to 2030 projects require up to five cables per phase. In order to deliver the necessary capacity, which requires a three phase 400kV double circuit, up to 30 parallel cables will be required. For electrical reasons, these cables need to be suitably spaced out.

To achieve the required spacing, a group of trenches at a combined width of over 40m wide would need to be excavated, typically between 1m and 3m deep. During the construction period, a working corridor of over 70m wide is required for cable installation. This can result in significant land use constraints during the construction phase, typically more so than overhead line construction activities, particularly for farming operations.

These cable trenches can also leave a residual visual impact on the landscape with a potential to result in significant environmental impacts and future land constraints.



*depths exceeding 3m or obstructions would require trenchless techniques

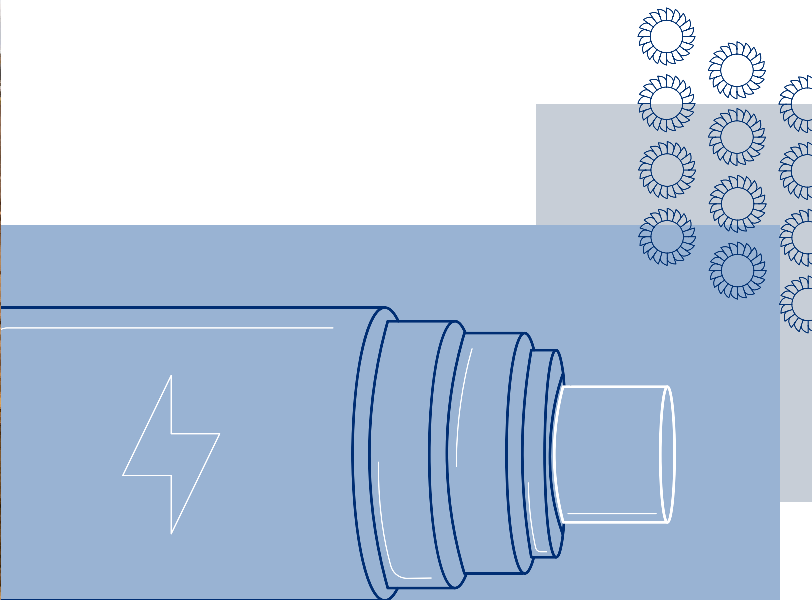
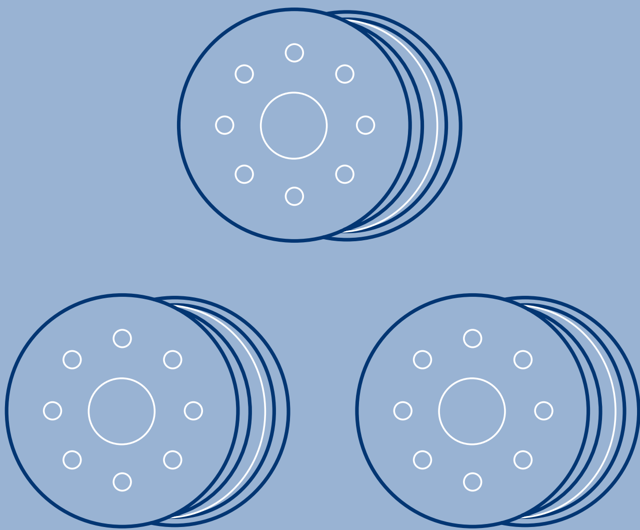


Image courtesy of National Grid Electricity Transmission

Additional infrastructure requirements

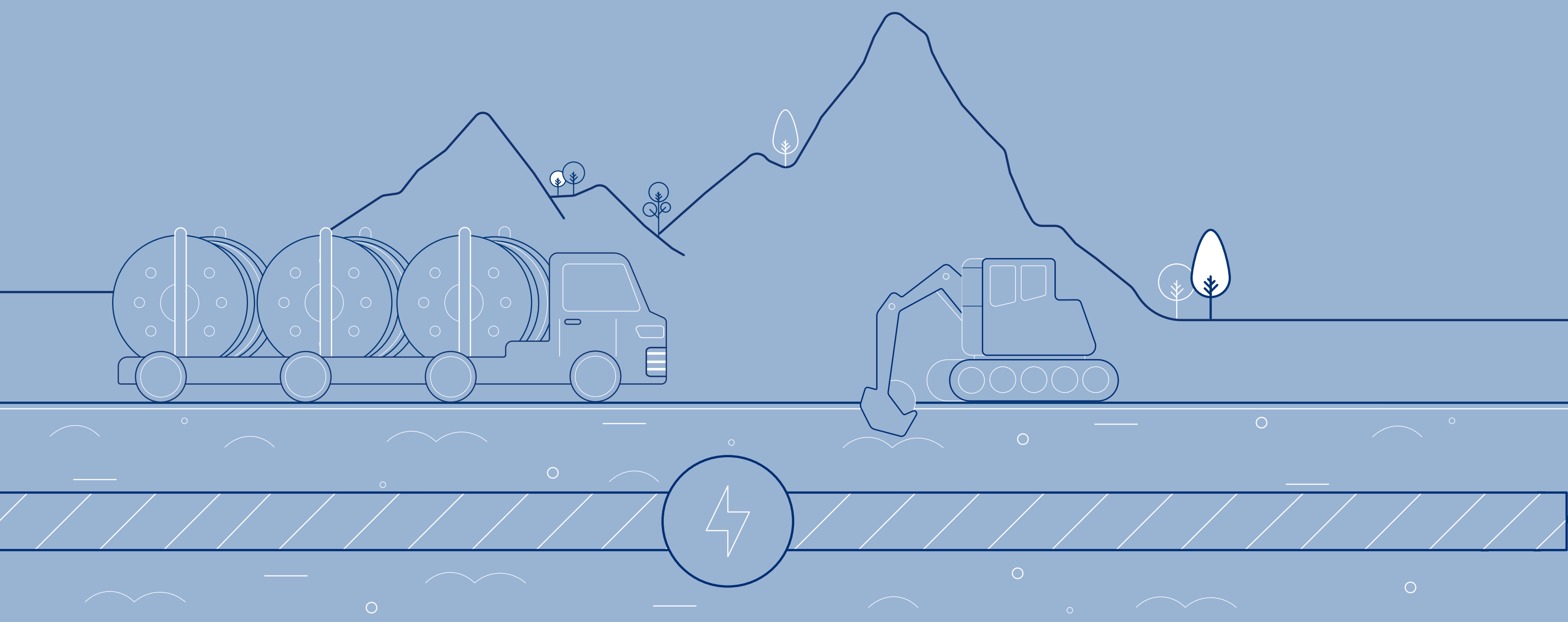
Cable joint bays

The lengths of cable that can be safely spooled and transported on a cable drum for installation, along with the maximum tensions that the cables can withstand during cable pulling operations during installation, are restricted due to their weight and dimensions. For electrical reasons, the maximum lengths for each section of 400kV cable with a high rating need to be further limited to approximately 400m. At each point where these sections of cable are jointed or connected together, there is a requirement for intermediate joint bays.



The footprint of these joint bays would exceed that of the width of the operational trench for the associated underground cable circuits, with the width of these joint bay locations likely to be around **45m wide.**

These cable joint bays would also result in some permanent above ground infrastructure in the form of manholes and link boxes which would be installed in a free-standing pillar arrangement to allow for ongoing maintenance access. For protection of the assets at these locations, the manholes and pillars would be contained within small, fenced compounds, with a footprint of approximately 5m x 5m and with one compound for each circuit.



Cable sealing ends

At each point an underground cable transitions to an overhead line there is a requirement for a Cable Sealing End compound. This would consist of a stoned hard standing platform with a security fence around its perimeter where the underground cabling would transition and connect to an overhead steel tower.

The footprint of these compounds is estimated to be around 70m x 70m.

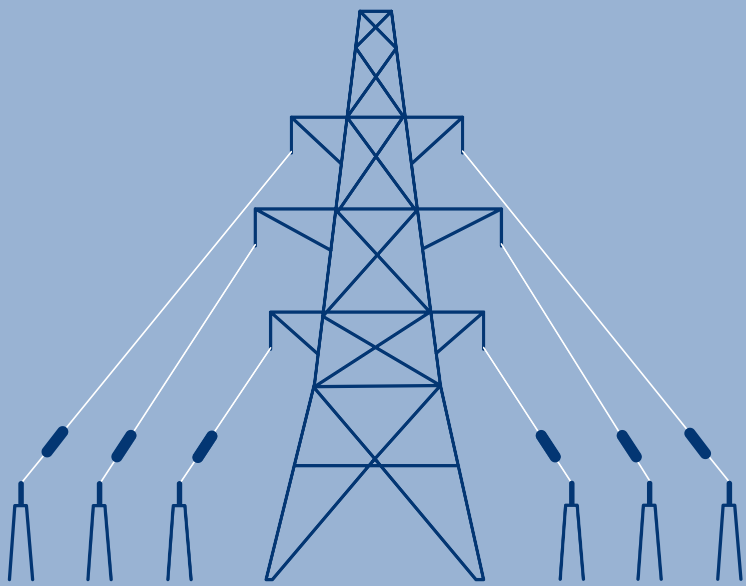
Reactive compensation

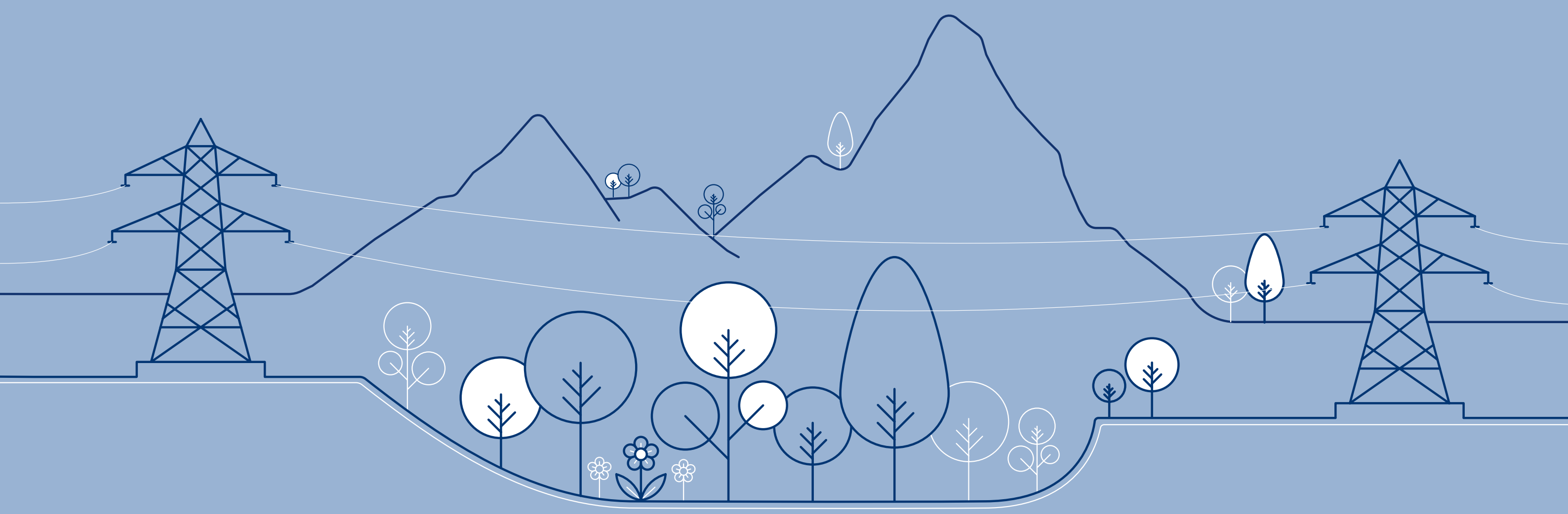
As underground cables operate less efficiently than overhead lines, particularly at high capacity and high voltage, the transmission of power becomes constrained. This leads to the requirement for reactive compensation equipment to be installed at substations connected to the overhead line to maximise the power flows.

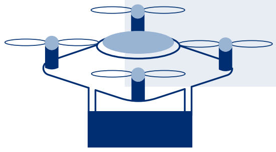
This additional equipment would result in a significant increase in the overall size of substation footprints at each end of transmission circuits and could increase landscape and visual impacts of these substation sites.

It is currently estimated that this type of equipment would be required for as little as 1–2km of 400kV underground cable installed.

The requirement to use reactive compensation equipment can make operation of the network significantly more difficult. In some situations, it can present significant risks to security of supply and network reliability.







Operational considerations

Maintenance and operation

The ongoing maintenance and inspection of underground cabling is significantly more challenging than that of overhead transmission infrastructure.

Cable insulation and bonding systems require periodic inspection and maintenance to avoid early deterioration of the cable system. The route must be surveyed periodically to ensure that the cable system is protected from external factors such as infrastructure development, ground movement and the risk of vandalism.

Restoring power in the event of a fault

Whilst minor faults on cables are less common than on overhead lines, when cable faults do happen, they result in major disruption. Restoring power in the event of a cable fault can take significantly longer than for an overhead line. Faults on overhead electricity lines typically take anything from a few hours to a few days to repair and are generally easy to locate.

Underground cable faults often require extensive works, specialist resource, tools and equipment to locate the fault, followed by significant civils work to expose the damage, replace the damaged section and then up to an additional month to carry out necessary cable jointing and testing of new sections. The mobilisation of specialist equipment to undertake fault repairs on underground cabling results in significant local impacts, particularly for landowners and public highways. This presents significant risks to security of supply and network reliability.

Land use constraints

The cable corridor width required for undergrounding at 400kV presents significant land use constraints, particularly during the construction phase but also during the operational lifetime of underground cable assets.

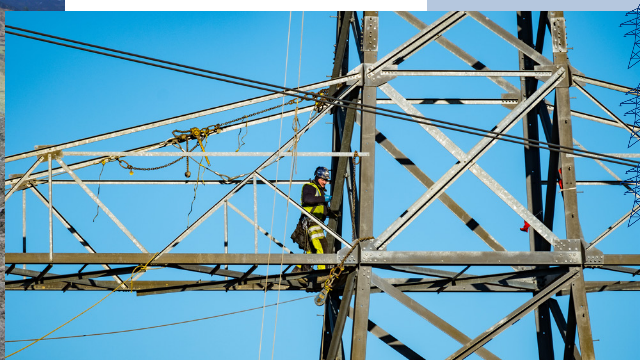
For overhead lines, the micro-siting of towers presents opportunities to greatly minimise impacts on future land use and we work very closely with affected landowners to locate this infrastructure in the most sensitive way.

Due to ongoing operational requirements and in particular, the need to be able to access cables to undertake inspections, maintenance and in the event of a fault, carry out repairs, undergrounding can constrain future land use such as some farming operations.

Routine inspections and maintenance are required over the lifetime of underground cable infrastructure. Ground based visual inspections can be as frequent as every year with more intrusive maintenance at all joint bay locations and Cable Sealing End Compounds necessary every four years. In contrast, overhead line inspections can generally be undertaken from the air, using specialist LiDAR flights or drone surveys.

An underground cable would be expected to have an operational life of around **40 years**, similar to an overhead transmission line conductor. However, steel lattice towers would typically be expected to have a lifetime of around **50–70 years** and when an overhead line conductor reaches the end of its design life, it can simply be replaced with limited impact to landowners.

The replacement of an underground cable would be significantly more intrusive, impactful and disruptive to both landowners, the wider local community and the environment.



Environmental considerations

Peat

Peat and carbon-rich soils present a significant challenge to underground cabling. The Scottish Government's National Planning Framework 4 (NPF4) clearly sets out that development proposals should seek to avoid or minimise peatland, carbon-rich soils and priority peatland habitat.

Where the development of essential infrastructure will affect peatland, the NPF4 clearly sets out that it would only be considered where there is a specific locational need and where it can be clearly demonstrated that no other alternative options are available to avoid excavating peat.

As overhead lines traverse over peatland, tower locations can be micro-sited to minimise impacts on peat, the footprint of development and subsequent excavation of peat can be significantly minimised using overhead line infrastructure rather than underground cable.

Installing cables in peatland presents significant risks of movement as watercourses and ground conditions change over time which can cause cable damage and faults. To mitigate against this, cables need to be installed in solid structures, like ducts and trenches, which can result in additional environmental impacts.

Woodland

Whilst every effort will be made to avoid the felling of trees for new transmission infrastructure, woodland removal may be required to install transmission circuits within a corridor that has been cleared of trees and other vegetation for installation and operational purposes—this being required for both overhead lines and underground cabling.

However, during construction of an overhead line, measures can be taken to reduce the width of the corridor and reduce the number and extent of tree felling required. This is particularly important when considering ancient woodland, veteran trees and native woodland habitats.

During construction of an overhead line, we can raise tower heights, increase or shorten span lengths, microsite tower and access track positions and consider different approaches to wiring that can all result in reductions in tree felling. In addition, once operational, low growing scrub habitats can be established under overhead lines which can help to maintain a connection with woodland on either side of the overhead line, supporting biodiversity.

Underground cable operational corridors need to maintain a set width and be clear of trees, to ensure root growth does not damage cables, limiting opportunities for tree retention in design, construction, and operation. There is not as much scope for flexibility.

Ground conditions

Underground cabling is highly sensitive to ground conditions and terrain, with much of the north of Scotland's mountainous, peaty and rocky terrain making it extremely difficult to install and maintain.

Excavation in mountainous terrain to create cable trenches and working areas can require significant rock breaking activities. This can permanently alter the landscape setting removing the natural appearance and creating hard edges, where a cable trench is positioned.

Re-establishing vegetation following ground disturbance in mountainous areas can take a long time due to the shorter growing season and adverse weather conditions, leaving a notable cable corridor visible at a landscape scale in open mountainous terrain.

Hydrology

Excavations involved with 400kV underground cable trenches have a higher likelihood to disrupt shallow groundwater systems which can result in the lowering of groundwater levels in the immediate vicinity of the excavations. In contrast, overhead lines are unlikely to alter groundwater flows.

Permanent access tracks for overhead lines have drainage designed to adapt to local conditions and tower bases have a small land take (approx. 15m x 15m). The land is restored under and around the tower bases resulting in natural conditions of groundwater being maintained. Cable trenches can also modify water drainage pathways to groundwater flows, with potential impacts on environmentally sensitive wetland habitats such as marshes, flushes; and heightened risk to groundwater fed Private Water Supplies (PWS).

Other environmental considerations

These range from impacts on local biodiversity, particularly ground nesting birds and mammals, to the risk of flood related pollution during both the installation phase and when undertaking repairs that require cable trenches to be reopened. For example, silt or peat pollutants, as well as the material used to stabilise cables, could be released into the local environment and watercourses following heavy rain or a flood event. Whilst steps will always be taken to mitigate and minimise such risks, these need to be carefully considered and balanced against a range of other factors when considering the technology choice for new electricity transmission infrastructure.

Economic considerations

The cost of investing in the electricity transmission network is ultimately paid for by GB electricity consumers and under Section 9 (2) of the Electricity Act 1989, we have a duty to develop and maintain an efficient, coordinated and economical system of electricity transmission.

It is acknowledged that undergrounding is considerably more expensive, which we estimate to be **at least five times more expensive,** the costs of which will ultimately be borne by GB consumers. In line with the above electricity transmission licence obligation, cost is therefore an important consideration.

Conclusion

In summary, whilst we are committed to exploring the possibility of undergrounding at sensitive locations where there is clear evidence to justify it, this presents significant challenges due to the technical, operational, environmental and economic factors. In particular, it may not represent the best solution for landowners due to the greater footprint and associated impact on agricultural land, as well as the requirement for additional onshore infrastructure to manage system requirements.