Feasibility of Undergrounding Transmission Lines

7/17/23

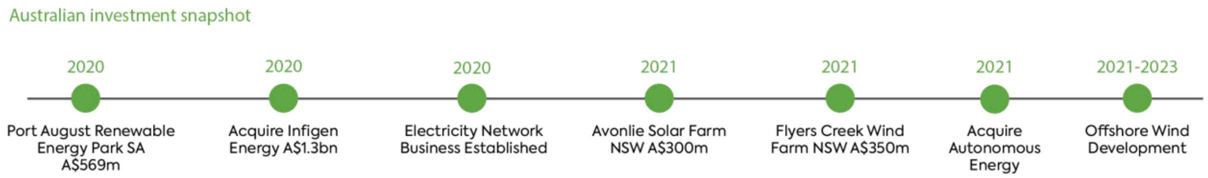
Index

Contents

1. Company Overview

Iberdrola Australia

Iberdrola Australia is part of the Iberdrola Group, a global energy leader, with a history of over 170 years, and a mindset of looking forward. Since 2020, Iberdrola Australia established its electricity networks business. Iberdrola Australia Networks is committed to supporting Australia's energy transition and its electricity grid transformation. We are here to support and participate in state-sponsored projects, deliver critical transmission projects, to create renewable energy zones as well as consider investment in grid infrastructure to access new renewable energy's frontiers.



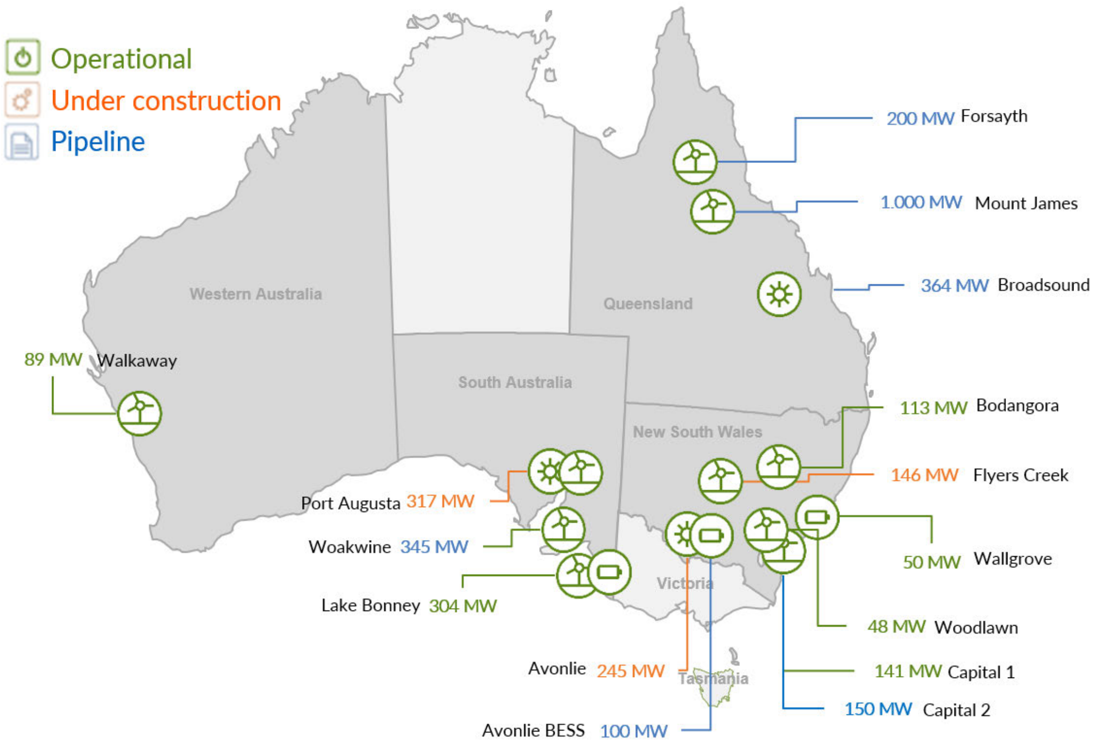
Our strategy is to put communities, traditional owners, workforce, and customers at the centre of the renewable energy transition. This means working closely with the communities in which we live and work to make an enduring contribution to social and economic wellbeing in regional Australia. In all our activities, we strive to be a trusted partner for stakeholders and government to deliver an orderly and integrated energy transition for the country. In doing so, we put the needs of our customers at the heart of our product offerings, providing firm supplies of affordable green energy to Australian businesses.

Iberdrola is leading Australia's transition to a clean future, today.

At Iberdrola Australia we operate one of the largest portfolios of renewable energy assets in the country and have invested in a fleet of flexible, fast start firming assets that manage intermittency risks.

Our portfolio includes:

- 1,377MW of wind and solar capacity
- 318MW of fast start firming capacity (including batteries and open cycle gas turbines)
- 224MW of contracted renewable energy capacity



Iberdrola has invested in excess of $2 billion in Australia over the last three years.

Iberdrola S.A.

The Iberdrola Group is recognised globally through building, operating and maintaining renewable energy generation facilities, electricity power lines, substations and other infrastructure to serve customers across Spain, UK, US, Australia and Brazil. Iberdrola S.A owns 100% of Iberdrola Australia Limited. It is a listed company in Spain and the largest renewable energy utility in Europe with the following attributes:

- Market capitalisation of €75 billion ($115 billion)
- Rated BBB+ by S&P Global Ratings
- Total assets exceeding €154 billion ($236 billion)
- Achieved 2022 revenues of €53.9 billion ($83 billion)
- 2022 net profit of €4.3 billion ($6.6 billion)
- Largest corporate green bond financier internationally

Iberdrola is a trusted Network Operator in multiple countries around the world. The Iberdrola Networks business employs over 20,000 people, globally, as well as owning and operating over 1,200,000km of transmission and distribution power lines over three continents under licence or concessions. We provide our 34 million customers around the world with reliable access to electricity supplies.

2. Introduction

2.1 Background

According to the Australian Energy Market Operator's (AEMO's) 2022 Integrated System Plan, Australia needs to build 10,000kms of transmission lines by 2030, to meet the Government's 82 per cent renewable energy target.

AEMO's CEO, Daniel Westerman has advised that investment in new clean electricity supply is not happening fast enough to replace the coal power stations that are reaching end of life and are closing. To connect the renewable generators, investment in transmission lines is required. The investment and building of transmission are lagging that which is required for the energy transition and is preventing the connection of new renewable generation.[1] Transmission infrastructure builds are being delayed by local community opposition and supply chain and workforce resourcing issues in NSW and Victoria. [2]

Delays in the build of transmission projects is resulting in solar and wind generation having to be curtailed due to lack of grid capacity. The level of curtailment has grown by almost 40 per cent in just 12 months[3]. In addition, delays to transmission projects have resulted in increases to customers' electricity bills. NEXA Advisory has modelled that on average across the National Electricity Market (NEM) that households would pay a total of approximately $600 more in electricity bills over 15 years if all transmission flow path augmentations are delayed by 2 years. This increase to a customer's energy bill increases to approximately $1800 over the same period with a transmission build delay of four-years[4].

Opposition from rural communities to the build of overhead transmission towers and lines is seen as one of the biggest hurdles to the transition to net zero and meeting emissions targets. The reasons for opposition to new overhead power lines includes the following:

- **Environment :** Communities see that the building of proposed towers and transmission lines will possibly see loss of significant native vegetation, old growth forests, homes of many endangered and near extinct species.
- **Rural Communities :** Communities believe that there will be negative impacts on the well-being of the population and economy in areas that rely heavily on tourism due to the negative visual impact of the poles and wires. Where transmission lines are routed through areas that are valued for their scenic qualities, there is a belief that towers can ruin the visual amenity and impact tourism. There is also a fear of health issues when living near or under power lines and/or towers.

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[1] https://www.aemc.gov.au/market-reviews-advice/transmission-planning-and-investment-review

[2] *The energy transition is far too slow, AEMO warns'*, Australian Financial Review, Angela Macdonald-Smith, 20 June 2023

[3] Daniel Westerman, AEMO CEO speech at the Australia Energy Week Conference Melbourne, 20 June 2023

[4] *Modelling electricity bill impact of transmission project delays*, Endgame Economics on behalf of NEXA Advisory Group, 7 June 2022

- **Lacking reliability :** Communities believe that there are issues with the reliability of the poles and wires impacted by tree branches falling onto powerlines, vehicles driving into poles, storm and wind activity, erosion and animal interference. The damage can cause extended power outages that in extreme cases cannot be restored for days or even weeks. The cost for repairing the physical damages can be in the billions of dollars. During long outages after a natural disaster or force majeure event, there are also associated intangible impacts to customers such as despair, discomfort, anxiety and helplessness. In addition to the intangible impacts, there are considerable direct economic impacts to customers resulting from lost economic activity, food spoilage, looting, etc.
- **Bushfire Risk :** Communities fear that the towers increase the risk of bushfires, loss of life and property. If a bushfire were to occur, there is also the fear that the communities will be out of power for prolonged periods of time if the overhead powerlines are impacted.

As a result of the community concerns, the NSW Minister for Climate Change, Minister for Energy, Minister for the Environment, Minister for Heritage, Leader of the Government in the Legislative Council listened to the communities' concerns and has requested an inquiry into the feasibility of undergrounding transmission infrastructure.

In particular, the inquiry focuses on:

- the costs and benefits of undergrounding
- existing case studies and current projects regarding similar undergrounding of transmission lines in both domestic and international contexts
- any impact on delivery timeframes of undergrounding, and
- any environmental impacts of undergrounding.

As Iberdrola has expertise in this area, Iberdrola would like to provide some assistance with understanding the benefits and concerns associated with undergrounding transmission lines. This report will focus on transmission lines, as opposed to distribution lines.

3. Technical Considerations of Overhead and Underground Power lines

Overhead high-voltage transmission lines are a reliable, low cost, easily maintained and established way to transport bulk electricity from generation sources to customers, often over long distances. However, communities that are being asked to host the overhead high-voltage power lines and towers on or near their properties have repeatedly requested that undergrounding options be explored.

In Australia, the highest power transmission voltage is 500kV. The first overhead high voltage alternating current (HVAC) power line, was a 500kV HVAC transmission line built in 1970 between Hazelwood to Melbourne. It is currently operated by AusNet Services. The first 500kV overhead HVAC powerline in NSW was built in the 1980s from Eraring Power Station to Kemps Creek. In both Victoria and NSW, the 500kV lines were expanded to connect coal fired power stations to major loads centres.

The primary benefit of overhead HVAC transmission lines is their ability to cost effectively transmit electricity over long distances, such as 2,500kms with minimal power losses.

Underground High Voltage Alternating Current or underground High Voltage Direct Current transmission lines have become more popular as they minimise risks from extreme weather and bushfires and they significantly reduce the impact on the environment and regional communities, including visual amenity.

The underground transmission cables are self-contained underground and are barely noticeable. They are often better suited for low voltage, highly populated areas, such as major CBDs and residential zones where congestion is a problem. The saved space can be better used for pedestrian crossings and public infrastructure.

3.1 Comparison

	OVERHEAD CABLES	UNDERGROUND CABLES
Construction	Relatively easy to construct – it is approximately 60% cheaper than undergrounding	Expensive, especially due to excavation work required.
Installation	Straightforward	Difficult, requires significant excavation along the cable route. Installation can take a long time as sterile enclosed environment is required for cable jointers to undertake their work on the cable, section by section. Specialised equipment and materials required for undergrounding.

		Ensuring requisite quality materials are available can add to delays.
Conductor Sizes	Smaller conductors due to natural cooling	Larger conductors
Repair/Maintenance	Easier to spot and repair faults	Can be difficult to locate and repair faults, costly and time consuming. Outages likely to be very long[5]. However, cable less likely to break.
Environmental Impact	Intrusive environmental impact	Some environmental benefits – reduced noise, loss of visual impact and less wildlife damage. Environmental impacts will arise during construction
Life Expectancy	Longer life span (average 70-80 years)	Shorter life span (average 35-40 years[6])
Safety	Exposed to more risks – vegetation falling, animals, car crashes etc.	Safer – contained underground. There is a risk of someone performing an excavation and accidentally hitting the cable. Cable can also be impacted by plant or tree roots and flooding, lightening, earthquakes which can impact cooling of cables as well as the cables themselves.
Visual Amenity	Very noticeable, limits public land use	Minimal visual impact – great for congested areas such as CBDs and residential zones.
Design	Relatively standard and within Australian skillset	Staff have niche skills, especially for high voltage underground cabling and specifically skilled staff have to be hired. Limited availability of skilled staff in Australia
Insulation	Overhead lines are air cooled and widely spaced for safety.	Underground cables, tend to retain the heat produced in the conductor.

[5] 'If a fault occurs on a 400kV underground cable, it is on average out of service for a period 25 times longer than 400kV overhead lines.' From 'Undergrounding high voltage electricity transmission lines', National Grid, January 2015
[6] Information provided by Central Maine Power in relation to Kennebec River Crossing, which is owned by Iberdrola subsidiary Avangrid.

		This heat then has to be dissipated to the surrounding environment. To compensate for this, underground cables are generally bigger to reduce their electrical resistance and heat produced. How the heat produced is dissipated will depend upon the cable installation method and can impact on footprint on the land for placement of the underground cables.
Physical	Easier for crossings on difficult terrains. Potentially reduces the length of the routes	Better applications on urban environments

The major considerations for the purpose of this report, is that each transmission underground line is specific to each location. In terms of this, we must take into account:

- the different types of topography, structures, ground conditions, environmental issues such as flooding, dry conditions, waterways, rocks, and others all need to be taken into considerations
- as well heritage, ecological impacts, and community disturbances.

There is also a requirement for specialised skilled workforce, that is required across the life cycle of the project, from design, construction to operation and maintenance. There is a limitation of available specialised skilled staff for these projects in general and in Australia particularly. For example, each project will require a customised cable and each cable will require customised parts, joints, earth sheaths etc. As these skills are in short supply globally, the cost for hiring these staff and the materials will be significant. After speaking to specific transmission line cable suppliers in the industry, we have been advised that the costs for undergrounding in Australia are much higher than other countries because the labour rates are very high. Also, there are usually long lead times for procuring custom built components and there are only limited suppliers globally.

Underground transmission lines installation is very specific to the nature of the location and will change as the terrain around the installation changes. This means that there is going to be significant types of installations within the transmission line route. Each installation type will require different materials, equipment, and skills. Examining, planning, and installing the underground transmission lines will take significantly longer time for construction that than those used for overhead lines.

When considering HVDC transmission systems, there is a requirement for an AC to DC converter station at each end of the line. The main benefit of HVDC is the low lossess in very long distances, but the cost and complexity of converter stations, make the implementation of HVDC less attractive for shorter distances. At a specific distance cost of HVDC Transmission is equal to the cost of HVAC system, that point is called breakeven distance. HVDC transmission is economical only for long-distance transmission lines having a length more than 600 km and for underground cables of length more than 50 km[7]. The HVAC transmission line has an advantage of enabling connection of more renewable generation along the transmission path with relatively very low cost of connection points compared to expensive additional converter stations required to be installed for the connection of generators to the HVDC transmission system.

3.2 Cable designs

Transmission cable designs

Further information to be considered with undergrounding relates to the cable design. Transmission underground cables range from voltages at 132,000 up to 500,000 voltages. These cables are very rare and are never "off the shelf". They are one-off designed and manufactured, developed specifically to suit the power requirements, soil profiles, route, and reliability requirements of the installing authority. Highly specialised cable jointers are required for this installation. In some cases, the manufacturers will send their own offshore specialists to site to complete the installation and cable jointing. Training is normally undertaken for local cable jointers to equip them with the knowledge to complete operation and maintenance (O&M) activities over the life of the cable.

Transmission trained cable jointers in Australia are very rare and typically brought in for specific projects by the cable manufacturer. Specialised cable trenching and pulling equipment is required for large transmission cables.

3.3 Cable installation types

The installation type or methodology for a transmission HV Cable is directly related to the nature of the environment surrounding the location of the route and it does change along the route to adapt to the location conditions. The most common methods for underground installation are the following:

Direct Buried

Underground cables are in many cases direct buried into the ground using a typical "trench profile". A trench profile will provide adequate soil cover to prevent mechanical loads, such as vehicles, from damaging the cable and provided necessary heat dissipation.

The voltage level will determine the trench profile and depth at which cables need to be buried. Higher voltages will require deeper and wider trenches and may require a particular cable geometry such that resonant frequencies and magnetic fields are reduced over the length of the line. Higher voltages require the soil to be analysed in the design of the cable to ensure it can sufficiently dissipate heat generated from the cable under high loads. If a particular soil type is not favourable, then new soil needs to be backfilled to improve the cables overall design.

[7] *'Western Victorian Transmission Network Project, High Level HVDC Alternative Scoping Report,'* Amplitude Consultants, 17 June 2021.

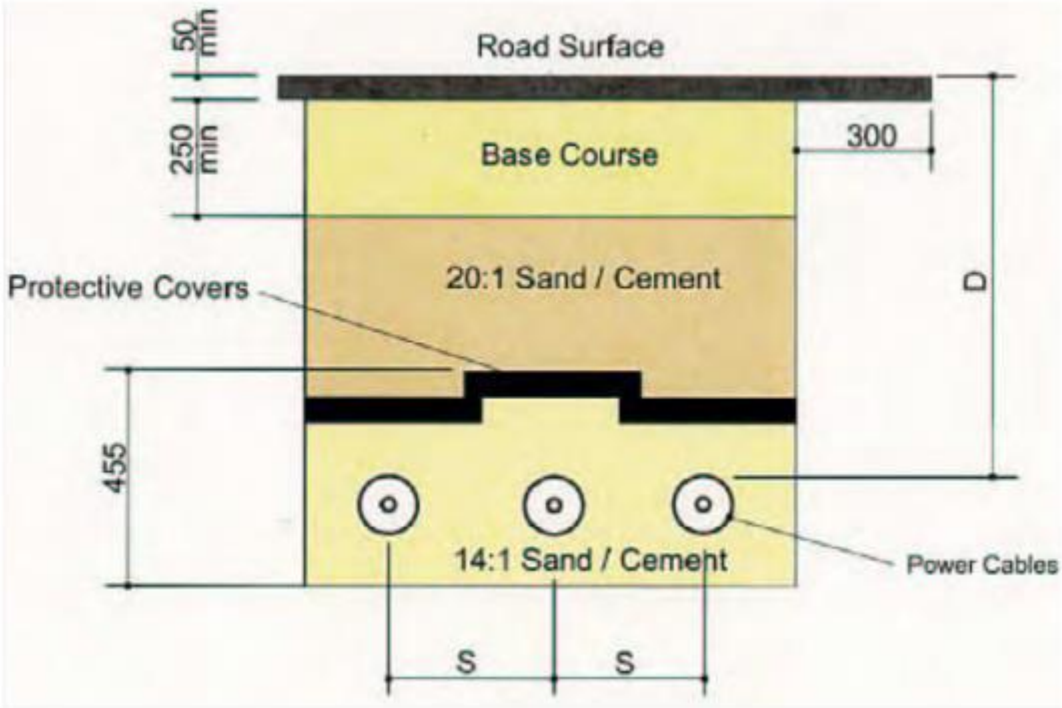

Figure 1 - Example of typical HV underground cable trench profile

Examples of direct buried Transmission cables are;

- TransGrids 330kV Powering Sydney's Future2
- Victorian Desalination Project3
- ElectraNet 275kV Adelaide Central Reinforcement

Conduits

HV cables can be placed into conduits, where the environmental conditions require additional protection. HV underground cables pose substantial safety and monetary risk if inadvertent contact is made.

Tunnels

Tunnels are at times used to house transmission and sub transmission cables. A tunnel can provide mechanical and environmental protection, whilst also providing security and greatly improved operations and maintenance performance. Tunnels are more commonly used in highly populated areas such as CBDs.

Figure 2 - Ausgrid's 132kV City West cable tunnel

Examples of HV cable tunnelling currently utilised in Australia are;

- 132kV City West Cable Tunnel
- 330kV Picnic Point to Haymarket
- Greenwich Electric Cable Tunnel

Above Ground Cable Structures

An above ground cable structure is typically a bridge or other elevated structure that the HV cable is attached too. This can be required to traverse roads, railway lines or other below ground obstacles. Where the layout design permits, existing bridges or structure can be utilised to house the cables instead of specific structure requiring to be built.

3.4 Route

Layout

HV underground cable routes typically follow a linear route that is constrained by familiar features, such as environmental sensitivities, cultural heritage, roads, dwellings, and so on. There are however constraints unique to HV cables that are not dissimilar to an underground water or gas main installation, including the soil profile, which can contain rock, clays, sands, and other silty type soils not favourable to an underground cable.

Trench

Trenching varies depending on the cable voltage, specific design, and soil conditions. There are however some generic values which can apply. Generally, for a 330kV cable the trench would be around 3m wide and 1.5 deep, while a 500kV cable would require a trench around 4m wide and 1.5m deep.

Rocky, hard soils or soft, sandy soils can pose significant construction challenges and costs to an underground cable due to the extensive excavation required.

Joint Bays

Because of the large thickness and limited bending angle of HV underground cables, a typical cable drum is around 30 tonne and can only accommodate relatively short lengths of cable. Thus, multiple drums are used, and lengths of cable must be joined with a complex joint bay by specialised personnel. A 330kV joint bay may occur every 850m, with 500kV requiring one ever 550m. Consideration needs to be given to the location for the many joint bays need along a cable route. Some locations may be less suitable than others.

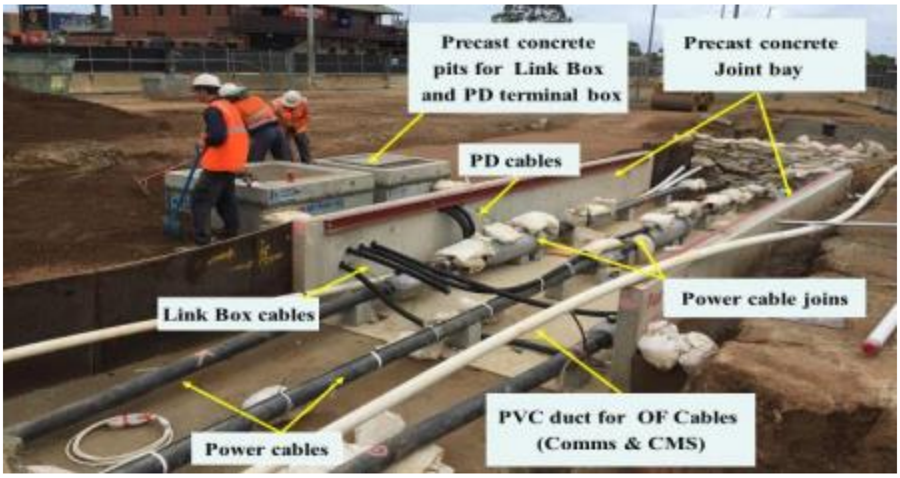

Figure 3 - Typical HV Joint Bay layout

Easements

Underground cables require smaller easements than the traditional overhead transmission lines as blowout and other conditions do not need to be included. Industry standard typical easement widths for underground cables are 24m for 330kV cable and 30m for 500kV cable.

Similarly, to overhead transmission lines, the easement grants the operating authority access for maintenance, and includes certain provisions that prevents construction or certain activities within an easement area.

Electric Magnetic Fields

Electric Magnetic Fields (EMF) are emitted due to current flowing through a conductor. The greater the voltage and current, the greater the magnetic field.
Typically, EMF generated from HV underground cables fall within the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines, however, specific design of the cable

can reduce the magnetic fields further. This can include trefoil arrangements, using thermally engineered backfill, and optimising the trench cross-section.

Underground routes are heavily dictated by the difficulty of terrain to be excavated, in addition to built up urban areas.

4. Cost considerations for undergrounding transmission lines

The cost of undergrounding transmission lines in comparison to overhead lines varies depending on each project. The costs for undergrounding transmission lines depend on country, line lengths, terrain, route, environmental and heritage factors, procurement of mainly customised materials and equipment, whether the project relates to undergrounding of a HVDC or HVAC, or whether there are resources such as the specifically skilled labour required for design, construction, and operation of underground lines. These projects have labour intensive construction work, which also significantly increases the cost and duration required to complete the projects.

Iberdrola has found that infrastructure costs, especially in construction have increased significantly in the last 12 months. In the energy sector, there has been multiple causes of these price increases, including cost increases due to the impact of COVID-19, the high demand for resources, scarcity of materials and equipment and a global skills shortage for engineers, field staff and others in the energy industry.

A benchmarking study for the Australian Energy Market Operator specifically addresses undergrounding versus overhead cost and states, "The costs of underground cables are approximately 4 to 25 times higher than overhead lines. Direct buried cables are at the lower end of this range, while tunnel installed cables are at the upper end[8]." Although the standard estimation assumed until recently was that undergrounding transmission lines is 10 times the cost of overhead transmission lines. This cost difference has been debated over the years, and the assumed difference, although, based on a case-by-case consideration, is closer to 4 times than 10.

A report from the UK endorsed by the Institution of Engineering & Technology[9] established the following:

- Costs per kilometre, for all technologies, tend to fall with increasing route length, and tend to rise with circuit capacity.
- Overhead transmission lines are the cheapest transmission technology for any given route length or circuit capacity, but they are the most have the most losses.
- Underground cable, direct buried, is the next cheapest technology after overhead line, for any given route length or circuit capacity
- Options using a deep tunnel, the largest single cost element is invariably the tunnel itself and therefore is the most costly

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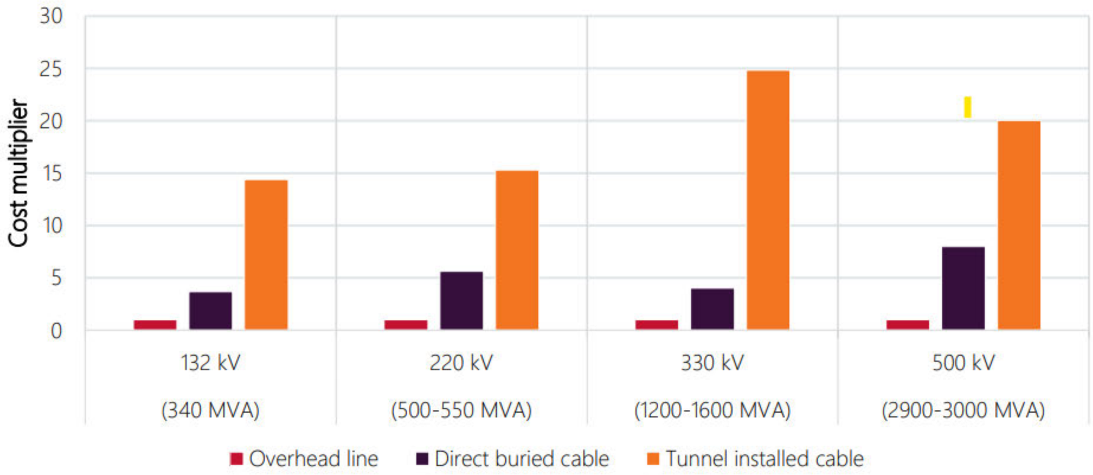
[8] *AEMO, 2021 Transmission Cost Report for the Integrated System Plan (ISP), Final report, August 2021*
[9] *Electricity Transmission Costing Study, An Independent Report Endorsed by the Institution of Engineering & Technology, prepared by Parsons Brinckerhoff, 30 March 2012*

- At 75kms, underground HVDC is still more expensive that overhead or HVAC direct buried underground transmission lines. However, they may be the most efficient over long distances.
- To connect solar farms, wind farm or batteries to an HVDC underground line requires a conversion station. These are not required for AC connections, as the NEM operates in AC. The DC conversion stations are very expensive to build. There are very few suppliers of the equipment needed to build these stations and there is a scarcity of skilled technicians to build them.
- Construction causes significant delays for all underground transmission projects, regardless of the technology used.

Figure 5 Indicative unit cost multiplier from HVAC overhead lines to HVAC underground cables



Notes:

- This chart shows cost factor increases relative to the respective overhead option on a generic unit cost basis. Underground 500 kV HVAC options cost more than 330 kV HVAC options, but the cost factor increase is higher when undergrounding a 330 kV HVAC option compared to undergrounding a 500 kV HVAC option.
- This chart has been prepared using AEMO's Transmission Cost Database and may not provide an appropriate comparison for all projects due to local circumstances.
- This cost comparison is indicative of the variable per unit cost of overhead lines and underground cables. The total project cost is sensitive to factors such as terrain, geotechnical constraints, and fixed cost factors associated with transition stations.

5. Case Studies

5.1 Humelink

One of the most recent studies performed in Australia to determine the benefit between undergound and overhead transmission lines, was the recent report completed by GHD for Transgrid for HumeLink Project. The key findings were:

- For Humelink, a 360Km 500Kv line estimated costs for underground HVAC was estimated $17.1 billion.
- Undergrounding HCDC was estimated to cost $11.5 billion, which is three times more than the entire project's overhead cost of $3.3 billion.
- The underground HVDC was expected to take 7 years to build. The overhead option was expected to take 4-5 years to build.
- Cost increases for undergrounding were said to be caused by the need to dig trenches and from labour, materials, plant and equipment, engineering, and project management costs[10].

5.2 Kennebec River Crossing (Iberdrola)

- Iberdrola, through its company, Central Maine Power is building a 320KV HVDC transmission line. The project is 207 miles (333.134kms) long, capable of transferring 1.2GW. 145 miles (233.35kms) is based in the United States, but the line terminates in the Appalaches Substation in Thetford Mines, Quebec, Cananda.
- This project will be undergrounded to cross the Kennebec River. The US State authorities have advised that due to the river being used for water activities and for environmental issues, planning approval will only be granted if the cable runs under the Kennebec River.
- This project is not complete, but it is expected to cost over 7 times what it would have cost to have overhead HVDC transmission lines. A spare cable will be installed for the underground crossing, should a cable or termination failure occur.

5.3 Plan Madrid (Iberdrola)

- Plan Madrid was a project completed by Iberdrola in 2014 which involved the undergrounding of 125km of transmission line and 16 substations associated to the network in the metropolitan area of Madrid to replace the aged overhead installation at the end of the service life.
- The key environmental objective for the project was to gain back areas for public use for a total of 355,000 square meters used on gardens, sport areas, community areas houses and office space, improve the visual amenity, protection of the fauna and the reduction of fire risks.

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[10]*Concept Design and Cost Estimate for the Humelink Project – Underground Study. GHD report, Revision* 3, dated 22 August 2022.

The new underground network will increase the capacity by 1,000 MVA, to service the increase demand in the metropolitan area and reducing the risk of failure in the network.

- The estimated cost of the transmission line being underground was about 4 times than the estimated cost of the equivalent overhead installation.

5.4 East Anglia One (Iberdrola)

- East Anglia One is an Offshore wind farm which Iberdrola completed off 43km the east coast of England in the Northern Sea. Iberdrola coordinated the offshore and onshore component of the transmission as well by installing 37km 220kV underground cable to link the 102 turbines to the network on land.
- The cost of the onshore underground installation was over AU$50 million.

5.5 Beauly to Denny 400kV (Iberdrola)

- Beauly to Denny line constructed by Iberdrola's company Scottish Power included a 220km of 400kV line through Scotland to unlock the northern part of the country renewables resources.
- Considering the criticality of the visual amenity impact expected from overhead transmission line, an assessment was completed to consider the benefits for an underground cable installation considering environmental, technical, and cost aspects.
- Overhead transmission line was the preferred option due to the lower impact on highly sensitive areas, the use of trees and other vegetation as a natural barrier to minimize the visual impact of the structures was an innovative strategy which achieved an efficient solution.

6. Operational Considerations

Maintenance requirements during operational life of the underground cable are normally less onerous than for overhead transmission, some of the key items for cable maintenance routine are informed by monitoring ratings, temperatures, cable sheath testing, partial discharge testing and monitoring of integrity and dielectric properties of cable sealing ends.

Underground transmission cables are designed to operate continuously within specific thermal limits, the temperature increases while in operation due to losses, this heat dissipates to the surrounding environment, therefore the importance of the installation methods and materials surrounding the cable. For cable temperature monitoring during operation, it’s often used a distributed temperature sensor, by the installation of an optic cable, either within or closely installed to the outer cover of the cable, which permits to determine any disruption to the normal activity expected along the line by interference on the optic cable signals.

Another critical preventive maintenance for cable transmission installations is the measurement of any leakage of the earthing sheath, this is completed by measuring voltages applied to the metallic cable sheath at the earth bonding links housed along the cable route, to perform this measurement, it is required the cable to be out of service due to the induced voltages needed to be injected to the cable sheath. The bonding and earthing are used to eliminate or reduce sheath currents, which in turn will reduce losses and improve the current rating of the cable

Regarding the cable sealing ends or cable terminations, it is critical to clean the insulators on the termination structures, as well as with the earth bonding test, this procedure needs to be completed when the cable is out of service. Although the frequency required for the cleaning of insulators on the termination structure will significantly be dependent of the pollution levels caused by the location and environmental conditions. Also, a regime of the dielectric properties of the cable sealing ends.

A cable transmission installation will require regular patrols along the route to identify any activity that may be a risk to the installation, including the growth of any vegetation, particularly trees, in the vicinity of the cables, as the tree roots can be highly damaging to the cable transmission system. These inspections are often performed as regularly as every 2 weeks.

Installations of high voltage cables for long distances will require shunt reactors, which will add to the maintenance requirements of the assets and for potential need of terminal stations along the route.

In summary, underground installations are more reliable than overhead, but the time and cost to fix underground cables in much higher than overhead lines. Typical outage duration from an overhead line can be as quick as few hours or a day, when an outage on an underground cable is a minimum from 7-9 days and needs to be completed by a very specific skill set of technicians and may incur additional delays if the required parts or the required skilled personnel are not available. Also, to consider, energization of the cables during operational conditions may require switching per sections, therefore a longer process.

7. Land Use Considerations

Working around underground cables may pose the risk of a potential contact with exposed energised parts, example of activities that pose a risk maybe digging trenches or holes with machinery or manual tools, driving pickets or fences on the ground or heavy vehicles becoming bogged and damaging the cables.

Before performing any work in the vicinity of the transmission cables, it is required to contact Dial Before you Dig and the relevant authorities and perform a risk assessment.

While the land within the easement of an overhead transmission line can be used for majority of agricultural and farming activities, there are significant limitations on the use of land on the underground cable easement due to the limitations on machinery and tools allowed to be used within the easement and the required vegetation clearance.

Overhead power allows opportunities for the land to be used for cropping within the easement, while with underground cables there is a limitation on the use of land.

In terms of agricultural use of the land, underground cable allows for aerial spraying activity, while it will limit the use of the land in the easement. On the other hand, underground cables do not limit the height of the machinery used but does limit the weight of the allowed traffic on the easement, exactly the opposite than with overhead lines.

Although, at negligible levels, overhead transmission lines have some operational noise, which is eliminated by underground cable installations.

The duration of the construction period for underground cables is significantly longer than overhead lines, therefore, more significant community impacts are to be expected, including, air quality due to the civil works, noise, traffic, etc. Access can be limited to some of the properties along the cable route. Utility outages can be extensive during construction. Some infrastructure along the route is likely to need modifications or removal for the installation of the underground cables, such as fences, minor roads, sheds, etc these restrictions can affect the land use around the easement for significant periods of time.

8. Environmental Considerations

Overhead transmission lines are expected to pose a higher impact on the fauna along the route due to the vegetation clearance requirements that will divide habitats, degradation of the easement during regular maintenance and potential collision with the lines.

Underground cable installations ensure limited land disruption following construction and extensive remediation, considering the width of the easement is smaller than with the equivalent overhead line.

Underground transmission cables can also be affected by the environmental conditions in the vicinity, such as earthquakes, flooding, and lighting strikes, which may have the potential to significantly damage the cable and require extensive repair works.

An underground cable installation requires high focus on the vegetation clearance in the vicinity of the route, it's highly critical to ensure limited vegetation grows along the line, especially trees which could damage the cable with their roots.

The installation of underground cables is more likely to impact areas of significance for the first nations due to the more invasive installation requirements. Also, considering the trenching requirements for the installation of underground cables, the likelihood of disturbing or exposing contaminated soil caused by past use of the land is high in certain areas, this disruption of contaminated land has a significant risk to the environment as well as a risk to the cost and time of the project.

The risk of bush fire is significantly reduced by the installation of underground cables instead of overhead lines. Although, there is a very low probability that a high voltage transmission line will cause a bush fire, none of the latest bush fire events in Australia have been known to be initiated by high voltage transmission lines. In relation to the concerns raised by communities recently in Australia, underground installations, do not limit the ability of bushfire fighting or emergency access, but again, any damaged to the line during bushfires, will be significantly more costly and timely to be fixed.

9. Conclusion

There are many benefits to undergrounding transmission lines, but they cost at a minimum four to five times the amount of overhead transmission lines. They can be useful for visual amenity and except for initially during the construction phase they can be used for reducing the environmental and potential hazard reduction impact. However, undergrounding projects take a lot longer to complete. We recommend that they be used in high density urban areas. Use for transmissions lines must be weighed carefully amongst other factors.

Iberdrola would be happy to discuss its experiences internationally with undergrounding transmission and distribution lines with the NSW Government further.

Please contact the following people for further information:

- Ricardo Da Silva at or
- Maheshini (Mesh) Weerackoon at

Thank you.