Climate ADAPT
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Adaptation Option

Adaptation options for electricity transmission and distribution networks and infrastructure

Description

Collapsing power cables causes temporary loss of power to users, and brings about additional reparation costs for power providers. Storms can damage power lines, and hence cause power outages and black-outs, through direct impact or indirect impact (e.g. falling trees). Furthermore, storms can increase the rate of lightning flashes, a further cause of power outages through damage to power lines. Tree fall, caused by several factors including strong winds, water accumulation in the soil (which results in easier uprooting), snow accumulation or lighting, can have the same result. Nevertheless, the extent to which precipitation and wind storms cause tree fall depends on the age and girth of the trees in question. The accumulation and subsequent accretion of snow on transmission and distribution lines, particularly in presence of high humidity and temperatures around 0°C (the so-called "wet snow"), can cause breakage of power lines and the collapse of high voltage power transmission towers.

Underground cabling allows adapting electricity transmission and distribution systems to climate change since it protects a key portion of the infrastructure from the aforementioned climate change impacts. The installation of underground cabling involves three predominant techniques: placing cabling in concrete-reinforced troughs, placing the cables in underground tunnels, or directly burying the cables.

By placing cabling underground, most of the adverse weather conditions that traditional transmission infrastructures are exposed to above-ground can be avoided. This refers largely to precipitation and windstorms. Underground cabling can alleviate the requirement for further and more frequent investments in transmission infrastructure maintenance and repairs. The expected benefits include a more secure energy supply with fewer instances of weather-related power outages, while also achieving cost savings in the long run due to reduced maintenance and repairs.

Storms are not the only climate-related hazard affecting electricity networks. Very high ambient temperatures, such as those occurring during heatwaves, threaten transmission and distribution, as they can cause lines to sag; their reduced clearance from land can be dangerous to the general public. Sagging may also result in contact with trees and other structures, which could result in electrocution or fires. Most European countries have regulations in place to maintain a minimum distance between power lines and the ground or structures, in order to ensure that potential instances of electrocution or fires are avoided. Higher ambient temperatures require that the electrical current that passes through overhead power lines must be reduced to prevent the overheating of equipment. Warmer power lines can also result in decreased efficiency (de-rating). These impacts increase the risks of accidents, power cuts and cascading network failures, with negative implications for the profitability of the utilities involved and for the well-being of the affected population. These impacts are compounded by increasing electricity demand, also due to increased air conditioning use. Adaptation options to deal with these impacts include:

- Installing higher power lines poles,
- Installing conductors with hotter operating limits or implementing the use of 'low-sag' conductors.
- Increasing the minimum design temperature of new overhead line routes is a particularly cost effective option, the achievement of which would typically increase the design height of wood poles by 0.5 metres.
- Developing a software tool to optimise overhead line ratings.

Additional Details

- IPCC categories
- Stakeholder participation
- Success and limiting factors
- Costs and benefits
- Legal aspects
- Implementation time
- Lifetime

Reference information

- Websites
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Adaptation Details

IPCC categories

Structural and physical: Engineering and built environment options, Structural and physical: Technological options

Stakeholder participation

Bar the case of optimizing software, all options in this class involve installing or modifying infrastructures on the ground, in urban, industrial, rural and natural areas. Stakeholder interaction at the local level (with land owners, local authorities and the general public) along the routes of the installed/upgraded grids is thus crucial in order to ensure social acceptability and the timely and cost-effective deployment of the infrastructures. For underground cables, coordination with other cabling entities can reduce economic costs and minimize the nuisance to local communities by limiting the duration of digging activities to the bare minimum.

Success and limiting factors

Underground cabling is dependent on the availability of the correct technology and know-how as to installation, monitoring and management. Co-operation with other underground cabling entities, such as telecommunications companies helps minimize disturbance to populations through digging activities, and cost sharing of digging operation reduces the costs borne by each entity. Although underground cabling could be exposed to new climate hazards, in particular from flooding and soil movements related to landslides, so far these risks remain hypothetical. Excavation due to other construction or maintenance activity represents a key risk of damage to installed underground cables. This risk can be reduced by applying digitalization and GIS technology to underground cables, to inform excavators about the location of underground cables.

A major difference between underground and overhead cables is the way electrical insulation is provided. Overhead cables are insulated by the air that surrounds them, the cheapest and simplest insulation solution available. Underground cables need to be insulated to avoid power losses and risks of electrocution through direct contact with the soil. The electric resistance generated by insulation generates heat and hence transmission losses. This calls for larger and/or multiple cables in order to compensate for the losses and, a cooling system (forced ventilation, water or gasses) to dissipate heat. Underground cables need to be buried in trenches, to be protected from accidental damages and to be accessed with ease when maintenance is needed. Overall, this results in a larger use of land by underground cables compared to overhead cables during installation, although once buried, the land use and visual impacts they generate is considerably lower.

Maintenance of underground cables is much more complex and costly than that of overhead cables: “if a fault occurs on a 400 kV underground cable, it is on average out of service for a period 25 times longer than 400 kV overhead lines. This is due principally to the long-time taken to locate, excavate and undertake technically involved repairs. These maintenance and repairs also cost significantly more” (National Grid, 2015).

Finally, there are technical limitations to land use in the vicinity of cables specific to underground lines. Beside the need to reserve some land to secure access to the lines for maintenance purposes, there are also restrictions on the planting of trees and hedges over the cables or within 3 m of the cable trench to prevent encroachment by vegetation. Tree roots may penetrate the cable backfill surround which in turn may affect the cable rating or even result in physical damage to the cable. Similarly for overhead lines, tree growth is discouraged and controlled beneath the overhead line conductors or within distances where trees could fall onto the lines. There will also be height restrictions for machinery or especially high vehicles, such as agricultural equipment, near overhead lines for safety reasons. In urban areas, the land surface used for buried cables far exceeds the one required for an equivalently rated overhead line. Cables have historically been routed under roads to avoid subtracting land from alternative uses; however traffic disruption during fault investigation and repairs can be significant. Where cables are installed by direct burial in rural areas, there are restrictions on the use of deep cultivating agricultural equipment to avoid the risk of damage. The burying of high voltage cables is also more complicated than the laying of gas and water pipes. In addition underground joint bays, which are concrete lined and wider than the trenches themselves, have to be built every 500–1,000m.

For the climate-proofing of overhead cables, a detailed knowledge of future local climate conditions at high resolution is crucial in order to plan the necessary interventions. A clear advantage of gaining the most accurate scenarios for overhead cables is related to understanding to what extent they can continue to be a valid option. If extreme events are projected to affect significantly the areas in which overhead cable networks are installed or planned, a switch to underground cabling may eventually be taken in consideration. Even in less extreme circumstances, identifying the routes that are going to be the least exposed in the future to the aforementioned threats to overhead cabling can help planning future network development.

Besides direct future climate impacts, for both underground and overhead networks, it is important to get insights on the future market conditions in which transmission system operators (TSOs) and distribution system operators (DSOs) will operate.

Costs and benefits

In general, the operation of underground cable costs roughly the same as that of overhead cables (National Grid, 2015). However, the capital costs related to building underground lines are much higher than those for overhead cables. Alonso and Greenwell (2013) report 4 to 14 times higher building costs for underground cables based on a 2011 study of the Public Service Commission of Wisconsin. The actual costs, however, depend on the geological and geographical characteristics of the cables' route, the installation method (tunnel installation costs more than direct burial), the transmission capacity of the line and the options chosen for insulating and cooling underground cables.

Raising pole height is relatively inexpensive: a case study on overhead lines in UK reports that the costs of procuring wooden overhead poles 0.5 meters taller depend on the height of the original pole, but they can be as little as around £10 (€11) per pole.

Legal aspects

For overhead cables, specific national norms in each EU country regulate the maximum height of the poles and the minimum clearance from the ground.

Building overhead or underground power lines is subordinated to national permitting regulations, as any other major infrastructure. There are a number of specific environmental drawbacks to be taken into account in the permitting process. In rural areas, disturbance to flora and fauna, land use and archaeological sites must be assessed. In this respect, overhead lines are normally less disruptive than underground cables and cause fewer disturbances. However, in specific cases underground cables can have a significant positive impact for some endangered species; for instance they can reduce mortality due to power line collisions in migrant or resident birds' populations (Bernardino et al., 2018). In both urban and rural environments, land disruption is greater when laying underground cables than when erecting overhead line towers. The volume of soil excavated for an underground cable, where two cables per phase are installed, is some 14 times more than for an equivalent overhead line route. Vegetation has to be cleared along and to the side of trenches to allow for construction and associated access for vehicles.

Implementation time

The implementation time varies according to local geographical and geological conditions and the installation method used. However, it is considerably longer for underground cables compared to overhead cables.

Lifetime

Cables, whether overhead or underground, are usually designed to be in operation for 60 years. A UK case study reports that the expected lifetime of wooden poles that support overhead lines is comparable: 40-60 years.

Reference information

Websites:

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References:

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EEA, (2019). Adaptation challenges and opportunities for the European energy system. EEA Report 1/2019.

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IPCC adaptation options categories:

Structural and physical: Engineering and built environment options, Structural and physical: Technological options

Climate impacts:

Extreme Temperatures, Ice and Snow, Storms

Adaptation Approaches:

Adaptation Measures and Actions

Sectors:

Business and industry, Energy

Governance level:

Local (e.g. city or municipal level)

Geographic characterisation:

Global

Case studies related to this option:

Replacing overhead lines with underground cables in Finland

Adapting overhead lines in response to increasing temperatures in UK