Executive briefing note

Assessing the case for power undergrounding

Challenge

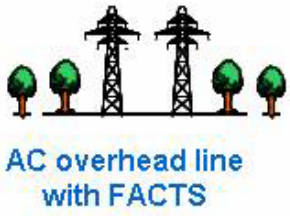
Extending and upgrading the EU's power transmission infrastructure has become necessary following steady growth in electricity demand, efforts to build an integrated European electricity market and the addition of renewable – and more remote – sources of energy to the power mix. As an example, a study by the German Energy Agency (DENA) in 2005 showed that strong growth of wind power generation in the north of the country was also leading to transmission bottlenecks as the renewable source is needed in the major load centers some 800km further to the south.

At the same time, public acceptance of visible new power infrastructure in populated or environmentally sensitive areas is extremely low. One of the most prominent concerns is over low-frequency magnetic fields. As a consequence, new ideas to reconcile Europe's requirement for secure, reliable, and sustainable power with its low tolerance towards the extension of infrastructure in sensitive areas are needed. This note aims to provide a technical basis for discussions that are frequently governed by emotions rather than commercial and technical facts.

Technology options

Two technology options, both connected to relatively recent advances in power semiconductors, offer proven remedies.

1. FACTS (Flexible Alternating Current Transmission Systems) offers a way of controlling power congestion using existing overhead lines and is a proven technology with more than 1,500 installations worldwide. FACTS devices can typically be added to existing substations and increase transmission capacity through existing lines by as much as 50 percent, as they control the power flow in situations where some lines are loaded to their limits while there is still reserve capacity in others.



2. The second approach, putting high-voltage cables underground, comes in two variants.

-Undergrounding of alternating current (AC) electricity is suitable for only relatively short distances (below 30km, though sometimes up to 50km, depending on the exact conditions).

-For longer distances, power undergrounding is done by converting AC to DC (direct current) electricity. High-voltage DC (HVDC) technology, which produces negligible magnetic fields, has traditionally been used for long-distance transmission of large amounts of power (eg, multi-gigawatt connections over more than 1,000km in China, India, Brazil, and Africa using overhead lines), for subsea or underground power links (HVDC with cable rather than overhead lines, eg, NorNed, Estlink, Sapei) and for the integration of renewable sources of energy into the power network (eg Nord E.ON 1, 400 MW offshore wind farm, including 75 km of underground cables).

Undergrounding with HVDC is described in more detail in the next section.

Undergrounding with HVDC

More than 50 HVDC projects using cables rather than overhead lines have been built so far, most of them involving cables laid underwater (eg SwePol, Estlink; see table below). The experience gained in these projects and the production volumes generated has contributed to a significant decline in the cost of this option. Whereas the cost of a typical 100-km line using underground DC was about 20 times higher than an equivalent overhead AC line when the technology was first developed, it is now 4-6 times higher.

The relative cost is generally lower the longer the cable, because the need for converter stations at each end of a DC line (to convert from AC and back) introduces a fixed cost that is independent of distance. Depending on the terrain and planned transmission route, the additional cost needs to be weighed against a number of external advantages for DC technology:
-the much narrower transmission corridors needed
-no visual impact
-avoiding low-frequency magnetic fields induced by AC transmission, a focus of public opposition
-faster and more predictable planning permission
-improved grid reliability and overall grid efficiency through control of reactive power

HVDC also plays a key role in integrating new sources of renewable power into the grid. Advanced HVDC technology makes it possible to connect large-scale offshore wind farms to typically weak grids in coastal areas, while still meeting the grid code requirements for reactive power, frequency and voltage control. If power is brought to shore by DC transmission, grid connection via underground transmission becomes particularly attractive, since the major fixed cost investment (ie, the AC/DC and DC/AC converters) has already been made and undergrounding becomes very competitive, regardless of transmission distances.

Technology and references

HVDC technology has advanced significantly since its first commercial application 50 years ago, thanks to progress in two enabling technologies, power semiconductors and cables based on new materials. While early HVDC designs were able to meet the needs of subsea cable and onshore overhead DC connections, today's combination of advanced converters and oil-free cables enables a new method of onshore power transmission that has little impact on the environment: it requires only minimum right of way, avoids overhead lines, and has negligible magnetic fields. As of today, a single underground HVDC connection is able to transmit up to 1,100 MW over a vast distance.

Table: Selected project examples

Project	Country	MW	Year	Main purpose
SwePol	Sweden-Poland	600	2000	Subsea cross-border inter-connection
Italy-Greece	Italy-Greece	500	2001	Subsea cross-border inter-connection
Murraylink	Australia	220	2002	Underground merchant grid inter-connection
Troll A	Norway	84	2005	Power to offshore gas platform from shore
Estlink	Estonia-Finland	350	2006	Underground/subsea cross-border inter-connect
NorNed	Norway-Netherlands	700	2008	Subsea cross-border inter-connection
Nord E.ON 1	Germany	400	2009	Underground/subsea offshore wind park
SAPEI	Italy	1000	2009	Subsea island connection
BritNed	UK-Netherlands	1300	2009	Subsea cross-border inter-connection