DOCUMENT

5.4.2A

2A Overview of Technology Options

National Grid (Richborough Connection Project) Order

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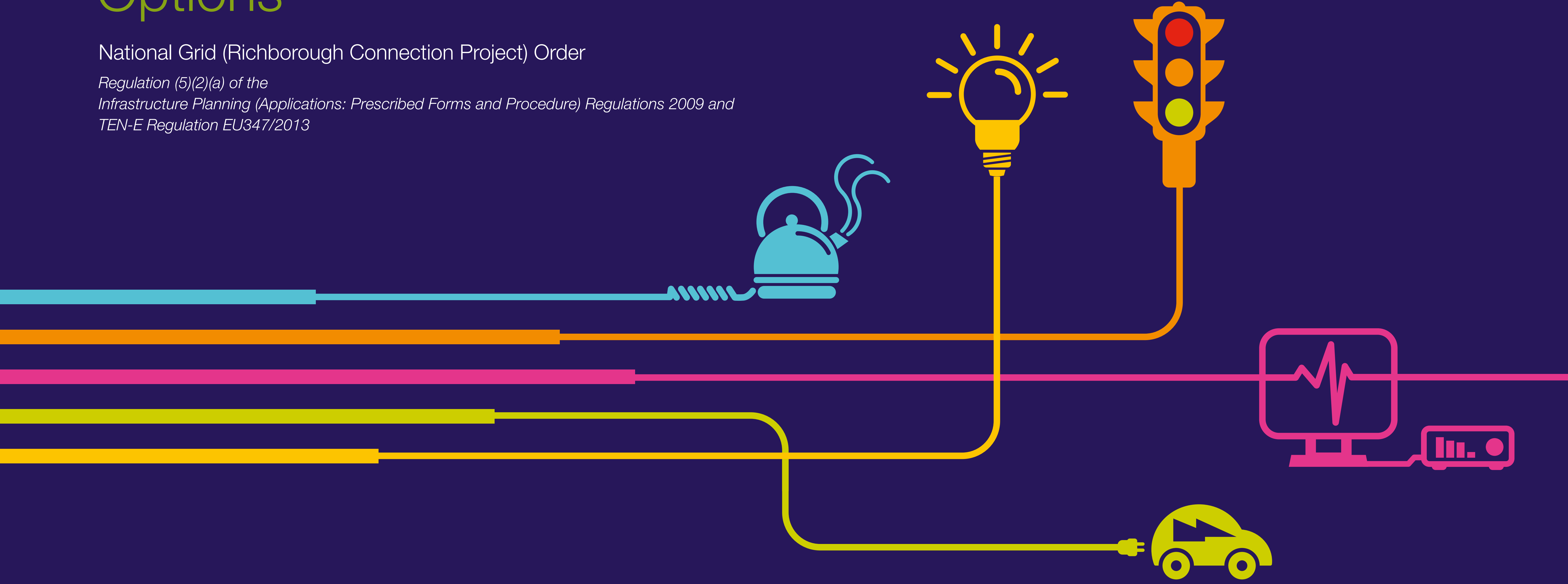

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5.4 Environmental Statement Appendices

5.4.2A Overview of Technology Options

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1. OVERVIEW OF TECHNOLOGY OPTIONS

1.1.1 This section has been taken from Appendix C of the Strategic Options Report produced by National Grid in June 2013 (**Volume 7 Document 7.4**). It provides an overview of the technologies available for the strategic options described in this Report. It provides a high level description of the relevant features of each technology.

1.1.2 The majority of electricity systems throughout the world are AC systems. Consumers have their electricity supplied at different voltages depending upon the amount of power they consume e.g. 230V for domestic customers and 11kV for large factories and hospitals. The voltage level is relatively easy to change when using AC electricity, which means a more economical electricity network can be developed for customer requirement. This has meant that the electrification of whole countries could be and was delivered quickly and efficiently using AC technology.

1.1.3 DC electricity did not develop as the means of transmitting large amounts of power from generating stations to customers because DC is difficult to transform to a higher voltage and bulk transmission by low voltage DC is only effective for transporting power over short distances. However, DC is appropriate in certain applications such as the extension of an existing AC system or when providing a connection to the transmission system.

1.1.4 In terms of voltage, the transmission system in England and Wales operates at both 275kV and 400kV. The majority of National Grid's transmission system is now constructed and operated at 400kV, which facilitates higher power transfers and lower transmission losses.

1.1.5 There are a number of different technologies that can be used to provide transmission connections. These technologies have different features which affect how, when and where they can be used. The main technology options for electricity transmission are:

- overhead lines
- underground cables
- gas Insulated Lines (GIL) and
- High Voltage Direct Current (HVDC).

1.1.6 This appendix provides generic information about each of these four technologies.

Overhead lines

1.1.7 Overhead lines form the majority of the existing transmission system circuits in Great Britain and in transmission systems across the world. As such there is established understanding of their construction and use.

1.1.8 Overhead lines are made up of three main component parts which are; conductors (used to transport the power), pylons (used to support the conductors) and insulators (used to safely connect the conductors to pylons)

1.1.9 **Figure 2A.1 overleaf** shows a typical pylon used to support two 275kV or 400kV overhead line circuits. This type of pylon has six arms (three either side), each carrying a set (or bundle) of conductors.

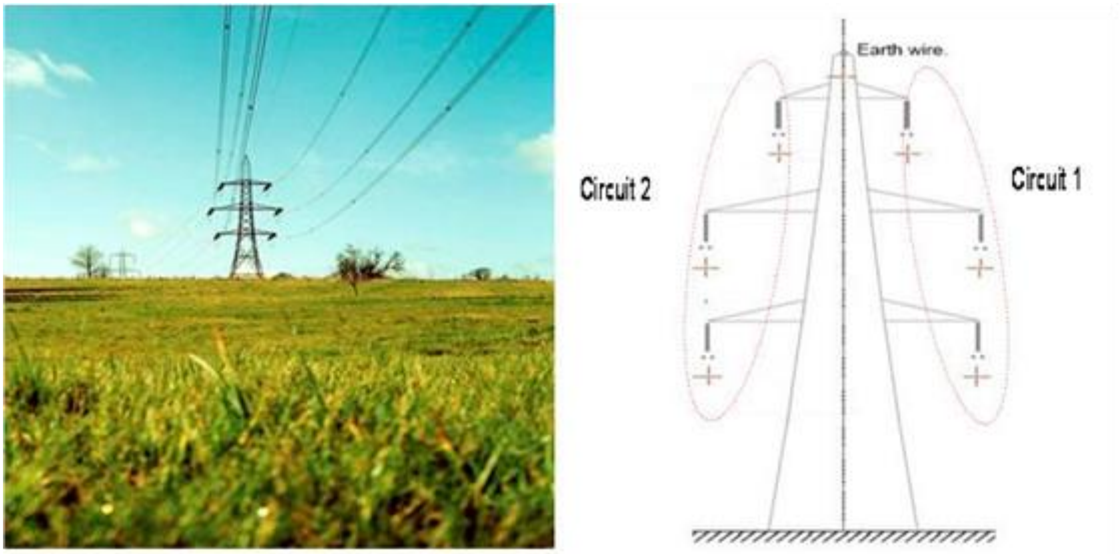

Figure 2A.1 Example of a 400kV Double-circuit Pylon

1.1.10 The number of conductors supported by each arm depends on the amount of power to be transmitted and will be either two, three or four conductors per arm. Technology developments have increased the capacity that can be carried by a single conductor and therefore, new overhead lines tend to have two or three conductors per arm.

1.1.11 With the conclusion of the Royal Institute of British Architects (RIBA) pylon design competition[1] and other recent work with manufacturers to develop alternative pylon designs, National Grid is now able to consider a broader range of pylon types, including steel lattice and monopole designs. The height and width is different for each pylon type, which may help National Grid to manage the impact on landscape and visual amenity better. **Figure 2A.2 overleaf**, shows an image on the winning design from the RIBA pylon design competition, a monopole design called the T-pylon.

[1] Press notice issued by DECC on 14 October 2011 http://www.decc.gov.uk/en/content/cms/news/pn11_82/pn11_82.aspx

Figure 2A.2 The T-Pylon

1.1.12 Pylons are designed with sufficient height to ensure that the clearances between each conductor and between the lowest conductor and the ground, buildings or structures are adequate to prevent electricity jumping across. The minimum clearance between the lowest conductor and the ground is normally at the mid-point between pylons. There must be sufficient clearance[2] between objects and the lowest point of the conductor as shown in **Figure 2A.3 below**.

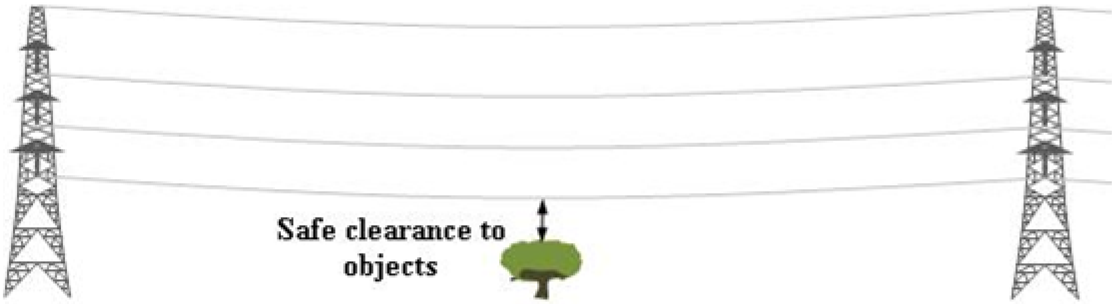

Figure 2A.3 Safe height between lowest point of conductor and other obstacle ("Safe Clearance")

1.1.13 The distance between adjacent pylons is termed the 'span length'. The span length is governed by a number of factors, the principle ones being pylon height, number and size of conductors (i.e. weight), ground contours and changes in route direction. A balance must therefore be struck between the size and physical presence of each pylon versus the number of pylons; this is a decision based on both visual and economic aspects. The typical 'standard' span length used by National Grid is approximately 360m.

[2] More information can be found in the brochure "Development near overhead lines" at http://www.nationalgrid.com/uk/LandandDevelopment/DDC/devnearohl_final/.

1.1.14 Lower voltages need less clearance and therefore the pylons needed to support 132kV lines are not as high as traditional 400kV and 275kV pylons. However, lower voltage circuits are unable to transport the same levels of power as higher voltage circuits.

1.1.15 National Grid has established operational processes and procedures for the design, construction, operation and maintenance of overhead lines. Circuits must be taken out of service from time to time for repair and maintenance. However, short emergency restoration times are achievable on overhead lines as compared, for example, to underground cables. This provides additional operational flexibility if circuits need to be rapidly returned to service to maintain a secure supply of electricity when, for example, another transmission circuit is taken out of service unexpectedly.

1.1.16 In addition, emergency pylons can be erected in relatively short timescales to bypass damaged sections and restore supplies. Overhead line maintenance and repair therefore does not significantly reduce security of supply risks to end consumers.

1.1.17 Each of the three main components that make up an overhead line has a different design life, which are:

- between 40 and 50 years for overhead line conductors;
- 80 years for pylons; and
- between 20 and 40 years for insulators.

1.1.18 National Grid expects an initial design life of around 40 years, based on the specified design life of the component parts. However, pylons can be easily refurbished and so substantial pylon replacement works are not normally required at the end of the 40 year design life.

Underground Cables

1.1.19 Underground cables at 275kV and400 kV make up approximately 10% of the existing transmission system in England and Wales, which is typical of the proportion of underground to overhead equipment in transmission systems worldwide. Most of the underground cable is installed in urban areas where achieving an overhead route is not feasible. Examples of other situations where underground cables have been installed, in preference to overhead lines, include crossing rivers, passing close to or through parts of nationally designated landscape areas and preserving important views.

1.1.20 Underground cable systems are made up of two main components – the cable and connectors. Connectors can be cable joints, which connect a cable to another cable, or overhead line connectors in a substation.

1.1.21 Cables consist of an electrical conductor in the centre, which is usually copper or aluminium, surrounded by insulating material and sheaths of protective metal and plastic. The insulating material ensures that although the conductor is operating at a high voltage, the outside of the cable is at zero volts (and therefore safe). **Figure 2A.4 overleaf** shows a cross section of a transmission cable and a joint that is used to connect two underground cables.

Figure 2A.4 Cable Cross-Section and Joint

1.1.22 Underground cables can be connected to above-ground electrical equipment at a substation, enclosed within a fenced compound. The connection point is referred to as a cable sealing end. **Figure 2A.5 below** shows two examples of cable sealing end compounds.

Figure 2A.5 Cable Sealing End Compounds

1.1.23 An electrical characteristic of a cable system is capacitance between the conductor and earth. Capacitance causes a continuous 'charging current' to flow, the magnitude of which is dependent on the length of the cable circuit (the longer the cable, the greater the charging current) and the operating voltage (the higher the voltage the greater the current). Charging currents have the effect of reducing the power transfer through the cable.

1.1.24 High cable capacitance also has the effect of increasing the voltage along the length of the circuit, reaching a peak at the remote end of the cable.

1.1.25 National Grid can reduce cable capacitance problems by connecting reactive compensation equipment to the cable, either at the ends of the cable, or, in the case of longer cables, at regular intervals along the route. Specific operational arrangements and switching facilities at points along the cable circuit may also be needed to manage charging currents.

1.1.26 Identifying faults in underground cable circuits often requires multiple excavations to locate the fault and some repairs require removal and installation of new cables, which can take a number of weeks to complete.

1.1.27 High voltage underground cables must be regularly taken out of service for maintenance and inspection and, should any faults be found and depending on whether cable excavation is required, emergency restoration for security of supply reasons typically takes a lot longer than for overhead lines (days rather than hours).

1.1.28 The installation of underground cables requires significant civil engineering works. These make the construction times for cables longer than overhead lines.

1.1.29 The construction swathe required for two AC circuits comprising two cables per phase will be between 35-50 m wide.

1.1.30 Each of the two main components that make up an underground cable system has a design life of between 40 and 50 years.

1.1.31 Asset replacement is generally expected at the end of design life. However, National Grid’s asset replacement decisions (that are made at the end of design life) will also take account of actual asset condition and may lead to actual life being longer than the design life.

Gas Insulated Lines (GIL)

1.1.32 GIL is an alternative to underground cable for high voltage transmission. GIL has been developed from the well-established technology of gas-insulated switchgear, which has been installed on the transmission system since the 1960s.

1.1.33 GIL uses a mixture of nitrogen and sulphur hexafluoride (SF6) gas to provide the electrical insulation. GIL is constructed from welded or flanged metal tubes with an aluminium conductor in the centre. Three tubes are required per circuit, one tube for each phase. Six tubes are therefore required for two circuits, as illustrated in **Figure 2A.6 overleaf**.

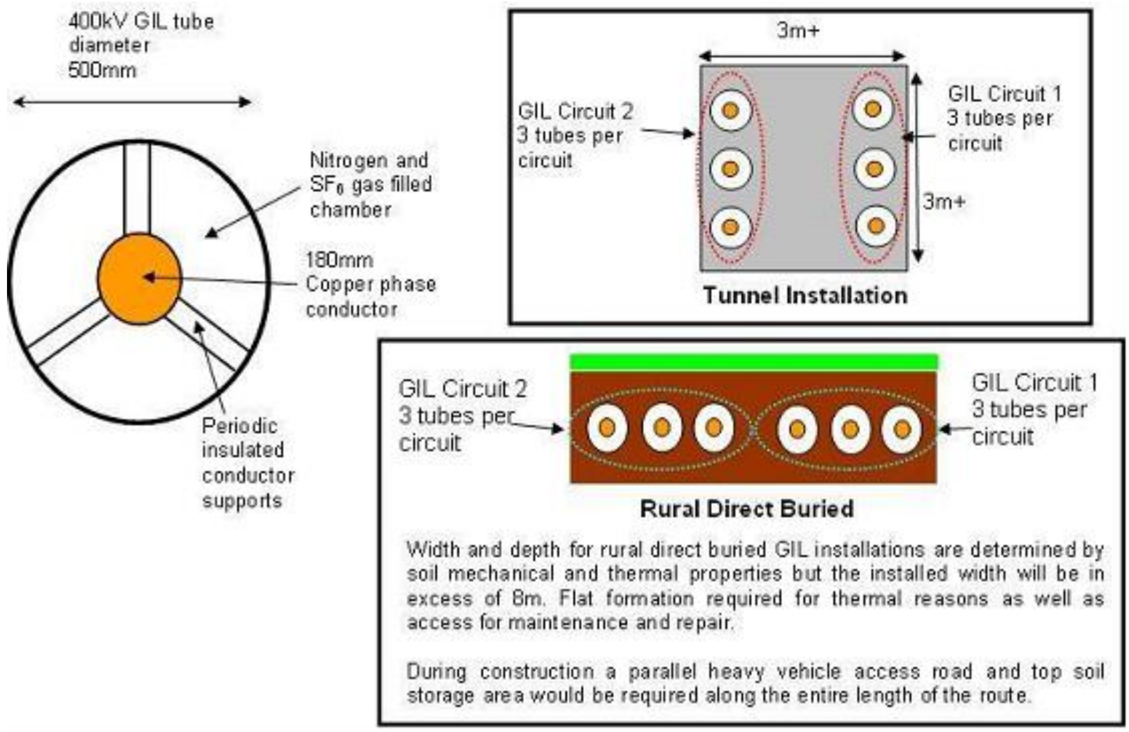

Figure 2A.6 Key Components of GIL[3]

1.1.34 GIL tubes are brought to site in 10 – 20m lengths and they are joined in situ. It is important that no impurities enter the tubes during construction as impurities can cause the gas insulation to fail. GIL installation methods are therefore more onerous than those used in, for example, natural gas pipeline installations.

1.1.35 A major advantage of GIL compared to underground cable is that it does not require reactive compensation.

1.1.36 The installation widths over the land can also be narrower than cable installations, especially where more than one cable per phase is required.

1.1.37 GIL can have a reliability advantage over cable in that it can be re-energised immediately after a fault (similar to overhead lines) whereas a cable requires investigations prior to re-energisation. If the fault was a transient fault it will remain energised and if the fault was permanent the circuit will automatically and safely de-energise again.

1.1.38 There are environmental concerns with GIL as the SF_6[4] gas used in the insulating gas mixture is a potent 'greenhouse gas'. Since SF_6 is an essential part of the gas mixture GIL installations are designed to ensure that the risk of gas leakage is minimised.

[3] The distances are based on initial manufacturer estimates of tunnel and buried GIL dimensions which would be subject to full technical appraisal by National Grid and manufacturers to achieve required ratings which may increase the separation required. It should be noted that the diagram does not show the swathe of land required during construction. Any GIL tunnel installations would have to meet the detailed design requirements of National Grid for such installations.

[4] SF6 is a greenhouse gas with a global warming potential, according to the Intergovernmental Panel on Climate Change, Working Group 1 (Climate Change 2007, Chapter 2.10.2), of 22,800 times that of CO2. www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html

1.1.39 There are a number of ways in which the risk of gas leakage from GIL can be managed, which include:

- use of high-integrity welded joints to connect sections of tube;
- designing the GIL tube to withstand an internal fault; and
- splitting each GIL tube into a number of smaller, discrete gas zones that can be independently monitored and controlled.

1.1.40 At decommissioning the SF_6 can be separated out from the gas mixture and either recycled or disposed of without any environmental damage.

1.1.41 GIL is a relatively new technology and therefore has limited historical data, meaning that its operational performance has not been empirically proven. National Grid has two GIL installations on the transmission system which are 545m and 150m long[5]. These are both in electricity substations; one is above ground and the other is in a trough. The longest directly buried transmission voltage GIL in the world is approximately one kilometre long and was recently installed on the German transmission system around Frankfurt Airport.

1.1.42 In the absence of proven design life information, and to promote consistency with assessment of other technology options, National Grid assesses GIL over a design life of up to 40 years.

High Voltage Direct Current ("HVDC")

1.1.43 HVDC technology can provide efficient solutions for the bulk transmission of electricity between AC electricity systems (or between points on an electricity system).

1.1.44 There are circumstances where HVDC has advantages over AC, generally where transmission takes place over very long distances or between different, electrically-separate systems, such as between Great Britain and countries such as France, The Netherlands and Ireland.

1.1.45 HVDC links may also be used to connect a generating station that is distant from the rest of the electricity system. For example, very remote hydro-electric schemes in China are connected by HVDC technology with overhead lines.

1.1.46 Proposed offshore wind farms to be located over 60km from the coast of Great Britain are likely to be connected using HVDC technology as an alternative to an AC subsea cable. This is because AC subsea cables over 60km long have a number of technical limitations, such as high charging currents and the need for mid-point compensation equipment.

1.1.47 The connection point between AC and DC electrical systems has equipment that can convert AC to DC (and vice versa), known as a converter. The DC electricity is transmitted at high voltage between converter stations.

1.1.48 HVDC can offer advantages over AC underground cable, such as:

[5] The distances are based on initial manufacturer estimates of tunnel and buried GIL dimensions which would be subject to full technical appraisal by National Grid and manufacturers to achieve required ratings which may increase the separation required. It should be noted that the diagram does not show the swathe of land required during construction. Any GIL tunnel installations would have to meet the detailed design requirements of National Grid for such installations.

- a minimum of two cables per circuit is required for HVDC whereas a minimum of three cables per circuit is required for AC.
- reactive compensation mid-route is not required for HVDC.
- cables with smaller cross sectional areas can be used (compared to equivalent AC system rating).

1.1.49 HVDC systems have a design life of about 40 years. This design life period is on the basis that large parts of the converter stations (valves and control systems) would be replaced after 20 years.

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