The Great Grid Upgrade

Sea Link

Sea Link

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Executive Summary

Ex1.1 Introduction

Ex1.1.1 This document outlines the compliance of the Proposed Project with relevant electric and magnetic field (EMF) exposure guidelines. The report is structured to provide a detailed assessment of both onshore and offshore EMF impacts, adhering to the guidelines set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the European Union (EU). The document includes an introduction to the project, the legislative and policy framework, baseline environmental conditions, and the methodology used for the assessment. It also covers the specific assessments of offshore and onshore EMF, including the effects on magnetic compasses and the compliance of various components such as DC cables, HVDC river crossings, AC cables, overhead lines, converter stations, and substations.

Ex1.2 Conclusions

Ex1.2.1 The report concludes that the Sea Link project complies with the established EMF exposure limits, ensuring the protection of both public health and marine life. The assessments demonstrate that the calculated magnetic fields for the proposed project are within the permissible limits, and the electric fields are effectively managed to avoid any adverse effects. The document also highlights the importance of considering potential indirect effects, such as interactions with implantable medical devices, and provides evidence of compliance through technical specifications and calculations. Overall, the report provides a thorough evaluation of the project's EMF impacts, ensuring adherence to regulatory requirements and safeguarding environmental and public health

1. Introduction

1.1 Introduction

1.1.1 The Sea Link Project (hereafter referred to as the 'Proposed Project') is a proposal by National Grid Electricity Transmission plc (hereafter referred to as National Grid) to reinforce the transmission network in the South East and East Anglia. The Proposed Project is required to accommodate additional power flows generated from renewable and low carbon generation, as well accommodating additional new interconnection with mainland Europe.

1.1.2 National Grid owns, builds and maintains the electricity transmission network in England and Wales. Under the Electricity Act 1989, National Grid holds a transmission licence under which it is required to develop and maintain an efficient, coordinated, and economic electricity transmission system.

1.1.3 This would be achieved by reinforcing the network with a High Voltage Direct Current (HVDC) Link between the proposed Friston substation in the Sizewell area of Suffolk and the existing Richborough to Canterbury 400kV overhead line close to Richborough in Kent.

1.1.4 National Grid is also required, under Section 38 of the Electricity Act 1989, to comply with the provisions of Schedule 9 of the Act. Schedule 9 requires licence holders, in the formulation of proposals to transmit electricity, to:

1.1.5 Schedule 9(1)(a) '…have regard to the desirability of preserving natural beauty, of conserving flora, fauna and geological or physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological interest;' and

1.1.6 *Schedule 9(1)(b) '…do what [it] reasonably can to mitigate any effect which the proposals would have on the natural beauty of the countryside or on any such flora, fauna, features, sites, buildings or objects'.*

1.1.7 The purpose of this document is to:

- provide an assessment of electric and magnetic fields (EMFs) associated with offshore and onshore assets for the Proposed Project.

1.2 The Proposed Project

1.2.1 The Proposed Project would comprise the following elements:

The Suffolk Onshore Scheme

- A connection from the existing transmission network via Friston Substation, including the substation itself. Friston Substation already has development consent as part of other third-party projects. If Friston Substation has already been constructed under another consent, only a connection into the substation would be constructed by the Proposed Project.

- A high voltage alternating current (HVAC) underground cable of approximately 1.9 km in length between the proposed Friston Substation and a proposed converter station (below).
- A 2 GW high voltage direct current (HVDC) converter station (including permanent access from the B1121 and a new bridge over the River Fromus) up to 26 m high plus external equipment (such as lightning protection, safety rails for maintenance works, ventilation equipment, aerials, similar small scale operational plant, or other roof treatment) near Saxmundham.
- A HVDC underground cable connection of approximately 10 km in length between the proposed converter station near Saxmundham, and a transition joint bay (TJB) approximately 900 m inshore from a landfall point (below) where the cable transitions from onshore to offshore technology.
- A landfall on the Suffolk coast (between Aldeburgh and Thorpeness).

The Offshore Scheme:

- Approximately 122 km of subsea HVDC cable, running between the Suffolk landfall location (between Aldeburgh and Thorpeness), and the Kent landfall location at Pegwell Bay.

The Kent Onshore Scheme:

- A landfall point on the Kent coast at Pegwell Bay.
- A TJB approximately 800 m inshore to transition from offshore HVDC cable to onshore HVDC cable, before continuing underground for approximately 1.7 km to a new converter station (below).
- A 2 GW HVDC converter station (including a new permanent access off the A256), up to 28m high plus external equipment such as lightning protection, safety rails for maintenance works, ventilation equipment, aerials, and similar small scale operational plant near Minster. A new substation would be located immediately adjacent.
- Removal of approximately 2.2 km of existing HVAC overhead line, and installation of two sections of new HVAC overhead line, together totalling approximately 3.5 km, each connecting from the substation near Minster and the existing Richborough to Canterbury overhead line.

1.2.2 The Proposed Project also includes modifications to sections of existing overhead lines in Suffolk (only if Friston Substation pursuant to another consent) and Kent, diversions of third-party assets, and land drainage from the construction and operational footprint. It also includes opportunities for environmental mitigation and compensation and enhancement (which could include hedgerow creation, native tree planting, or habitat creation). The construction phase will involve various temporary construction activities including overhead line diversions, use of temporary towers or masts, working areas for construction equipment and machinery, site offices, parking spaces, storage, accesses, bellmouths, and haul roads, as well as watercourse crossings and the diversion of public rights of way (PROWs) and other ancillary operations.

1.3 Purpose of the Report

1.3.1 This report describes EMFs produced by the operation of the proposed converter stations, the associated high voltage Direct Current (DC) bipole connecting the proposed converter stations, and overhead and underground cable connections to the existing transmission system and two new 400 kV substations in the onshore and offshore environments, one of which maybe not be built depending on Scottish Power Renewables DCO application.

1.4 Introduction to Electric and Magnetic Fields

1.4.1 All equipment that generates, transmits, distributes or uses electricity produces EMFs. In the UK electricity is normally generated, transmitted, distributed and consumed as Alternating Current (AC). The UK power frequency for AC is 50 Hertz (Hz), which is therefore the principal frequency of the EMFs produced which are also known as Extremely Low Frequency (ELF) EMFs. The Proposed Project uses DC technology which has a frequency of 0 Hz and will produce static EMFs. The proposed converter Stations will then convert DC transmission to AC 50 Hz transmission which can be connected to the existing National Grid transmission system.

1.4.2 All static and alternating fields can have different effects, but in both cases, there are exposure limits set by independent organisations, designed to prevent all established effects of EMFs on people.

Electric fields

1.4.3 Electric fields depend on the operating voltage of the equipment producing them and are measured in V/m (volts per metre). The voltage applied to equipment is a relatively constant value. Electric fields are shielded by most common building materials, trees and fences and diminish rapidly with distance from the source.

1.4.4 As a consequence of their design, some types of equipment do not produce an external electric field. This applies to underground cables (both AC and DC) and gas insulated switchgear (GIS), which are enclosed in a metal sheath (a protective metal layer within the cable) and have solid metal enclosures respectively. These screen the electric field altogether and as such electric fields are not considered further for these types of equipment.

1.4.5 In the marine environment the movement of the sea through the magnetic field will result in a small localised electric field being produced. The induced electric fields that occur in the sea will be assessed in Section 5.3.

Magnetic fields

1.4.6 Magnetic fields depend on the electrical currents flowing, which vary according to the electrical power requirement at any given time and are measured in µT (microtesla). They are not significantly shielded by most common building materials or trees. Magnetic fields diminish rapidly with distance from the source.

1.4.7 Magnetic fields are found in all areas where electricity is in use (e.g. offices and homes), arising from electric cabling and equipment in the area. In UK houses, typical ELF magnetic fields will be in the range of 0.01 – 0.2 µT, with higher values in localised areas close to electrical appliances.

1.4.8 The earth also produces its own DC magnetic field, which in the UK is around 49 µT, but this can vary due to geomagnetic material such as ferromagnetic rocks.

1.4.9 The proposed project uses both AC and DC technology, so both static and alternating EMFs will be produced. The underground cables entering the proposed converter station via the marine route will use DC, so they will produce steady EMFs that always point in the same direction. There will also be AC cables installed between the proposed converter stations and 400 kV substations which will operate at 50 Hz.

1.4.10 The proposed converter station will contain specialist electrical equipment which will produce both DC and AC fields which are assessed in this report.

1.4.11 This report will assess the EMF from the project in line with the requirements of National Policy Statement (NPS) EN-3 and EN-5.

2. Legislation and Policy

2.1 Policy and Assessment Guidelines for the Protection of People

2.1.1 At high enough levels, EMFs can cause biological effects, which depending on the frequency of the fields can impact nerve function or blood flow. Whilst there are no statutory regulations in the UK that limit the exposure of people to power-frequency EMFs, responsibility for implementing appropriate measures for the protection of the public lies with the UK Government, which has a clear policy, restated in January 2024 and incorporated in NPS EN-5 (Department for Energy Security and Net Zero, 2024), on the exposure limits and other policies they expect to see applied. Practical details of how the policy is to be implemented are contained in Codes of Practice agreed between industry and the Government.

2.1.2 UK Government policy on EMF requirements for all electricity infrastructure projects is given in NPS EN-5. Table 2.1 sets out the main EMF requirements in NPS EN-5.

Table 2.1 Summary of NPS EN-5 Requirements relevant to EMF

Paragraph	Requirement	Section of this Report	Compliance Assessment
2.09.54	These guidelines also form the basis of the Control of Electromagnetic Fields at Work Regulations 2016. Resulting from these recommendations, government policy is that exposure of the public should comply with the ICNIRP 1998 guidelines. The electricity industry has agreed to follow this policy. Applications should show evidence of this compliance as specified in 2.10.11	6	The Proposed Project has been designed and assessed in line with the Code of Practice-Power Lines: Demonstrating compliance with EMF exposure guidelines. All the EMF produced would comply with the Government-adopted ICNIRP 1998 guidelines, as demonstrated in this report.
2.10.11	The applicant should have considered the following factors: Height, position, insulation and protection (electrical or mechanical as appropriate) measures subject to ensuring compliance with the Electricity Safety, Quality and Continuity Regulations 2002	2.12, 2.6 and 6.2	The proposed overhead line has been designed to comply with the statutory requirements of the Electricity Safety, Quality and Continuity Regulations 2002 (SQSS, 2002). EMF requirements can, for some designs of overhead line, result in conductor clearances to ground (one of the requirements

Paragraph	Requirement	Section of this Report	Compliance Assessment
	That optimal phasing of high voltage overhead power lines is introduced wherever possible and practicable in accordance with the Code of Practice to minimise effects of EMF. Any new advice emerging from the Department of Health relating to Government policy for EMF exposure guidelines.		of these regulations) being increased but never reduced compared to the requirements of the Electricity Safety, Quality and Continuity Regulations 2002. The minimum conductor clearance information provided in this report demonstrates this compliance. The overhead line has been designed in line with the policy on optimum phasing as specified in the Code of Practice on Optimum Phasing. This has been considered in this chapter, and all current advice has been used for the assessment. The assessment has been carried out against the current Government-recommended EMF exposure guidelines and policies.
2.10.12	Where it can be shown that the line will comply with the current public exposure guidelines and the policy on phasing, no further mitigation should be necessary	6	This report shows that the Proposed Project would be compliant with the current public exposure guidelines of ICNIRP 1998 and the policy on phasing using the principles in the Codes of Practice on Compliance and Optimum Phasing.
2.11.10	Before granting consent to an overhead line application, the Secretary of State should be satisfied that the proposal is in accordance with the guidelines, considering the evidence provided by the applicant and any other relevant evidence. It may also need to take expert advice from the Department of Health and Social Care.	6	The cables and all other assets associated with the Proposed Project are demonstrated in this report to comply with the Government-adopted ICNIRP 1998 guidelines.
2.11.11	Industry currently applies optimal phasing to 275kV and 400kV overhead lines voluntarily wherever operationally possible, which helps to minimise the	6.2	The overhead lines have been designed in compliance with the policy on optimum phasing as specified in the Code of Practice

Paragraph	Requirement	Section of this Report	Compliance Assessment
	effects of EMF. The government has developed with industry a voluntary Code of Practice, 'Optimum Phasing of high voltage double-circuit Power Lines – A Voluntary Code of Practice'30, published in March 2012, that defines the circumstances where industry can and will optimally phase lines with a voltage of 132kV and above.		on Optimum Phasing, as demonstrated in this report.
2.11.16	The diagram below shows a basic decision tree for dealing with EMF from overhead power lines to which the IPC can refer.	2.2 in Plate 2.1	This decision tree has been replicated in Plate 2.1 and forms the basis for the assessment of EMF from the reinforcement.

2.1.3 A simplified route map for dealing with EMF is provided in NPS EN-5 and is reproduced in Figure 2.1.

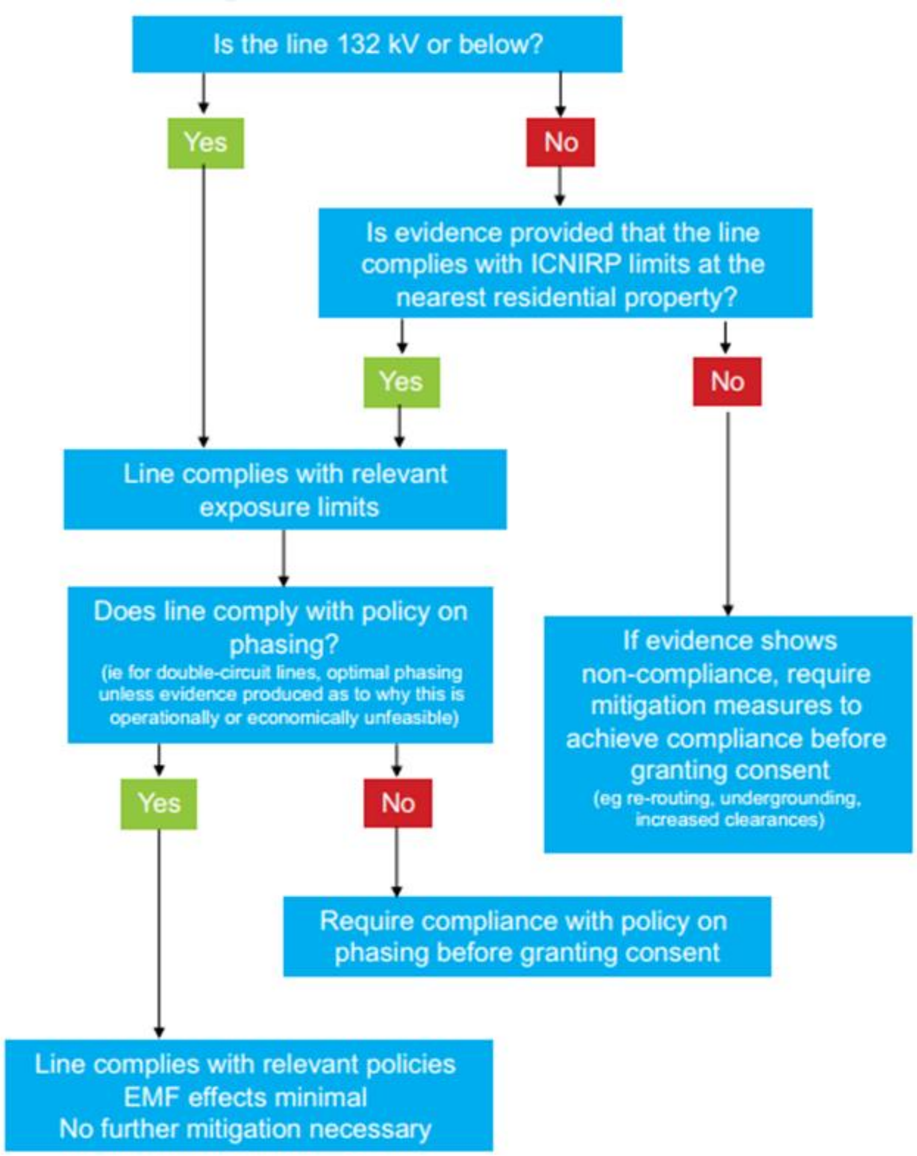

Plate 2.1 Simplified Route Map for Dealing with EMF. Reproduced from NPS EN-5 (page 23)

2.1.4 The ICNIRP guidelines (International Commision on Non-Ionizing Radiation Protection, 1998) are based on the avoidance of known adverse effects of exposure to EMF at frequencies up to 300 GHz, which includes the 50 Hz EMF associated with electricity transmission. This equates, at 50 Hz, to public exposure limits of:

- 9.0 kV/m for electric fields; and
- 360 µT for magnetic fields.

2.1.5 The European Union (EU) recommendation noted in the Code of Practice (European Council, 1999) adopts ICNIRP guidelines for DC magnetic field exposure (ICNIRP, 1994). Acute public exposure should not exceed 40,000 µT (40 millitesla). However, ICNIRP's 1994 guidance, states that there are potential indirect effects, such as injuries due to flying ferromagnetic objects and potential interactions with implantable medical devices which could occur at levels below the exposure limits, which should also be considered but are not thresholds.

2.1.6 Therefore, a lower restriction of 500 µT should be considered where indirect effects may be an issue. The assessment would demonstrate a significant impact if non-compliance with the EMF exposure limits was demonstrated using the principles set out in Codes of Practice ‘Power Lines: Demonstrating compliance with EMF public exposure guidelines – a voluntary Code of Practice’ (Department for Energy and Climate Change, 2012).

Table 2.2 Exposure limits for power frequencies

Public exposure limits	Electric fields	Magnetic fields
	AC	
Basic restrictions (induced current density in central nervous system)	2 mA/m2	
Field corresponding to the basic restriction	9,000 V/m	360 µT
	DC	
Exposure limit	No limit*	40,000 µT

2.2 Policy Framework for the Protection of Marine Life

2.2.1 NPS EN-3 for renewable energy infrastructure (Department for Energy Security and Climate Change, 2024) provides the primary basis for decisions by the Infrastructure Planning Commission (IPC) on applications it receives for nationally significant renewable energy infrastructure. There are no limits or guidelines for EMF exposure in the marine environment, but potential impacts on marine life should be assessed.

2.2.2 NPS EN-3 sets out Government policy on Renewable Energy Infrastructure including offshore HVDC connections, like those proposed as part of this project. Table 2.3 sets out the key EMF requirements of NPS EN-3.

Table 2.3 Summary of NPS EN-3 Requirements relevant to EMF

Paragraph	Requirement	Section of this Report	Compliance Assessment
2.8.151	Applicant assessments should identify the potential implications of underwater noise from construction and unexploded ordnance including, where possible, implications of predicted construction and soft start noise	5	The EMF from the Proposed Project has been assessed in Section 5 of this report and will feed into the marine impact assessment.

Paragraph	Requirement	Section of this Report	Compliance Assessment
	levels in relation to mortality, permanent threshold shift (PTS), temporary threshold shift (TTS) and disturbance, and addressing both sound pressure and particle motion) and EMF on sensitive fish species		
2.8.310	The use of external cable protection has been suggested as a mitigation for EMF (by increasing the distance between fish species and individual cables). However, the Secretary of State should also consider any negative impacts from external cable protection on benthic habitats, and a balance between protection of various receptors must be made, with all mitigation and alternatives reviewed.	5	The Proposed Project has been designed with cable protection and this report will feed into the marine impact assessment.
2.8.246	Burial of the cable increases the physical distance between the maximum EMF intensity and sensitive species. However, what constitutes sufficient depth to reduce impact may depend on the geology of the seabed.	5	The EMF assessment for the Proposed Project includes target burial depth.

2.2.3 The mitigation methods suggested in NPS EN-3 include the use of armoured cables for interarray and export cables. Armoured cables are to be used for the Proposed Project. Burial depth can reduce the magnetic fields at distance but to a lesser extent than cable bundling. Therefore, mitigation of EMF from offshore cables can also occur by the separation of the cables in each bipole system. The closer the cables, the more cancellation of the field occurs and the lower the fields. Cables depths will vary along the route, ranging between 0.5 m where bedrock exists to 2.5 m in other areas, depending on requirements.

2.2.4 This report will provide the EMF details to inform the marine impact assessment and ensure compliance with Government exposure guidelines for the onshore installation.

2.3 Effects on Magnetic Compasses

2.3.1 Magnetic compasses, whether traditional magnetic needle designs or alternatives such as fluxgate magnetometers, operate from the Earth’s magnetic field, and are susceptible to any perturbation to the Earth’s magnetic field by other sources.

2.3.2 This is a potential issue with DC conductors or cables, which produce a static magnetic field that perturbs the geomagnetic field. These are assessed in Section 5.5.

2.3.3 The magnetic fields produced by the AC assets would be 50 Hz fields. These oscillate far too quickly (50 times per second) for a magnetic compass needle to be affected. Fluxgate magnetometers are capable of responding to 50 Hz fields, but, when used as a compass, always have filtering to eliminate unwanted frequencies including 50 Hz. They can cease working correctly if saturated by a high-enough field, but the field required is orders of magnitude higher than would be produced by the Proposed Project.

3. Baseline Environment

3.1 Onshore

3.1.1 All equipment that generates, distributes or uses electricity produces EMFs. The UK power frequency is 50 Hz, which is the principal frequency of the EMFs produced, although HVDC circuits are also present which will be a source of additional DC fields.

3.1.2 Electric and magnetic fields both occur naturally. The Earth's magnetic field, which is caused mainly by currents circulating in the outer layer of the Earth's core, is approximately 50 µT in the UK. This field may be distorted locally by ferrous minerals or by steelwork such as in buildings. At the Earth's surface there is also a natural electric field, created by electric charges high up in the ionosphere, of approximately 100 V/m in fine weather and more in stormy weather.

3.1.3 As detailed earlier in this report, the Earth's natural electric and magnetic fields are static, and the power system produces alternating fields. In homes in the UK that are not close to high-voltage overhead lines or underground cables, the average "background" power-frequency magnetic field (the field existing over the whole volume of the house) ranges typically from 0.01 – 0.2 µT with an average of approximately 0.05 µT, normally arising from currents in the low voltage distribution circuits that supply electricity to homes. The highest magnetic fields to which most people are exposed in the home arise close to domestic appliances that incorporate motors and transformers. For example, close to their surface, fields can be 2000 µT for electric razors and hair dryers, 800 µT for vacuum cleaners, and 50 µT for washing machines. The electric field in most homes is in the range 1 – 20 V/m, rising to a few hundred V/m close to appliances (Swanson & Renew, 1994).

3.1.4 The Earth has its own natural DC magnetic field which we are surrounded by all the time. The Earth's magnetic field is around 49 µT in the areas where this Proposed Project is proposed. There is also a natural static electric field everywhere on the surface of the earth with an intensity of about 100 V/m. This varies significantly and are very dependent on atmospheric conditions. When a thunderstorm approaches, the electric field reaches much higher values, on the order of 10 kV/m to 20 kV/m at ground level (Bennett, 2007).

3.2 Offshore

3.2.1 The current offshore environment where Sea Link cables are proposed, has naturally occurring DC magnetic fields, which again is around 49 µT. As well as the earth's geomagnetic field, there are also other cables, shipwrecks and ferromagnetic rocks, which will add to the background DC EMF in the area.

3.2.2 The Earth's magnetic field can induce an electric field in sea water. The movement of the sea through the magnetic field will result in a small localised electric field being produced. It has been stated that the magnitude of the electric field induced will be dependent upon magnetic field strength, sea water chemistry, viscosity and its flow velocity and direction relative to the lines of magnetic flux. The background geomagnetic field in the area is around 49 µT. Given this, the background induced electric field could range between 4.9 and 61.3 µV/m in tidal velocities ranging between 0.1 m/s and 1.25 m/s.

4. Assessment methodology

4.1 Methodology

4.1.1 In order to demonstrate compliance with the exposure guidelines, Industry and Government have published a Code of Practice, "Power Lines: Demonstrating compliance with EMF public exposure guidelines" (Department for Energy and Climate Change, 2012). As part of the Code of Practice, the Energy Networks Association maintain a publicly-available list on its website of types of equipment where the design is such that it is not capable of exceeding the ICNIRP exposure guidelines, with evidence as to why this is the case. Such types of equipment include:

- overhead power lines at voltages up to and including 132kV;
- underground cables at voltages up to and including 132kV; and
- substations at and beyond the publicly accessible perimeter without air-cored reactive equipment.

4.1.2 "*Compliance with exposure guidelines for such equipment will be assumed unless evidence is brought to the contrary in specific cases."* (Page 5)

4.1.3 This list includes all substations which do not contain any air-cored reactors. At the perimeter fence, the highest fields are invariably produced by any overhead lines or underground cables at transmission voltages entering the substation; the compliance of these items of equipment is considered on a case-by-case basis.

4.1.4 The Energy Networks Association's publicly available list can be found on the National Grid EMF website (http://www.emfs.info/compliance/public/). This confirms that substations (that do not contain a static var compensator), such as those proposed by the Proposed Project, are within the class of equipment which are regarded as inherently compliant without the need for case-by-case specific assessments.

4.1.5 To assess compliance with exposure limits, the Code of Practice on Compliance specifies that the maximum fields the overhead line or underground cable is capable of producing should be calculated using the following conditions:

- electric fields: for nominal voltage and design minimum clearance;
- magnetic fields: for the highest rating that can be applied continuously in an intact system (i.e., including ratings which apply only in cold weather, but not including short-term ratings or ratings which apply only for the duration of a fault elsewhere in the electricity system) and design minimum clearance; and
- electric and magnetic fields: for 1 m above ground level, of the unperturbed field, taking account of the correct wire type and bundle size, taking account of the basic pylon geometry for the design of overhead line in question, but ignoring variations in conductor spacing at angle pylons etc., of the 50 Hz component ignoring harmonics, ignoring zero-sequence currents and voltages and currents induced in the ground or earth wire, and using the infinite-straight-line approximation.

4.1.6 The same provisions apply, where relevant, to assessing the fields from underground cables.

4.1.7 Therefore, the calculations for the Proposed Project were performed using worst-case conditions including minimum conductor clearances for overhead lines. The circuits are unlikely to operate at this maximum rating routinely, resulting in lower typical magnetic fields on a day-to-day basis.

4.1.8 Electric fields (but not magnetic fields) are readily perturbed by conducting objects, including, for example, buildings, fences and trees. The fields calculated here are unperturbed fields, as specified by the Code of Practice on Compliance. These give a valid indication of the size of any electric-field related phenomena over the area concerned, but the local value, close to a source of perturbation, would vary. In practice, perturbations within or to the sides of buildings and other fixed objects usually act so as to reduce, not increase, the electric field. Fields inside any buildings are generally much reduced. However, the Code of Practice specifies that it is acceptable to demonstrate compliance by reference to the unperturbed fields.

4.1.9 For the assessment of effects from a DC system, the proposed converter station and underground cables are required to provide evidence of compliance. In line with the Code of Practice, this report sets out the technical specifications of the proposed Converter Stations to demonstrate how the development complies with EMF exposure guidelines and provides a calculation of the maximum magnetic fields directly over the underground cable route.

4.1.10 These calculations assume that there is no attenuation of magnetic fields from any surrounding material (e.g., seabed, earth, grout mattresses, etc.) and that there are no unbalanced currents flowing along the outer sheaths of the cables.

4.2 Assessment of Effects

4.2.1 The onshore Proposed Project would be assessed as having an adverse effect if non-compliance with the EMF exposure limits was demonstrated, using the principles set out in Codes of Practice (Department for Energy and Climate Change, 2012). Conversely, as specified in NPS EN-5, if the Proposed Project complies with the exposure limits, EMF effects are assessed as not significant, and no mitigation is necessary.

4.2.2 For the marine environments, total field values are produced and compared to the requirements of NPS EN-3 and used to assess potential impacts to marine life. This report will inform the marine impact assessment.

5. Assessment of Offshore EMF

5.1 Assessment Introduction

5.1.1 The Proposed Project will be a new, primarily offshore HVDC electrical transmission link operating at 0 Hz (DC). The transmission link will consist of a bipole system with two cables.

5.1.2 The majority of the offshore route will be installed as a bundled bipole, meaning the two cables are installed together, touching one another. The cable manufacturer is yet to be determined, but a standard diameter of 0.137m for each cable was used for the calculations. Burial depth will depend on seabed composition. Where cables are buried in sediment, burial depth will range between 1.0 – 2.5 m and where bedrock is present cables will be buried at 0.5m depth.

5.1.3 Where the offshore cables transition on to land, Horizontal Directional Drilling (HDD) or a trenchless solution will be used as the installation technique. This technique results in the cables separating but getting deeper, then progressively becoming closer together. The maximum separation distance of 45 m and burial depth of 10 m were taken to represent a worst-case situation. Both the bundled and trenchless installation techniques have been considered.

5.1.4 The HVDC cables will operate at ±525 kV carrying 2 GW of power. The maximum current rating of the cables has been used for all calculations.

5.2 Magnetic Field Assessment

5.2.1 All calculations were performed assuming maximum circuit separation and minimum burial depth, giving a worst-case scenario at maximum 100% rating. For information calculations were also performed for 50% load, which are presented in Appendix A.

5.2.2 The maximum magnetic field for each different installation technique was calculated at vertical distances of 0 to 50 meters from the seabed, and horizontal drop off along the seabed. For bundled cable installation a worst-case (minimum) burial depth of 0.5 m was used to represent areas where bedrock is present and 1.0 – 2.5 m depth if located in sediment.

5.2.3 Table 5.1 gives the maximum magnetic field at vertical distances from the cables for all installation methods and depths. Plate 5.1 to Plate 5.5 shows the maximum magnetic field from the cable only and the total magnetic field when combined with the geomagnetic field for the bundled cables at various burial depths and trenchless installation options respectfully.

Table 5.1 Calculated maximum cable magnetic fields at vertical distances from the seabed for the offshore Sea Link cable circuit options

	Magnetic fields (µT)						
	Distance above seabed (m)						
	Seabed	**0.5**	**1**	**2**	**5**	**10**	**20**
Bundled: 0.5 m depth	204.9	52.0	23.3	8.4	1.7	0.47	0.12
Bundled: 1.0 m depth	51.5	23.2	12.9	5.8	1.44	0.43	0.12
Bundled: 1.5 m depth	23.2	13.0	8.4	4.3	1.2	0.39	0.11
Bundled: 2.5 m depth	8.3	5.8	4.2	2.6	0.92	0.33	0.10
Trenchless	38.1	36.3	34.6	25.4	25.4	19.1	12.2

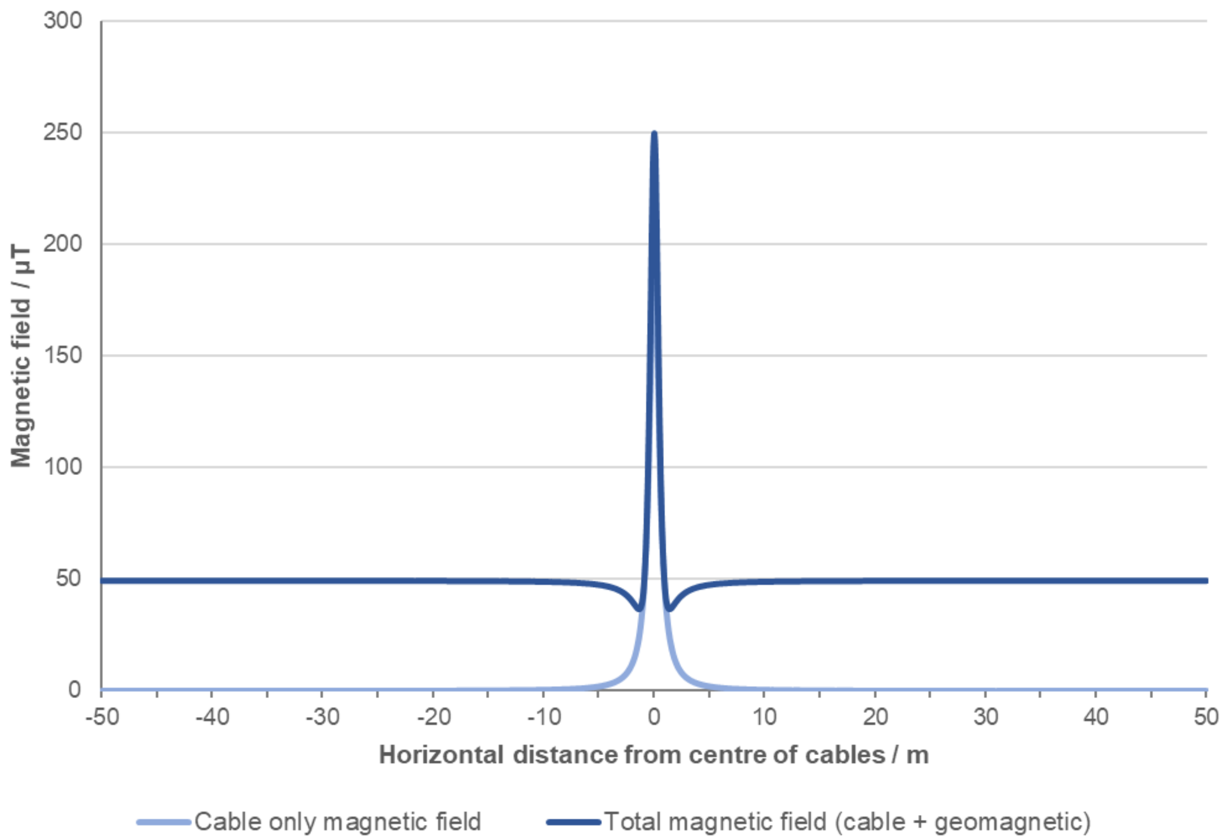

Plate 5.1 Calculated maximum magnetic fields horizontally along the seabed for bundled cables, 0.5 m depth.

5.2.4 The light blue line shows the maximum magnetic field from the cables only. The dark blue line shows the total magnetic field when combined with the earths geomagnetic field.

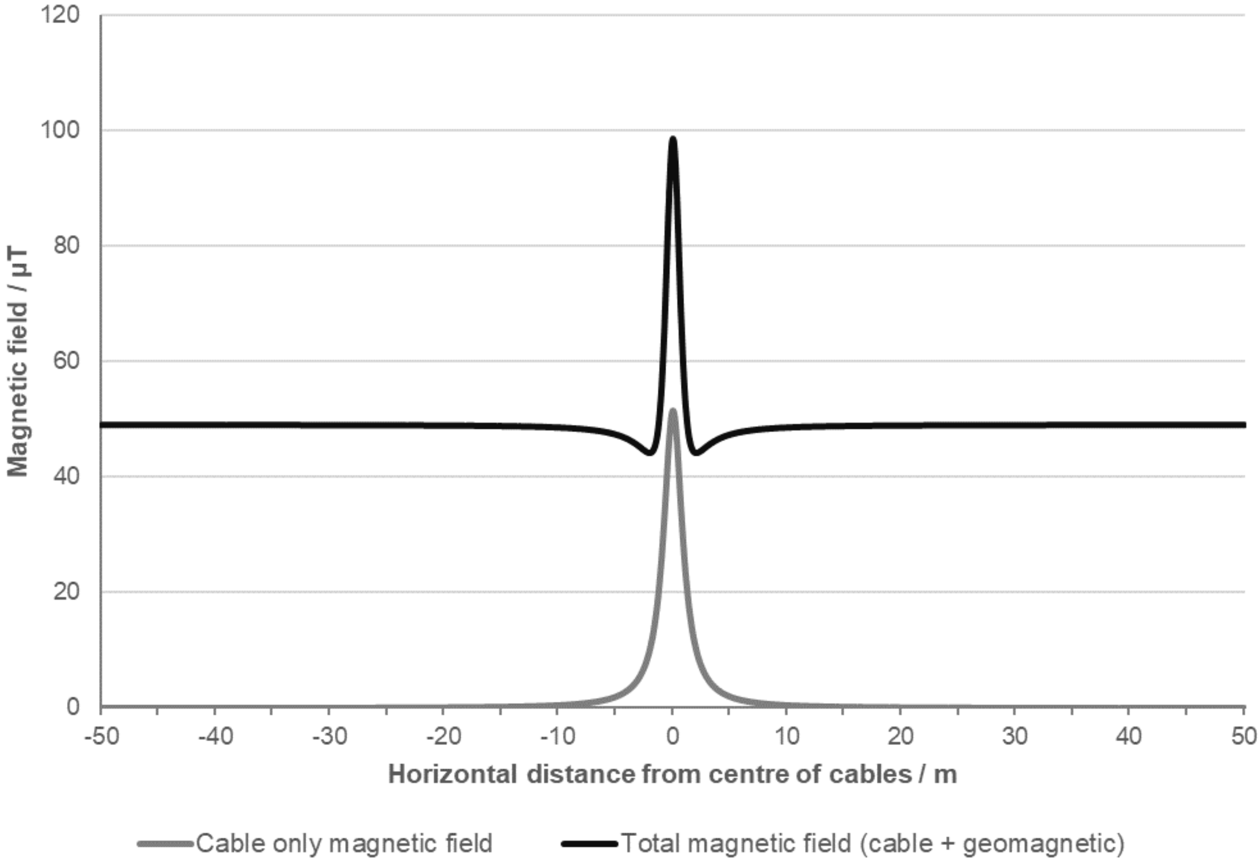

Plate 5.2 Calculated maximum magnetic fields horizontally along the seabed for bundled cables, 1.0 m depth

5.2.5 The light grey line shows the maximum magnetic field from the cables only. The black line shows the total magnetic field when combined with the earths geomagnetic field.

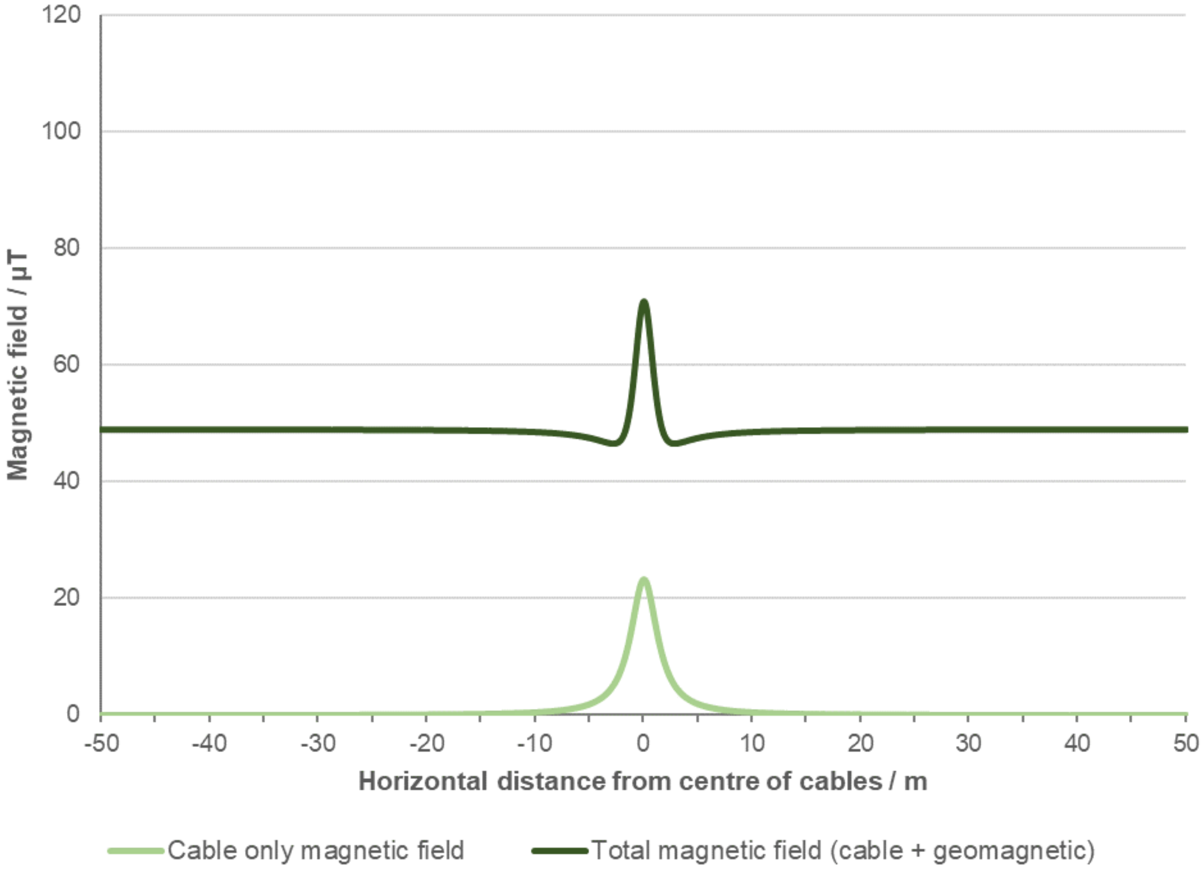

Plate 5.3 Calculated maximum magnetic fields horizontally along the seabed for bundled cables, 1.5 m depth

5.2.6 The light green line shows the maximum magnetic field from the cables only. The dark green line shows the total magnetic field when combined with the earths geomagnetic field.

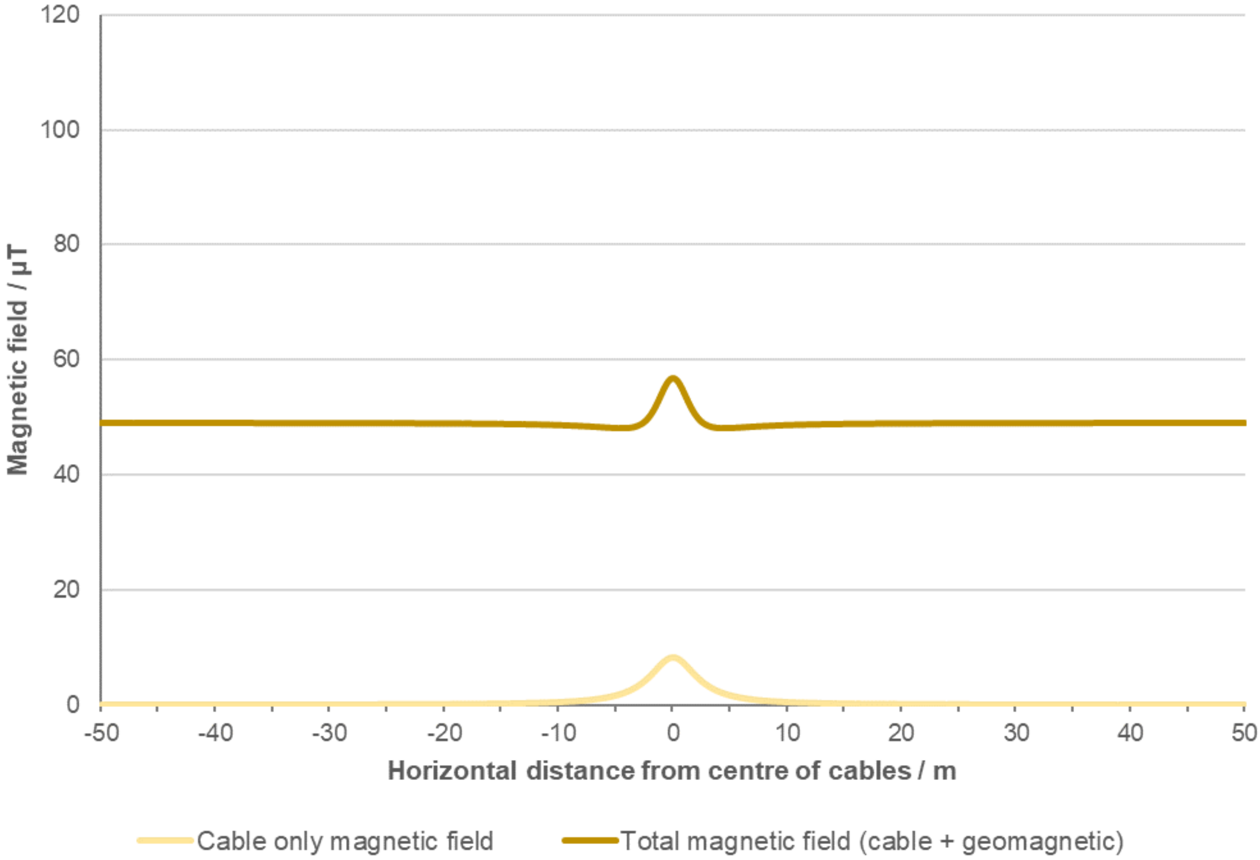

Plate 5.4 Calculated maximum magnetic fields horizontally along the seabed for bundled cables, 2.5 m depth

5.2.7 The light-yellow line shows the maximum magnetic field from the cables only. The dark yellow line shows the total magnetic field when combined with the earths geomagnetic field.

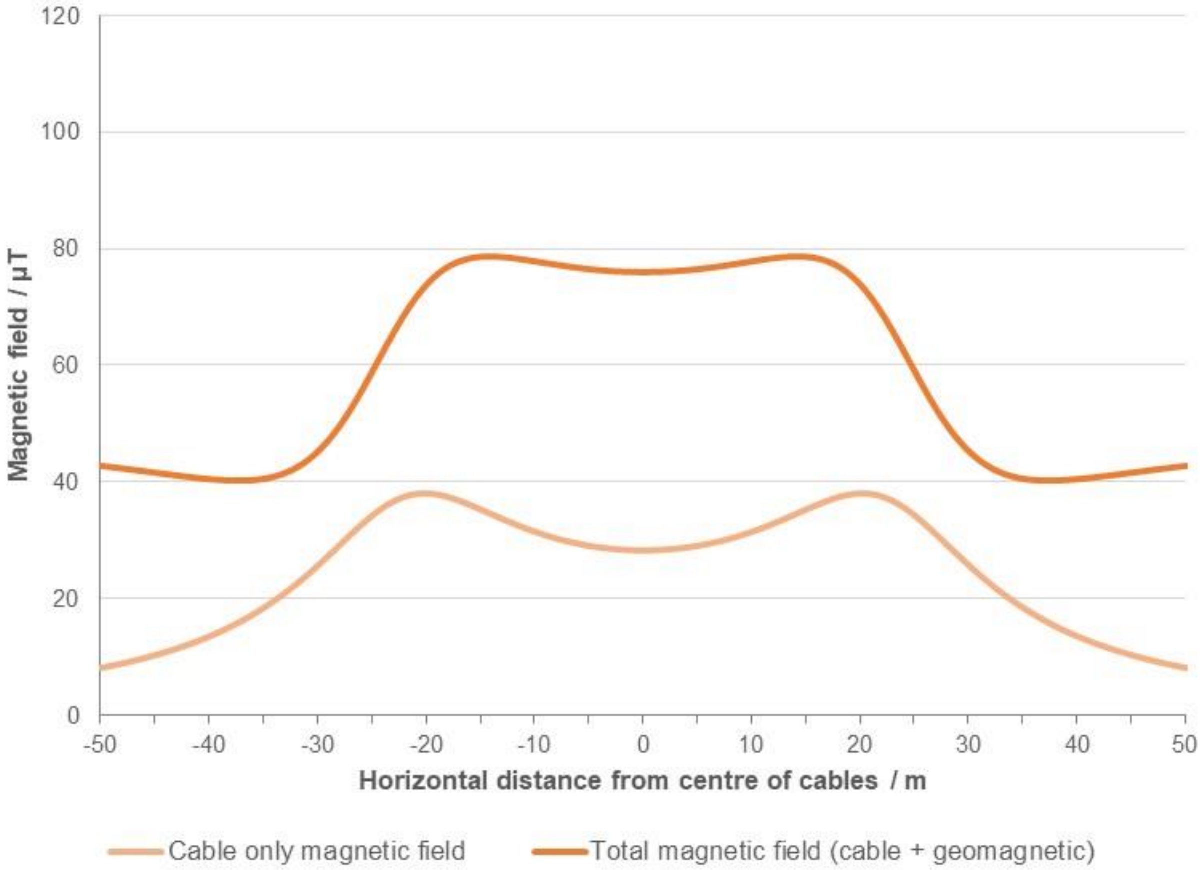

Plate 5.5 Calculated maximum magnetic fields horizontally along the seabed for trenchless, 10 m depth

5.2.8 The light orange line shoes the maximum magnetic field from the cables only. The dark orange line shoes the total magnetic field when combined with the earths geomagnetic field.

5.2.9 The calculated magnetic fields are greatest on the seabed and reduce rapidly with vertical and horizontal distance from the circuits (Table 5.1 and Plate 5.1 to Plate 5.5). The highest magnetic fields were observed when the burial depth of the cables was shallowest. Irrespective of the burial depth the magnetic fields reduce rapidly with distance from the cables due to bundling of the cables. The maximum magnetic fields calculated for cables buried 0.5 m deep and at the seabed were 204.9 µT compared to 46.4 µT when cabled were buried 2.5 m deep the magnetic fields were 8.3 µT.

5.3 Induced Electric Fields

5.3.1 The HVDC cable will produce a magnetic field which decreases with distance from the cables. The movement of sea water through the magnetic field will result in a small localised electric field being produced. A background electric field will be present in the sea due to the geo-magnetic field and localised magnetic anomalies. The strength of this field varies continuously due to the strength, speed and directions of the tide.

5.3.2 The convention for calculating induced electric fields for the other HVDC projects including Basslink, BritNed HVDC and Western Link connections is:

Induced electric field (µV/m) = Velocity (m/s) x Magnetic field (µT)

5.3.3 This is a vector cross product which means that the strength of the electric field is proportional to the component of the velocity perpendicular to the magnetic field and is in a direction perpendicular to both. The tidal velocities for the Proposed Project are evaluated for values up to 4 knots, to represent a very worst-case situation.

5.3.4 The average geomagnetic field along the Proposed Project's route is approximately 49 µT, which is used for the calculations of background induced electric field. This background magnetic field induces an electric field that could range between 49 and 101 µV/m in tidal velocities ranging between 0.5 and 4 knots. This does not take account of localised magnetic anomalies, which could result in higher localised electric fields, or of greater tidal velocities.

5.3.5 Appendix Table A.1 in Appendix A gives the calculated induced electric field for each of the five designs modelled.

5.3.6 These simplistic calculations are an overestimate of the induced electric field present close to the seabed. Water velocity distribution is non uniform due to friction that occurs at the seabed, where the magnetic field is greatest, which will reduce the resulting induced electric field.

5.4 Compass Deviations Along Route

5.4.1 The magnetic field from the cables, if large enough, will combine with the earth's magnetic field causing a compass to indicate north in a different direction to the magnetic north pole.

5.4.2 It is the horizontal component of the geomagnetic field that is used for navigation, and this varies between 19.12 µT in the Sizewell area and 19.59 µT in the Richborough area. A value of 19.6 µT is used for the studies.

5.4.3 Although not public guidance, the Marine Management Organisation (MMO) have previously provided the following guidance for other offshore cabling projects, which has been applied here given the similarity of the projects:

"In relation to Electromagnetic deviation on ships' compasses, the MMO would be willing to accept a three-degree deviation for 95% of the cable route. For the remaining 5% of the cable route no more than five degrees will be attained. The MMO would however expect a deviation survey post the cable being laid; this will confirm conformity with the consent condition. This data must be provided to the UKHO via a hydrographic note (H102), as they may want a precautionary notation on the appropriate Admiralty Charts."

5.4.4 The magnetic fields and compass deviation at the sea's surface were calculated for the Proposed Project's cable route. The assessments were performed using cable orientation and depth from Bathymetry data. The orientation of the cables to north, separation and depth, as well as the current flowing in the cable, will all impact extent a compass is deviated from the earth's magnetic north. proposed cable burial depths were taken along the entire route for calculations, except those areas where trenchless installation was considered which were excluded. These areas are very close to the shoreline in shallow water depths. Typically, trenchless installations have deeper burial depths reducing the magnetic field.

5.4.5 The maximum compass deviation for each of the design and route has been calculated along its length where cables are bundled for the maximum current in the cable. The results are shown in Appendix Plate C.1in Appendix C. The compass deviation is shown as a green line, with angle of cable to north as a red line and sea depth along route as a blue line. Compass deviation is calculated at the level of the sea surface.

5.4.6 Table 5.2 gives the percentage of the Proposed Project's route that would meet the MMO requirements stated in 5.4.3 for each of the cable design options.

Table 5.2 Percentage of the Proposed Project's route resulting in compass deviations of less than 3° and 5° variations

	Proportion of route within compass deviation threshold
Bundled cables	
Less than 3º deviation	98.5%
Less than 5º deviation	99.3%

5.4.7 Very low compass deviation occurs over the majority of the route. The bundled cable design achieves less than 3º compass deviation, and less than 5º compass deviation for 99.3%, meeting the MMO compass requirements.

6. Onshore Assessment and Demonstrating Compliance with the Requirements of NPS EN-5

6.1 DC Cables

Construction Effects

6.1.1 During construction and prior to energisation, transmission equipment would not produce any EMF as no voltage is applied or current flowing in the equipment. Therefore, construction effects are not considered further.

Operational Effects

6.1.2 There is one onshore HVDC circuit proposed in both Suffolk and Kent each of which consists of two cables in a single trench, operating as a bipole.

6.1.3 The cables will be installed in a trench with a minimum cable depth of 1 m and will be installed at a maximum of 1 m apart. The trench itself will have a typical width of 2.3 m and a depth of 1.6 m.

6.1.4 As the cables operate as a bipole system, the current in each cable runs in opposition to the other leading to a significant cancellation of the magnetic field. The magnetic field has been calculated using the maximum current rating of the cable at 1 m above ground.

6.1.5 The earthed metallic shield that is applied over the insulation of HVDC cables ensures that the electric field will be contained entirely within the insulation, and no external electric field will be emitted. The proposed underground cables produce no external electric fields, so are not considered further.

6.1.6 The DC magnetic fields from the cable itself and the combined fields from the cable and geomagnetic field were calculated in accordance with the provisions of the Code of Practice and a presented in Table 6.1 and Plate 6.1. All calculations were performed assuming maximum load, minimum cable separation and minimum burial depth, giving a worst-case scenario.

6.1.7 The maximum magnetic field calculated at 1 m above ground for the cable itself and its combination with the earth’s geomagnetic field is 88.0 µT and 135.6 µT respectively.

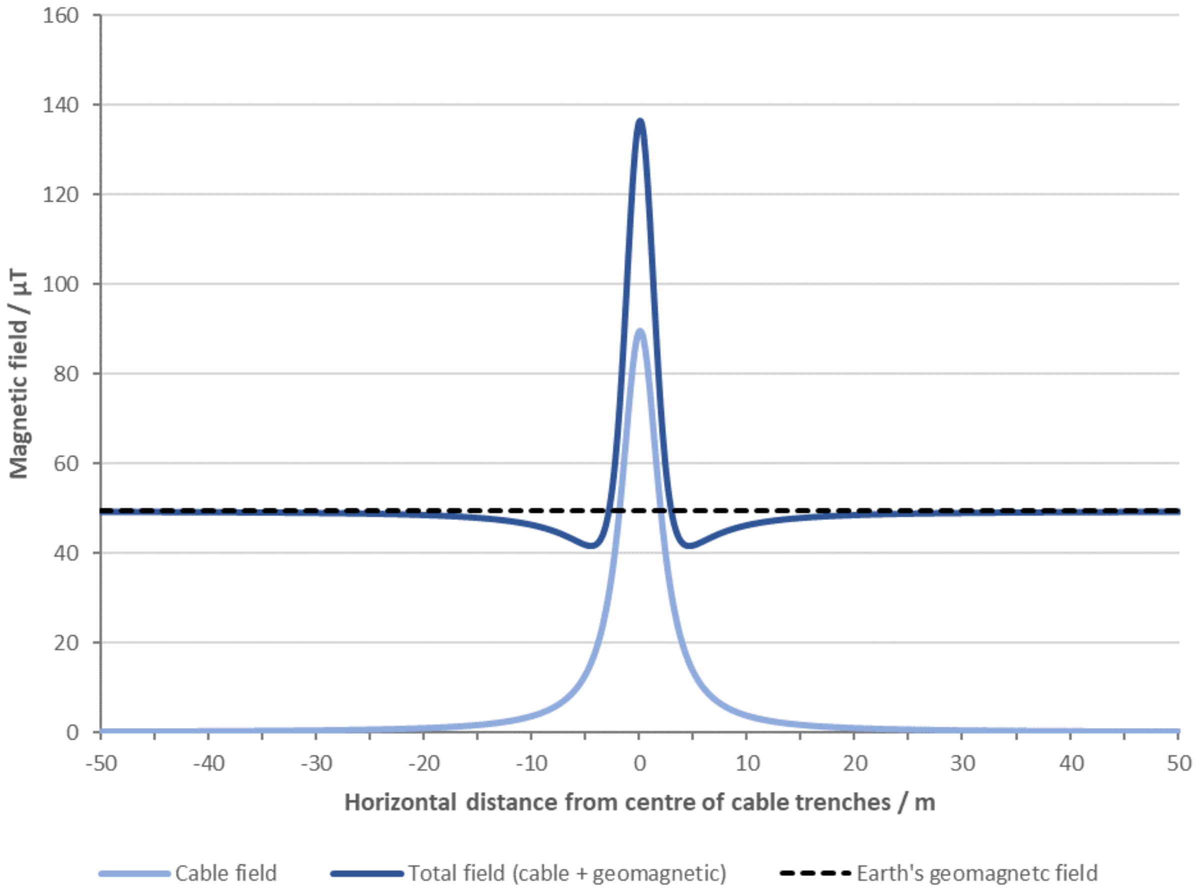

Plate 6.1 Maximum calculated magnetic fields from onshore HVDC cable circuits

6.1.8 The magnetic field from the cable alone is demonstrated by the light blue line and the total combined field with the geomagnetic field shown by the dark blue line.

6.2 HVDC River Crossing Assessment.

6.2.1 The onshore HVDC cables will cross a river using trenchless of open cut installation methods. The cables will cross the river perpendicularly usually in an east-west direction. The cables will be installed at minimum depth of 1 m below the riverbed using trenchless and open cut installation. The two HVDC cables will be installed 1 m apart in both installation methods resulting in the same magnetic fields for both.

6.2.2 Calculations of the magnetic fields have been performed at the riverbed, 1 m, 2 m, 5 m and 10 m above the riverbed for maximum 100% current ratings operations and are provided in Table 6.1.

6.2.3 The maximum magnetic fields will occur on the riverbed, reducing rapidly with distance.

Table 6.1 Maximum magnetic field calculations for proposed river crossing DC cables.

	Magnetic fields (µT)				
	Distance from cable circuit (m)				
	Riverbed	1	2	5	10
Trenchless and open cut installation	304.8	89.6	41.2	10.5	3.1

6.3 AC Cables – Suffolk

6.3.1 The HVAC circuit is proposed as two circuits each with one cable per phase, totaling six cables. Each circuit, consisting of three cables will be installed in a trench totaling two trenches separated by a central temporary haul road. The trenches are proposed as approximately 2.45 m wide and 1.5 m deep, with trenches separated typically by 10 m (centre phase to centre phase distance). The cables will be installed at a minimum depth of cable depth of 1 m. The HVAC cables will connect between the convertor stations to the proposed substations.

6.3.2 The magnetic field for each design has been calculated using the maximum continuous current rating of each circuit (1535 Amps) at 1 m above ground. The maximum magnetic field calculated at 1 m above ground is 65.5 µT directly above the cables. Magnetic fields reduce quickly with distance from source and Table 6.1 sets out the magnetic field strength at various distances from source. Plate 6.2 shows the magnetic field at 1 m above ground and how the magnetic fields reduce with distance from the cables.

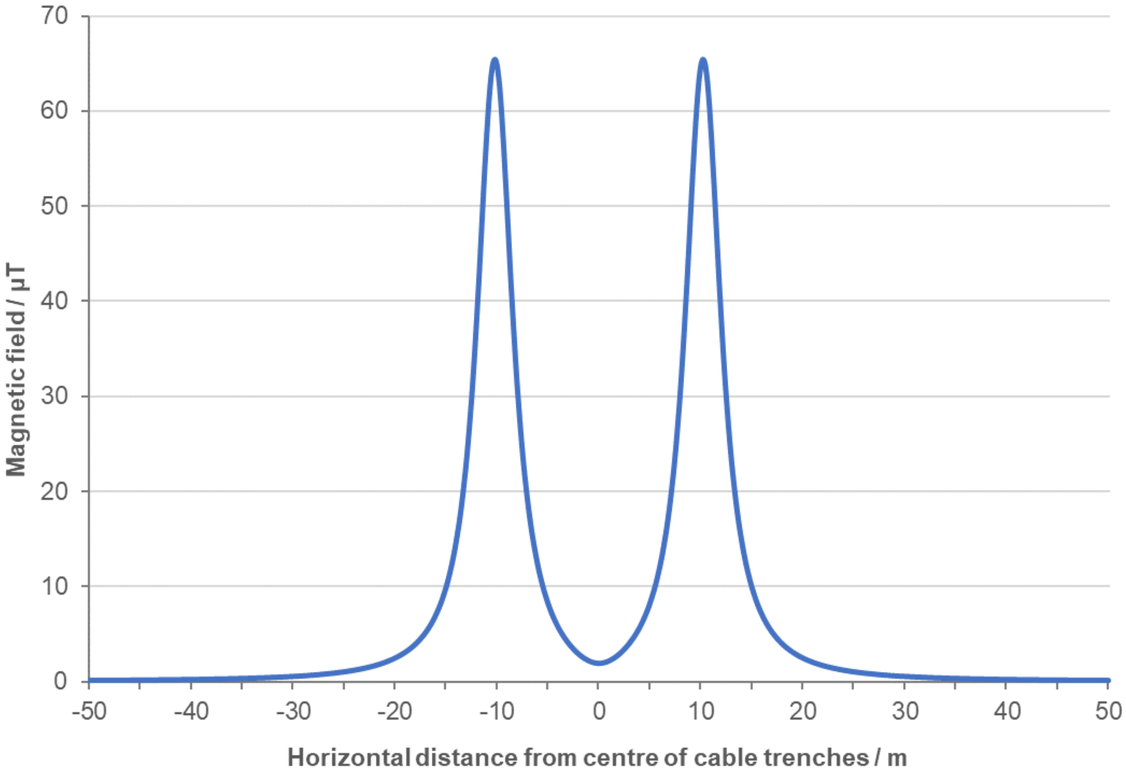

Plate 6.2 Maximum calculated magnetic fields from onshore 400 kV cable circuits

6.3.3 Two peaks represent each of the cable circuits.

6.4 AC Overhead lines – Kent and Suffolk

6.4.1 Two modifications to existing overhead lines are necessary in Kent and Suffolk to connect Sea Link to the existing Transmission system. The existing 400 kV PC in Kent and 4ZW routes in Suffolk will be modified to allow the existing overhead lines to connect to the new substation.

6.4.2 The modified lines will have the following designs:

- PC route: 400 kV operating voltage, standard and low height pylons, twin curlew conductors, 2610 Mega Volt Ampere (MVA) pre-fault continuous rating, 7.6 m minimum conductor to ground clearance.
- 4ZW route: 400 kV operating voltage, standard pylons, quad zebra conductors, 1170 MVA pre-fault continuous rating, 7.6 m minimum conductor to ground clearance.

6.4.3 Calculations were performed for each overhead line at the pre-fault continuous rating and nominal voltage (400 kV) at 1 m above ground. The results of these calculations are provided in Plate 6.3 (for magnetic fields) and Plate 6.4 (for electric fields). The highest calculated electric and magnetic fields produced by the modified PC overhead line using the worst-case conditions are 8.74 kV/m and 87.4 µT. The highest calculated electric and magnetic fields produced by the modified 4ZW overhead line using the worst-case conditions are 8.89 kV/m and 31.5 µT. Calculations were performed in accordance with the conditions set out in the Codes of Practice (Department for Energy and Climate Change, 2012).

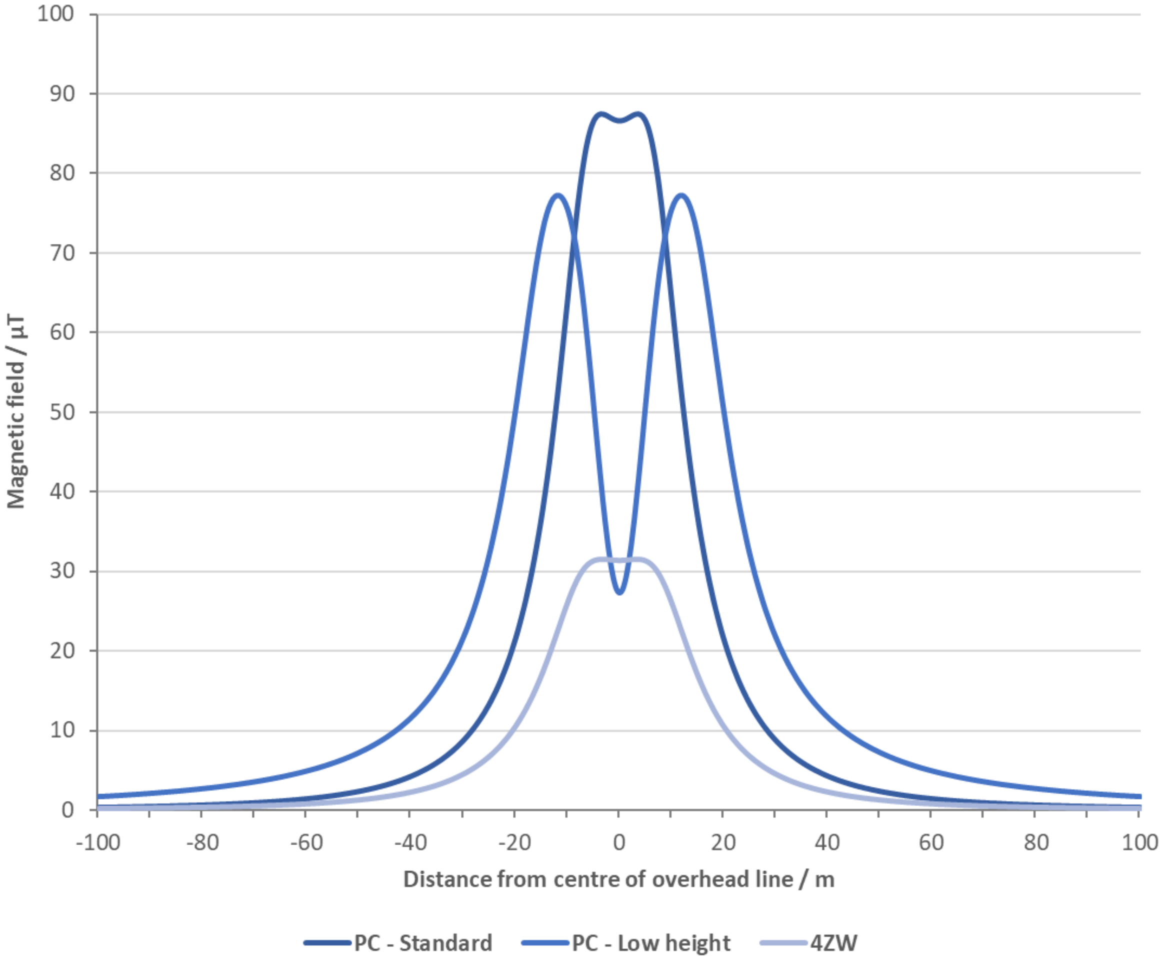

Plate 6.3 Maximum calculated magnetic fields from modified PC and 4ZW route overhead lines

6.4.4 PC route has two pylon types, standard pylons represented by dark blue line and low height pylons represented by mid-blue line.

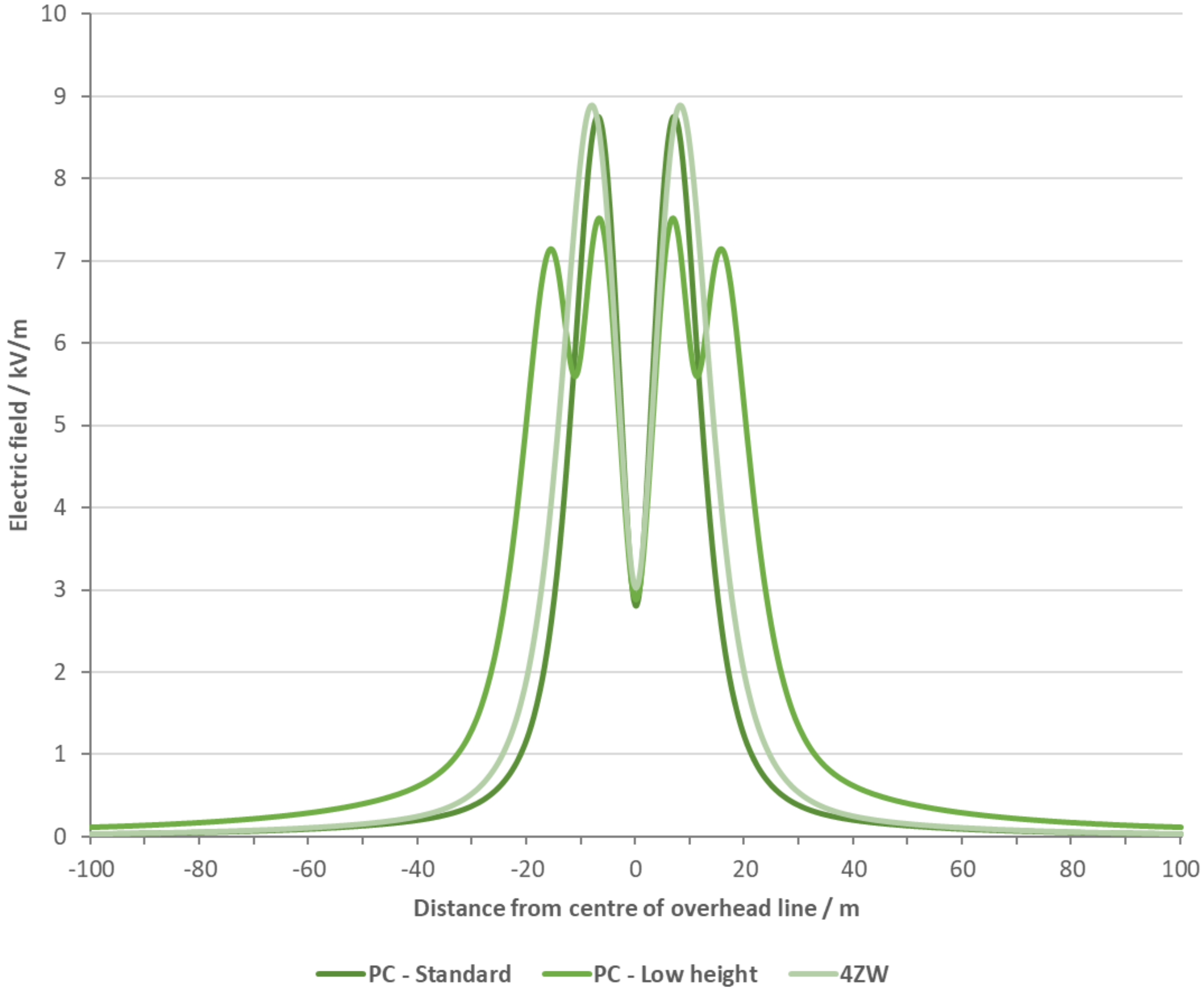

Plate 6.4 Maximum calculated electric fields from modified PC and 4ZW route overhead lines

6.4.5 PC route has two pylon types, standard pylons represented by dark green line and low height pylons represented by mid-green line

6.5 Convertor Stations

6.5.1 The proposed converter stations will use Current Source Converter (CSV) technology and contain air-cored reactive equipment and as such compliance with the ICNIRP public exposure guidelines needs to be demonstrated, as per the Code of Practice. Specific EMF design criteria were incorporated into the proposed Converter Station's technical specification to ensure that the finalised design is compliant with public exposure limits at and beyond the Converter Station boundary. These specifications will ensure the following criteria are employed in the design:

- Static magnetic fields at the boundary fence of the proposed Converter Station site will not exceed the ICNIRP public exposure limits defined above; and
- AC magnetic fields at the boundary fence of the proposed Converter Station site shall not exceed the general public exposure limit defined above.

6.5.2 The proposed converter station may have some bare conductors in the central portion of the site which will operate at 50 Hz. These will produce an electric field which will diminish quickly increasing with distance from source. The palisade security fencing and buildings, however, will screen the electric field at the boundary of the site. These types of bare conductors have been demonstrated to be inherently compliant with exposure guidelines. As such, electric fields have not been considered further in the assessment.

6.6 Suffolk and Kent 400 kV Substations

6.6.1 As explained in paragraph 4.1.1, substations without air-cored reactive equipment are treated, according to the Code of Practice on Compliance, as inherently compliant with the exposure limits. This equipment is deemed compliant with the guidelines and do not require a detailed demonstration of compliance.

6.6.2 The highest fields around substations are usually from any overhead lines or underground cables entering them and not from equipment within the substation itself. This compliance includes any lengths of underground cable or overhead lines making connections within the overall boundary of the substation.

6.7 Summary of Onshore Assessment

6.7.1 For onshore power-frequency (AC) and static (DC) fields, the maximum EMF produced is less than the relevant exposure limit. Therefore, all the assets associated with the Proposed Project are compliant with the policies in place in the UK to protect public health and are assessed as having no significant adverse effects. The maximum magnetic fields produced by the onshore underground cables and overhead lines are detailed in Table 6.2.

6.7.2 Where cables are proposed to cross waterways, the highest magnetic fields will be at the riverbed and reduce quickly with distance demonstrated in Table 6.1Table 6.2 Maximum magnetic field calculations for proposed DC cables, AC cables and overhead line installations.

	Magnetic fields (μT)				
	Distance from cable circuit (m)				
	Directly above	10	25	50	100
Direct buried DC cables	89.6	3.67	0.61	0.15	0.04
Direct buried AC cables	65.5	2.46	0.31	0.06	0.01
PC route overhead line	87.4	64.0	13.6	2.38	0.35
4ZW route overhead line	31.5	26.1	6.88	1.28	0.19

7. Conclusions

7.1 Offshore

7.1.1 NPS EN-3 states that:

7.1.2 *“Where it is proposed that mitigation measures of the type set out in paragraph 2.6.76 below are applied to offshore export cables to reduce electromagnetic fields (EMF) the residual effects of EMF on sensitive species from cable infrastructure during operation are not likely to be significant. Once installed, operational EMF impacts are unlikely to be of sufficient range or strength to create a barrier to fish movement.”*

7.1.3 The Sea Link project proposes to use armoured cables which mitigates both the direct electric fields and to an extent the magnetic fields. NPS EN-3 states burial depth can mitigate against EMF impacts. However, a more effective measure is to bundle the cables, which significantly reduces the magnetic and induced electric fields and is proposed for the Proposed Project, both in magnitude and extent.

7.1.4 Bundled cables produced the lowest magnetic fields and is the most effective mitigation for the total route length, except for very short lengths where cables transition to land. In these locations cables are installed via trenchless techniques to come ashore, the magnetic fields at the seabed are similar to those of bundled cables due to the additional burial depth. As electric fields are proportional to the magnetic fields produced by the cables, the above statements also apply to the induced electric fields for both installation techniques.

7.1.5 The proposed bundled cable design and burial depths throughout the route result in very low compass deviations occurring across the entire bundled cable route, which meets the MMO requirements set out in Section 5.5.3. Trenchless installation is proposed where the cables come ashore for very short distances in shallow waters resulting in greater compass deviations, despite the reduced magnetic fields produced. However, the given the shallow sea depths in the transition areas, very close proximity to the shoreline and limited distance the magnetic fields extend, navigation via compass in this particular situation is unlikely to be an issue.

7.1.6 There are no formal limits for EMF exposure which apply to the marine environment, but the proposed project has used cable bundling to limit the magnetic and induced electric field exposure.

7.2 Onshore

7.2.1 The Government, acting on the advice of authoritative scientific bodies, has put in place appropriate measures to protect the public from EMFs. These measures comprise compliance with the relevant exposure limits, and one additional precautionary measure, optimum phasing, applying only to high-voltage overhead power lines. These measures are set out in a Written Ministerial Statement, NPS EN-5, and various Codes of Practice.

7.2.2 For onshore HVDC cables, the maximum magnetic fields produced is less than the relevant ICNIRP exposure limit detailed in Section 2.1. Therefore, the HVDC cables are compliant with the policies in place in the UK to protect public health and are assessed as having no significant adverse effects.

7.2.3 All of the HVAC electrical assets assessed produced magnetic fields significantly below the ICNIRP public exposure limits. Under maximum normal loading conditions, the maximum calculated magnetic fields from overhead lines were less than 25% of the exposure limit and for underground cables less than 19%. All other operating conditions result in lower magnetic fields.

7.2.4 All of the proposed onshore Proposed Project cable designs would be fully compliant with the Government policy. Specifically, all the fields produced would be below the relevant exposure limits. Therefore, there would be no significant EMF effects resulting from this proposed development.

7.2.5 All magnetic fields produced by the Proposed Project will be significantly below the interference thresholds for active implantable medical devices, such as pacemakers.

7.2.6 No mitigation measures for this cable design are necessary as both technology options have been demonstrated to comply with the current public exposure guidelines as detailed in NPS EN-5. If these requirements are met NPS EN-52 states that "*no further mitigation should be necessary.*"

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Appendix A Calculated magnetic field at 50% load for the offshore HVDC design options

A.1 Calculated magnetic field at 50% load for the offshore HVDC design options for the Sea Link project

A.1.1 Calculations are provided for increasing vertical distance from the seabed and maximum current load. All calculations were performed for a minimum burial depth of 1 m.

	Magnetic fields (μT)						
	Distance above seabed (m)						
	Seabed	0.5	1	2	5	10	20
Bundled: 0.5 m depth	102.5	26.0	11.6	4.2	0.86	0.24	0.06
Bundled: 1.0 m depth	25.8	11.6	6.5	2.9	0.72	0.21	0.06
Bundled: 1.5 m depth	11.6	6.5	4.2	2.1	0.62	0.20	0.06
Bundled: 2.5 m depth	4.1	2.9	2.1	1.3	0.46	0.17	0.05
Trenchless	19.0	18.1	17.3	15.9	12.7	9.5	6.1

Appendix Table A.1 Calculated magnetic field at 50% load for the for offshore HVDC design options for the Sea Link project

Appendix B Induced electric field calculations

B.1 Induced electric field calculations

B.1.1 The induced electric field was calculated for a range of tidal velocities at increasing vertical distances from the cables.

			Induced electric field (µV/m)				
			Tidal Velocity (knots)				
	Distance above seabed	**Magnetic field (µT)**	**0.5**	**1**	**2**	**3**	**4**
Bundled: 0.5 m depth	Seabed	204.9	53.3	104.5	211.1	315.6	422.2
	0.5m	51.2	13.5	26.5	53.5	80.0	107.0
	1 m	23.2	6.0	11.8	23.8	35.7	47.7
	5 m	1.7	0.45	0.88	1.8	2.7	3.6
	10 m	0.47	0.12	0.24	0.49	0.73	0.98
	20 m	0.12	0.03	0.06	0.13	0.19	0.26
Bundled: 1.0 m depth	Seabed	51.6	13.4	26.3	53.1	79.4	106.2
	0.5m	23.2	6.0	11.8	23.8	35.7	47.7
	1 m	12.9	3.4	6.6	13.3	19.9	26.7
	5 m	1.4	0.37	0.73	1.5	2.2	3.0
	10 m	0.43	0.11	0.22	0.44	0.66	0.88
	20 m	0.12	0.03	0.06	0.12	0.18	0.24
Bundled: 1.5 m depth	Seabed	23.2	6.0	11.8	23.8	35.7	47.7
	0.5m	13.0	3.3	6.7	13.4	20.1	26.8
	1 m	8.4	2.2	4.3	8.6	12.9	17.2
	5 m	1.2	0.32	0.63	1.3	1.9	2.5
	10 m	0.39	0.10	0.20	0.41	0.61	0.81
	20 m	0.11	0.03	0.12	0.12	0.17	0.23
			Induced electric field (µV/m)				

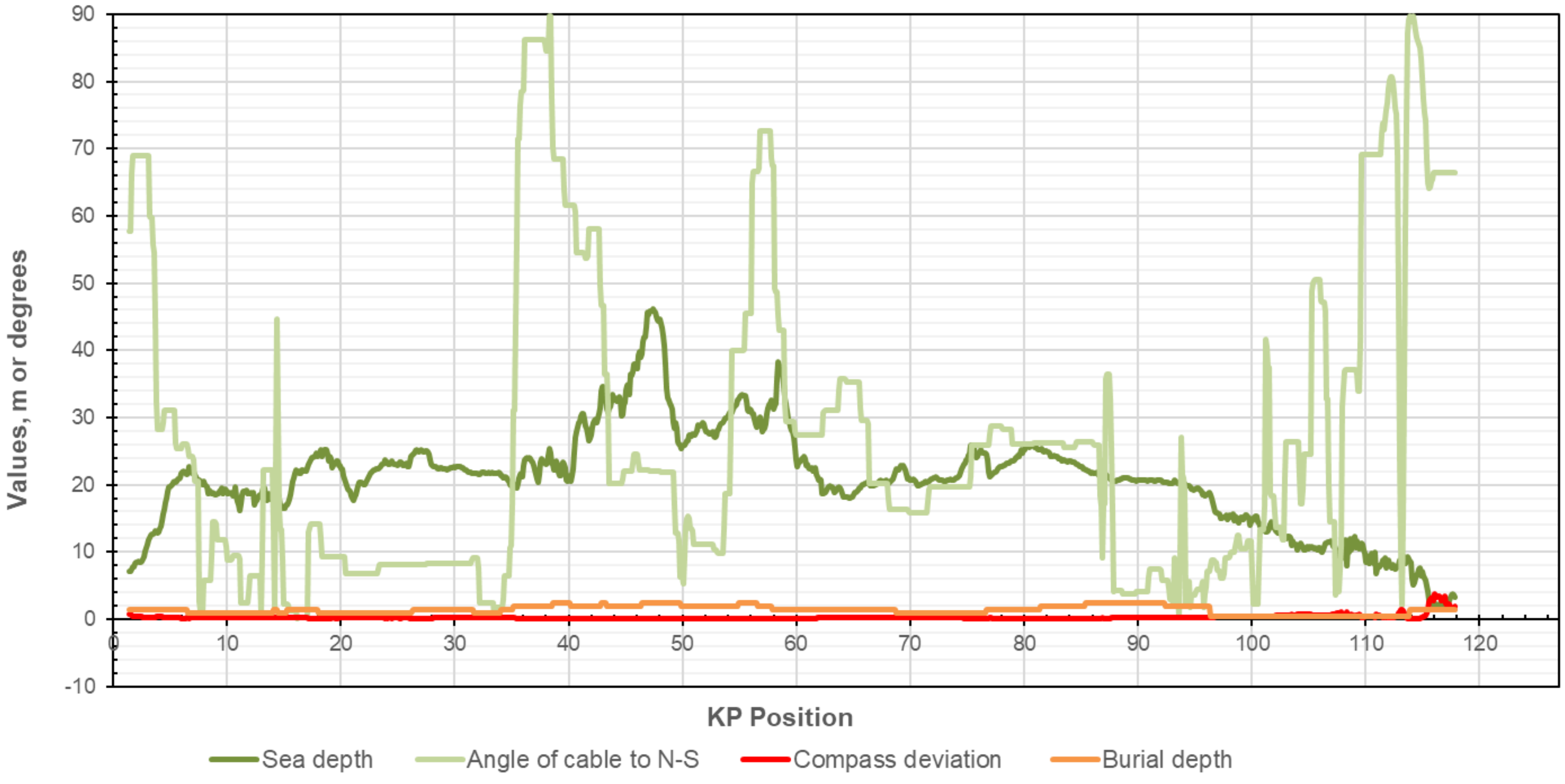
			Tidal Velocity (knots)				
	Distance above seabed	**Magnetic field (μT)**	**0.5**	**1**	**2**	**3**	**4**
Bundled: 2.5 m depth	Seabed	8.3	2.2	4.2	8.5	12.8	17.1
	0.5m	5.8	1.5	2.9	5.9	8.9	11.9
	1 m	4.2	1.1	2.2	4.6	6.5	8.7
	5 m	0.92	0.24	0.47	0.95	1.4	1.9
	10 m	0.33	0.09	0.17	0.34	0.51	0.68
	20 m	0.10	0.03	0.05	0.11	0.16	0.21
Trenchless	Seabed	38.1	9.9	19.4	39.2	58.7	78.5
	0.5m	36.3	9.4	18.5	37.4	55.6	74.7
	1 m	34.6	9.0	17.7	35.7	53.4	71.4
	5 m	25.4	6.6	13.0	26.2	39.1	52.3
	10 m	19.1	5.0	9.7	19.6	29.3	39.2
	20 m	12.2	3.2	6.2	12.6	18.8	25.1

Appendix Table B.1 Calculated induced electric field for each cable design using the calculated magnetic fields provided in Table 5.1

Appendix C Compass deviations

C.1 Compass deviations

C.1.1 Compass deviations at sea level were calculated along the entire route using the depth to seabed, burial depth and cable angle to vertical for each station mark.



Appendix Plate C.1 Calculated compass deviations for Sea Link with bundled design

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