
Environmental Impact Assessment Report
Volume 1, Chapter 9: Electromagnetic Fields

# MarramWind Offshore Wind Farm

December 2025

MarramWind

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| **Document code:** | MAR-GEN-ENV-REP-WSP-000089 |
| **Contractor document number:** | 852346-WEIS-IA-O1-RP-E7-150004 |
| **Version:** | Final for Submission |
| **Date:** | 08/12/2025 |
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| **Accepted by:** | MarramWind Limited |

# Contents

# 9. Electromagnetic Fields

## 9.1 Introduction

9.1.1.1 This Chapter presents the electromagnetic fields (EMF) analysis undertaken to support the Environmental Impact Assessment (EIA) Report for the Project. It provides the technical foundation for assessing EMF-related effects on ecological receptors as detailed in other chapters of the EIA Report.

9.1.1.2 The modelling outputs presented in this Chapter have informed the assessments of ecological receptors presented in **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**, **Chapter 11: Marine Mammals**, **Chapter 12: Offshore and Intertidal Ornithology**, **Chapter 13, Fish Ecology**, **Chapter 14: Commercial Fisheries,** and **Chapter 23: Terrestrial Ecology and Ornithology**.

9.1.1.3 This Chapter of the EIA Report explains the context of EMF as a Project emission and explains the inter-relationship with other chapters. As a technical emissions-led chapter, does not assess the likely significant effects of EMF directly but provides essential data and context for the other receptor-led assessments noted in the chapters above.

### 9.1.2 Context of electric and magnetic fields for EIA

9.1.2.1 Electrical cables can be a source of EMF emissions, and exposure to EMF can result in behavioural and/or ecological changes to various biological receptors (Tethys, 2019). EMF emissions are a result of electricity flowing through a cable, which produces an electrical field and a magnetic field. EMF can endure with attenuation over distance from the source. The strength of the electrical field can be insulated by non-conductive materials but the magnetic field cannot be insulated in this way.

9.1.2.2 The Earth has its own levels of EMF that are naturally occurring from its geomagnetic field. The background levels of the Earth's magnetic field are considered for the purposes of assessment as 25 microtesla (μT) to 65μT. Any EMF values above background levels around the cables have the potential to influence the behaviour of electro-magnetically sensitive species (Hutchison *et al.*, 2020).

9.1.2.3 The electrical cables used for the Project fundamentally consist of a high voltage electrical conductor at the core, which is surrounded by other layers of non-conducting (insulating) materials to protect and insulate the conductor, and prevent short circuits. Cable armour and the grounded screen of the high voltage conductor within the cable structure prevent the electrical field escaping beyond the cable. However, these do not prevent the magnetic fields from radiating into the adjacent environment.

9.1.2.4 Induced electrical fields can occur through movement around a cable within the magnetic field. Both magnetic fields and induced electrical fields are attenuated with distance from the source cable. EMF emissions are likely to result in an localised impact zone around cables associated with the Project infrastructure (Normandeau, 2011).

9.1.2.5 EMF from the Project is anticipated to occur while the Project is generating power during the operation and maintenance (O&M) stage only. Therefore, the assessment of EMF relates to the O&M stage only.

9.1.2.6 This Chapter should be read in conjunction with the project description provided in **Chapter 4: Project Description** and the relevant parts of the following chapters and appendices (which identify receptors as having sensitivity to EMF):

- **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**: Some benthic and epibenthic species are capable of detecting EMF and are known to use this in certain natural behaviours. The introduction of an EMF source in the marine environment therefore has the potential to influence the behaviour of electro-sensory organisms. As such, there is potential for EMF emissions to affect benthic, epibenthic and intertidal ecology due to the presence of marine cable infrastructure within the seabed. Therefore, the EMF chapter has been used to inform the benthic, epibenthic and intertidal ecology assessment, with potential impacts of EMF on benthic, epibenthic and intertidal species identified and assessed within the benthic, epibenthic and intertidal ecology chapter as relevant.
- **Chapter 11: Marine Mammals**: There is potential for EMF emissions to affect some prey species for marine mammals so this Chapter has been used to inform the marine mammal assessment as an inter-related effect.
- **Chapter 12: Offshore and Intertidal Ornithology**: There is potential for EMF emissions to affect some prey species for seabirds so this Chapter has been used to inform the offshore and intertidal ornithology assessment as an inter-related effect.
- **Chapter 13: Fish Ecology**: Some marine fish species are capable of detecting EMF and are known to use this in certain natural behaviours. EMF emissions from the Project have the potential to cause behavioural changes or create a barrier effect to electro-sensory marine fish species. Therefore, this Chapter has been used to inform the fish ecology assessment with potential impacts of EMF on fish species assessed within the fish ecology chapter as relevant.
- **Chapter 14: Commercial Fisheries:** EMF emissions have the potential to affect commercial fisheries by altering the behaviour of target fish and shellfish species. Therefore, information from this Chapter has been used to inform the commercial fisheries assessment.
- **Chapter 23: Terrestrial Ecology and Ornithology:** Impacts to wildlife in rivers are addressed in the EIA Report as terrestrial ecology. Similarly to marine fish, freshwater fish and diadromous fish such as salmonids during their migrations up-river are also capable of detecting EMF and are known to use this in certain natural behaviours. EMF from the Project, specifically at watercourse crossings made by the onshore export cables, has the potential to cause behavioural changes in freshwater and diadromous electro-sensory fish species. Information from this Chapter has therefore been used to inform the assessment of impacts on relevant fish species within the terrestrial ecology and ornithology chapter.

9.1.2.7 This Chapter describes:

- the legislation, planning policy, guidance and other documentation that has informed the assessment (**Section 9.2: Relevant legislative and policy context and technical guidance**);
- the outcome of consultation and engagement that has been undertaken to date, including how matters relating to EMF have been addressed (**Section 9.3: Consultation and engagement**);
- the scope of the analysis for EMF (**Section 9.4: Scope of the analysis**);
- the data sources for gathering baseline data (**Section 9.5 Methodology for baseline data gathering**);
- the overall environmental baseline (**Section 9.6: Baseline conditions**);
- the basis for the EIA Report (**Section 9.7: Basis for the EIA Report** );

- methodology for EMF analysis (**Section 9.8 Methodology for EMF analysis**);
- analysis of EMF emissions (**Section 9.9: Analysis of EMF**) with a summary and conclusions of the EMF analysis (**Section 9.10: Summary and conclusions**);
- consideration of transboundary effects (**Section 9.11: Transboundary effects**;
- consideration of inter-related effects and cumulative effects (**Section 9.12: Inter-related effects** and **Section 9.13: Cumulative effects assessment**);
- a reference list is provided (**Section 9.14: References**); and
- a glossary of terms and abbreviations is provided (**Section 9.15: Glossary of terms and abbreviations**).

## 9.2 Relevant legislative and policy context and technical guidance

### 9.2.1 Legislative and policy context

9.2.1.1 This Section identifies the relevant legislation and policy context that has informed the scope of the EMF analysis. Further information on policies relevant to the EIA and their status is set out in **Chapter 2: Legislative and Policy Context**, which provides an overview of the relevant legislative and policy context for the Project. **Chapter 2** is supported by **Volume 3, Appendix 2.1: Planning Policy Framework**, which provides a detailed summary of international, national, marine and local planning policies of relevance to the EIA. Individual policies of specific relevance to this assessment and associated appendices have been taken into account.

9.2.1.2 In order to recognise the legislative and policy basis for this Chapter, this Section presents a summary of legislation and policies relevant for the EMF analysis.

9.2.1.3 The legislation and international agreements relevant to EMF include:

- The Marine Strategy Regulations 2010;
- Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive); and
- International Regulations for the Prevention of Collisions at Sea (International Maritime Organisation (IMO), 1972/1977).

9.2.1.4 The policies relevant to EMF include:

- Draft Updated Sectoral Marine Plan Update (Scottish Government, 2025).
- Sectoral Marine Plan for Offshore Wind 2020 (Scottish Government, 2020); and
- Scottish National Marine Plan 2015 (Scottish Government, 2015);

### 9.2.2 Relevant technical guidance

9.2.2.1 Other information and technical guidance relevant to the EMF analysis include:

- International Commission on Non-Ionizing Radiation protection (ICNIRP) Guidelines (ICNIRP, 2020); and

- Department of Energy and Climate Change (DECC) Demonstrating Compliance with EMF Public Exposure Guidelines (DECC, 2012).

# 9.3 Consultation and engagement

## 9.3.1 Overview

9.3.1.1 This Section describes the consultation and stakeholder engagement undertaken on the Project in relation to EMF. This includes early engagement, the outcome of and response to the Scoping Opinions (Scottish Government, 2023; Aberdeenshire Council, 2023) in relation to EMF, non-statutory consultation, and the findings of the Project's Statutory Consultation. An overview of engagement undertaken for the Project as a whole can be found in Section 5.5 of **Chapter 5: Approach to the EIA**.

## 9.3.2 Key issues

9.3.2.1 A summary of the key issues raised during statutory and non-statutory consultation, specific to EMF, is outlined below in **Table 9.1**, together with how these issues have been considered in the production of this EIA Report.

## Table 9.1 Stakeholder issues responses – EMF

| Stakeholder | Stakeholder issue ID | Date, document, forum | Stakeholder comment | How is this addressed in the EIA Report |
|---|---|---|---|---|
| **MD-LOT (Marine Directorate – Licensing Operations Team)** | 307 | 12 May 2023, MD-LOT Scoping Opinion (Scottish Government, 2023). | "*5.5.1 The Scottish Ministers welcome the Developer's proposal to include an EMF assessment as an appended technical report to the EIA Report, which is a view supported by NatureScot. The Scottish Ministers highlight the representation from Dee DSFB and emphasise the importance of including the effects of EMF against salmon within any EMF assessment. The Scottish Ministers are broadly content with the EMF effects noted across the receptor groups, but in line with the NatureScot advice, the Scottish Ministers advise that further consideration should be undertaken in respect of EMF effects on elasmobranchs*". | The EMF chapter has analysed the extent to which EMF emissions could occur in the aquatic environment as a result of the Project. These findings have then been interpreted in relation to sensitive fish species including salmon and elasmobranchs in **Chapter 13: Fish Ecology** and **Chapter 23: Terrestrial Ecology and Ornithology**. |
| **MD-LOT** | 308 | 12 May 2023, MD-LOT Scoping Opinion (Scottish Government, 2023). | "*5.5.2 The Scottish Ministers are content with the data sources included in Table 5.4.4. and the technical guidance included in Table 5.4.2 of the Scoping Report; however, recommend that the additional data sources highlighted by NatureScot are used to inform the EIA Report*". | **Table 9.4** provides the data sources to inform the EMF analysis. Technical guidance is included in **Section 9.2.2.**<br><br>See Stakeholder Issue ID 50 below for the additional data source highlighted for inclusion by NatureScot in relation to EMF. |
| **MD-LOT** | 309 | 12 May 2023, MD-LOT Scoping Opinion (Scottish Government, 2023). | "*5.5.3 Regarding the potential for cumulative effects on EMF to arise, the Scottish Ministers agree with the proposed approach considered by the Developer in sections 5.4.25 and 5.2.26 of the Scoping Report. The Scottish Ministers highlight the Green Volt representation*". | The approach described in the Scoping Report has been followed in the EIA chapter. |

| Stakeholder | Stakeholder issue ID | Date, document, forum | Stakeholder comment | How is this addressed in the EIA Report |
|---|---|---|---|---|
| **Dee District Salmon Fishery Board** | 405 | 12 May 2023, MD-LOT Scoping Opinion, Appendix I: Consultation Responses & Advice (Scottish Government, 2023). | "*Wild Salmon Strategy and Conservation regulations*<br>*In January 2022, the Scottish Government released its Wild Salmon Strategy which gave a clear message that there is sadly now unequivocal evidence that populations of Atlantic Salmon are at crisis point. The Strategy calls on government agencies, as well as the private sector, to prioritise the protection and recovery of Scotland's wild Atlantic salmon populations.*<br><br>*One of the key pressures identified in the strategy is marine development, with marine renewables highlights as having the potential to impact salmon through noise, water quality and effects on electromagnetic fields (EMF) used by salmon for migration*". | This EIA chapter identifies the EMF emitted by the Project, with the potential impacts to salmon assessed in **Chapter 13: Fish Ecology** and **Chapter 23: Terrestrial Ecology and Ornithology**. |
| **NatureScot** | 509 | 12 May 2023, MD-LOT Scoping Opinion, Appendix I: Consultation Responses & Advice (Scottish Government, 2023). | *"With regard to data sources relating to fish and EMF, we recommend that a recent MSc paper by Lucie Hervé "An evaluation of current practice and recommendations for environmental impact assessment of electromagnetic fields from offshore renewables on marine invertebrates and fish" is included as a data source in Table 5.4.4. We can supply a copy of this paper on request".* | The recommended paper has been used to inform the assessment of EMF on marine invertebrates and fish in **Chapter 10: Benthic Epibenthic and Intertidal Ecology** and **Chapter 13: Fish Ecology** respectively. |
| **NatureScot** | 525 | 12 May 2023, MD-LOT Scoping Opinion, Appendix I: Consultation Responses & Advice (Scottish Government, 2023). | "*We note that cable burial/ Cable Burial Risk Assessment are listed as embedded environmental measures (Table 5.8.15). However we highlight research by Hutchinson et al. (2020) which establishes that cable burial may actually generate a response from sensitive species, as it reduces EMF levels to the 'normal' range that species use to hunt prey or navigate.*<br><br>*Hutchison, Zoe & Gill, A. B. & Sigray, Peter & He, Haibo & King, John. (2020). Anthropogenic electromagnetic fields (EMF) influence the behaviour of bottom-dwelling marine species. Scientific Reports. 10*". | The recommended paper has been used to inform the assessment of EMF on marine invertebrates and fish in **Chapter 10: Benthic Epibenthic and Intertidal Ecology**. |

| Stakeholder | Stakeholder issue ID | Date, document, forum | Stakeholder comment | How is this addressed in the EIA Report |
|---|---|---|---|---|
| **Ugie District Salmon Fishery Board** | 854 | 5 November 2024, HRA Screening Response. | "*I would like to know what the Marram Wind Farm project is going to do to make sure that during the construction of the project and during its lifetime, that there will be no adverse effect to the resident juvenile salmon and sea trout in the River Ugie and when they are migrating to feeding ground in the sea. The Ugie District Salmon Fishery Board have a statutory duty to protect and enhance the populations of salmon and sea trout in the river Ugie*". | Potential impacts to Atlantic salmon and sea trout are presented in and **Chapter 23: Terrestrial Ecology and Ornithology** and **Volume 3, Appendix 23.8: Screening rationale for assessment of important ecological and ornithological features**. |
| **Ugie District Salmon Fishery Board** | 914 | 16 July 2025, Email. | "*Ugie salmon fishery board members still have concerns regarding the cumulative effect of the number of high voltage cables crossing burns and the River Ugie, and the negative effect they may have on the populations of salmon and seatrout in the river*". | Potential impacts to Atlantic salmon and sea trout are presented in **Chapter 13: Fish Ecology**, **Chapter 23: Terrestrial Ecology and Ornithology** and **Volume 3, Appendix 23.8**. |

# 9.4 Scope of the analysis

## 9.4.1 Overview

9.4.1.1 This Section sets out the scope of the analysis for EMF. This scope has been developed as the Project's design has evolved and responds to stakeholder feedback received to-date, as set out in **Section 9.3**.

9.4.1.2 This Chapter includes an analysis of the EMF emissions generated by the Project, which have been considered by other receptor specific assessments as required (see **paragraph 9.1.2.6**).

## 9.4.2 Spatial scope and study area

9.4.2.1 The spatial scope of the EMF analysis is defined by the locations proposed for the array cables and the offshore export cables. This is because the Project design parameters for these cables have been used as the worst case for the analysis (see **Section 9.7.2** for further detail). These will be located within the Option Agreement Area (OAA), and offshore export cable corridor respectively. The study area for the EMF assessment therefore refers to all areas of the **Volume 2, Figure 4.2: Offshore Red Line Boundary**.

9.4.2.2 It is acknowledged that **Chapter 23: Terrestrial Ecology and Ornithology** assesses the potential for EMF to cause behavioural changes in fish at locations where the onshore export cables cross watercourses. These locations have not been included within the study area for the EMF analysis because the offshore cable parameters have been used as a worst case. Potential effects at these onshore locations are included in the study area for **Chapter 23** as appropriate.

9.4.2.3 The wider EIA Chapters referenced in **paragraph 9.1.2.6** have their own aspect-specific study areas that are relevant to the sensitive receptors defined within those chapters. Individual chapters should be referred to for any study area refinement relating to EMF.

## 9.4.3 Temporal scope

9.4.3.1 The temporal scope of the assessment of EMF relates only to the stages of the Project when power is being generated and therefore, when there are electrical currents passing through the cables installed. This relates to the O&M stage of the Project only.

9.4.3.2 It is anticipated the first phase of the Project will become fully operational by 2037. It is anticipated that the second phase of the Project would become fully operational by 2040 and the third phase by 2043. The operational lifetime of the Project for each phase is expected to be 35 years.

## 9.4.4 Identified receptors

9.4.4.1 The receptors identified as having sensitivity to EMF are specified in the chapters referenced in **paragraph 9.1.2.6**. Individual chapters should be referred to for detail on the receptors identified relating to EMF.

## 9.4.5 Potential effects

9.4.5.1 Potential effects on EMF receptors that have been scoped in for assessment are summarised in **Table 9.2**.

### Table 9.2 Potential effects for EMF

| Receptor | Activity or impact | Potential effect |
|---|---|---|
| **Operation and maintenance stage** | | |
| **Benthic, epibenthic and intertidal ecology** | Offshore EMF exposure from cables within the marine environment. | Impact biodiversity and commercial fisheries within the area. |
| **Marine mammals** | | |
| **Offshore and intertidal ornithology** | | |
| **Fish ecology** | | |
| **Commercial fisheries receptors** | | |
| **Terrestrial ecology (freshwater and diadromous fish) receptors** | EMF exposure from onshore export cables at watercourse crossings. | Potential for disturbance or changes to fish behaviour. |

## 9.4.6 Effects scoped out of assessment

9.4.6.1 One potential effect has been scoped out from further assessment, resulting from a conclusion of no likely significant effect. This conclusion has been made based on the knowledge of the baseline environment, the nature of planned works and the professional judgement on the potential for impact from such projects more widely. The conclusion follows (in a site-based context) existing best practice. The scoped out activity or impact is considered in **Table 9.3**.

### Table 9.3 Activities or effects scoped out of assessment

| Activity or impact | Rational for scoping out |
|---|---|
| **Onshore EMF human exposure in the terrestrial environment from cables and onshore substation.** | The Project will generate EMF from onshore cable circuits and equipment housed within the onshore substation. The underground cables and onshore substation will be designed and operated in accordance with all relevant health and safety legislation and the occupational exposure guidelines for EMF (such as The Control of Electronic Fields at Work Regulations (2016); International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines (2020); and the Department of Energy & Climate Change (DECC) Demonstrating Compliance with EMF Public Exposure Guidelines (DECC, 2012). This will ensure safe distances between electrical components and publicly accessible points. Furthermore, due to the manufacturing design of underground cables, limited emissions of EMF, if any, will occur. The maximum EMF level that the public will be exposed to will be significantly below the guideline for public exposure limits which are set to protect health (ICNIRP, 2020). Therefore, human exposure to EMF related to onshore infrastructure will not be considered further and is scoped out of the EIA. |

# 9.5 Methodology for baseline data gathering

## 9.5.1 Overview

9.5.1.1 Baseline data collection has been undertaken to obtain information over the study area described in **Section 9.4: Scope of the analysis**. The current and future baseline conditions are presented in **Section 9.6: Baseline conditions.**

9.5.1.2 There were no site-specific surveys completed in order to inform this assessment. This is because receptor information and data related to this topic can be readily collected through desk-based review and consultation with relevant stakeholders.

## 9.5.2 Desk study

9.5.2.1 The data sources that have been collected and used to inform this Chapter are summarised in **Table 9.4**.

### Table 9.4 Data sources used to inform the EMF chapter

| Source | Summary | Coverage of study area |
|---|---|---|
| **National Oceanic and Atmospheric Administration (NOAA) National Centres for Environmental Information, 2025** | The Magnetic Field Calculators provided by the National Geophysical Data Centre are online tools that let users calculate the Earth's magnetic field parameters (such as declination, inclination, total intensity, horizontal and vertical components) for any location and date, based on geomagnetic reference models like the World Magnetic Model or International Geomagnetic Reference Field. | Information on baseline EMF emissions for the study area. |
| **Green Volt Limited, 2022** | Green Volt offshore wind farm will have similar impacts to this Project and is a valuable source of information for assessing the impacts from EMF. | N/A |
| **Erebus Environmental Statement Volume 3. Technical Appendix: 7.2 EMF Assessment, (MarineSpace Ltd., 2021)** | Erebus floating offshore windfarm will have similar impacts to this Project and is a valuable source of information for assessing the impacts from EMF. | N/A |
| **Hervé, 2021** | This MSc thesis provides an evaluation of current practice and recommendations for environmental impact assessment of electromagnetic fields from offshore renewables on marine invertebrates and fish. | N/A |
| **Bureau of Ocean Energy Management (BOEM), 2020** | This fact sheet explains that while export and array cables in offshore wind farms generate EMF, emission levels detected at the seafloor are significantly lower than human exposure safety limits—and are often comparable to or weaker than those emitted by everyday household electronics such as televisions or hair dryers. | Information on EMF emissions from cables – applicable to the full study area. |

### 9.5.3 Data limitations

9.5.3.1 There are no known data limitations at the time of this study relating to EMF that affect the robustness of the analysis in this Chapter.

## 9.6 Baseline conditions

### 9.6.1 Current baseline

9.6.1.1 The Earth has naturally-occurring electric and magnetic fields. As noted in **Section 9.1.2**, the Earth's natural electric and magnetic fields are caused mainly by currents circulating in the outer layer of the Earth's core. The Earth's magnetic field ranges globally from 25 to 65μT, and is currently approximately 50μT in the United Kingdom, including in Scotland within the Project Red Line Boundary. The Earth's magnetic field within the Offshore Red Line Boundary including the offshore export cable corridor and where the array cables are proposed within the Option Agreement Area (OAA) has a naturally occurring direct current (DC) magnetic field, which is also around 50μT (NOAA, 2025).

9.6.1.2 The Earth's magnetic field can induce an electric field in water. The movement of the water through the Earth's magnetic field results in a small localised electric field being induced. The magnitude of the electric field induced is dependent upon magnetic field strength, water chemistry, viscosity and its flow velocity and direction relative to the lines of magnetic flux.

9.6.1.3 The background electrical field within the Offshore Red Line Boundary depends upon the tidal flow moving through the local geomagnetic field. Using a conservative estimate of maximum seabed flows of 1.2m/s, background electric fields could therefore be expected to reach a maximum of approximately 60 microvolts per metre (μV/m).

### 9.6.2 Future baseline

9.6.2.1 The future baseline within the context of the Project lifetime is not expected to change as EMF are not significantly impacted by climate change or external conditions and naturally occurring changes occur very slowly, on a geological timescale. The intensity of EMF from human-made sources is relatively stable and within established safety guidelines.

## 9.7 Basis for the EIA Report

### 9.7.1 Design context

9.7.1.1 The Project may operate using both alternating current (AC) and DC technology. AC magnetic fields will induce an electric field within a marine or freshwater organism located in or moving through the AC magnetic field produced by the cable, which is the important consideration for biological impacts (Fisher and Slater, 2010). Project emissions of EMF become relevant to ecological receptors where EMF increases above background levels.

9.7.1.2 The induced electric field will depend on the size of the organism, its orientation or direction of travel in the field and how close it is to the cable. These effects tend to be highly localised as magnetic fields from cables reduce quickly with distance from source. The lower the magnetic field, the lower the induced electric field. The effect is greatest when organisms are traveling along the length of the cables. If the organism is at a different angle to the cables or offset to the side of the cables, the induced electric field will be lower because the magnetic fields will be lower.

9.7.1.3 DC cables produce static magnetic fields, which decrease with distance from the cable. The static magnetic fields generated is added or subtracted locally to the Earth's natural static magnetic field. Where the outgoing and return paths of a DC circuit (two cables) are in close proximity, their magnetic fields cancel within relatively short distances from the cables. High levels of EMF (i.e. radiated EMF levels above 10V/m if not shielded) can cause interference with electronic equipment, magnetic equipment and communications such as radios and compasses. A number of marine species can detect electric and / or magnetic fields and utilise them during feeding, predator detection and navigation. These species use electro-sensory organs to detect electrical fields emitted by other organisms to assist in prey identification and location, and to detect the Earth's magnetic field for navigational purposes. DC EMF can mask or alter natural cues of some marine species, potentially affecting foraging, orientation and migration. However, DC cables produce a static magnetic field, therefore voltage will only be induced if an organism moves through the magnetic field.

## 9.7.2 Maximum design scenario

9.7.2.1 The process of using a parameter-based design envelope approach means that the assessment considers a maximum design scenario whilst allowing the flexibility to make improvements in the future in ways that cannot be confirmed at the time of submission of the planning application, marine licences applications and s.36 consent.

9.7.2.2 The identification of the maximum design scenario for EMF establishes the basis for the technical aspect chapters to assess impacts on relevant receptors. As a result of defining the maximum design scenario, effects of greater adverse significance would not arise under any other lesser scenario (as described in **Chapter 4: Project Description**).

9.7.2.3 The maximum design scenario parameters that have been identified to be relevant to EMF are outlined in **Table 9.5** and are in line with the Project design envelope (**Chapter 4: Project Description**).

9.7.2.4 An offshore scenario has been used for the purposes of this analysis. The burial depth range for the offshore export cables is already defined by the Project as typically 1m to 2m below the seabed where burial is possible. For watercourse crossings, the depth at which the export cable ducts are installed is not yet defined as it depends on the topology and geology at the crossing site and the nature of the feature being crossed. The onshore export cables will therefore likely be buried deeper below the riverbed at watercourse crossings than the offshore export cable burial minimum of 1m and therefore, the effect of EMF will be reduced at the riverbed relative to at the seabed. Therefore, the offshore scenario is considered to more onerous than the onshore scenario in terms of the export cable burial depths. The offshore burial depths also represents the scenario where more certainty exists over the anticipated burial depths, which further underpins its selection as the appropriate scenario for use in the EMF analysis.

9.7.2.5 The HVDC (i.e. +320kV or +525kV) onshore and offshore export cable designs are broadly similar in terms of the conductor, electrical insulation, and screens. However, the separation of poles onshore will be smaller than offshore, which reduces the EMF in the onshore scenario.

9.7.2.6 The HVAC (i.e. 275kV) onshore and offshore export cable designs are different. At river crossings, single core cables are installed in flat formation while offshore, cables are installed in trefoil formation. The trefoil cable formation magnetic fields cancel each other to the maximum, which could result in the onshore scenario producing marginally larger EMF than the offshore scenario. However, since onshore cables will likely be buried much deeper than offshore cables as noted above, the distance between the organisms and the EMF source will be larger. With a greater attenuation distance between the source and the organism, the effect of the EMF experienced by the organisms will also be consequentially less.

9.7.2.7 Secondly, the onshore and offshore export cable design parameters are broadly similar in terms of their core and insulation design configurations, both comprising a conductor with electrical insulation material, screens, communication fibre, and protective armour layers (see **Chapter 4: Project Description**).

9.7.2.8 The HVDC export cable scenario comprises similar circuits for both onshore and offshore infrastructure (i.e. ±320kV or ±525kV depending on what type of HVDC technology is used, both onshore and offshore). The onshore and offshore HVDC scenarios are therefore identical for the purposes of the EMF analysis.

9.7.2.9 Similarly, in relation to the HVAC export cable scenario, the 275kV scenario both onshore and offshore will produce comparable levels of EMF due to the identical electrical parameters. The 275kV HVAC scenario is therefore representative for both onshore and offshore cables.

9.7.2.10 For the 400kV HVAC onshore export cable, the electric field would be 1.45 times greater relative to the 275kV scenario (i.e. 400/275=1.45), either onshore or offshore. This is because the electric field is a function of voltage. However, the magnetic field of the 400kV HVAC onshore cable will be similar to that of the 275kV as it is a function of current which is the same (884A) between the two cables. Given the relatively small difference in the expected electric field and given the uncertainty over cable burial depth at onshore water crossings, the offshore scenario is considered to be a reasonable worst case and it has been used for the purposes of EMF modelling.

9.7.2.11 In relation to the array cables, both the 66kV and the 123kV cable scenarios will have a current of 884A, which represents the maximum cable rating for both array cable scenarios. As a result, the results for the 66kV offshore HVAC array cable are also representative of the 132kV array cable scenario.

9.7.2.12 The cable currents and voltages presented in **Table 9.5** are based upon the following calculations, which are considered to be the reasonable worst case for the Project:

- 320 kilovolts (kV) symmetric monopole, DC 1400 megawatts (MW)

$$I_{320kV} = \frac{1400 * 10^6}{2x320 * 10^3}$$

  Where $I_{320kV\ DC}$ = 2,187.5$A$

- 525 kilovolts (kV) bipole, DC 1800 MW

$$I_{525kV} = \frac{1800 * 10^6}{2x525 * 10^3}$$

  Where $I_{525kV\ DC}$ = 1,715$A$

  (bipole (525kV, 1800MW) = 1,715A)

- 275kV offshore export cable, AC 400MW

$$I_{275kV} = \frac{400 * 10^6}{\sqrt{3} * 275 * 10^3 * PF}$$

  Where PF = 0.95 $I_{275kV\ AC}$ = 884$A$

- 66kV, array cable (also 132kV)

  Where PF = 0.95 $I_{66kV\ AC}$ = 884$A$

### Table 9.5 Maximum design scenario for impacts on EMF

| Impact / activity | Maximum design scenario parameter | Justification |
|---|---|---|
| **Operation and maintenance** | | |
| **Impact O1: Offshore EMF exposure from cables within the marine environment** | **Array cables (3 core in trefoil configuration):**<br>• maximum number of 225 cables.<br>• maximum cable diameter (3-phase 66kV) of 194mm.<br>• up to 8 cables connected to subsea distribution centres, with a separation distance of 6.5m.<br>• maximum cable voltage of 132kV (3 phase).<br>• maximum power factor of 0.95.<br>• maximum array cable length for the full 3GW expected to be up to 680km .<br>• where buried, a minimum cable burial depth of 1m. maximum current of 884A represents the worst case for both 66kV and 132kV<br><br>**Export cables (HVDC)– single core):**<br>• maximum export cable length of 140km.<br>• maximum cable diameter of 132mm.<br>• maximum 5 number of export circuits.<br>• minimum separation distance between offshore export cables (bipole conductors) of 30m.<br>• maximum symmetric monopole cable voltage of 320kV or bipole cable voltage of 525kV.<br>• maximum power of 1400MW (monopole) and 1800MW (bipole)<br>• maximum cable current of 2,187A (monopole) or 1,715A (bipole).<br>• minimum cable burial depth of 1m (with target range between 1-2m).<br><br>**Export cables (HVAC) – 3 core trefoil configuration):**<br>• maximum export cable length of 140km.<br>• maximum cable diameter of 292mm.<br>• maximum 5 number of export cables.<br>• minimum separation distance between offshore export cables of 30m;<br>• maximum voltage of 275kV (3-phase).<br>• maximum power of 400MW with 0.95 power factor.<br>• maximum current of 884A.<br>• minimum cable burial depth of 1m (with target range between 1m to 2m). | This scenario generates the maximum field that might affect marine biota.<br><br>It should be noted that while minimum and target cable burial depths are presented for context, magnetic fields are not attenuated by the ground, earth or sediment. Therefore, the EMF analysis results as field profiles are equally applicable to buried cables, cables on the seabed, and those in the water column (i.e., array cables). |

### 9.7.3 Embedded environmental measures

9.7.3.1 As part of the Project design process, a number of embedded environmental measures have been adopted to reduce the potential for adverse impacts on biological receptors from EMF. These embedded environmental measures have evolved over the development process as the EIA has progressed and in response to consultation.

9.7.3.2 These measures also include those that have been identified as good or standard practice and include actions that would be undertaken to meet existing legislation requirements. As there is a commitment to implementing these embedded environmental measures, and also to various standard sectoral practices and procedures, they are considered inherently part of the design of the Project and are set out in the EIA Report.

9.7.3.3 **Table 9.6** sets out the relevant embedded environmental measures within the design and how these affect the EMF analysis.

9.7.3.4 Further detail on the embedded environmental measures in **Table 9.6** is provided in the **Volume 3, Appendix 5.2: Commitments Register**, which sets out how and where particular embedded environmental measures will be implemented and secured.

## Table 9.6 Relevant EMF embedded environmental measures

| ID | Environmental measure proposed | Project stage measure introduced | How the environmental measures will be secured | Relevance to EMF assessment |
|---|---|---|---|---|
| **M-001** | Underground cables will be used to connect from the landfall(s) transition joint bays to the onshore substations. An additional section of the onshore export cable corridor will run from the onshore substations to the grid connection point at SSEN Netherton Hub. Cables are typically installed in ducts in a standard buried trench arrangement with appropriate insulation, providing protection from temperature extremes and changes in soil moisture. | Scoping Amended at EIA Report. | **Volume 4: Outline Construction Environmental Management Plan** and planning conditions. | This measure reduces public exposure to EMF. |
| **M-021** | All aspects of the construction work will be in accordance with the Health and Safety at Work Act 1974 and regulations made under the Act, and the Construction (Design and Management) Regulations 2015. | Scoping | **Volume 4: Outline Construction Environmental Management Plan** and planning conditions. | This measure ensures that EMF-related risks are managed in line with established health and safety legislation. By adhering to the legislation, the Project commits to identifying, assessing and mitigating potential EMF exposure during construction, protecting both workers and the public. |
| **M-028** | An **Outline Scour Protection Plan** has been submitted within this Application (**Volume 4**), and includes details of the need, type, quantity and installation methods for scour protection. A Final Scour Protection Plan will be completed prior to construction commencing and will include measures during the O&M stage such as periodic inspection and maintenance requirements and will be submitted to MD-LOT for approval. | Scoping Amended at EIA Report. | Section 36 (s.36) conditions and marine licences conditions. | This measure supports EMF management by ensuring that buried cables remain securely in place. Stable cable positioning helps maintain consistent EMF containment and minimises unintended exposure or interference. |

| ID | Environmental measure proposed | Project stage measure introduced | How the environmental measures will be secured | Relevance to EMF assessment |
|---|---|---|---|---|
| **M-054** | A detailed Cable Burial Risk Assessment (CBRA) will be undertaken to enable informed judgements about burial depth. This should reduce the risk of buried cables reemerging whilst also limiting the amount of sediment disturbance to that which is necessary. The array and export cables will typically be buried at a target burial depth between 1 to 2m below the seabed surface. The final depth of the cable will be dependent on the seabed mobility and CBRA. The CBRA will manage and mitigate risks from loading and sediment transport across the seabed. The CBRA will be included within the Final Cable Plan. | Scoping Amended at EIA Report. | s.36 conditions and marine licences conditions. | This measure ensures cables remain securely buried, minimising the risk of re-emergence and maintaining consistent EMF containment. Stable burial will also reduce potential EMF exposure in the marine environment. |
| **M-057** | Burial of the cables where possible and / or use of external cable protection such as rock placement and / or concrete mattressing. Concrete mattresses only used in isolation in non-fished areas to ensure no snagging issues for fisheries industry. Where appropriate, nature-inclusive design options will be considered in the selection and placement of cable protection measures. | Scoping Amended at EIA Report. | Project description. | This measure will reduce potential exposure in the marine environment. |
| **M-058** | Safe distances between electrical components and publicly accessible points. | Scoping | Occupational Exposure Guidelines for Electromagnetic fields. | Ensure that EMF levels remain well within accepted safety thresholds for the general public, reducing potential health risks and aligning with regulatory guidance with EMF emissions. |

# 9.8 Methodology for EMF analysis

## 9.8.1 Introduction

9.8.1.1 The project-wide approach to assessment is set out in **Chapter 5: Approach to EIA**. Whilst this has informed the approach that has been used in the EMF analysis, this Chapter follows a different aspect-specific methodology because it does not assess the significance of effects of EMF on sensitive receptors. This is addressed in **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**, **Chapter 11: Marine Mammals**, **Chapter 12: Offshore and Intertidal Ornithology**, **Chapter 13: Fish Ecology**, **Chapter 14: Commercial Fisheries,** and **Chapter 23: Terrestrial Ecology and Ornithology**.

9.8.1.2 An EMF analysis was undertaken to quantify the level of electromagnetic disturbance from the Project on the aquatic environment. This quantification has been used to inform the assessment of significance for any impacts to any biological receptors from EMF resulting from the Project, which is assessed in the chapters noted above.

## 9.8.2 EMF analysis technique

9.8.2.1 In this analysis, the electromagnetic emissions from the various conductors forming part of the offshore infrastructure were determined. Analytical modelling based on Biot-Savart theory was used in calculating the magnetic fields produced by the conductors. This was implemented in MATLAB software. As each current carrying conductor will be enclosed in a metallic screen, no direct electric field is expected.

9.8.2.2 The calculations were performed for the following circuits as a worst case: 66kV AC array cables, HVDC export cables (including 320kV monopole and 525kV bipole configuration) and 275kV HVAC export cables.

9.8.2.3 The specified circuits have been analysed as the worst-case scenario for the Project, as described in **Section 9.7.2**. This is particularly conservative for the array cables as the 66kV circuit would have relatively higher current than at 132kV for a similar amount of power. Also, the 884A current assumed is similar to the maximum current rating of a 275kV cable, which ensures that the analysis remains pessimistic for scenarios where the 275kV has higher power.

9.8.2.4 In order to determine the potential maximum EMF from the Project, the cable circuit scenarios that have been analysed represent the maximum possible number of cables, under two scenarios of HVAC and HVDC transmission respectively. This assumes that the Project is delivered via 100% HVAC or 100% HVDC transmission. In reality, the Project design is likely to deliver a combination of HVAC and HVDC transmissions across three phases of construction and energisation. The specifics of these phases are not yet defined with adequate accuracy to enable the EMF analysis scenarios to be more specific. Therefore, two maximised scenarios for HVAC and HVDC have been applied to define an absolute worst case for the purposes of EIA. It is acknowledged that this absolute worst case is highly conservative and is not a realistic scenario, due to the Project's intention to use a likely (but not yet determined) combination of HVAC and HVDC. These two scenarios effectively bound the maximum design scenario for EMF, to provide a quantified output that can be considered in the assessment of EMF on receptor groups presented in the wider EIA Report chapters.

## 9.9 Analysis of EMF: operation and (live) maintenance stage

9.9.1.1 EMF from the Project is anticipated to occur while the Project is generating power during the operational stage including during live maintenance. Therefore, the assessment of EMF relates to the O&M stage only. The EMF has potential to occur from the array cables and the offshore export cables.

9.9.1.2 All proposed HVAC offshore cable designs consist of 3-core conductor cables, which vary in cross-sectional area, depending on the required rating. Within each single cable, the three conductors vary with distance from one another, which can influence the magnetic field produced. In each scenario the worst-case option was considered. The DC cables comprise 2 poles (i.e. positive and negative poles).

9.9.1.3 The magnetic field produced by the cables will in turn induce electric fields in organisms present within or passing through the field. This will be proportional to the magnetic field, the size of the organism, and the distance between the organism and the source. The direction of travel and location over the cables will also be considered by the relevant ecology chapters specified in **Section 9.1.2** where relevant. Magnetic field intensities reduce as a function of distance from the source and are highly localised.

9.9.1.4 The cable design parameters have been calculated assuming maximum-load, minimum circuit separation and minimum burial depth (where relevant, accepting that dynamic sections of the array cables will not be buried), giving a worst-case scenario for the magnetic fields. This scenario may only occur where multiple array cables are converging to terminate at a subsea distribution centre or offshore platform. The majority of the total array cable length will not be in close proximity to other array cables.

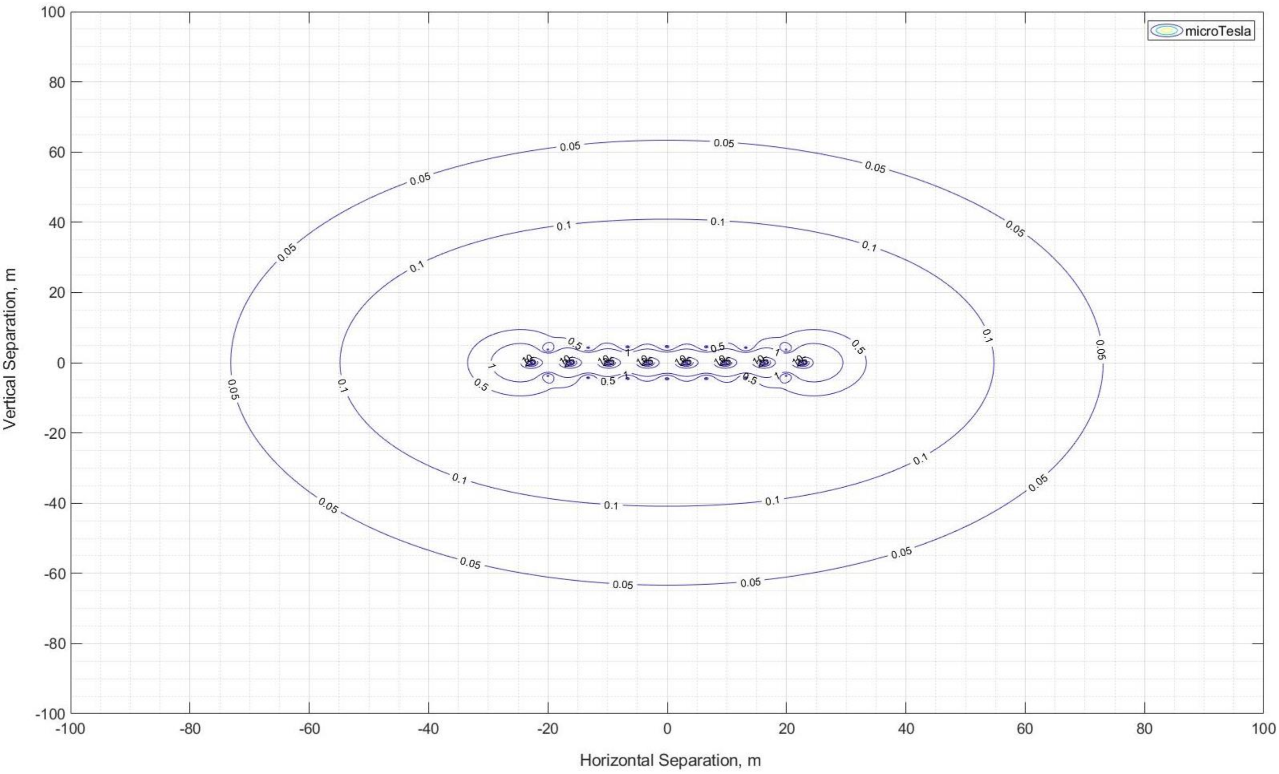
9.9.1.5 As the EMF effect by the cable design is primarily due to magnetic fields produced by electric currents, and the magnetic fields are not insulated, attenuated or augmented by the seabed materials and sediments, the scenario modelled can be applied to various positioning of the cables. Therefore, the results presented below are representative of buried cables as well as cables on the seabed or those that are dynamic in the water column. The results can be read from the plots by applying the appropriate offset to account for the location of the seabed. Note the cables are currently modelled at location zero (0) along the vertical axis.

9.9.1.6 Results for 66kV HVAC array cables are shown in **Plate 9.1** to **Plate 9.3**.

9.9.1.7 **Plate 9.1** shows the field profile for a 100m radius around the centre of the cables, showing attenuation to 0.1μT over 40m and 0.05 μT by 60m distance from the cable.

9.9.1.8 **Plate 9.2** and **Plate 9.3** show the same results at a higher resolution with a focus on the 50μT zone, which is limited to a distance of approximately 0.8m around each cable.

### Plate 9.1 66kV array cable (8x cables) field profile around the cables




### Plate 9.2 66kV array cable between two cables

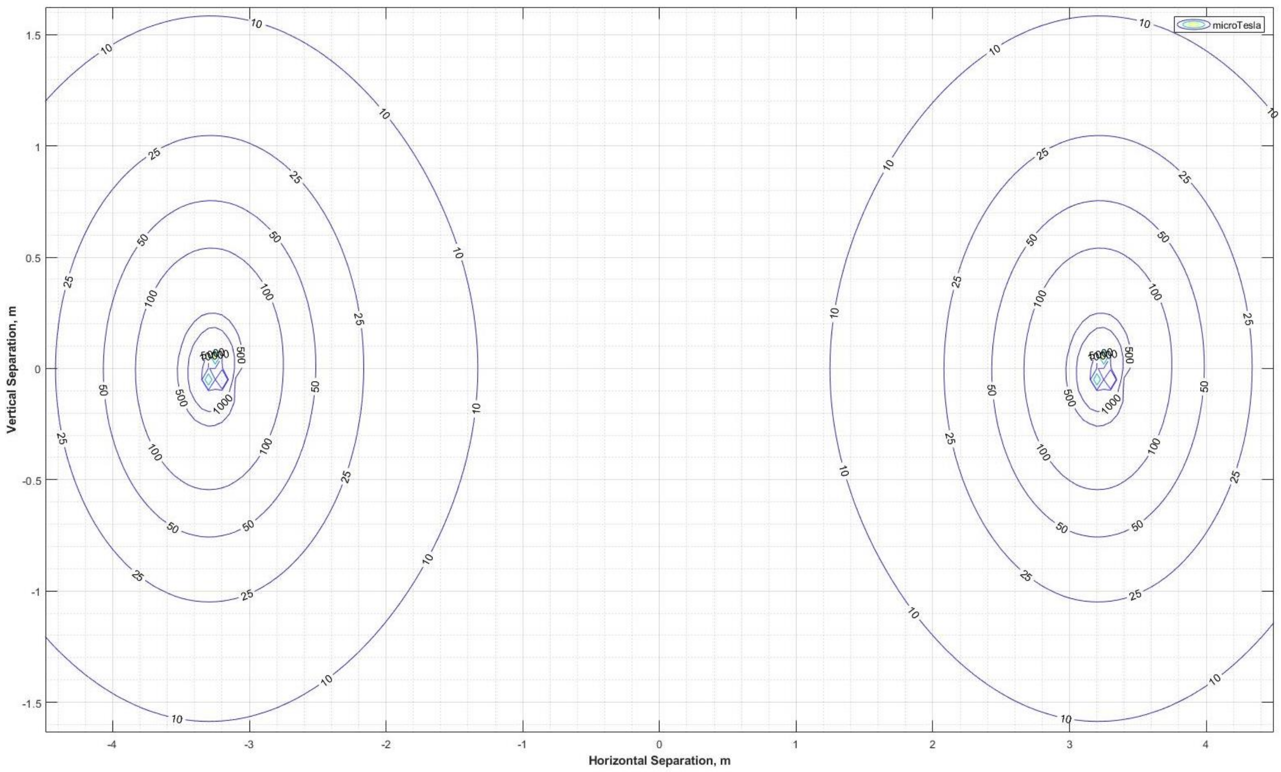
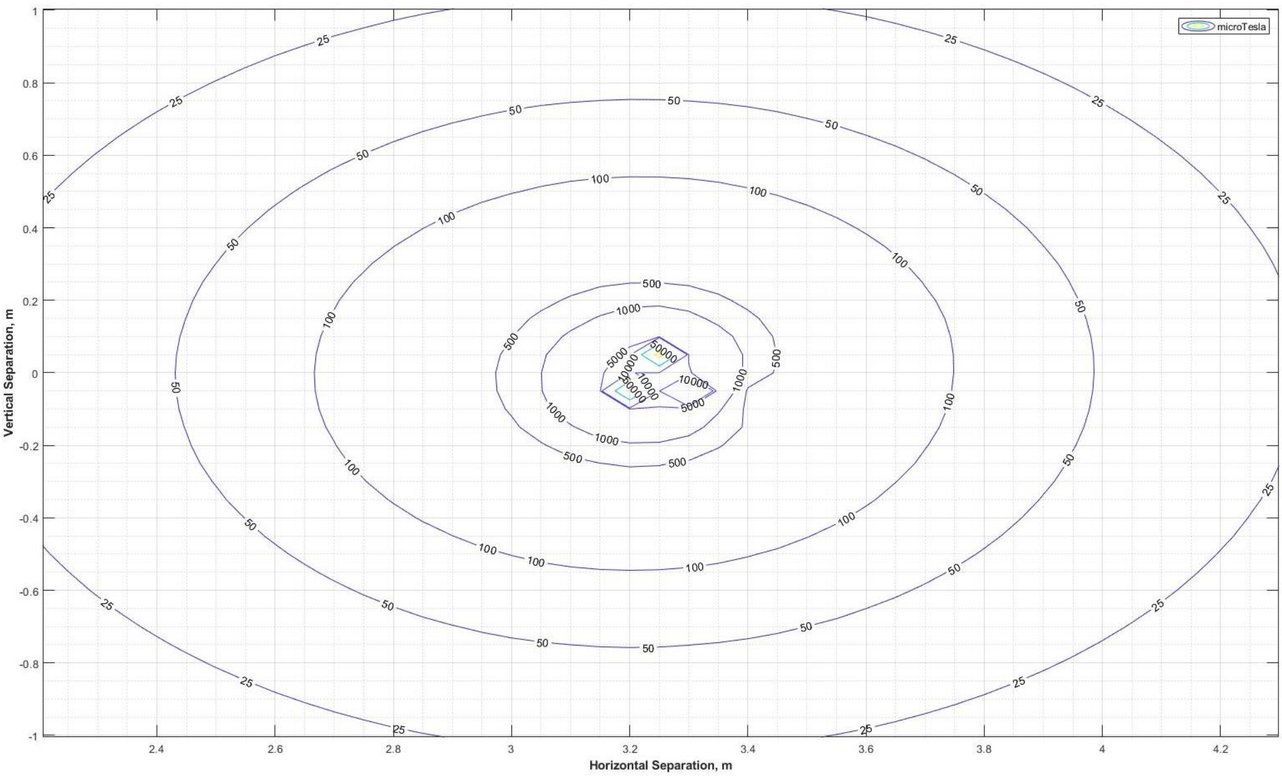


**Plate 9.3 66kV Array Cable Field Profile showing the 50μT zone**

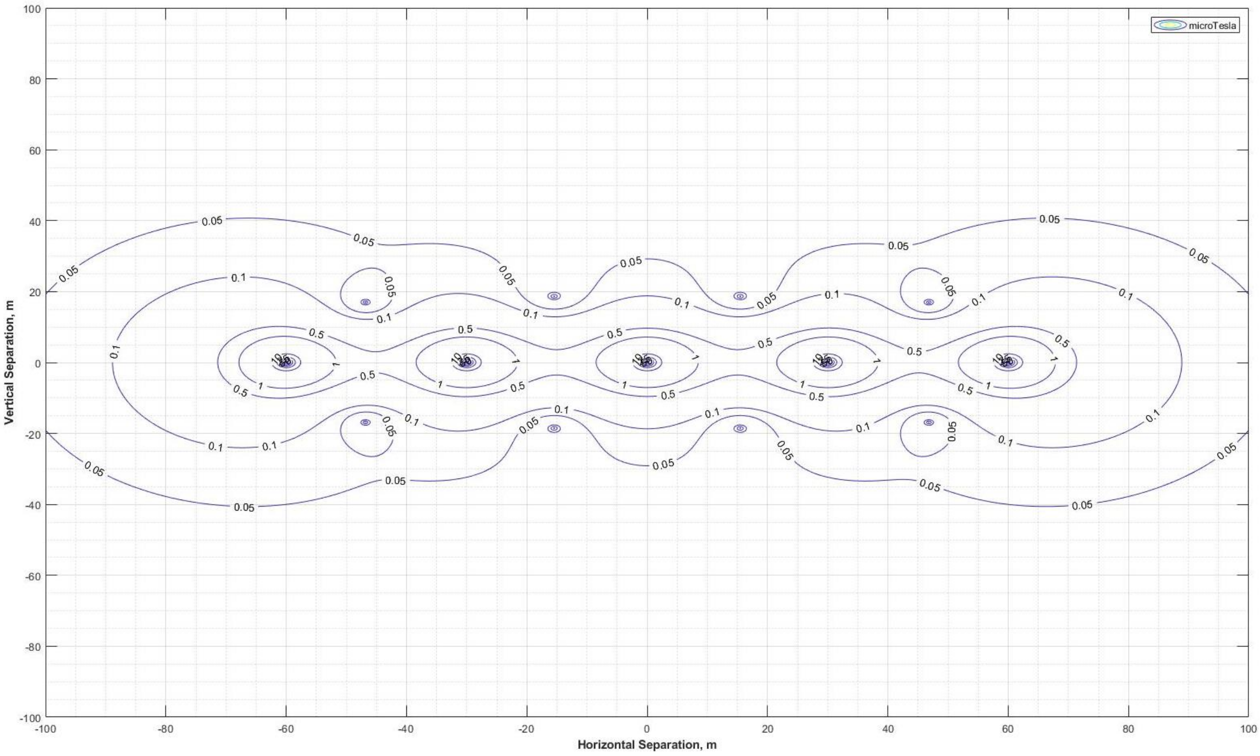



9.9.1.9 The results for the HVDC offshore export cables are shown in **Plate 9.4** to **Plate 9.7**. **Plate 9.4** and **Plate 9.6** show the field profile for a 100m radius around the centre of the cables for the 320kV and 525kV (monopole and bipole) respectively.

9.9.1.10 **Plate 9.5** and **Plate 9.7** show the same results at a higher resolution with a focus on the 50μT zone, which is limited to approximately 1.1m around a monopole cable (320kV), and approximately 11m around any single pole of the bipole cable (525kV).

9.9.1.11 The results for the 525kV bipole circuit present the worst case because of the high current and separation between the DC pole conductors. Though the 320kV monopole circuit has higher current, but the fields generated by the DC poles cancel each other more effectively as the poles are positioned close together.

## Plate 9.4 HVDC field profile for the monopole 320kV – 5x cables




## Plate 9.5 HVDC field profile monopole 320kV 50μT zone

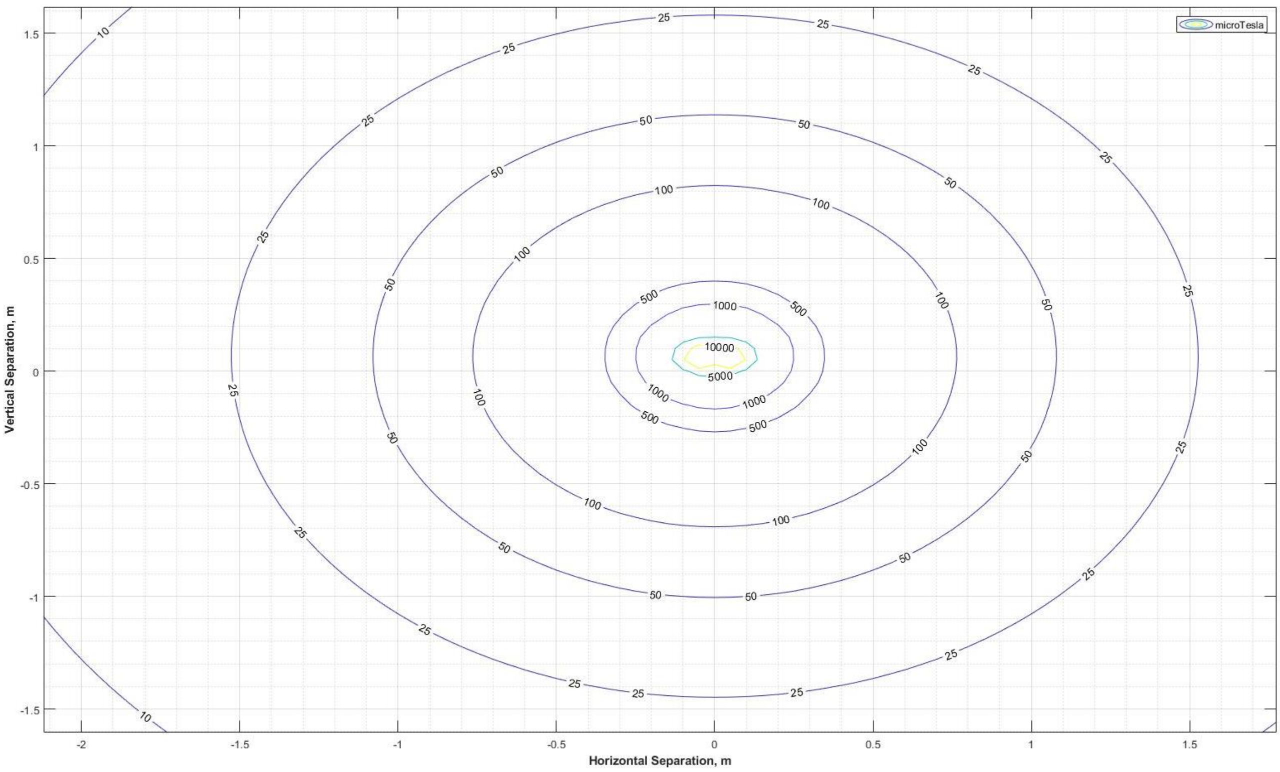


**Plate 9.6 Field profile for the bipole 525kV (single circuit)**

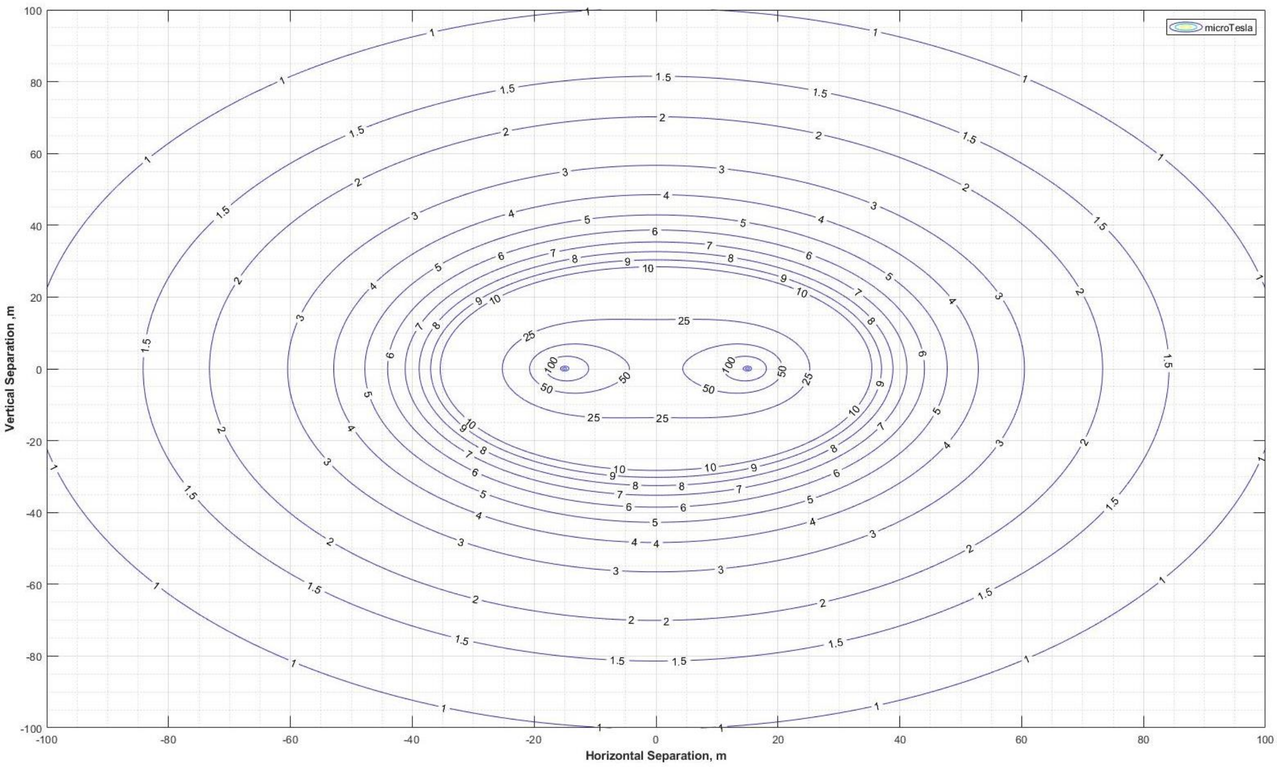
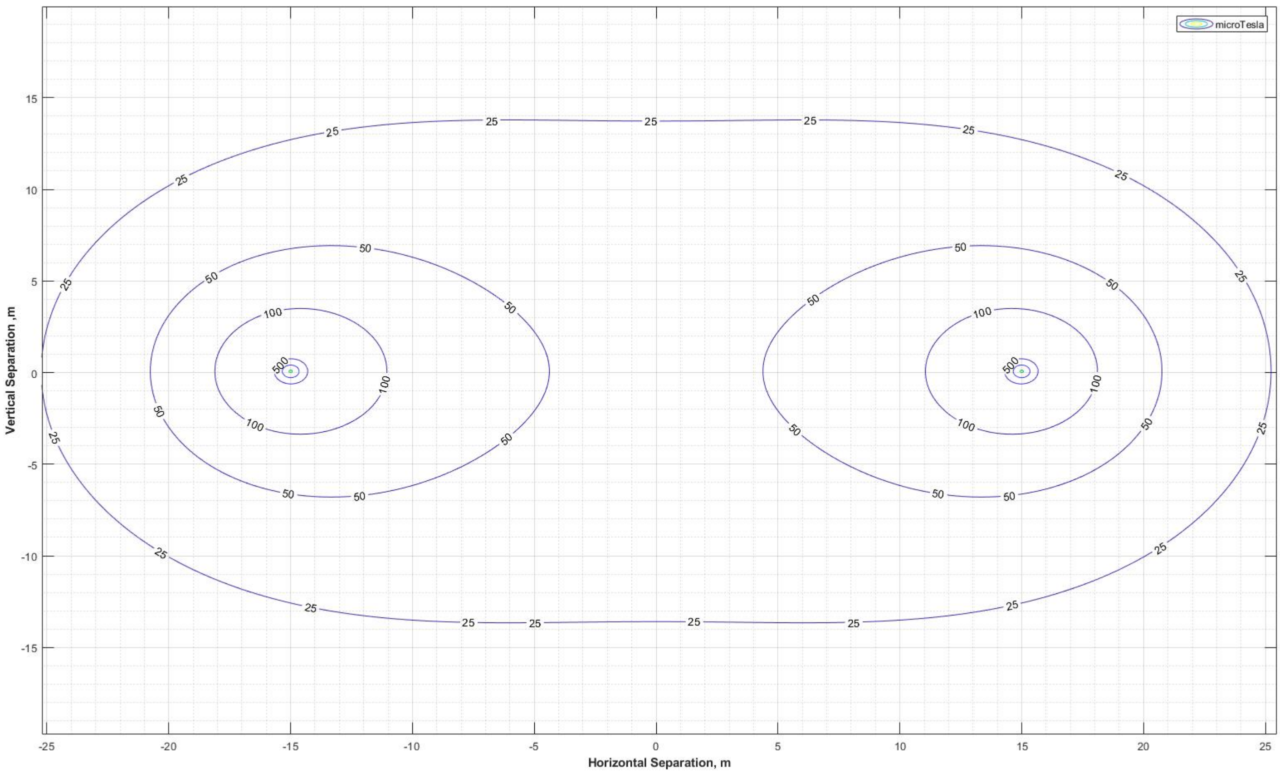


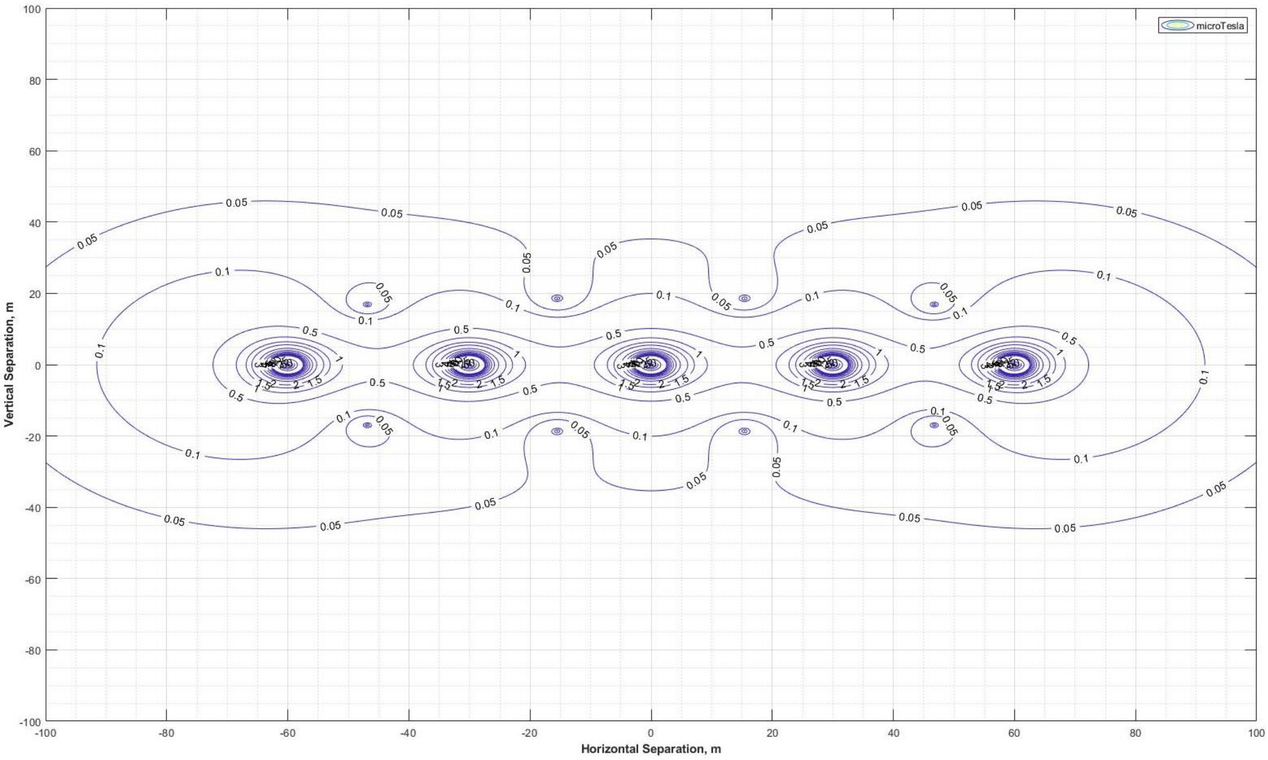

**Plate 9.7 Field profile for the bipole 525kV showing 50μT zone**



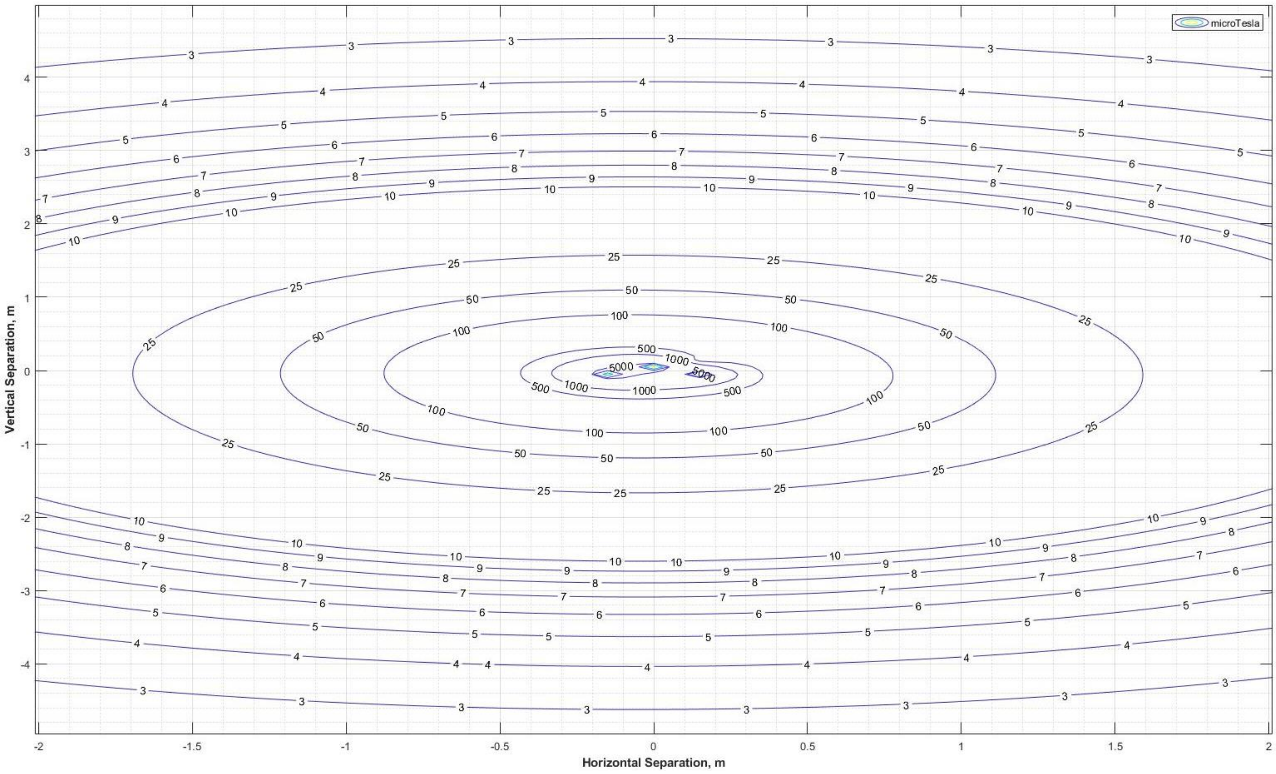
9.9.1.12 The results for five parallel 275kV HVAC export cables are shown in **Plate 9.8** to **Plate 9.9**.

9.9.1.13 **Plate 9.8** shows the field profile for a 100m radius around the centre of the cables, which shows attenuation to low levels of 0.5μT to 0.1μT (i.e. well below background levels) within 10m to 20m. **Plate 9.9** shows the same results at a higher resolution with a focus on the 50μT zone, which is limited to approximately 1.15m around a cable.

### Plate 9.8 275kV HVAC field profile for 5 circuits



### Plate 9.9 275kV HVAC field profile showing 50µT zone



## 9.10 Summary and conclusions

9.10.1.1 A quantitative analysis of EMF from the Project's operational stage (including for live maintenance) has been undertaken to determine the worst case fields of electro-magnetism that may be experienced by ecological receptors present or passing by the location of the Project's electrical cables. This has been considered in relation to the array and offshore export cables.

9.10.1.2 In the case of the offshore export cables, consideration has been given to an absolute worst case for HVAC and HVDC transmission. This means that the scenarios modelled include for all export cables being either HVAC or HVDC. It is acknowledged that ongoing Project design will result in the Project being developed through three phases of construction and energisation, and that these will involve a combination of both HVAC and HVDC transmissions.

9.10.1.3 Background levels of the Earth's magnetic field within the Project's Red Line Boundary are approximately 50μT. Project emissions of EMF become relevant to ecological receptors where EMF increases above background levels. The EMF analysis has determined the distances from the cable cores over which EMF above background levels may occur.

9.10.1.4 The results have shown that the worst case of eight 66kV HVAC array cables in close proximity to each other will emit EMF at 50μT over a distance of approximately 0.8m from each array cable. This finding is representative of array cables that are buried, unburied on the seabed, or dynamic in the water column. This attenuates to 0.1μT over 40m and 0.05 μT by 60m distance from the cable.

9.10.1.5 The 66kV HVAC scenario was considered as representative of the 132kV HVAC scenario, which was therefore not modelled.

9.10.1.6 The results for five HVDC offshore export cables show a worst case of EMF with a 50μT zone that is limited to approximately 1.1m around a 320kV cable, and approximately 11m around any single pole of the 525kV cable.

9.10.1.7 The results for the five 275 kV HVAC offshore export cables show a worst case of EMF with a 50μT zone that is limited to approximately 1.15m around each cable.

9.10.1.8 The modelling results are summarised within **Table 9.7** and indicate that the 525kV voltage scenario would be the worst-case as the field extends horizontally for 11m before being attenuated to the 50μT background level, and the vertical field extends 7m around any single pole of the 525kV bipole cables.

### Table 9.7 Summary of EMF modelling results

| Voltage scenario | Horizontal attenuation distance to 50μT background (m) | Vertical attenuation distance to 50μT background (m) |
|---|---|---|
| **66kV** | 0.8 | 0.7 |
| **275kV** | 1.15 | 1.0 |
| **320kV** | 1.1 | 1.1 |
| **525kV** | 11.0 | 7.0 |

9.10.1.9 The implications of the EMF described in this Chapter, where these may be perceptible to ecological receptors are described and assessed as relevant in **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**, **Chapter 11: Marine Mammals**, **Chapter 12: Offshore and Intertidal Ornithology**, **Chapter 13: Fish Ecology**, **Chapter 14: Commercial Fisheries,** and **Chapter 23 Terrestrial Ecology and Ornithology**.

## 9.11 Transboundary effects

9.11.1.1 Transboundary effects arise when impacts from a development with one European Economic Area (EEA) State affects the environment of another EEA State(s). A screening of transboundary effects have been carried out and is presented in Appendix 4B of the Scoping Report (MarramWind Ltd., 2023).

9.11.1.2 The receptors identified as having sensitivity to EMF (referenced in **paragraph 9.1.2.6**) are assessed in the relevant Chapter if there is potential for any transboundary effects in relation to EMF.

## 9.12 Inter-related effects

9.12.1.1 A description and assessment of the likely inter-related effects arising from the Project from EMF on receptors that are sensitive to EMF is provided in **Chapter 32: Inter-Related Effects**.

## 9.13 Assessment of cumulative effects

9.13.1.1 A description and assessment of the cumulative effects arising from the Project in relation to EMF is provided in **Chapter 33: Cumulative Effects Assessment**.

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# 9.15 Glossary of terms and abbreviations

## 9.15.1 Abbreviations

| Acronym | Definition |
|---|---|
| **AC** | Alternating Current |
| **DC** | Direct Current |
| **DECC** | Department Of Energy And Climate Change |
| **EEA** | European Economic Area |
| **EIA** | Environmental Impact Assessment |
| **EMF** | Electromagnetic Fields |
| **HVAC** | High Voltage Alternate Current |
| **HVDC** | High Voltage Direct Current |
| **ICNIRP** | International Commission On Non-Ionizing Radiation |
| **kV** | kilovolt |
| **MD-LOT** | Marine Directorate – Licensing Operations Team |
| **MW** | Megawatt |
| **NOAA** | National Oceanic And Atmospheric Administration |
| **O&M** | Operation And Maintenance |
| **OAA** | Option Agreement Area |
| **s.36** | Section 36 |
| **UK** | United Kingdom |

## 9.15.2 Glossary of terms

| Term | Definition |
|---|---|
| **AC** | Alternating current (AC) is an electrical current that periodically reverses direction, unlike direct current (DC) which flows in only one direction. In AC, the voltage and current oscillate, typically in a sinusoidal waveform, meaning they fluctuate between positive and negative values over time. |
| **EMF** | Electromagnetic fields (EMF) are physical fields produced by moving electric charges, and they consist of both electric and magnetic fields. These fields are intertwined, and a disturbance in one can create a |

| Term | Definition |
|---|---|
| | disturbance in the other, leading to oscillations known as electromagnetic waves. |
| **DC** | Direct current (DC) is an electrical current that flows in one direction, maintaining a constant polarity. Unlike alternating current (AC), where the current direction reverses periodically, DC provides a steady, unidirectional flow of electrical charge |
| **High Voltage Alternating Current** | High voltage alternating current is the bulk transmission of electricity by alternating current (AC), whereby the flow of electric charge periodically reverses direction. |
| **High Voltage Direct Current** | High voltage direct current is the bulk transmission of electricity by direct current (DC), whereby the flow of electric charge is in one direction. |

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