MarineSpace

Making Sense of the Marine Environment ™

Volume 3. Technical Appendix: 7.2 EMF Assessment

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Glossary

Term	Definition
AC	Alternating Current
BGW	Blue Gem Wind
DC	Direct Current
EMF	Electromagnetic Field
ES	Environmental Statement
FLOW	Floating Offshore Wind
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
iE	Induced Electrical Field
SBE	Simply Blue Energy
WTG	Wind Turbine Generators
µT	Microtesla

Contents

List of Figures

List of Tables

1. Introduction

1.1. The Project

Project Erebus (the Project) is a proposed demonstration scale Floating Offshore Wind (FLOW) development in the Celtic Sea region, approximately 35 km southwest of the Pembrokeshire coastline. The developer Blue Gem Wind (BGW) is a joint venture between Simply Blue Energy (SBE) and TotalEnergies, set up to create a new low carbon offshore energy sector in the region, that contributes to climate change targets, supply chain diversification and energy security.

The Project comprises 6 to 10 Wind Turbine Generators (WTG) with a total generating capacity up to 100 MW. Each WTG is housed on a semi-submersible floating platform with a mooring system comprising a maximum of five catenary mooring lines, up to 870 m in length, and a range of foundation options including drag embedment anchors, driven piles, drilled piles and/or suction piles. Up to 10 dynamic array cables are proposed, with a lazy wave configuration from the semi-submersible floating platform to the seabed. The offshore export cable, up to 49 km in length, links the array area to landfall at West Angle Bay, Pembrokeshire.

1.2. Objective of Document

This chapter focuses on the electromagnetic field (EMF) emissions from the array cables and offshore export cable. Assessment of the onshore cable and the effects of EMF on human health is assessed in Chapter 27: Socio-Economic, Tourism and Recreation (including Human Health).

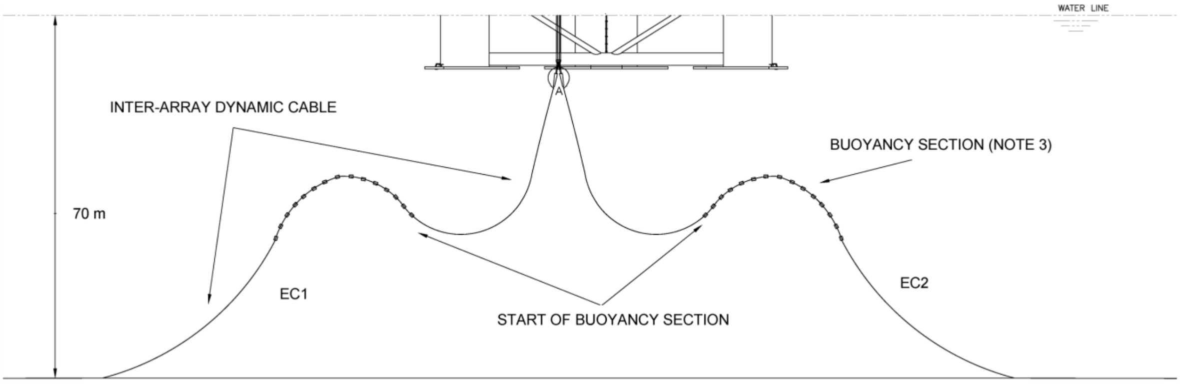
An EMF is created by the transmission of electricity and magnetic fields through power cables and comprises both electric and magnetic components. Some marine organisms are particularly sensitive to EMF, including species that have electroreceptors that may be affected by EMF.

This document is intended to provide information on EMF that may potentially be produced via the Project that can inform the impact assessments on benthic organisms (Chapter 9: Marine and Coastal Ecology), Chapter 10: Fish and Shellfish and Chapter 12: Marine Mammals presented in the main Environmental Statement (ES).

1.3. Project Electrical Infrastructure

The Project will comprise up to 10 dynamic array cables, a total length of up to 23.9 km, connecting up to 10 WTGs within the array area. 22.5 km of the array cable will be in contact with the seabed and a maximum of 20 array hangoffs (from hulls to seabed) are included in the Project design (equivalent to all 10 turbines with 2 hangoffs). The connection of array cables to the WTGs will be via a ‘lazy wave’ configuration (see Figure 1.1).

Figure 1.1 Lazy wave configuration example



The offshore export cable will be up to 49 km in length, providing transmission from the array to landfall at West Angle Bay. Here it will be connected to the onshore export cable which will run from West Angle Bay to the onshore substation, near to the existing Pembroke Power Station.

All marine cables will be buried, where possible, at depths of 0-3 m, with a target depth of 1.5 m for the export cable. The worst-case scenario in terms of EMF effects is for the export cable to be surface-laid (in areas where burial is not possible) but with external cable protection installed (rock berms/concrete mattresses). The worst-case scenario in terms of EMF affects for the array cables is considered to be surface laid cables with rock bags placed at set intervals to add stability.

The maximum amount of rock protection within the array area is estimated to be 67,250 m^2 (0.067 km^2) (based on a combination of cable protection at selected locations and rock bags to stabilise the cables at intervals along the cables). A maximum of 3,300 m of cable will be present entirely within the water column in the form of hangoffs from up to 10 semi-submersible platforms.

The worst-case scenario for the export cable will be that approximately 16% of the cable will require rock protection which equates to an estimated area of 83,380 m^2 (0.083 km^2). The export cable maximum rock protection footprint will be 11 m base width by 2 m in height.

EMF emissions are strongly related to the length of the cables, protection material present (if any), voltage through the cable, the type of cable and the diameter of the cable. The parameters associated with the cable works are presented in Table 1.1 below.

Table 1.1: Cable parameters for the Erebus floating offshore windfarm array and export cable corridor.

Parameters	Array Cable	Export Cable
Max Cable Diameter (mm)	300 mm	300 mm (per cable)
Max Total Length (km)	23.9 km (max total length) 22.5 km (in contact with the seabed)	49 km
Cable Type	HVAC	HVAC
Voltage (kV)	72.5 kV	66 kV
Type	Dynamic cable array	3 core HVAC single or bundled subsea cable and fibre optic
Cable Protection Requirements	Rock protection and stabilisation at intervals along the inter array cables **Area = 67,250 m^2**	Approximately 16 % of the 49 km export cable requiring protection via 11 m base width rock berm (2 m height) **Area = 83,350 m^2**

1.4. Electromagnetic Fields

Background levels of EMF from the Earth's geomagnetic field are estimated to be between 25-65 (µT) (Hutchison *et al.*, 2020). Electricity moving through a cable induces both an electric (E field) and magnetic field (B field), which are collectively referred to as EMF (National Grid and Energinet, 2017a). EMFs can persist at a distance from the source, but this is dependent on the density of the surrounding material (Tethys, 2019).

Shoreward transmission of electricity generated at offshore windfarms requires multiple cables, each of which emits EMF into the marine environment. EMF could potentially affect the sensory mechanisms of various species of marine organisms, particularly those that use the Earth's magnetic fields for orientation, migration, and prey location (Inger *et al.*, 2009; Fisher and Slater, 2010).

There is no electric field outside of the cable due to the: high voltage conductor of a cable, the grounded screen, and the armour. The armour has the same electric potential as the ambient environment outside, which prevents escape of the electric field from the cable (Normandeau *et al.*, 2011). In comparison, the magnetic field can radiate into the surrounding environment as the cable material is permeable to this field, but this field will lessen with distance from the source. Induced electric fields (iE fields) occur through the movement of water or organisms through the magnetic fields (Normandeau *et al*., 2011). As iE fields are dependent on magnetic fields, iE is therefore also reduced with distance from the cable.

The maximum length of array and export cable within the Project design is 72.9 km (Table 1.1). Based on similar projects effects from EMF are expected to be limited to the localised area immediately surrounding the cable route (BOEM, 2020).

The background geomagnetic field for the Celtic Sea is approximately 48.7 µT (Natural Resources Canada, 2019). The naturally occurring iE field changes continuously, based on the flow of the water. The background iE field for the Celtic Sea has been calculated using the equation below (National Grid and Energinet, 2017a):

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

Using the peak tidal current velocities for the ebb and flood tide, based on the maximum tidal current speed (1.03 m/s) at mean spring tides within the array area and offshore cable corridor (Sager and Sammler, 1968), the background iE field is estimated to be 50.16 µV/m (*1.03 (m/s) x 48.7 (µT) = 50.16* µV/m).

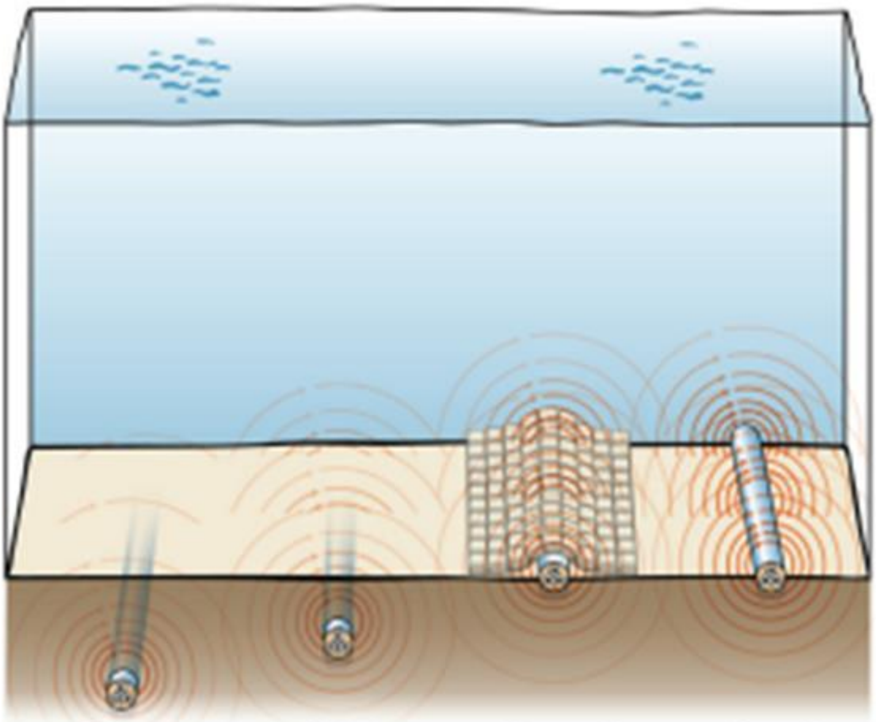
1.5. Electromagnetic Fields and Marine Organisms

There have been a number of studies investigating the behavioural and physiological responses that marine benthic species and fish may have to EMF. Benthic species exposed to EMF exhibited no change in stress related parameters, however physiological and behavioural changes were observed (Scott *et al*., 2018; Stankevičiūtė *et al*., 2019; Jakubowska *et al*., 2019). With respect to shellfish there is some conflicting responses reported. Some species such as the juvenile European lobster *Homarus gammarus* demonstrated that EMF had no effect on exploratory and sheltering behaviours. Whilst it has been shown that decapods (e.g. crabs and lobsters) in Vancouver were less abundant around 230 kV cables, compared to control sites (Dunham *et al*., 2015), recent research has demonstrated that the brown crab *Cancer pagurus* reduced their roaming behaviour and exhibited an attraction to EMF, despite potential physiological stress (Scott *et al.,* 2021). Although there have been some studies on the effects on benthic species, results are highly species specific, and thus there is still a knowledge gap for many marine species.

Various studies have shown behavioural changes in electroreceptive fish (e.g. shark Elasmobranchii and stingray Myliobatoidei species) in areas where EMF is present (Gill and Taylor, 2001; Gill *et al*., 2009; Olsson and Larsson, 2010; Gill *et al*., 2020). Behavioural responses such as avoidance or attraction have been observed in several different fish species (e.g. nursehound *Scyliorhinus stellaris*, blonde ray *Raja brachyuran* and Atlantic herring *Clupea harengus*) some of which are known to use the Project area (Gill and Taylor, 2001; Gill *et al*., 2009; Olsson and Larsson, 2010; Gill *et al*., 2020). It has been evidenced that although marine mammals respond to EMF, due to the high mobility of the various species, their exposure to EMF is normally low.

Cable burial is seen as the optimal mitigation against potential adverse impacts from EMF on marine organisms (Figure 1.2). This is simply a result of the cable being situated further away from the water column and, therefore, reducing the potential for interaction between EMF and sensitive ecological receptors. A study in Tasmania found that a third of a cable route was visually undetectable within 2 years, and after 3.5 years the colonising benthic species were similar to those nearby hard-bottom species (Sherwood *et al*., 2016).

Figure 1.2: Illustrative example of electromagnetic field emission from cables on the seabed (From: BOEM, 2020)



1.6. Heat Emissions

Electricity transmission within the marine environment will cause cables to become heated relative to the ambient environment. Cables that are laid on the sea floor are expected to have minimal effects on surrounding water temperatures as consistent water flow will dissipates excess heat energy (Worzyk, 2009). However, surface laid cables may result in heating of the seabed upon which they are places, and heat energy from cables that are buried below the surface is likely to be retained within surrounding sediments. These heating effects on benthic substrata introduces risk of impacts on benthic receptors.

Any demersal, pelagic or epibenthic species will not be impacted by any heat effects due to the high heat capacity of water and the water flow around the cable. The potential of heat effects may exist for burrowing fauna. The effect of heat loss from the cables is small increases in temperature within a few centimetres of the cable (Boehlert and Gill, 2010). BirdNed interconnector cable found that the immediate sediment in summer may increase by 0.5-5.5 ˚C when the cable is buried at a depth of 1 m. At a burial depth of 3 m the temperature was calculated to be between 0.5-1.8 ˚C (Moray Offshore Windfarm Ltd, 2018; National Grid and Energinet, 2017b). The temperature increase from the cables will be extremely low and very localised (within the first couple of centimetres of the cable) as it is likely to dissipate quickly.

The assessment will use a maximum of 2.5 ˚C change as observed in the field experiment for Nysted offshore windfarm within the first 50 cm of the cable. The mean difference in temperature observed at this site was 0.8 ˚C (Meißbner *et al*., 2006).

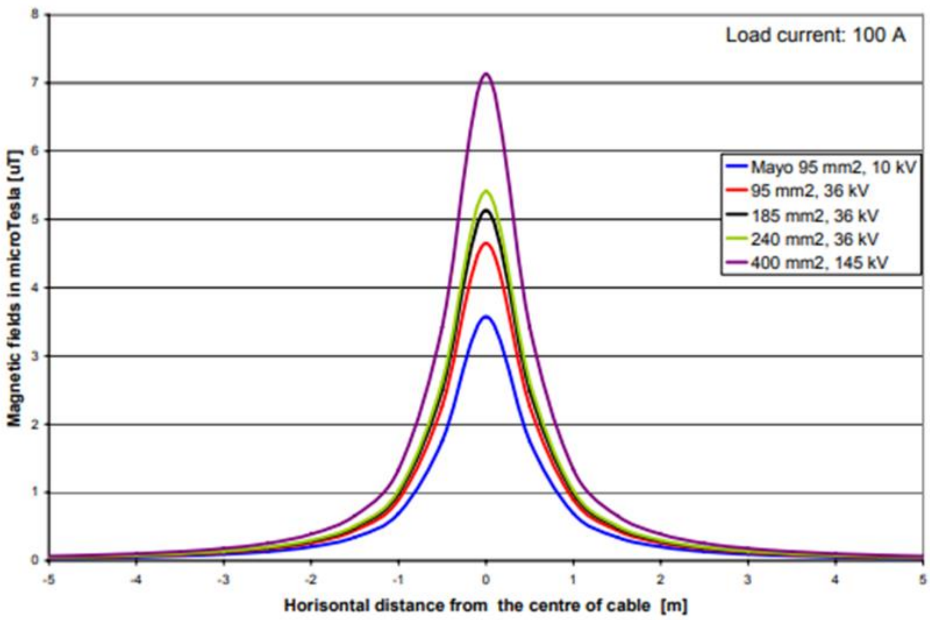
2. Thresholds of EMF Detection

2.1. Buried Cables

As summarised in Section 1.5, the effects of EMF on marine organisms are still unknown for most species. However, experiments have been conducted to estimate the depth of burial that would be required for the emissions from EMF to be negligible at the seabed, and thus using this information the potential risk to sensitive receptor groups can be understood.

Moray Offshore Renewables Ltd (2019) produced modelled outputs for levels of EMF transmitted from AC (alternating current) cables for 5 single cables, each with different voltages. The model applied Biot-Savarts Law to estimate the magnetic field within the water column based on a burial depth of 0.5 m (Figure 2.1). For a 145 kV AC, the highest EMF value was 7 µT horizontally at 0 m from the centre of the cable with a burial depth of 0.5 m, and this dropped to 0.3 µT at 2 m from the centre of the cable. The 145 kV AC cable is more than double the voltage that will be used in the Project (Table 1.1). The voltage of a cable is proportionate to the amount of EMF that radiates from the cable.

Figure 2.1: Calculated magnetic fields from different types of alternating current (AC) cables along the seafloor with a burial of 0.5 m (From: Moray Offshore Renewables Ltd, 2019)



Normandeau *et al.,* 2011 measured the EMF transmitted from cables for 10 different offshore cable and windfarm projects. The highest EMF of a surface laid cable was 17 µT at 0 m horizontal distance along the seabed, this was observed for the Nysted offshore windfarm (Figure 2.2).

Another key observation in Figure 2.2 is that the magnetic field attenuates close to 0 µT around 4 m from the cables for a number of projects.

Table 2.1: lists the average magnetic fields calculated across these ten projects. The field strength drops from 7.85 µT at 0 m, to 0.35 µT at 5 m vertically from the seabed, and to 1.47 µT at 4 m horizontally from the cable.

Figure 2.2: Alternating current (AC) magnetic field profiles across the surface of the seabed for 10 submarine cable systems (From: Normandeau *et al.,* 2011)

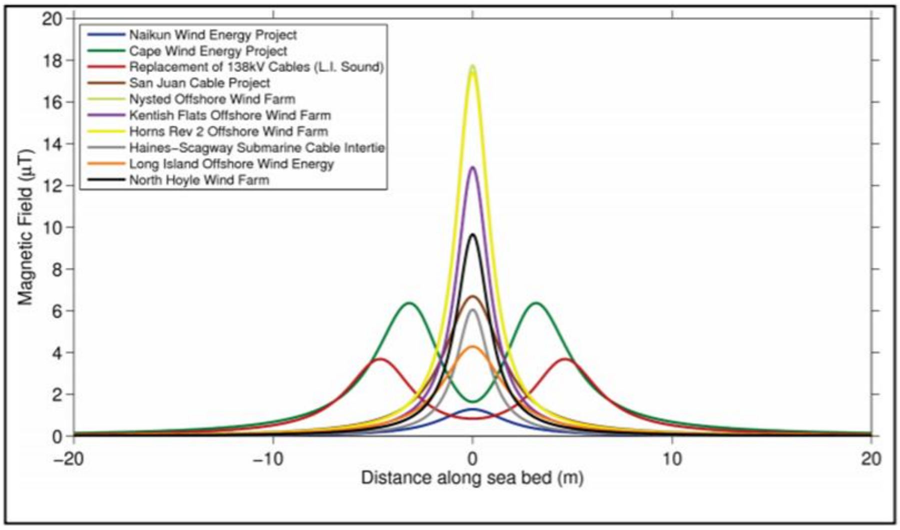


Table 2.1: Alternating current (AC) magnetic fields (µT) reflecting averaged values from 10 projects at intervals above, and horizontally along the seabed, assuming 1 m burial (From: Normandeau *et al.,* 2011)

	Average Magnetic Field Strength (µT)		
Distance Above Seabed (m)	Horizontal Distance from Cable (m)		
	0 m	4 m	10 m
0 m	7.85	1.47	0.22
5 m	0.35	0.29	0.14
10 m	0.13	0.12	0.08

2.2. Surface Laid Cables and Cables in the Water Column

Cable burial has been shown to reduce EMF at the seabed, as the magnetic and electric fields attenuate with distance from the source (see Section 2.1). There are, however, limited data on the potential effects of EMF from surface-laid cables or cables within the water column. However, based on the monitoring undertaken by Normandeau *et al.* (2011) and the Moray offshore renewables (2019) reports, EMF will be detectable by marine organisms up to a 4 m radius around any surface laid (unburied cables) and/or cables in the water column.

This distance of 4 m was calculated for the Telford, Stevenson, MacColl WindFarm and Associated Transmission Project Environmental Statement (Moray Offshore Renewables Ltd, 2019), and for a greater voltage (145 kV) than the cables that will be used in this Project. The 4 m distance represents, therefore, the worst-case scenario and pre-cautionary approach based on a higher voltage of 145 kV. Figure 2.1 also shows that the magnetic field is significantly reduced at 4 m horizontally across the seabed with a 0.5 m burial depth, therefore, it is unlikely that effects of EMF will occur at this distance from the cable. In recognition of this, effects from cables within the water column will be assessed within the individual receptor chapters, as sensitivity to EMF will differ between species.

The worst-case scenario, in assessing the effects of EMF, is that all of the array cable in contact with the seabed (22.5 km) will be surface laid and a maximum of 3,300 m of cable, in the form of hangoffs from up to 10 semi-submersible floating platforms, will be present in the water column. A 4 m radius around the 22.5 km of array cables and 3,300 m of cables from hangoffs will be used to assess the effects of EMF on the receptors presented in the relevant ES chapters, specifically Volume 1 Chapter 9: Marine and Coastal Ecology, Chapter 10: Fish and Shellfish, and Chapter 12: Marine Mammals.

2.3. Cable Crossings

Increased EMF is typically associated with any cable crossing area as the cable being installed usually needs to be surface laid (with cable protection then applied) over any existing cable. Along the offshore export cable corridor, there is only 1 cable crossing; this is with the Greenlink Interconnector cable, a 320 kV HVDC cable. The Greenlink Interconnector comprises two cables with currents flowing in opposite directions. Therefore, the magnetic fields are anti-directional and are likely to cancel each other out. The magnetic field around the HDVC cable decreases rapidly as a function of distance from the cable. There is limited information on EMF emissions from crossings between HVDC and HVAC cables (Intertek EWCS, 2019).

Therefore, the cable crossing for the Project has been assessed using the worst-case additive effect of the magnetic field around both cables:

- The magnetic field at the seabed for the Greenlink Cable is estimated to be 21 µT and for the Project export cable 15 µT (based on the graph in
- Figure 2.3)(Intertek EWCS, 2019);

- These values, in consideration of the background geomagnetic field levels of 48.7 µT (see Section 1.4), results in an overall 84.7 µT magnetic field at the seabed (based on an additive effect); and
- Figure 2.4 shows the attenuation of EMF with distance from the cable - a magnetic field of ~80 µT attenuates around 5 m.

Therefore, a magnetic field of around 84.7 µT would be expected to attenuate around 5 m and a 5 m buffer will be used to assess risk of effects from EMF emissions around the cable crossing.

The array area is bisected by the SOLAS telecommunication cable, a fibre optic submarine telecommunications cable likely to be in the range of 1-6.3 µT at 1 m from the cable (Gill *et al.*, 2005).

- A maximum of two array cable crossings have been assessed. The magnetic field at the seabed for the SOLAS Cable is estimated to be 6 µT and for the Project array cable 13 µT (based on the graph in Figure 2.5);
- These values, in addition to the background geomagnetic field levels of 48.7 µT (see Section 1.4), results in an overall 67.7 µT magnetic field at the seabed (based on an additive effect);
- Figure 2.4 shows the attenuation of EMF with distance from the cable - a magnetic field of ~80 µT attenuates around 5 m. A value of 60 µT is likely to be less than this but a precautionary radius of 5 m will be used.

2.4. Heat Emission Thresholds

Any cables that are in contact with the water column are likely to have negligible risk of impacts due to the dissipation of heat energy within water flow. However, surface laid cables may result in heating of the seabed upon which they are places, and heat energy from cables that are buried below the surface is likely to be retained within surrounding sediments. Heat emissions are likely to be dissipate within the first few centimetres of buried cables. Heat emissions will be considered for the cables within a 50 cm distance around the cable and a maximum increase of 2.5 ˚C has been used although this is likely to be much lower. This is considered a conservative approach as heat energy is likely to be dissipate within the first couple of centimetres from the cable.

EMF will be based on a 5 m radius around each of the cable crossings for both the Greenlink cable crossing and the two SOLAS cable crossings.

Figure 2.3: Magnetic field expected from 630 mm^2 66 kV alternating current (AC) inter-platform cables, assuming a 1 m burial depth (From: Moray Offshore Renewables Ltd, 2019)

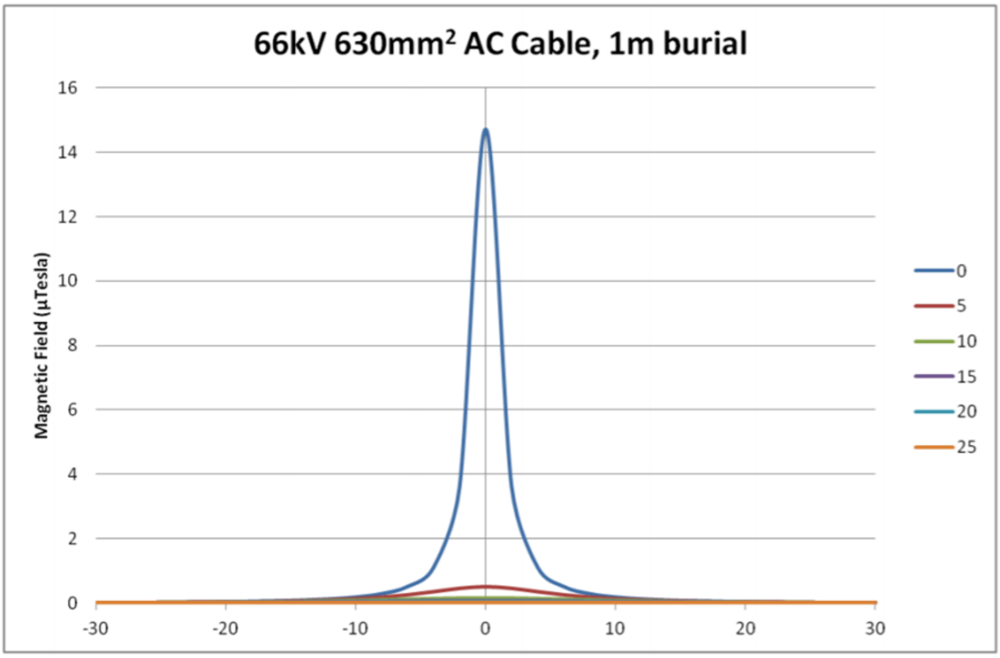


Figure 2.4: Magnetic field at the seabed surface for direct current (DC) cables with 1 m burial (From: Normandeau *et al.,* 2011)

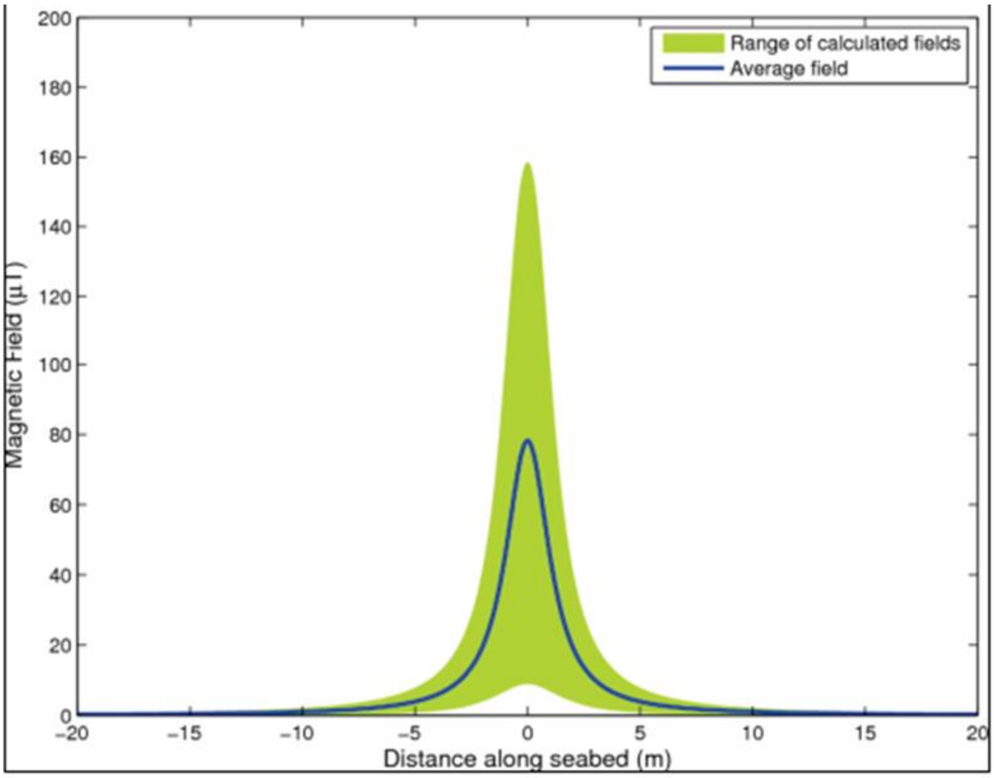
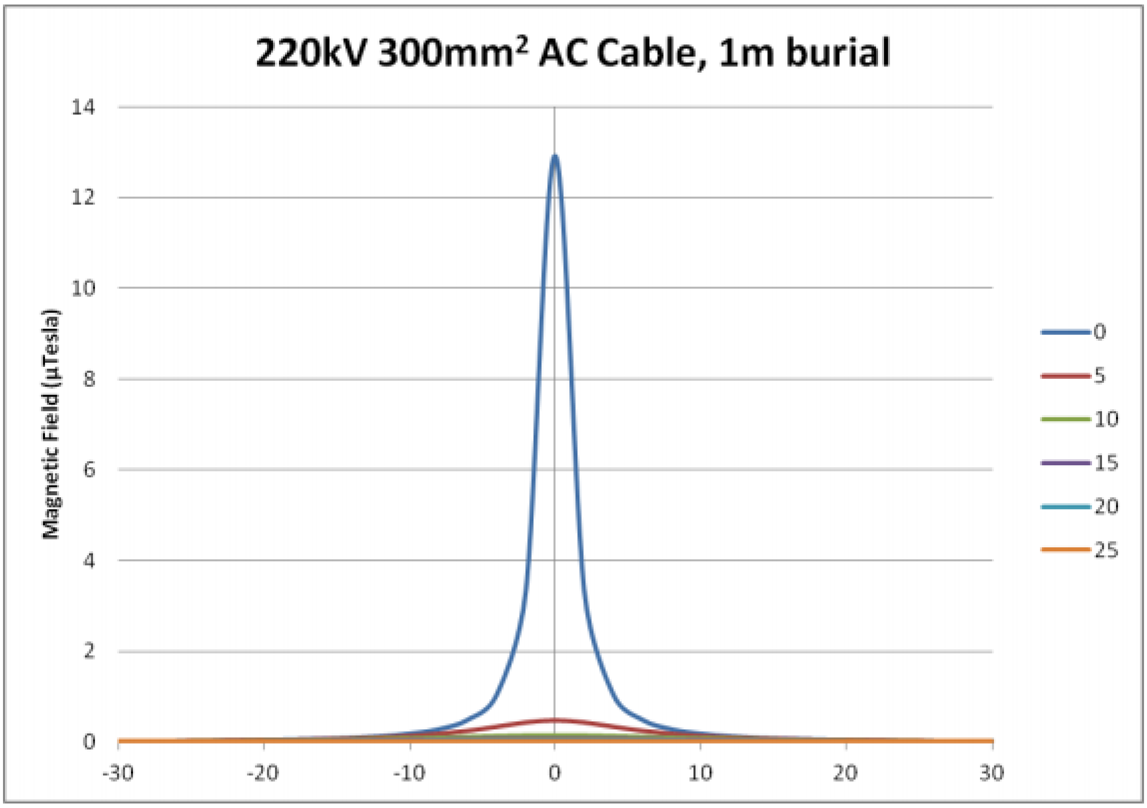


Figure 2.5 Magnetic field expected from 300 mm² 220 kV alternating current (AC) inter-platform cables, assuming a 1 m burial depth (From: Moray Offshore Renewables Ltd, 2019)



3. Assessment Parameters

The worst-case scenario from the EMF emissions is 4 m radius from all surface laid cables. At distances further than 4 m from the source the EMF field is likely to be indistinguishable from background levels.

During cable crossings it is possible that this area of influence will increase to 5 m. A total of three cable crossings across the Project area are expected of which two are within the array area and one is along the offshore export cable. For the purposes of this assessment the length of cable crossing has been based on a 5 m length although it is likely to be much smaller.

For cables laid on the surface of the seabed in the absence of cable protection half of the area of EMF influence will be present within the water column, and half will be within the seabed. A maximum of 3,300 m of cable will be present entirely within the water column in the form of hangoffs from up to 10 semi-submersible floating platforms

Therefore, the total area of EMF influence is calculated as:

$$V = \pi\,(r^2) \times h$$

Where:

- V = Volume of EMF influence;
- r = Radius of cable (0.15 m) + radius of EMF influence (4 m);
- h =Cable length.

Predicted volume of EMF from surface laid cables excluding cable crossings (both array and export cables and inclusive of cable hangoffs):

$$\pi\,(4.15^2) \times 72885 = 3{,}943{,}522\ \text{m}^3$$

5 m EMF emissions from three cable crossings:

$$\pi\,(5.15^2) \times 15 = 1{,}250\ \text{m}^3$$

Total volume of EMF across the Project

$$3{,}943{,}522 + 1{,}250 = 3{,}944{,}772\ \text{m}^3$$

Volume of EMF effects within the water column from hangoffs:

$$\pi\,(4.15^2) \times 3300 = 178{,}550\ \text{m}^3$$

Total volume of EMF effects within the seabed:

$$(\pi\,(4.15^2) \times (72{,}885\ \text{m} - 3300\ \text{m}))/2 = 1{,}882{,}486 + (1250\ \text{m}^3/2) = 1{,}883{,}111\ \text{m}^3$$

Total volume of EMF effects within the water column:

$$1883111 + 178550 = 2{,}061{,}661\ \text{m}^3$$

Total volume of EMF influence: 3,944,772 m^3 (0.0039 km^3) of which a maximum of 2,061,660 m^3 (0.0021 km^3) will affect the water column and 1,883,110 m^3 (0.0019 km^3) will affect the seabed.

4. Summary

The effects from EMF attenuate with distance from the source i.e. the cable. Cable burial reduces the effects of EMF by creating distance between the water column and the cable. Achieving 2 m cable burial is sufficient to reduce EMF emissions to background levels at the seabed. This is likely to reduce the effects of EMF on mobile species such as marine mammals and fish, however there may be EMF effects on benthic species living within the sediments.

Impacts to ecological receptors in areas where the cables are exposed (e.g. surface laid and/or in the water column), will be assessed within the corresponding receptor group chapters specifically Volume 1 Chapter 9: Marine and Coastal Ecology, Chapter 10: Fish and Shellfish, and Chapter 12: Marine Mammals and reflect specific receptor responses. As EMF is reduced with distance, a 4 m radius around all surface-laid cables and/or cables in the water column will be used to assess the potential effects and risk of EMF on the different receptor groups.

Cable crossings can amplify EMF emissions, and as such, a radius of 5 m around cable crossings will be used to assess potential effects and risk of EMF receptor groups.

Impacts from heat emissions from the cables will be considered for buried and surface laid cables, where the cables are in contact with sediment. Cables that in the water column or in contact with the water will have negligible impacts due to the water flow around the cables, which dissipates the heat energy.

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