European Offshore Wind Deployment Centre

Environmental Statement

Chapter 13: Electromagnetic Fields

A project part-funded by the European Union under the European Economic Plan for Recovery in the field of Energy

13 ELECTROMAGNETIC FIELDS

13.1 Background Introduction

1 The transportation of electricity within cables can cause electric and magnetic fields (EMF) to be generated. This has been a cause of concern amongst stakeholders regarding potential impacts upon marine life. These concerns relate to the behaviour of animals found near the source of the EMFs, specifically whether the fields result in the attraction or repulsion of animals from areas around cables and whether the fields influence migration behaviour of certain commercially important or protected fish species.

2 The purpose of this section is to explain the types of EMF that can be generated within subsea cables associated with offshore wind farms and to summarise the potential environmental impacts of EMFs. This section is not an impact assessment, the impacts of EMFs are considered in more detail in the impact assessments for Marine Ecology (Chapter 9) and Marine Mammals (Chapter 12) and Salmon and Sea Trout (Chapter 22). This section has been prepared by Genesis Oil and Gas Consultants.

13.2 Data information and Sources

3 The subject of EMFs has received much attention from the renewable energy industry and Collaborative Offshore Wind Research in the Environment (COWRIE) has commissioned several reports on the subject. The first of these reports provided a review of the potential for electromagnetic fields generated by the offshore wind energy industry (CMACS, 2003; Gill et al., 2005). A second COWRIE report tested fish responses to EMFs from the sub-sea cables (Gill et al., 2009). Both reports are discussed within this chapter.

4 Additional information considered in this report includes an internal report produced by Vattenfall on the impact of EMF from submarine cables on marine organisms (Olsson and Larsson 2010) and a literature review produced by Scottish Natural Heritage (SNH) on the potential effects of electromagnetic fields on protected species (Gill et al., 2010).

13.3 Introduction to EMF Fields

5 EMFs are generated every time electricity is produced, transported or used, with all electric equipment including power cables having the potential to produce EMFs.

6 The principal source of EMFs in offshore wind farm developments are the subsea cables. There are three components to the EMFs from the Alternating Current (AC) submarine power cables considered for the proposed EOWDC (Gill *et al*., 2010). These are:

- an electric field that is contained within an insulated conductor and earthed metallic screen
- a magnetic field which radiates into the surrounding medium
- an induced electric field (iE). This can be generated by water and/or fish movement through the magnetic field. Induced iE fields have also been

shown to arise from the fluctuating magnetic fields produced by AC cables (Gill et al., 2010)

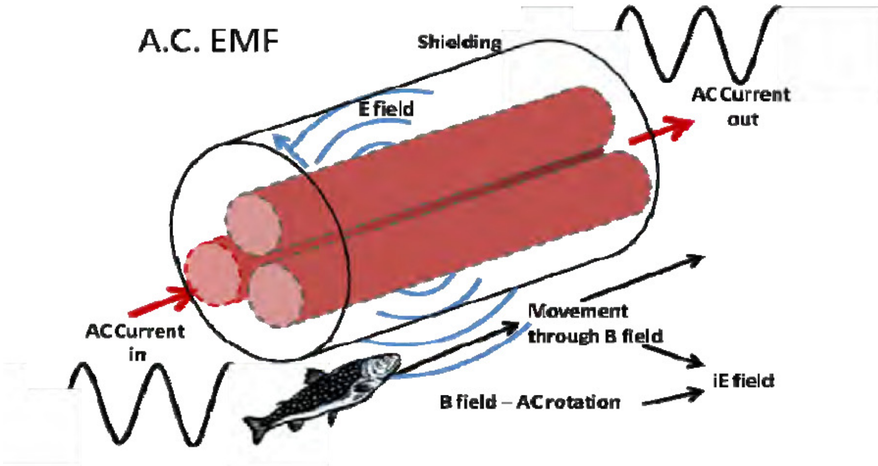

Figure 13.1 Subsea AC cable showing the three cores with the alternating current following a typical oscillating sine wave pattern through each core. (Reproduced from Gill et al., 2010)

7 Electric field strength is measured in volts per meter (V/m). The magnetic filed can be described in terms of the the B-field or the H-field. 'B' fields describe the magnetic flux density (T), whilst 'H' fields describe the magnetic field strength in amperes per metre (A/m), referenced to a particular point (Table 13.1). B fields are generally used to describe the magnetic field generated within a medium as they are more easily measured than H fields.

TABLE 13.1
Components of the electric and magnetic field

Field	**Denotation**	**Unit**	**Proportional to**
Electric	E-field	Volt / meter (V/m)	Voltage (V)
Magnetic	Flux density (B-field)	Telsa (T)	Current (I)
Magnetic	Intensity (H-field)	Ampere / meter (A/m)	Current (I)

8 The coating of electric subsea cables ensures that electric fields are contained within the cable, however magnetic fields can radiate from the cable. Whilst it is theoretically possible to contain the magnetic fields through cable burial, it is likely that burial to depths realistically achievable offshore makes no significant difference to the resultant magnetic fields or the distance over which they propagate (CMACS, 2008). The decay in the resultant magnetic fields occurs over a very short scale, at a distance of 10 m they will be undetectable.

13.4 Cable Configuration and Potential for EMFs at the Proposed EOWDC

9 The final cable design and route corridors for the proposed EOWDC have yet to be determined, however it is expected that there would be a maximum of 4 export power cables required, with a total maximum length of 26 km. The precise power requirements of the cables have yet to be established, although it is expected that they would be 33 kV AC cables.

10 The AC cables are three-phase such that there would be three separate cores each of which would be shielded by an insulation screen. As mentioned previously, the use of insulation screens confines any electric fields produced within the cable and reduces the risk of causing electric shocks.

11 There would also be inter-array cables connecting the wind turbines which would have the same power requirements as the export cables. It is expected the inter-array cabling arrangements and associated electrical infrastructure would be comparable to other existing wind farms.

12 A study employing modelling of EMFs from cables with contrasting conductor sizes and current loads at the Kentish Flats Offshore Wind Farm site was undertaken by the University of Liverpool, the results of which are applicable to the proposed EOWDC (Gill et al., 2002). Table 13.2 provides the estimated output parameters for industry standard cables buried 1.5 m in the seabed. These models predicted that the B field on both the surface of a 33 kV cable (millimetres from the source) and the seabed directly above the cable was of the order of 40 µA m-2 or 1.5 µT. Assuming the seabed has a conductivity of 1 S m-1 the resultant electric field would have a probable strength of 40 µVm-1. The electric field within the seabed was modelled to dissipate rapidly to only 1 or 2 µV m-1 within a distance of approximately 10 m from the cable.

13 The magnetic fields produced by the cables would be 1.5 µT which is the equivalent of less than 15 % of the Earth's magnetic field (ie 10 µT).

TABLE 13.1
EMF Output Parameters for Industry Standard Cables Buried 1.5 m in the Seabed (Gill *et al.*, 2002)

Conductor size (mm2)	500
Maximum voltage (kV)	33
Maximum current (A)	530
Maximum B field in seabed (µT)	1.5
Maximum B field in sea (µT)	0.03
Maximum current density in seabed above cable (µA m-2)	40
Maximum current density in sea at seabed surface (µA m-2)	10
Maximum iE field in seabed (µVm-1)	40
Maximum iE field in sea (µVm-1)	2.5
Estimated normal iE field in seabed (µV m-1)	20
Estimated normal B field in sea (µT)	0.015

14 The magnetic and induced electric fields generated by the cables are expected to naturally decay to the extent that electrical fields above 0.5 μVm^{-1} will not be detectable beyond 10 m in any direction from the cable (ie in the water column or the seabed).

15 Each cable is expected to generate similar magnetic and electric fields. Modelling of magnetic and induced electrical fields undertaken for other windfarm developments has identified that broadly comparable fields would be generated by a range of cabling scenarios. The effects of the electric and magnetic fields are expected to become additive when the separation distance between the cables is less than 10 m.

16 The export and inter-array cables would be buried. The burial of the cables increases the separation distance between the cable and any swimming

animals and thereby reduces the magnitude of potential EMF effects. The cable would need to be buried approximately 10 m to avoid the potential for any magnetic fields to be detectable on the surface, which as mentioned previously is uneconomical for an offshore cable installations.

13.5 Existing Anthropogenic Sources of EMF in the Vicinity of the Proposed EOWDC

17 A review of Kingfisher cable awareness charts, SeaZone and Admiralty chart data, shows that there are no other cables in Aberdeen Bay that may produce EMFs. Two telecommunications cables near to The Crown Estate EOWDC lease area were identified however these do not generate EMFs.

18 Gas pipelines can be heated electrically in order to minimise the potentially of hydrates forming, and this can produce EMFs. The St. Fergus gas terminal situated 35 km north of Aberdeen processes 20 % of the UK's gas supply from 8 main pipelines delivering gas from fields across the North Sea. None of the gas pipelines are known to be electrically heated and hence are not expected to act as EMF sources.

19 For the purposes of the environmental assessment of the proposed EOWDC, the effects of EMFs have been considered in isolation from any potential effects from other planned offshore wind farms in the Moray Firth or the Firth of Forth area.

13.6 Use of EMFs by Marine Biological Receptors and Potential Sensitivity of These Receptors to EMFs

20 Naturally occurring EMFs in the form of geomagnetic fields are the predominant EMF that occurs in the marine environment. In addition electric fields are also naturally emitted as a result of biochemical, physiological and/or neurological processes that can occur within an organism, these are known as bioelectric fields. Induced Electric fields can also occur as a result of the animal itself or oceanic waters interacting with the geomagnetic field.

21 A number of biological mechanisms are known by which marine organisms are able to detect an electric and/or magnetic field. Species can be broadly separated into those that are either electroreceptive and / or those that are magneotoreceptive.

22 Electroreception is believed to be closely linked to the mechanisms involved in finding prey, locating conspecifics (other individuals), finding mates and in some instance for navigation, while magnetoreception is believed to primarily be linked to navigation and homing behaviours.

23 The available information on animals detection mechanisms for EMFs is limited, however three possibilities have been proposed:

- electromagnetic induction
- magnetic field dependent chemical reactions, and
- magnetite based magnetoreception

24 Magnetite is a magnetically sensitive material that occurs within the skeletal structure of a large variety of marine organisms and is commonly considered

to have a role in the direction finding using the Earth's geomagnetic field (Kirshvink, 1997).

25 Behavioural experiments have demonstrated that diverse animals, including representatives from all five vertebrate classes, can sense the Earth's magnetic field and use it as an orientation cue (Lohman and Johnsen 2000). The list of animals that is known to possess magnetic compasses includes isopods, sea turtles, spiny lobsters, rays, eel and salmon (Lomann et al., 2008; Westerberg and Lagenfelt, 2008).

26 An unproven hypothesis that some animals possess an additional mapping sense that allows them to determine their position relative to their destination has been proposed. The use of magnetic positional information has been demonstrated in several diverse animals which suggest that such systems are widespread amongst the animal kingdom and have functional abilities across a range of scales (Lohmann, 2007).

27 Responses to induced electric (iE) fields are generally assumed to aid navigation and may either be passive or active on the part of the animal. In active navigation the organism generates its own EMF to interact with the horizontal component of the Earth's magnetic field, whereas passive detection is derived from the interaction of the tide or wind driven currents and the vertical component of the Earth's geomagnetic field (Von der Emde, 1998). Species such as eels and salmonids are able to detect voltage gradients associated with water movement through the geomagnetic field. This mechanism is not fully understood but it is believed that species can detect fields in the range of 8-25 µV/m associated with peak tidal flows.

28 Cartilaginous fish are the major group of organisms that are known to be electroreceptive, this group includes the sharks, skates and rays, collectively known as elasmobranchs. Elasmobranchs register electric fields through a series of pores in the surface skin connected to electroreceptors which enable them to detect small voltage gradients in the environment (CMACS, 2003). The paddlefish, bichirs, lungfish and catfish are also electroreceptive but are not known to be present in the developmental area. There are a number of mostly tropical species that are electrogenic in that they can actively produce electricity, an example being the electric eel.

29 In terms of other groups of marine mammals being electroreceptive, there has been no evidence of any marine mammals species or of any invertebrates using electroreception, but this could be attributed to a lack of research targeting this area as noted for the invertebrates by Bullock (1999).

30 For most magnetoreceptive or electroreceptive species there is little or no information present on how, or if, submarine AC cables affect their behaviour. To date, research has focused on effects of submarine cables on migrating eels and elasmobranchs.

31 In the UK, research has been conducted on elasmobranchs in various controlled environments. The fish are exposed to EMFs which replicate EMFs from subsea cables. Results show that the emitted EMFs may be detectable by the fish, although the response is categorised as a behavioural change that varied between species and between individuals within the same species. No conclusions as to whether the behavioural changes of the elasmobranchs are positive, negative, or have no environmental impact have been drawn (Gill *et al.*, 2009).

13.7 Potential Impact of EMFs Generated from Anthropogenic Sources

32 Any potential impacts of EMFs are restricted to the operational phase when the cables would be transporting electricity, with no impacts being anticipated during either the construction or decommissioning phases. The impacts can be summarised as follows:

- animals may confuse EMF signals with those of potential prey species and may hence waste energy hunting in areas containing prey, or be attracted to areas where they believe conspecifics are present
- repulsion of animals would result in the reduction of available habitat or disrupt the movement or migration of animals throughout Aberdeen Bay creating barrier effects to the natural movement of animals
- disruption to the navigation or orientation may arise for those species using the Earth's geomagnetic field to orientate or time behavioural movements in response to daily events such as tidal cycles. Depending on the magnitude and persistence of the magnetic field, the impact could be a relatively minor temporary change in swimming direction or a more serious impact on migration
- the potential physiological effects on marine organisms may include impacts on cellular development

13.8 Summary

33 The potential EMF generated from the proposed EOWDC submarine cables has been presented, with the marine groups sensitive to the electric and magnetic fields being identified. The detailed impact assessments of the marine species potentially sensitive to EMF has been provided in the impact assessments for Chapter 9 Marine Ecology, Intertidal Ecology, Sediment and Water Quality and Chapter 12 Marine Mammals and Chapter 22 Salmon and Sea Trout.

34 The ecological significance of EMFs is the subject of ongoing research. To date, studies have shown that there is potential for impacts on marine species, however field tests have been inconclusive and both the offshore wind industry and regulators recognise the need for improved understanding in this area.

13.9 References

Bullock, T.H. (1999). The future of research on electroreception and electro communication. The Journal of Experimental Biology, 202: 1455-1458.

CMACS (2003). A baseline assessment of electromagnetic fields generated by offshore windfarm cables. Centre for Marine and Coastal Studies, University of Liverpool. Report to Collaborative Offshore Wind Research into the Environment (COWRIE) COWRIE.

Gill, A. B., Gloyne-Phillips, I., Neal, K. J. & Kimber, J.A. (2005). The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms – a review. Report to Collaborative Offshore Wind Research into the Environment (COWRIE) COWRIE.

Gill, A. B., Huang, Y., Gloyne-Philips, I., Metcalfe, J., Quayle, V., Spencer, J. & Wearmouth, V. (2009). COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2: EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry. Report to Collaborative Offshore Wind Research into the Environment (COWRIE) COWRIE.

Gill, A. B. & Bartlett, M. (2010) Literature review on the potential effects of electromagneitc fields and subsea noise from marine renewable erngy developments on Atlantic salmon, sea trout and European eel. Scottish Natural Heritage (SNH) Commissioned Report No. 401.

Kirschvink, J. L. (1997) Magnetoreception: homing in on vertebrates, Nature, 390: 339-340.

Lohman, K.J & Johnsen, S., (2000). The neurobiology of magnetorecpetion in vertebrate animals, TINS Vol. 23, No. 4, 2000

Lohmann, K.J., Lohmann C.M.F., Putman, N.F., (2007). Magnetic maps in animals: nature's GPS. The Journal of Experimental Biology 210: 3697-3705.

Lohmann, K.J., Lohmann C.M.F., Endres, C.S., (2008). The sensory ecology of ocean navigation. The Journal of Experimental Biology, 211: 1719-1728.

Olsson, T & Larsson (2010) A. Impact of Electric and Magnetic Fields From Submarine Cables on Marine Organisms. Vattenfall Research and Development Peter Bergsten & Johan Nissen, Vattenfall Power Consultants

Von der Emde, G. (1998). Electroreception. The Physiology of Fishes pp 313-343. CRC press.

Westerberg, H. & Langenfelt, I. (2008). Sub-sea power cables and the migration behaviour of the European eel. Fisheries Management and Ecology, 15: 369-375.