Neart na Gaoithe Offshore Wind Development

HVAC EMF STUDIES

- V1.1
- 11 March 2013

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Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
1.0	01/03/2013	CJ Jones	CJ Jones	01/03/2013	Final
1.1	11/03/2013	CJ Jones	CJ Jones	11/03/2013	Comment added on cable sheath bonding

Distribution of copies

Revision	Copy no	Quantity	Issued to
1.0	1	1 - Electronic	Pedro Cendoya Alvarez - Mainstream
1.1	1	1 - Electronic	Pedro Cendoya Alvarez - Mainstream

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Name of organisation:	Mainstream Renewable Power
Name of project:	Neart na Gaoithe Offshore Wind Development
Name of document:	HVAC EMF Studies
Document version:	V1.1
Project number:	VP01287

1. Executive Summary

SKM have calculated the maximum Electromagnetic Field (EMF) densities associated with sections of the Neart na Gaoithe offshore wind development. These can be compared to the reference level provided by the International Commission on Non Ionising Radiation Protection (ICNIRP) of 100 μT. Calculations have been made for a number of proposed cable arrangements. The study covers the following connections:

- Offshore 33 kV Inter-array cable
- Offshore 220 kV HVAC cable connection from the offshore HVAC transformer platform to the shore
- The Inter-tidal/sea defence section of the HVAC cable

Table 1 - Summary of Maximum Calculated EMFs

Connection	Number of Circuits	Capacity per Circuit (MW)	Voltage	Maximum EMF Density
Inter-array	1	30	33 kV	**3.3 μT**
Offshore HVAC	2	225	220 kV	**8.0 μT**
Inter-tidal/Sea Defence	2	225	220 kV	**8.6 μT**

It can be seen from the summary of results in Table 1 above that the maximum calculated EMF is considerably below the 100 μT reference level in all cases.

2. Scope of Report

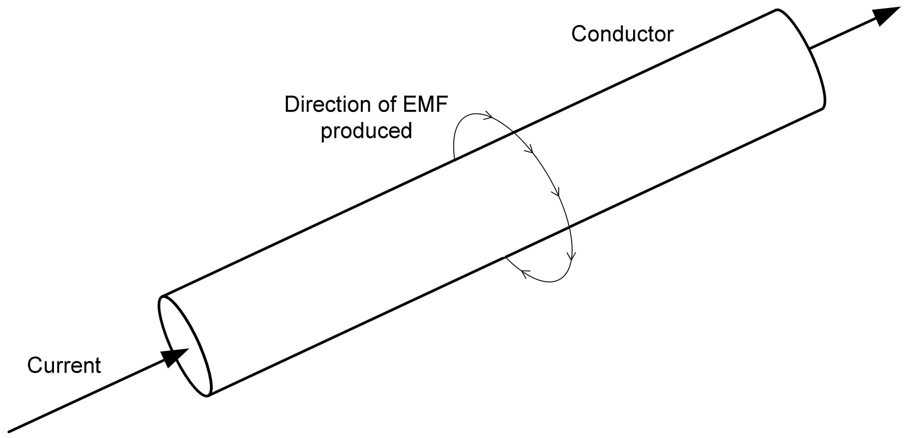
Mainstream has been awarded a licence by The Crown Estate to develop approximately 450MW of wind capacity off the coast of Fife. As part of the initial design process Mainstream has requested SKM to study the Electromagnetic Field (EMF) densities produced by each of the cable connection arrangements that are being considered for the development zone. This report covers the following arrangements associated with the HVAC connection design:

- Offshore 33 kV Inter-array cable
- Offshore 220 kV HVAC export cable connection from the offshore HVAC transformer platform to the shore
- The Inter-tidal/sea defence section of the HVAC export cable

Calculations of the maximum expected EMFs in the vicinity of the cable trench have been made which include the combined effect of the export cables operating in parallel.

3. Sources of EMF

When a current passes through a conductor a magnetic field is produced around the conductor. The direction of the field depends on the direction of current flow in the conductor as shown below in Figure 1.



- **Figure 1 - EMF Produced by Current in Conductor**

With an AC current source the density and direction of the field will vary with the current. The density of the magnetic field is proportional to the current flowing through the conductor and the distance between the conductor and point of measurement. The magnitude of the field density is calculated using the Biot-Savart law, from which the following equation can be derived:

$$B = \frac{\mu_0 \times I}{2 \times \pi x R}$$

- **Equation 1 - Electromagnetic field density**

Where:
B = Electromagnetic flux density (T)
μ_0 = Permeability of free space = 4 x π x 10^{-7}
I = Current through conductor (A)
R = Distance from centre of Conductor (m)

Each conductor in the cable group will therefore produce an EMF which has a magnitude proportional to the current flowing through it and a direction which depends on the direction of the current. At any given point the total EMF can be calculated as the resultant of the vector quantities of the EMFs produced by each conductor at that point (i.e. fields in opposing directions will cancel, fields in the same direction will add). The physical arrangement of the cables in the trench therefore affects the densities and directions of the fields produced at a given point on the surface.

Other power cables and which may exist in the area may also interact with the EMF produced from the Neart na Gaoithe cables if they are in close proximity. The full details of these cables and (if any exist) are not known in detail and have not been considered in the calculations at this stage.

4. Cable Configuration

The detailed layout of the cables within the cable corridors as provided by Mainstream is shown for each arrangement considered, along with the calculated results in section 6. Some general assumptions which apply to all arrangements are detailed below.

4.1. Sheath Bonding

When a cable sheath is bonded to the earth grid at both termination ends, an A.C. current flowing through the conductor will induce a circulating current in the cable sheath. This current will flow in the opposite direction to the current in the conductor. This will therefore produce an EMF in the opposite direction to the EMF produced by the conductor, reducing the resultant EMF of the cable. If the sheath is bonded at one end only (or cross-bonded) then the circulating current does not occur and no reduction occurs, however excessive sheath voltages can occur.

The sheath bonding arrangements depend on a number of factors and the length of the cable is often the main factor. For the purposes of this study it has been assumed that the HVAC cables are not bonded at both ends, therefore no reduction in EMF occurs due to circulating currents. This is a worst case assumption as the length of this cable is likely to require bonding at both ends to manage standing sheath voltages which can occur. Indeed it is understood that it is the intention on the Neart na Gaoithe project is for the cable sheaths to be bonded at both ends, thus confirming the report is based on an unlikely worst case scenario.

5. EMF Limits (ICNIRP Guidelines)

The International Commission on Non Ionising Radiation Protection (ICNIRP) published exposure guidelines in 1998 to reduce any risk to health. These exposure limits have been adopted by the European Union (EU) through Council Directive 2004/40/EC. In March 2004 the Health Protection Agency recommended that the UK should adopt the Guidelines drawn up by the ICNIRP. The reference level set for the public is **100 μT** for alternating (AC) magnetic fields.

The Department of Energy and Climate Change (DECC) has published[1] a voluntary Code of Practice document detailing the recommended approach for demonstrating compliance with EMF exposure guidelines. The DECC guidelines implement the ICNIRP guidance for AC fields under the terms of the EU Recommendation in the UK context and sets a public exposure limit for unperturbed fields of **360 μT** for alternating (AC) magnetic fields

[1] http://www.decc.gov.uk/assets/decc/What%20we%20do/UK%20energy%20supply/Development%20consents%20and%20planning%20reform/1256-code-practice-emf-public-exp-guidelines.pdf

6. Calculations and Results

Calculations of the expected maximum magnetic field densities have been carried out for the various arrangements associated with the two connections as described in section 1. In each case the EMF density profile is plotted to a distance of 15m either side of the cable corridor.

The current in each conductor is based on the expected current at the peak rating of the wind farm.

EMF densities have been calculated at ground level (seabed). As distance above the seabed increases, the resultant EMF density will reduce.

6.1. Inter-array cabling

The inter-array cabling is assumed to have the following parameters:

- Nominal voltage – 33 kV
- Core Arrangement –1 x 3 Phase Cable
- Cable outer diameter – approx 157 mm
- Conductor cross sectional area – 500 mm^2
- Minimum burial depth – 1 m

The maximum power carried by a section of inter-array cabling is expected to be 30 MW which results in a maximum loading of 584 A_{rms} (assuming 0.9 power factor).

The arrangement of the cable is shown below in Figure 2.

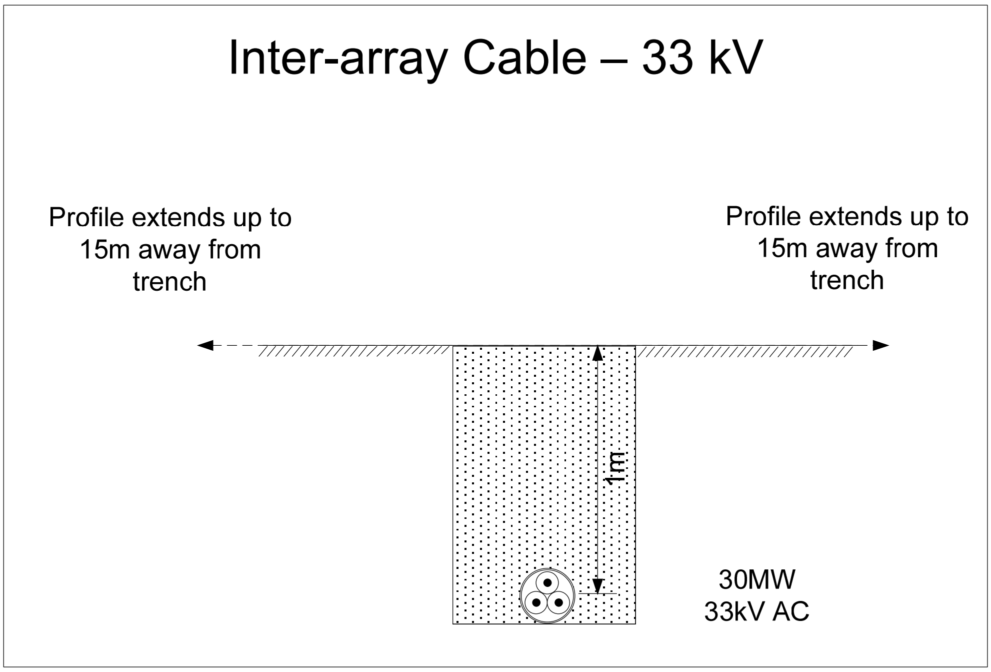
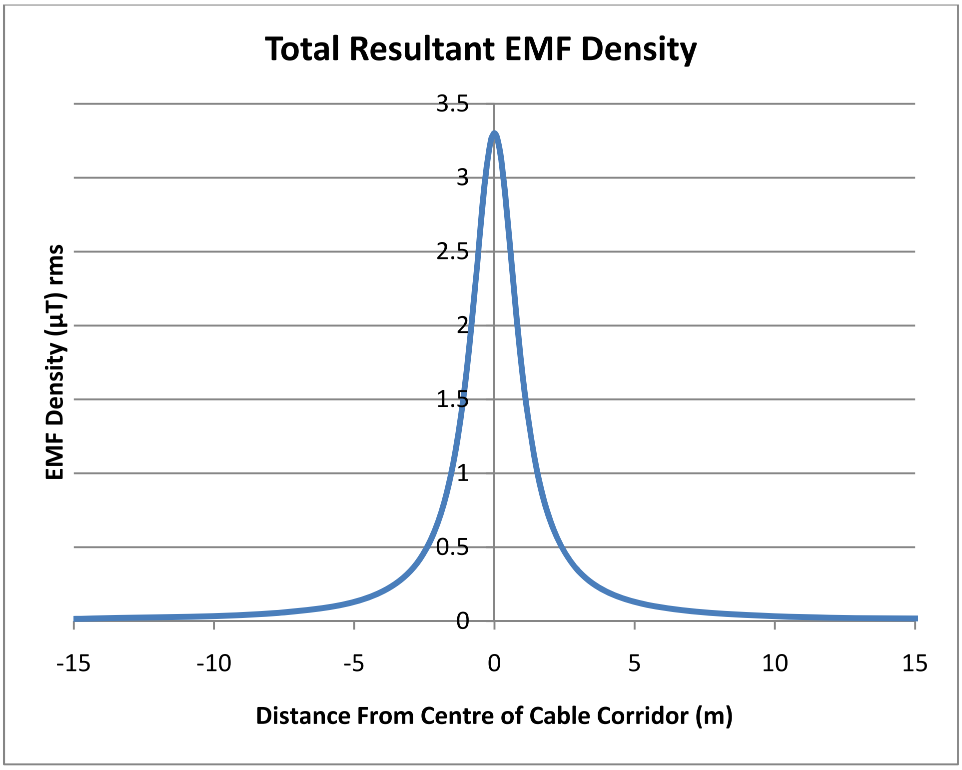


Figure 2 – 33 kV Inter-array Cable Arrangement

The cable will be a three-phase design which will significantly reduce the resultant EMF from each circuit compared to 3 x single core cables. The separation between the cores in each cable will depend on the diameter of the each of the cores (including insulation). This will depend on the specific design of the cable manufacturer. For the purposes of this study a 34mm diameter has been assumed which is likely to be the largest potential diameter and therefore represents the worst case scenario for bundled cables.

Figure 3 below shows the EMF densities across the profile studied.



- **Figure 3 - EMF Density due to 1 x 33 kV Inter-array Cable**

Table 2 below summarises the EMF densities calculated in this configuration.

- **Table 2 - Results Summary for 1 x 33 kV Inter-array Cable Arrangement**

	EMF Densities (µT) at Distance from Centre Line of cable				
	0m (Centre)	1.0 m	5.0 m	10.0 m	15.0 m
33 kV Inter-array	3.30	1.67	0.13	0.03	0.01

The maximum calculated EMF density is **3.30 µT** which occurs directly above the centre of the cable.

6.2. Offshore HVAC Export Cable

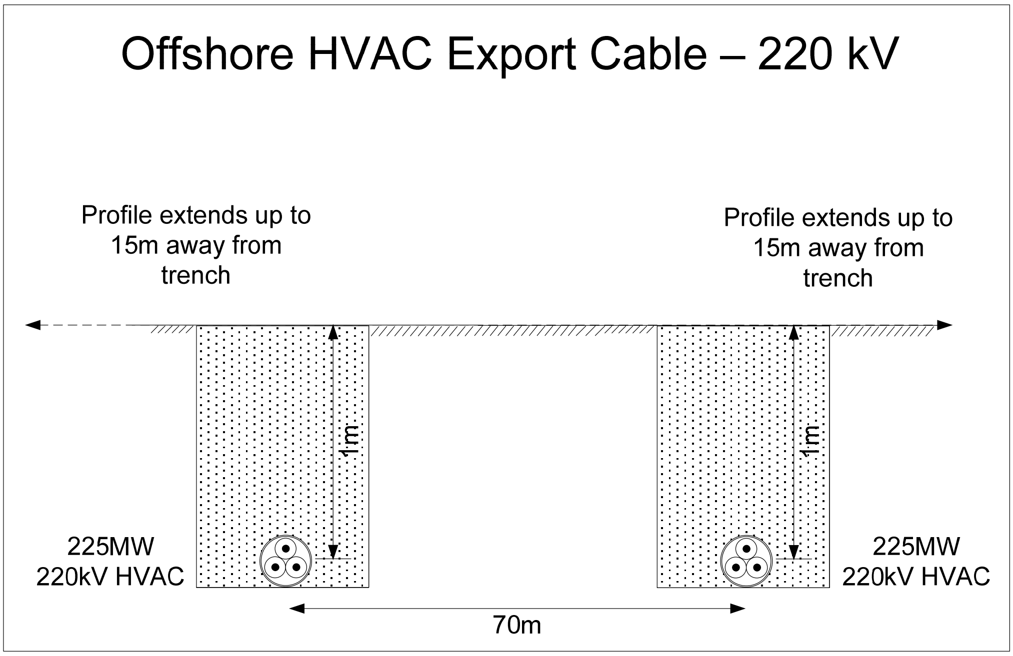
The offshore HVAC cabling used to connect the offshore platform to the joint of the intertidal/sea defence is assumed to have the following parameters:

- Nominal voltage – 220 kV
- Core Arrangement –1 x 3 Phase Cable

- Cable outer diameter – approx 234mm
- Conductor cross sectional area – 800mm^2
- Minimum burial depth – 1m
- Minimum spacing between adjacent circuit – 70m

Two cables are used for the 450 MW connection and therefore the maximum power carried by a section of HVAC export cabling is expected to be 225MW which results in a maximum loading of 657 A_{rms} (assuming 0.9 power factor).

The arrangement of the cable is shown below in Figure 4.



- **Figure 4 – 220 kV Offshore HVAC Export Cable Arrangements**

Figure 5 below shows the EMF densities across the profile studied.

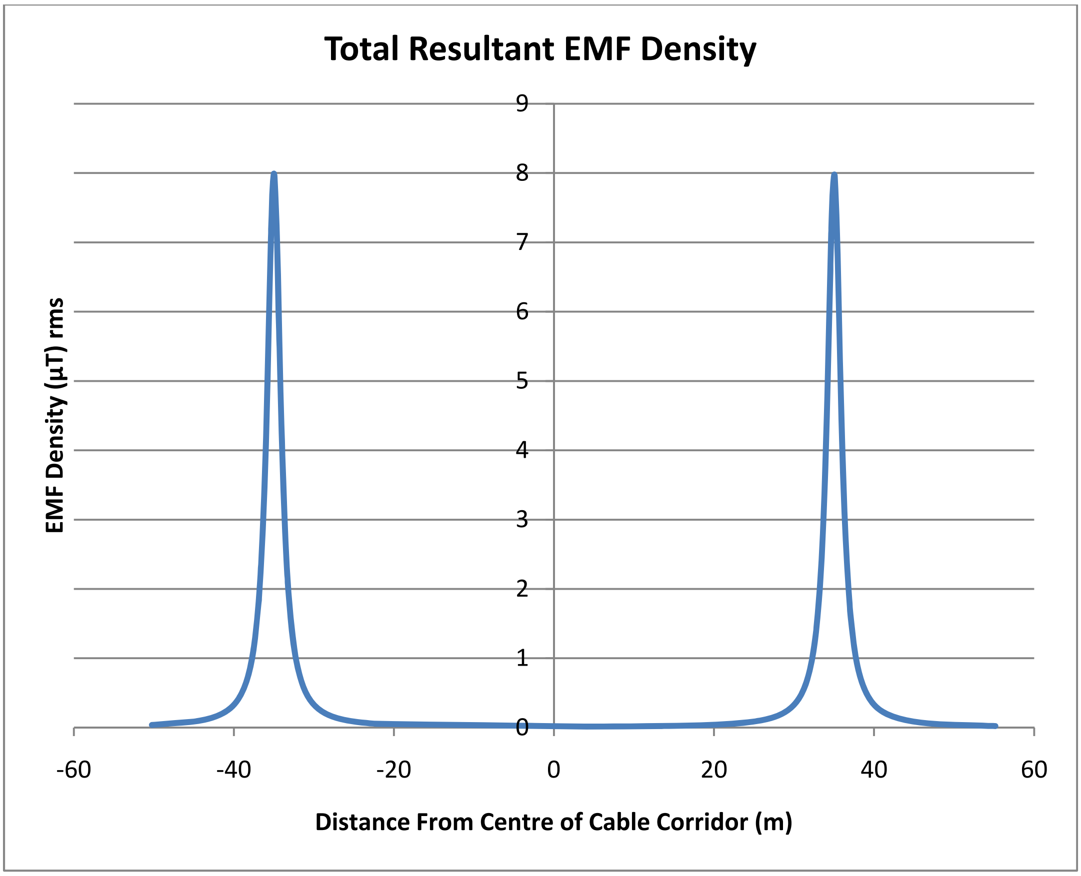


Figure 5 - EMF Density due to 2 x 220 kV HVAC Export Cable

Table 3 below summarises the EMF densities calculated in this configuration.

Table 3 Results Summary for 2 x 220 kV HVAC Offshore Export Cable Circuit Arrangement

	EMF Densities (µT) at Distance from Centre Line of each cable					
	Midpoint of two circuits	0.0 m	1.0 m	5.0 m	10.0 m	15.0 m
220 kV HVAC Cable	0.01	7.99	4.13	0.33	0.09	0.04

The maximum calculated EMF density is **7.99 µT** which occurs above the centre of each circuit.

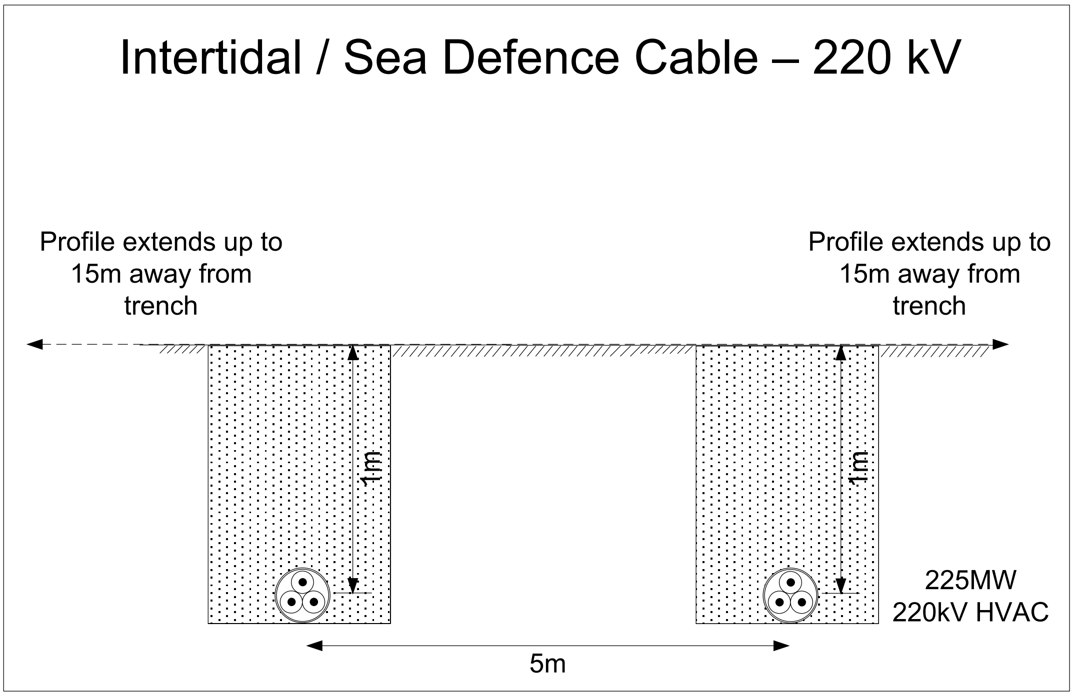
6.3. Intertidal/Sea Defence Cable

The HVAC cabling used in the intertidal area and beneath the sea defence is assumed to have the following parameters:

- Nominal voltage – 220 kV
- Core Arrangement –1 x 3 Phase Cable
- Cable outer diameter – approx 280 mm
- Conductor cross sectional area – 1000 mm^2
- Minimum burial depth – 1 m
- Minimum spacing between adjacent circuit – 5 m

Two cables are used for the 450 MW connection and therefore the maximum power carried by a section of HVAC export cabling is expected to be 225 MW which results in a maximum loading of 657 A_{rms} (assuming 0.9 power factor).

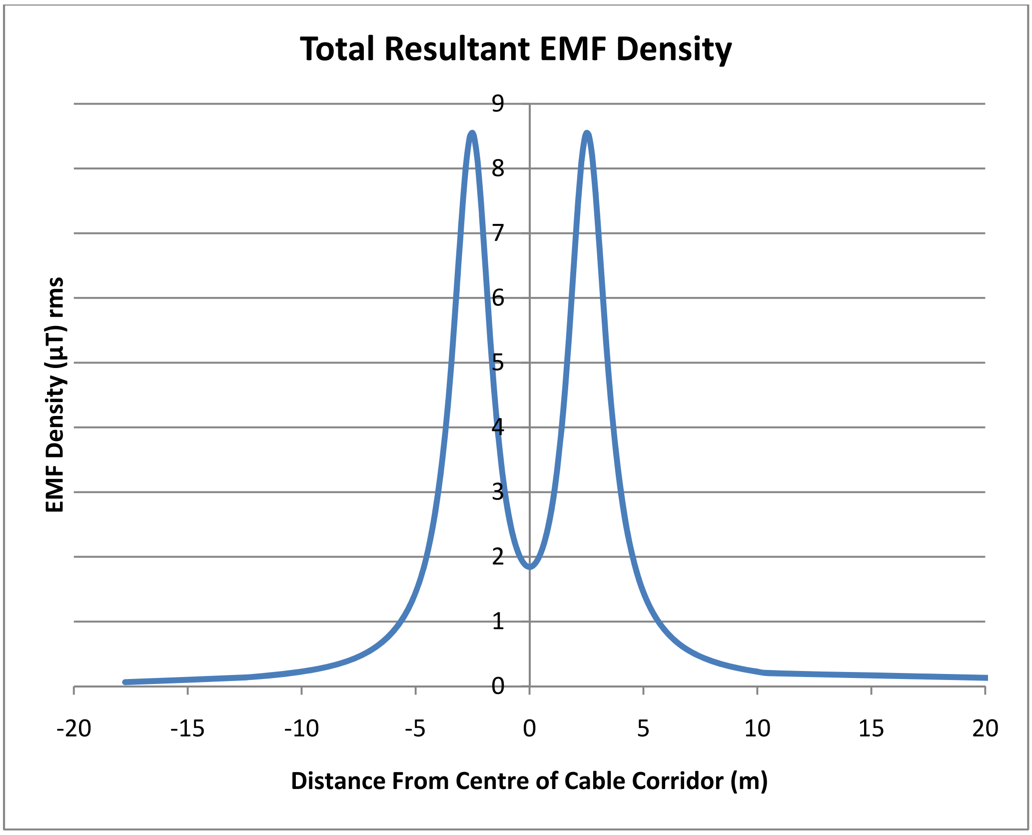
The arrangement of the cable is shown below in Figure 6.



- **Figure 6 - 220 kV Intertidal/Sea Defence HVAC Cable Arrangements**

The arrangement shown above assumes that an open cut trenching technique is used to install the cable beneath the sea defence. It is recognised that a Horizontal Directional Drilling (HDD) technique may be employed. For an HDD solution this would result in a deeper burial depth and therefore produce EMF densities lower than those calculated for the open-cut trenching method studied.

Figure 7 below shows the EMF densities across the profile studied.



- **Figure 7 - EMF Density due to 2 x 220 kV Intertidal/sea Defence HVAC Cable**

Table 4 below summarises the EMF densities calculated in this configuration.

- **Table 4 Results Summary for 2 x 220 kV Intertidal/sea Defence HVAC Circuit Arrangement**

	EMF Densities (µT) at Distance from Centre Line of each cable					
	Midpoint of two circuits	0.0 m	1.0 m	5.0 m	10.0 m	15.0 m
220 kV HVAC Cable	1.85	8.55	4.69	0.46	0.14	0.07

The maximum calculated EMF density is **8.55 µT** which occurs above the centre of each circuit.

7. Conclusions

The report determines the maximum EMF densities that will be produced by the offshore cable sections of the connection of the 450 MW Neart na Gaoithe offshore wind development. Results have been obtained for the inter-array cable sections, the offshore HVAC connection and the HVAC Intertidal/sea defence sections of the circuit.

The inter-array cables are manufactured as single 3 core cables with the cores arranged in a trefoil formation which minimises the resultant EMF density produced. The maximum EMF density has been calculated as 3.3 µT as shown in section 6.1.

The offshore HVAC cables (i.e. from the offshore substation to the intertidal area) have a minimum of 70 m spacing between adjacent circuits. This distance is sufficient to ensure that any interaction between circuits is negligible as shown in Figure 5. The separate cores of each circuit will be close together due to the cable construction and in a trefoil arrangement which minimises the resultant EMF density. From the results presented in section 6.2 it can be seen that the maximum calculated EMF density produced by the cables is 7.99 μT.

The HVAC cables connecting used at the intertidal/sea defence area are constructed similarly to those used for the offshore HVAC connection. As the separation between the circuits is much smaller, some interaction occurs between the EMF produced by each of the cables. However, the maximum expected EMF density has been calculated as 8.55 μT as shown in section 6.3.

Whilst there is no specific EMF limit offshore it can be seen that the EMF densities produced are below the 100 μT reference level for constant exposure of humans. Effects of EMF on the marine ecological environment are less clear and subject to ongoing research.

All of the above EMF densities are the maximum values produced by the connection. In practice a number of factors will reduce the EMF densities experienced:

- These maximum values are based on the connections being 100% loaded (i.e. maximum current). On average it is expected they will be loaded to approximately 50% which gives average EMF densities of 50% of those provided in the report
- These maximum values occur within the cable corridor. The EMF density reduces significantly as distance from the cable corridor increases.
- These are based on minimum burial depth. Where the cable is buried deeper, the EMF density is reduced at the surface.