nationalgrid

ELECTRIC AND MAGNETIC FIELD REPORT

May 2021

ELECTRIC AND MAGNETIC FIELDS

1 INTRODUCTION

1.1.1 This report provides an assessment of the electric and magnetic fields (EMFs) associated with the DWNO Project. This Project involves uprating the existing XX and XR overhead line routes from 275 kiloVolts (KV) to 400 kV, in part or fully. As well as the increase in voltage, the conductors on each route will be replaced, which can impact the EMFs produce. Each design option which forms the DWNO Project will be assessed individually.

1.1.2 All equipment that generates, distributes or uses electricity produces EMFs. The UK power frequency is 50 Hz, which is therefore the principal frequency of the EMFs produced which are also known as Extremely Low Frequency (ELF) EMFs.

1.2 Electric fields

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

1.3 Magnetic fields

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

1.3.2 Magnetic fields are found in all areas where electricity is in use (e.g. offices and homes), arising from electric cabling and equipment in the area, typically ranging between 0.01 – 0.2 μT[1].

2 POLICY, LEGISLATION AND GUIDANCE

2.1.1 In the absence of any specific Scottish Government guidelines, those set by the UK Government remain applicable for this project.

2.1.2 This report provides an assessment and conclusions of the compliance of EMF produced by the Project with the requirements of National Policy Statement (NPS) EN-5, which reiterates the UK Governments policy on EMF. All relevant policies and guidance, such as those contained within the National Policy Statements EN-1[2] and EN-5[3] have been reviewed and applied to this assessment. These policies, guidance and legislation are explained and documented below.

2.1.3 Although this project is to uprate and reconductor existing overhead lines, the principles of compliance have been followed in the same way as a new overhead line proposal.

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

2.1.5 Whilst there are no statutory regulations in the UK that limit the exposure of people to power-frequency EMF, responsibility for implementing appropriate measures for the protection of the public lies with the UK Government. In 2004, the Government adopted guidelines published in 1998 by the

[1] Swanson, J. & Renew, D.C., (1994) *Power-frequency fields and people*, Engineering Science and Education Journal, pg 71-79

[2] Department of Energy and Climate Change (2025) *Overarching National Policy Statement (NPS) for Energy* (EN-1)

[3] Department of Energy and Climate Change (2025) *National Policy Statement for Electricity Network Infrastructure* (EN-5)

International Commission on Non-Ionizing Radiation Protection (ICNIRP)[4] in line with the terms of the 1999 EU recommendation[5] on public exposure to EMFs. National Policy Statement EN-5[3] documents this policy. Table 2.2 below summarises the relevant ICNIRP 1998 values for power frequencies.

Table 2.2 – Exposure Limits For Power-Frequency EMF

Public Exposure Limits	Electric Fields	Magnetic Fields
Basic restriction (induced current density in central nervous system)	$2mA/m^2$	
Reference level (external unperturbed field)	5kV/m	100μT
Field corresponding to the basic restriction (external unperturbed field)	9kV/m	360μT

2.1.6 The EMF guidelines documented in NPS EN-5[3] and their application are explained in the Code of Practice, 'Power Lines: Demonstrating compliance with EMF public exposure guidelines – a voluntary Code of Practice'[6] published by the Department of Energy and Climate Change (DECC). It is the electricity industry's policy to comply with Government guidelines on EMF, and this Code of Practice forms an integral part of this policy.

2.1.7 There is also a second Code of Practice, 'Optimum Phasing of high voltage double-circuit Power Lines'[7], which sets out the principles for optimum phasing of overhead lines. This details the Government supported precautionary measures recommended by the Stakeholder Advisory Group on extremely low frequency electric and magnetic fields (ELF EMFs) (SAGE) in its First Interim Assessment[8].

2.1.8 This assessment has been performed in line with the principles of both Codes of Practice[6,7].

2.1.9 There has been extensive research in an attempt to establish whether or not long term exposure to fields at lower levels than the ICNIRP guidelines[4] might be a cause of ill health in humans; this research has been extensively reviewed by bodies such as UK Health Security Agency (UKHSA; formally the Health Protection Agency)[9] and the World Health Organization (WHO)[10]. There is some evidence to suggest that high magnetic fields may be associated with an increased risk of one particular disease, childhood leukaemia. However, the weight of scientific evidence is against electric and magnetic fields causing ill health in humans at levels below the ICNIRP guideline limits[4]. The

[4] International Commission on Non Ionising Radiation Protection (1998) *Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields*, Health Physics

[5] EU Council (1999) *Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)* (1999/519/EC)

[6] Department of Energy and Climate Change (2012) *Power Lines: Demonstrating compliance with EMF public exposure guidelines. A voluntary Code of Practice*

[7] Department of Energy and Climate Change (2012) *Optimum Phasing of high voltage double-circuit Power Lines. A voluntary Code of Practice*

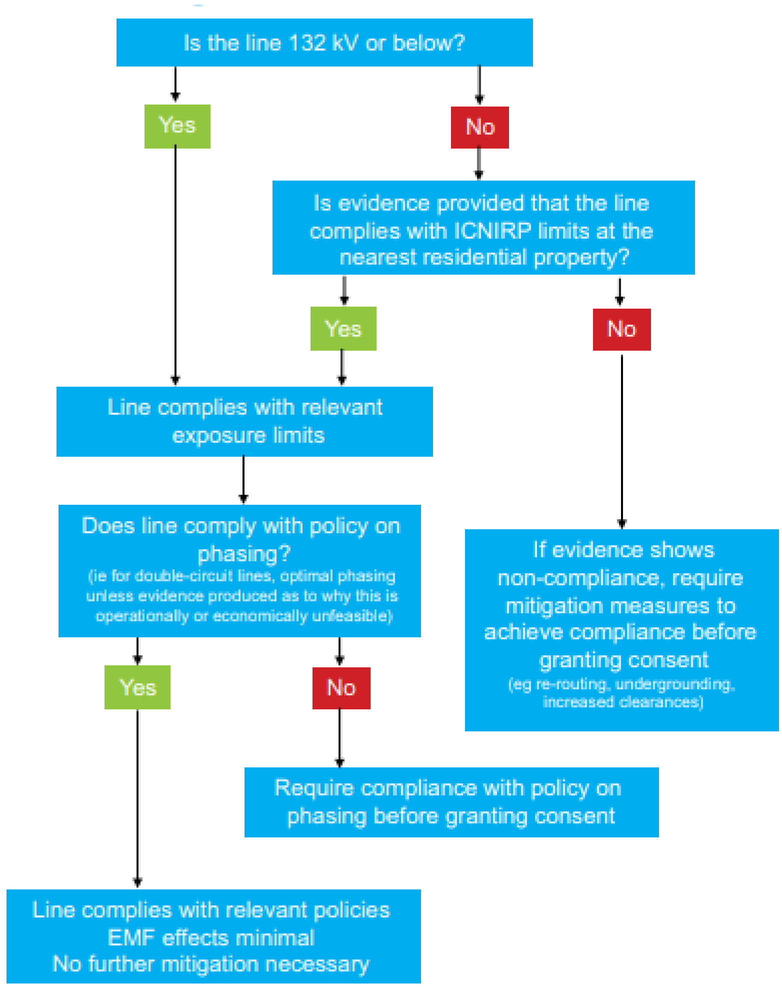
[8] SAGE First Interim Assessment http://www.emfs.info/NR/rdonlyres/39CDF32F-4E2E-AD30 - A2B0006B8ED5/0/SAGEfirstinterimassessment.pdf

[9] National Radiological Protection Board (NRPB) (2004). *Review of the scientific evidence for limiting exposure to electromagnetic fields (0-300 GHz)*. Doc NRPB, 15(3), 1-215

[10] World Health Organisation (2007) *Environmental Health Criteria Monograph No 238 on Extremely Low Frequency Fields*

Government has addressed this uncertainty by adopting precautionary measures, set out in the Code of Practice - Optimum Phasing of high voltage double-circuit Power Lines[7], which the electricity industry follows.

Figure 2.1: Simplified Route Map for Dealing with EMFs Reproduced from National Policy Statement EN-5 (Pg. 23)



2.2 Occupational Exposure Limits

2.2.1 Occupational exposures to EMFs in England, Wales and Scotland are controlled by the Control of Electromagnetic Fields at Work Regulations 2016[11] (Herein called 'The Regulations'), which implement a 2013 EU Directive[12]. For power frequencies, these are based on a more recent ICNIRP

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[11] Statutory Instrument, 2016 No. 588, Health and Safety, The Control of Electromagnetic Fields at Work Regulations 2016

[12] Directive 2013/35/EU of the European Parliament and of the Council of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC

publication, ICNIRP 2010[13] rather than the ICNIRP 1998[4] that is the basis for the public exposure limits.

2.2.2 The Regulations are based on limiting the same underlying physical quantity, the current induced in the body by external exposure to EMFs, as for public exposure, but the quantity is expressed in a different way, as the induced field rather than the induced current density, and different values are given for the head and for the rest of the body. This makes direct comparison between the occupational and public limits difficult, but the occupational limits are always higher than the public limits, typically by factors of two or more. Therefore, where the fields are compliant with the public limits, any occupational activities would also be compliant with the relevant occupational limits.

2.2.3 Employers have a duty of care to their employees. Employers discharge that duty of care in relation to EMFs primarily by complying with the relevant exposure limits. As noted above, occupational exposure limits are higher than the public exposure limits which the overhead line would be compliant with in all areas accessible to the public and to employees of third parties. Therefore, all exposures from the overhead line would be compliant with the occupational exposure limits and employers need take no additional action specific to the Project in order to comply (The Regulations impose certain general duties on all employers which would apply regardless of the Project).

[13] International Commission on Non Ionising Radiation Protection. ICNIRP Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (1 Hz-100 kHz), Health Physics. 2010, 99(6): p.818

3 METHOD

3.1 Baseline Environment

3.1.1 The existing overhead line operates at 275kV and there will be other existing electrical assets collocated throughout the route. All equipment that generates, distributes or uses electricity produces EMFs. The UK power frequency is 50 Hz which is the principal frequency of the EMFs produced.

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

3.1.3 In UK homes that are not close to high-voltage overhead lines or underground cables, the average "background" power-frequency magnetic field (the field existing over the whole volume of the house) ranges typically from 0.01 – 0.2 μT with an average of approximately 0.05 μT, normally arising from currents in the low voltage distribution circuits that supply electricity to homes[1]. The highest magnetic fields to which most people are exposed arise close to domestic appliances that incorporate motors and transformers. For example, close to the surface, fields can be 2000 μT for electric razors and hair dryers, 800 μT for vacuum cleaners, and 50 μT for some TVs and washing machines. The electric field in most homes is in the range 1-20 V/m, rising to a few hundred V/m close to appliances[14].

3.1.4 Electric and magnetic fields have been assessed as per the conditions set out in the Code of Practice[6] and compared with UK Government exposure guideline levels to ensure the proposed modifications continue to comply with these requirements. This assessment is a desk-based exercise using validated electric and magnetic field calculation software.

3.2 EMF Calculation methodology

3.2.1 EMFs have been assessed as per the conditions set out in the Code of Practice on Compliance and compared with UK Government exposure guideline limits. This assessment is a desk-based exercise using electric and magnetic field calculation software including industry standard modelling package EFC-400.

3.2.2 The Code of Practice states that calculations should be performed at the maximum continuous rating of the conductors. minimum conductor clearance, nominal voltage, 50 Hz only and at 1m above ground, which has been used for this assessment. The calculations for the proposed overhead line modifications were thus performed using worst case conditions including minimum conductor clearances for overhead lines. The circuits are unlikely to operate at this maximum rating routinely, therefore resulting in lower typical magnetic fields on a day-to-day basis.

3.3 Assessment of Effects

3.3.1 The proposed overhead line modifications would be assessed as having a significant effect if non-compliance with the EMF exposure limits was demonstrated, using the principles set out in Codes of Practice 'Power Lines: Demonstrating compliance with EMF public exposure guidelines6. Conversely, as specified in NPS EN-5[3], if the proposed overhead line modifications comply with the exposure limits and with the policy on phasing[7], EMF effects are assessed as not significant and no mitigation is necessary.

3.3.2 The UK Government's adopted guidelines are those of ICNIRP 19984, which are based on the avoidance of known adverse effects of exposure to EMFs at frequencies up to 300 GHz, which includes the 50 Hz EMFs associated with electricity transmission. These guidelines equate to a public exposure limit for uniform electric and magnetic field exposure of 9.0 kV/m and 360 μT respectively[6]. They apply particularly to residential properties.

[14] *J. Swanson & D.C. Renew, Power-frequency fields and people, Engineering Science and Education Journal, 1994, p 71*

4 ASSESSMENT OF EMF EXPOSURE AGAINST GOVERNMENT POLICY

4.1 Operational Effects

4.1.1 Energised high voltage overhead transmission lines are a source of both electric and magnetic fields. The electric field generated by an overhead line is mainly dependent on the voltage of the line and remains more or less constant once the overhead line is operational. The magnetic field will vary depending on the current flowing in the conductors. The EMFs produced by an overhead line will be highest directly under the line and will rapidly decrease at increasing distance from the line. The overhead line design influences the EMFs produced and therefore the changes to the overhead line route options have been assessed separately.

4.1.2 Both the XX and XR routes are double circuit overhead lines, with one circuit on each side of the tower. There are two uprating scenarios being considered: both circuits operating at 400 kV or one circuit will operate at 400 kV and the other at 275 kV. Each voltage uprating option also has different conductor options. Each of the potential scenarios are detailed in Table 4.1.

Table 4.1: Uprating design options for the DWNO project assessed

	Design	Circuit 1	Circuit 2
Option 1	**Voltage**	400 kV	275 kV
	Conductor bundle	Twin Drake	Twin Drake
	Pre-fault continuous rating	3370A	3370A
Option 2	**Voltage**	400 kV	275 kV
	Conductor bundle	Twin Gap	Twin Gap
	Pre-fault continuous rating	3760A	3760A
Option 3	**Voltage**	400 kV	400 kV
	Conductor bundle	Twin Drake	Twin Drake
	Pre-fault continuous rating	3370A	3370A
Option 4	**Voltage**	400 kV	400 kV
	Conductor bundle	Twin Gap	Twin Gap
	Pre-fault continuous rating	3760A	3760A

4.1.3 Magnetic fields result from the current flowing in the conductor. The circuit rating for Drake conductors operating at 275 and 400 kV is the same, and this is also the case for Gap conductor, as shown in Table 4.1. Therefore, magnetic field calculations only need to be carried out for the two different conductor bundles considered, as they will be the same irrespective of operating voltage.

4.1.4 Electric fields result from the voltage, but the diameter of the conductor is also important. As this varies throughout the options so each option was modelled.

4.1.5 Both the XX and XR routes are constructed of L8 towers and the minimum conductor design clearance to ground is 7.6m. Calculations were performed at the nominal voltage of each circuit and the pre-fault continuous ratings included in Table 4.1 at 1m above ground. All calculations were performed in accordance with the conditions set out in the codes of practice.

Figure 4.1: Calculated maximum magnetic fields from XX and XR Overhead Line routes operating at 400/400 kV and 400/275 kV with Drake conductor system. These represent Options 1 and 3 in Table 4.1 which gives the electrical parameters and design information.

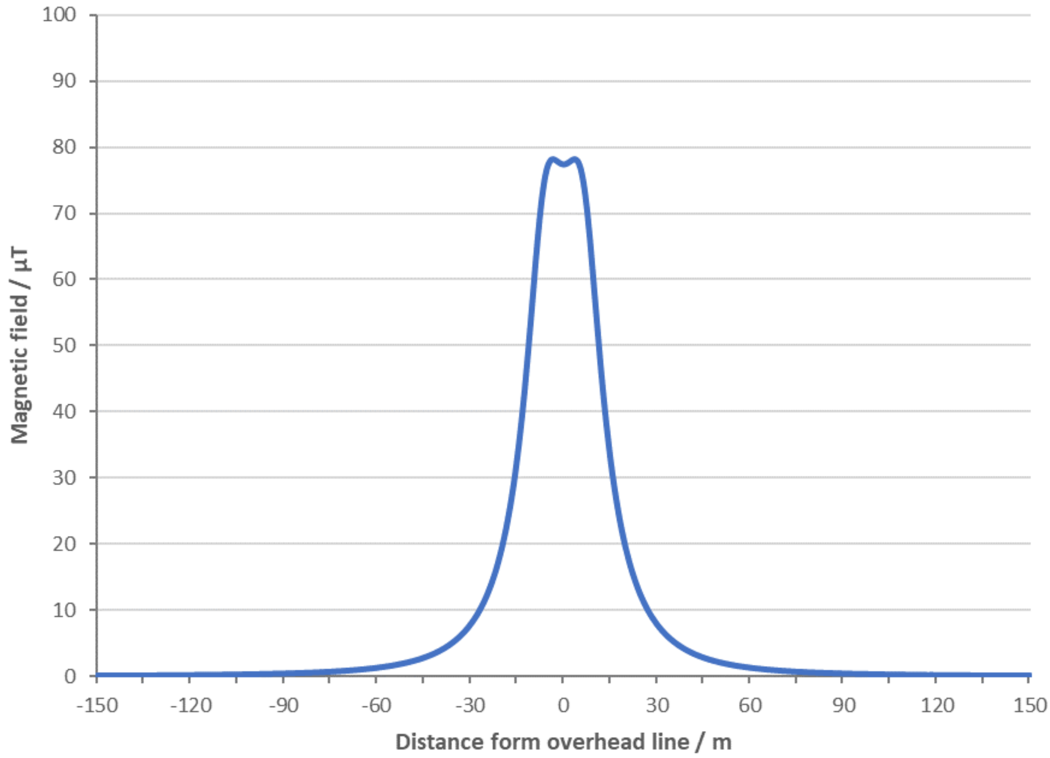


Figure 4.2: Calculated maximum magnetic fields from XX and XR Overhead Line routes operating at 400/400 kV and 400/275 kV with Gap conductor system. These represent Options 2 and 4 in Table 4.1 which gives the electrical parameters and design information.

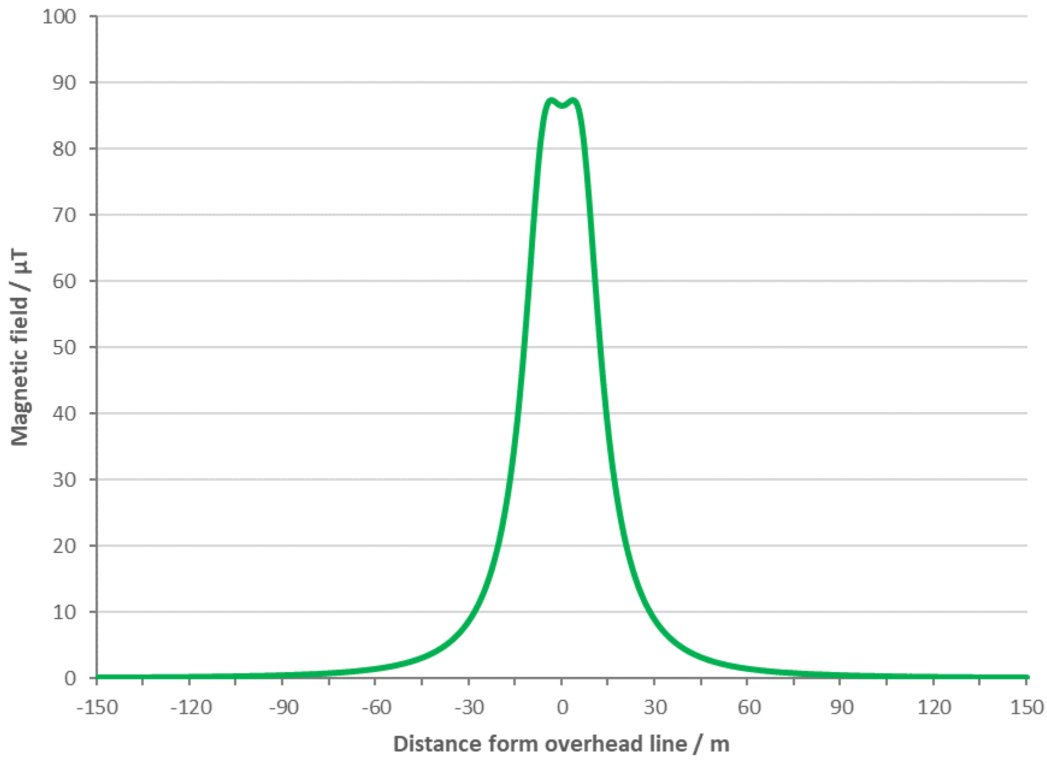


Figure 4.3: Calculated maximum electric fields from XX and XR Overhead Line routes operating at 400/275 kV with Drake conductor system. This represents Options 1 in Table 4.1 which gives the electrical parameters and design information.

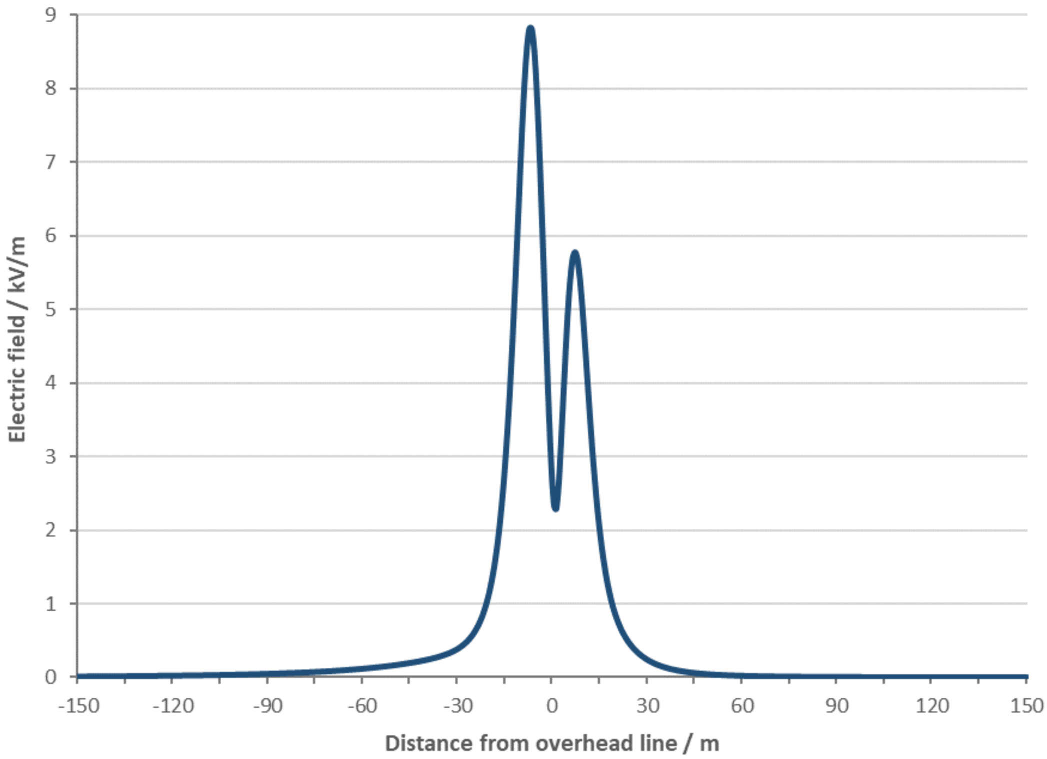


Figure 4.4: Calculated maximum electric fields from XX and XR Overhead Line routes operating at 400/275 kV with Gap conductor system. This represents Options 2 in Table 4.1 which gives the electrical parameters and design information.

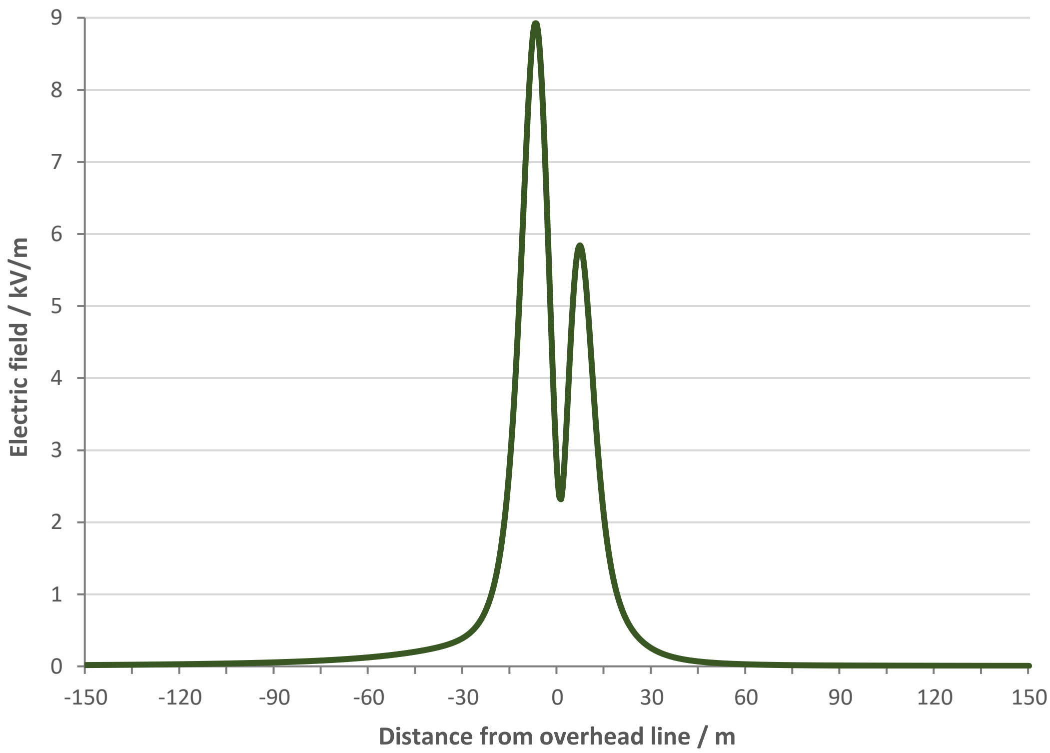


Figure 4.5: Calculated maximum electric fields from XX and XR Overhead Line routes operating at 400/400 kV with Drake conductor system. This represents Options 3 in Table 4.1 which gives the electrical parameters and design information.

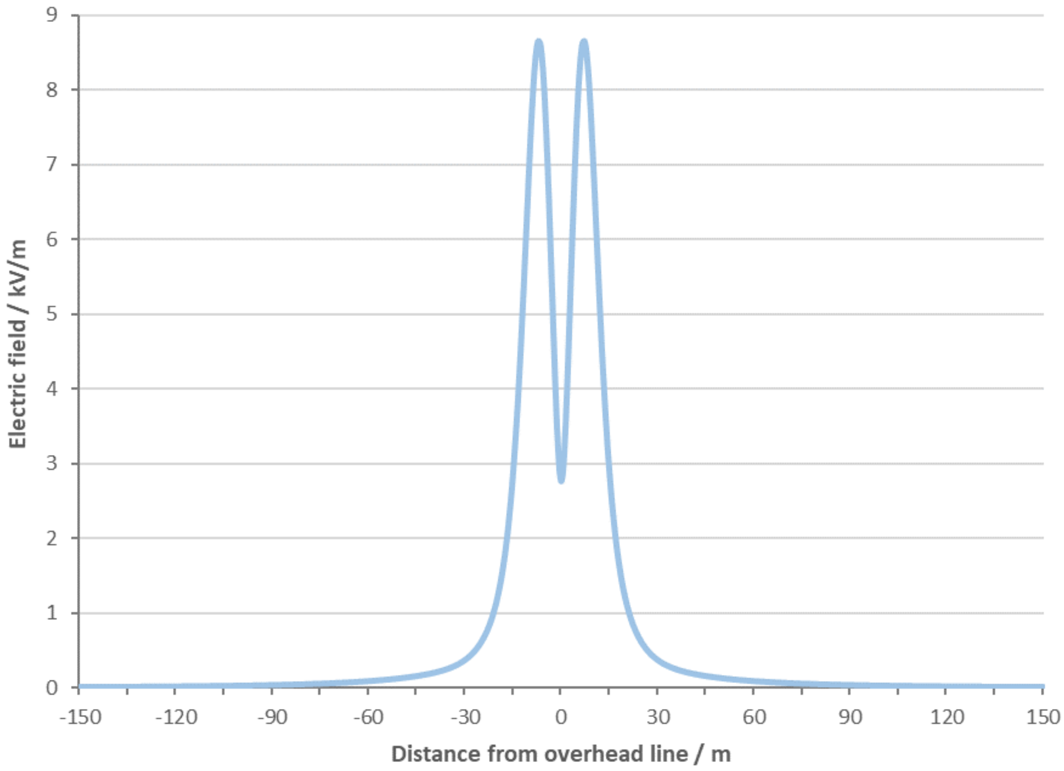
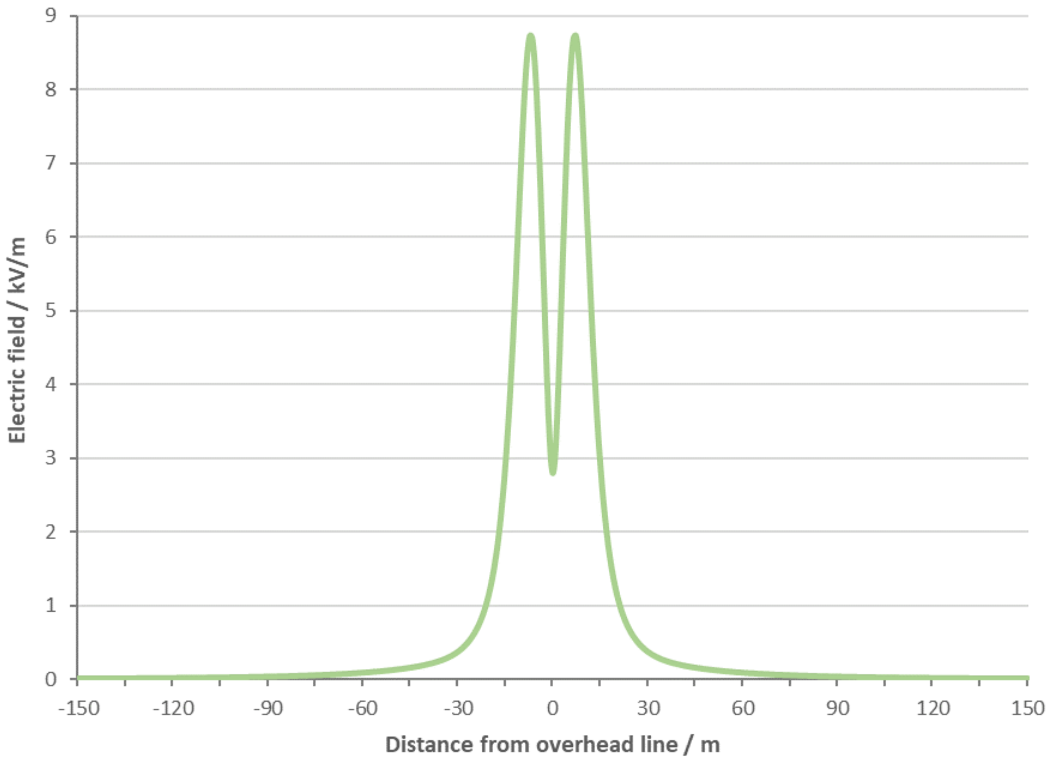


Figure 4.6: Calculated maximum electric fields from XX and XR Overhead Line routes operating at 400/400 kV with Gap conductor system. This represents Options 4 in Table 4.1 which gives the electrical parameters and design information.



4.1.6 The results presented in Figures 4.1 and 4.2 are the maximum magnetic fields the overhead lines would be capable of producing (i.e. the rating level) with Drake and Gap conductors, as specified in the Code of Practice on Compliance. Figures 4.3 to 4.6 show the maximum electric fields produced by the four design options detailed in Table 4.1, again in worst case conditions.

4.1.7 Tables 4.2 and 4.3 demonstrate the maximum magnetic and electric fields and levels at 10m, 20m 50m, 100m and 150m lateral distances from the centre of the overhead lines for the different options considered.

Table 4.2: Calculated maximum magnetic fields for DWNO project design options.

	Magnetic field (µT)					
Distance from centre of overhead line	Maximum	10m	20m	50m	100m	150m
Option 1: 400/275 kV – Drake conductor	78.2	59.6	19.6	2.15	0.32	0.11
Option 2: 400/275 kV – Gap conductor	87.3	66.4	21.9	2.40	0.36	0.12
Option 3: 400/400 kV – Drake conductor	78.2	59.6	19.6	2.15	0.32	0.11
Option 4: 400/400 kV – Gap conductor	87.3	66.4	21.9	2.40	0.36	0.12

Table 4.3: Calculated maximum electric fields for DWNO project design options.

	Electric field (kV/m)					
Distance from centre of overhead line	Maximum	10m	20m	50m	100m	150m
Option 1: 400/275 kV – Drake conductor	8.84	6.85	1.08	0.17	0.04	0.02
Option 2: 400/275 kV – Gap conductor	8.93	6.92	1.09	0.17	0.04	0.02
Option 3: 400/400 kV – Drake conductor	8.65	7.33	1.22	0.13	0.03	0.01
Option 4: 400/400 kV – Gap conductor	8.75	7.41	1.23	0.13	0.03	0.01

4.2 Compliance with Policy on Phasing

4.2.1 The existing XX and XR overhead line routes are designed with transposed phasing, meaning that they are optimally phased as per the Code of Practice[7]. Therefore, the two circuits on each overhead line route are arranged to produce the greatest degree of cancellation between the magnetic fields produced by the two circuits and hence the lowest resultant magnetic field. This will remain the same after the proposed modifications.

4.3 Overhead Lines – Assessment

4.3.1 Two voltage and two conductor options are considered for the DWNO uprating scheme. The maximum calculated magnetic field is the same for both 400/275kV or 400/400 kV operating as the maximum current that both voltages can carry is the same. The maximum magnetic field from the uprated overhead line, calculated according to the Code of Practice on Compliance, will be 87.3 μT if Gap conductor is chosen or 78.2 μT with Drake conductor. The option which produces the largest electric field is one circuit 400 kV and the other 275 kV with Gap conductor. The maximum calculated electric field for this option is 8.92kV/m, and all other options gave slightly lower electric fields. The respective exposure limits for the general public are 360μT and 9kV/m.

4.3.2 The assessment presented above shows that the maximum value of the fields produced by all uprating and reconductoring options would be compliant with the public exposure limits, even directly under the overhead lines. There is no minimum lateral distance from the overhead line required in order to achieve compliance, but the EMFs reduce quickly with distance from the overhead lines. Although not required for assessing compliance, the graphs presented above can be used to estimate the maximum fields at any given distance from the line.

4.3.3 The calculated EMF are presented for compliance purposes using worst-case conditions. Typically, the overhead line would produce EMF lower than these levels for two reasons: the circuits are unlikely to operate at the maximum rating routinely, and a typical current on a day-to-day basis would be around 50% or less of this; and for overhead lines typically the conductors would be higher than the minimum design clearance used for assessing compliance, reducing the EMF at ground level, with the minimum clearance found only in a limited area towards the middle of certain spans.

5 MITIGATION

5.1.1 No mitigation measures are necessary as the uprating and reconductoring proposed for the DWNO Project have been demonstrated to comply with the current public exposure guidelines as detailed in NPS EN-5[3]. If these requirements are met NPS EN-5 states that '*no further mitigation should be necessary*.'

6 CONCLUSIONS

6.1.1 All the uprating and reconductoring options proposed for the DWNO project are deemed to be fully compliant with the current public exposure guidelines for EMFs documented in NPS EN-5[3]. Therefore, there will be no significant EMF effects resulting from these proposed modifications.

6.1.2 The NPS for Electricity Networks Infrastructure (EN-5) (July 2011) in Part 2, section 2.10.6 states '*The balance of scientific evidence over several decades of research has not proven a causal link between EMFs and cancer or any other disease.'*

6.1.3 There is some scientific evidence of possible effects at lower levels at 50 Hz. The electricity industry takes this evidence seriously and recognises that it can generate public concern. However, the evidence has been extensively reviewed, and the UK Government has not considered it appropriate to implement any restrictions or guidelines on the basis of this evidence. In addition to this, Government-adopted precautionary measures have been applied to further reduce EMFs.

6.1.4 The DWNO Project will meet the UK Government adopted exposure limits as demonstrated using the principles set out in the DECC Code of Practice[6].

APPENDIX – A

June 2024

A.1 Introduction

This appendix details calculated EMF levels for four spans that are being modified as part of the DWNO project; three spans on the XX route and one span on the XR route. These spans are of particular interest because they are close to residential properties. These specific calculations are to provide reassurance that the project will be complaint with the EMF exposure limits after the modifications proposed.

A.2 Calculations

Calculated EMF levels have been produced for all 4 overhead line options, detailed in Table 4.1 of the main report for each span. All calculations were performed in accordance with the conditions set out in the codes of practice as detailed in Sections 3.2 and 3.3. Electric and magnetic field levels have been calculated at the centre of the span where the clearance is lowest which produces the highest fields. Additional calculations have also been performed for any building located directly below the overhead line.

A.2.1 Maximum calculated EMF for span XX020 to XX021: Grantown Gardens

The electric and magnetic field levels have been calculated for the maximum levels produced by this span which occurs at the midpoint of the span where the clearance of the conductors to ground is lowest. These are presented in table A.2.1.1 for the magnetic fields and table A.2.1.2 for the electric fields. The EMFs have also been calculated for the apartment building located underneath this overhead line section for ground level electric and magnetic fields (table A.2.1.3) and for magnetic fields only within the top floor of the building (table A.2.1.4). The building itself will significantly screen the electric fields, so are not considered within the building.

Table A.2.1.1: Calculated maximum magnetic field levels at the centre of span XX020 to XX021 at Grantown gardens.

	Magnetic field (µT)					
Distance from centre of overhead line	Maximum	10m	20m	50m	100m	150m
Option 1: 400/275 kV – Drake conductor	35.3	27.5	13.4	1.96	0.31	0.10
Option 2: 400/275 kV – Gap conductor	39.4	30.7	14.9	2.19	0.35	0.12
Option 3: 400/400 kV – Drake conductor	35.3	27.5	13.4	1.96	0.31	0.10
Option 4: 400/400 kV – Gap conductor	39.4	30.7	14.9	2.19	0.35	0.12

Table A.2.1.2: Calculated maximum electric fields for span XX020 to XX021.

	Electric field (kV/m)					
Distance from centre of overhead line	Maximum	10m	20m	50m	100m	150m
Option 1: 400/275 kV – Drake conductor	3.65	3.5	1.23	0.11	0.04	0.02
Option 2: 400/275 kV – Gap conductor	3.69	3.54	1.25	0.11	0.04	0.02
Option 3: 400/400 kV – Drake conductor	3.43	3.34	1.23	0.08	0.03	0.01
Option 4: 400/400 kV – Gap conductor	3.47	3.38	1.24	0.08	0.03	0.01

Table A.1.3: Calculated maximum field levels outside apartment building.

	Electric field (kV/m)	Magnetic field (μT)
Option 1: 400/275 kV – Drake conductor	2.74	26.4
Option 2: 400/275 kV – Gap conductor	2.77	29.6
Option 3: 400/400 kV – Drake conductor	2.53	26.4
Option 4: 400/400 kV – Gap conductor	2.56	29.6

Table A.1.4 Calculated filed levels on top floor of apartment building. Electric fields are shielded by the building materials.

	Electric field (kV/m)	Magnetic field (μT)
Option 1: 400/275 kV – Drake conductor	N/A	128
Option 2: 400/275 kV – Gap conductor	N/A	143
Option 3: 400/400 kV – Drake conductor	N/A	128
Option 4: 400/400 kV – Gap conductor	N/A	143

A.2.2 Span XX024 to XX025 : Stirling road

Maximum EMFs have been calculated for this span. The maximum fields occur at the centre of the span where the ground clearance is at the minimum. The minimum clearance to ground for this span is 8.73m. The maximum field levels are presented in table A.2.2.1 for the magnetic fields and A.2.2.2 for the electric fields. EMFs have also been calculated for the building that is directly below this span and are given in table A.2.2.3.

Table A.2.2.1: Calculated maximum magnetic fields for span XX024 to XX025.

	Magnetic field (μT)					
Distance from centre of overhead line	Maximum	10m	20m	50m	100m	150m
Option 1: 400/275 kV – Drake conductor	64.9	49.3	18.1	2.11	0.32	0.11
Option 2: 400/275 kV – Gap conductor	72.4	55.0	20.2	2.36	0.36	0.12
Option 3: 400/400 kV – Drake conductor	64.9	49.3	18.1	2.11	0.32	0.11
Option 4: 400/400 kV – Gap conductor	72.4	55.0	20.2	2.36	0.36	0.12

Table A.2.2.2: Calculated maximum electric fields for span XX024 to XX025.

	Electric field (kV/m)					
Distance from centre of overhead line	Maximum	10m	20m	50m	100m	150m
Option 1: 400/275 kV – Drake conductor	7.10	5.84	1.10	0.16	0.04	0.02
Option 2: 400/275 kV – Gap conductor	7.14	5.90	1.11	0.16	0.04	0.01
Option 3: 400/400 kV – Drake conductor	6.87	6.11	1.24	0.12	0.03	0.01
Option 4: 400/400 kV – Gap conductor	6.94	6.17	1.25	0.12	0.03	0.01

Table A.2.2.3: Calculated field levels at ground level for the location of the building directly beneath the span.

	Electric field (kV/m)	Magnetic field (μT)
Option 1: 400/275 kV – Drake conductor	1.58	14.7
Option 2: 400/275 kV – Gap conductor	1.60	16.5
Option 3: 400/400 kV – Drake conductor	1.41	14.7
Option 4: 400/400 kV – Gap conductor	1.43	16.5

A.2.3 Span XX043 to XX044: Chapelhall

The maximum calculated EMFs for the span XX043 to XX044 at Chapelhall are presented in tables A.2.3.1 and A.2.3.2. These occur in the centre of the span where the minimum clearance for this is 13.04m. The level of EMFs for the building that is below this span have also been calculated and are presented in table A.2.3.3.

Table A.2.3.1: Calculated maximum magnetic fields for span XX043 to XX044.

	Magnetic field (μT)					
Distance from centre of overhead line	Maximum	10m	20m	50m	100m	150m
Option 1: 400/275 kV – Drake conductor	34.3	26.8	13.2	1.95	0.31	0.10
Option 2: 400/275 kV – Gap conductor	38.3	29.9	14.7	2.18	0.35	0.12
Option 3: 400/400 kV – Drake conductor	34.3	26.8	13.2	1.95	0.31	0.10
Option 4: 400/400 kV – Gap conductor	38.3	29.9	14.7	2.18	0.35	0.12

Table A.2.3.2: Calculated maximum electric fields for span XX043 to XX044.

	Electric field (kV/m)					
Distance from centre of overhead line	Maximum	10m	20m	50m	100m	150m
Option 1: 400/275 kV – Drake conductor	3.55	3.33	1.14	0.11	0.04	0.02
Option 2: 400/275 kV – Gap conductor	3.58	3.36	1.15	0.11	0.04	0.02
Option 3: 400/400 kV – Drake conductor	3.33	3.25	1.22	0.08	0.02	0.01
Option 4: 400/400 kV – Gap conductor	3.36	3.28	1.23	0.08	0.03	0.01

Table A.2.3.3: Calculated field levels at the building.

	Electric field (kV/m)	Magnetic field (μT)
Option 1: 400/275 kV – Drake conductor	2.17	20.7
Option 2: 400/275 kV – Gap conductor	2.19	23.1
Option 3: 400/400 kV – Drake conductor	1.97	20.7
Option 4: 400/400 kV – Gap conductor	2.00	23.1

A.2.4 Span XR043 to XR044: Wishaw Road

The calculated EMFs for the span XR043 to XR044 at Wishaw Road are given here for the minimum clearance above ground for the span. Minimum clearance for this span is 13.45m. This is the location where the maximum EMFs will occur. Tables A.2.4.1 and A.2.4.2 detail the maximum calculated magnetic and electric fields respectively for each of the four options considered for the project. Table A.2.4.4 is the maximum calculated field levels at the location of the property that is below this span. For this span, the building is located in the centre of the span where the clearance is at the minimum.

Table A.2.4.1: Calculated maximum magnetic fields for span XR043 to XR044.

	Magnetic field (μT)					
Distance from centre of overhead line	Maximum	10m	20m	50m	100m	150m
Option 1: 400/275 kV – Drake conductor	32.5	25.5	12.8	1.94	0.31	0.10
Option 2: 400/275 kV – Gap conductor	36.2	28.5	14.2	2.16	0.35	0.17
Option 3: 400/400 kV – Drake conductor	32.5	25.5	12.8	1.94	0.31	0.10
Option 4: 400/400 kV – Gap conductor	36.2	28.5	14.2	2.16	0.35	0.12

Table A.2.4.2: Calculated maximum electric fields for span XR043 to XR044.

	Electric field (kV/m)					
Distance from centre of overhead line	Maximum	10m	20m	50m	100m	150m
Option 1: 400/275 kV – Drake conductor	3.35	3.17	1.13	0.10	0.04	0.02
Option 2: 400/275 kV – Gap conductor	3.39	3.20	1.14	0.10	0.04	0.02
Option 3: 400/400 kV – Drake conductor	3.14	3.08	1.21	0.07	0.02	0.01
Option 4: 400/400 kV – Gap conductor	3.17	3.11	1.22	0.07	0.02	0.01

Table A.2.4.3: Calculated field levels at the building.

	Electric field (kV/m)	Magnetic field (μT)
Option 1: 400/275 kV – Drake conductor	3.35	32.5
Option 2: 400/275 kV – Gap conductor	3.39	36.2
Option 3: 400/400 kV – Drake conductor	3.14	32.5
Option 4: 400/400 kV – Gap conductor	3.17	36.2

A.3 Summary

For each span considered in this appendix all of the uprating and reconductoring options considered by the DWNO project will produce electric and magnetic fields that are fully compliant with the public exposure guidelines for EMFs.

Calculations of the maximum electric and magnetic fields at Grantown Gardens, Stirling Road, Chapelhall and Wishaw Road both outside and within the buildings demonstrate that the exposures are significantly below the Government exposure limits of 360 μT.

APPENDIX – B

May 2026

B.1 Introduction

B.1.1 This appendix details calculated EMF levels for the triple Angus conductor system for the XX and XR routes as described in Section 4. As for the previous calculations, this conductor has been modelled for two separate voltage conditions; both circuits at 400kV, and one circuit at 400kV with the other operating at 275kV. This gives an additional two uprating design options for the DWNO project as described in Table B.1.1

Table B.1.1 Additional uprating design options for DWNO project

	Design	Circuit 1	Circuit 2
Option 5	**Voltage**	400 kV	400 kV
	Conductor bundle	Triple Angus	Triple Angus
	Pre-fault continuous rating	3719A	3719A
Option 6	**Voltage**	400 kV	275 kV
	Conductor bundle	Triple Angus	Triple Angus
	Pre-fault continuous rating	3719A	3719A

B.2 Assessment of EMF exposure against government policy

B.2.1 Operational effects

Calculated EMF levels have been produced for both overhead line options, described in Table B.1.1. All calculations were performed in accordance with the conditions set out in the codes of practice as detailed in Sections 3.2 and 3.3. Electric and magnetic field levels have been calculated at the centre of the span where the clearance is lowest which produces the highest fields.

B.2.2 As described in Section 4, both the XX and XR routes are constructed of L8 towers and the minimum conductor design clearance to ground is 7.6m. Calculations were performed at the nominal voltage of each circuit and the pre-fault continuous ratings included in Table B.1.1 at 1m above ground. All calculations were performed in accordance with the conditions set out in the Code of Practice[6].

Figure B.2.1 Calculated maximum magnetic fields from XX and XR Overhead Line routes operating at 400/400 kV and 400/275 kV with Angus conductor system. These represent Options 5 and 6 in Table B.1.1 which gives the electrical parameters and design information.

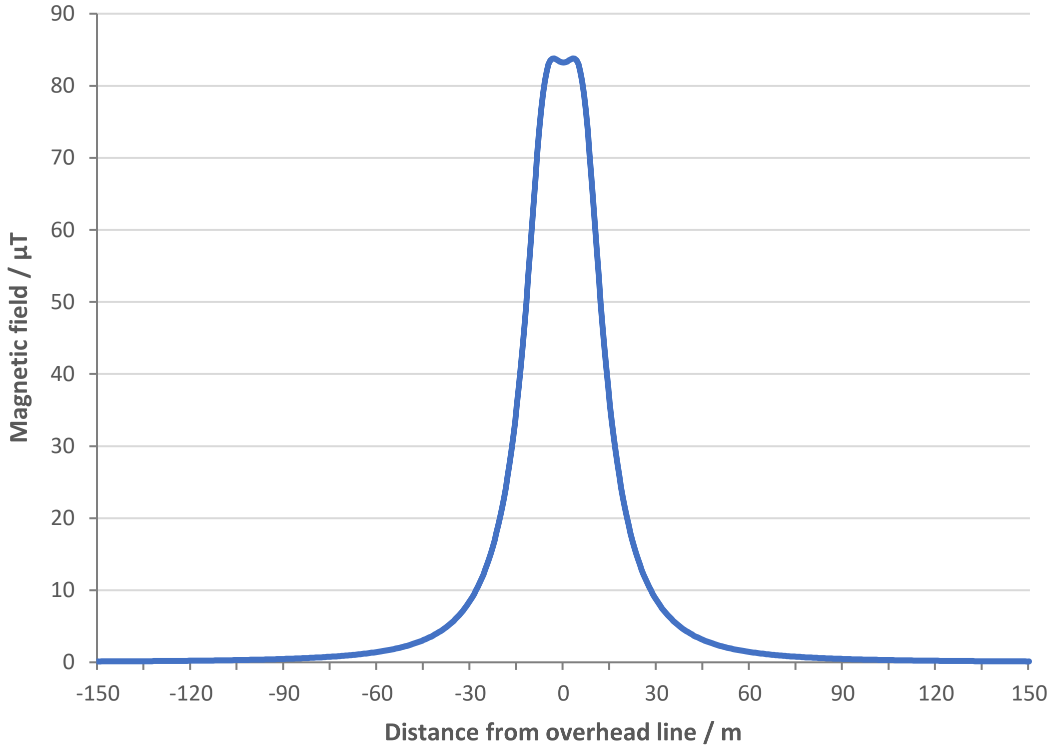


Figure B.2.2 Calculated maximum electric fields from XX and XR Overhead Line routes operating at 400/400 kV with Angus conductor system. This represents Options 5 in Table B.1.1 which gives the electrical parameters and design information.

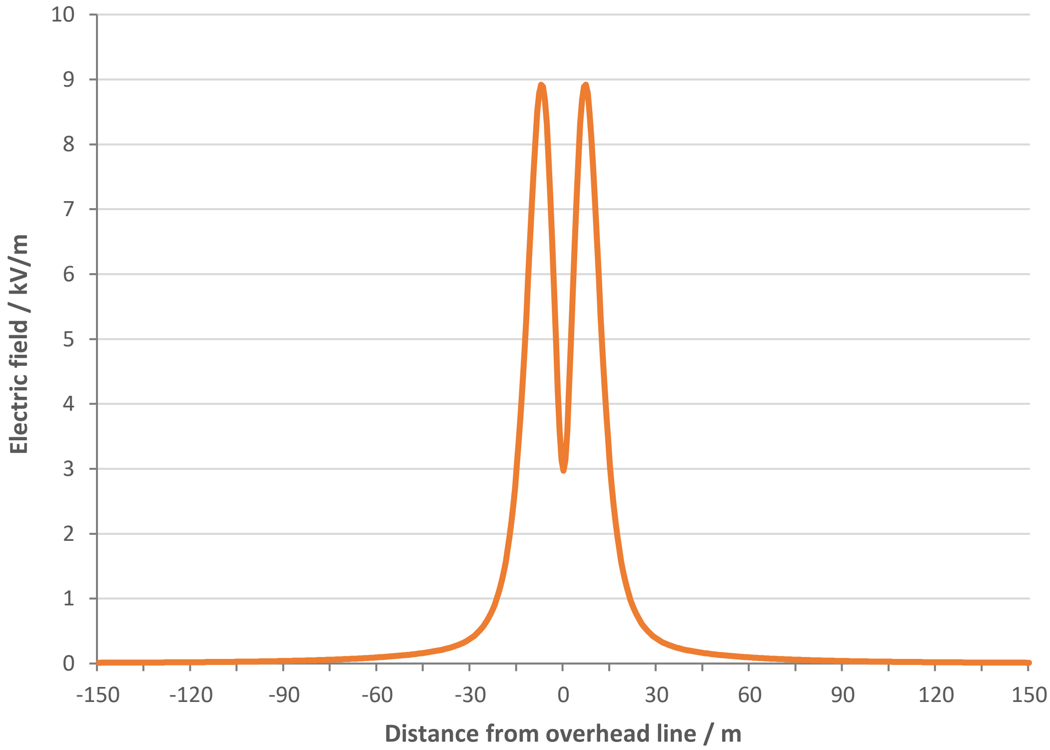
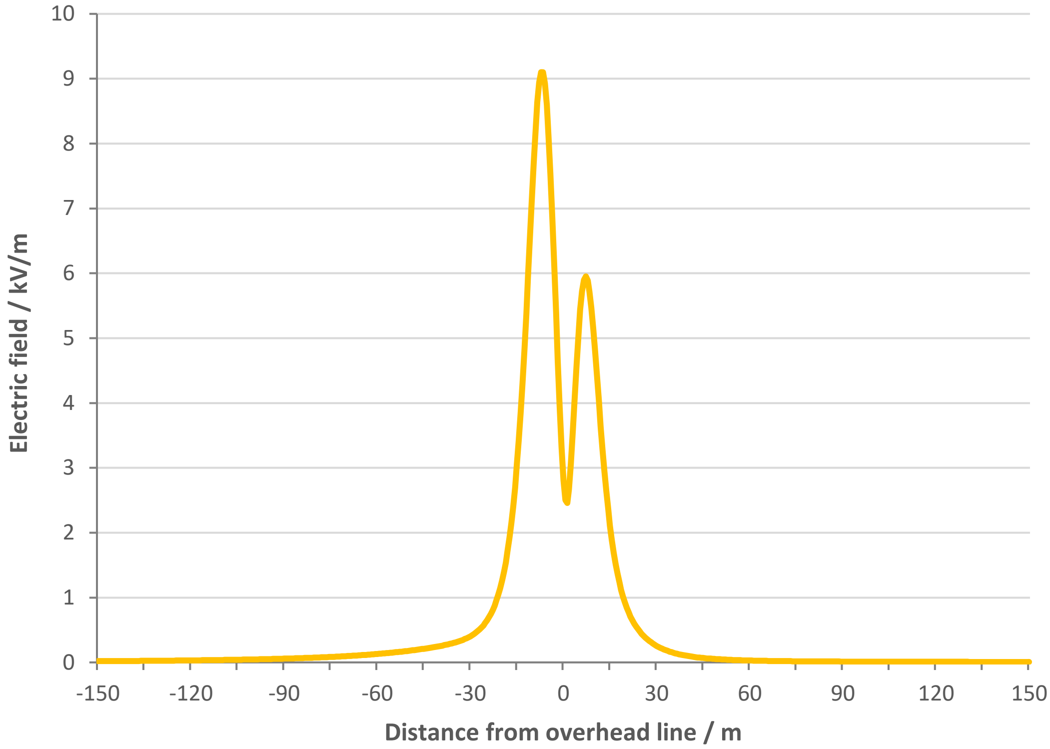


Figure B.2.3 Calculated maximum electric fields from XX and XR Overhead Line routes operating at 400/275 kV with Angus conductor system. This represents Options 6 in Table B.1.1 which gives the electrical parameters and design information.



B.2.3 Tables B.2.1 and B.2.2 demonstrate the maximum magnetic and electric fields and levels at 10m, 20m 50m, 100m and 150m lateral distances from the centre of the overhead lines for the different options considered.

Table B.2.1: Calculated maximum magnetic fields for the additional DWNO project options.

	Magnetic field (µT)					
Distance from centre of overhead line	Maximum	10m	20m	50m	100m	150m
Option 5: 400/400 kV – Angus conductor	83.8	63.8	21.4	2.37	0.35	0.12
Option 6: 400/275 kV – Angus conductor	83.8	63.8	21.4	2.37	0.35	0.12

Table B.2.2: Calculated maximum electric fields for the additional DWNO project options.

	Electric field (kV/m)					
Distance from centre of overhead line	Maximum	10m	20m	50m	100m	150m
Option 5: 400/400 kV – Angus conductor	8.92	7.61	1.29	0.14	0.03	0.01
Option 6: 400/275 kV – Angus conductor	9.10	7.14	1.14	0.18	0.05	0.02

B.2.4 The maximum calculated magnetic field is the same for both 400/275kV or 400/400 kV conductor options as the maximum current that both voltages can carry is the same. The maximum magnetic field from both options 5 and option 6, calculated according to the Code of Practice[6], will be 83.8 μT. For both options this is below the public exposure guideline level of 360 μT.

B.2.5 For conductor system option 5, the maximum calculated electric field for this option is 8.92kV/m. This is below the electric field guideline level of 9kV/m and therefore this option is compliant with guideline levels with no further mitigation required.

B.2.6 Conductor system option 6 with the circuits at different voltage has a maximum electric field of 9.1kV/m. This occurs below the 400kV and results from less cancellation if the electric fields compared with a conductor system with both circuits at the same voltage. As the electric field level is above the EMF exposure guideline level of 9 kV/m mitigation would be required for this option 6 if used. For overhead lines typically the conductors would be higher than the minimum design clearance used for assessing compliance, reducing the EMFs at ground level, with the minimum clearance found only in a limited area towards the middle of certain spans.

B.3 Mitigation

B.3.1 Conductor option 5, as described in table B.1.1 produces maximum electric and magnetic fields at levels below the relevant guidelines, and therefore is compliant and requires no further mitigation.

B.3.2 For conductor system option 6, as described in table B.1.1, the electric field exceeds the guideline level of 9kV/m given in NPS-EN 5[3] at minimum design clearance and therefore mitigation would be required if this electric field level was produced at a residential property as described in the Code of Practice[6] in Section 2.

B.3.3 Mitigation to reduce the electric field level could include increasing the clearance below the overhead line from the minimum 7.6m to 7.7m if the minimum clearance crosses a residential use area. This would result in a maximum electric field level of 8.9 kV/m.

B.4 Summary

B.4.1 For the two Andrew conductor systems considered in this appendix, option 5 with both circuits at 400kV will produce electric and magnetic fields that are fully compliant with the public exposure guidelines for EMFs.

B.4.2 Option 6 considered in this appendix will produce electric field level that exceeded the guideline level when the clearance to ground is the minimum 7.6m design clearance, and therefore consideration of the land use below the line will be required in areas with minimum clearance.