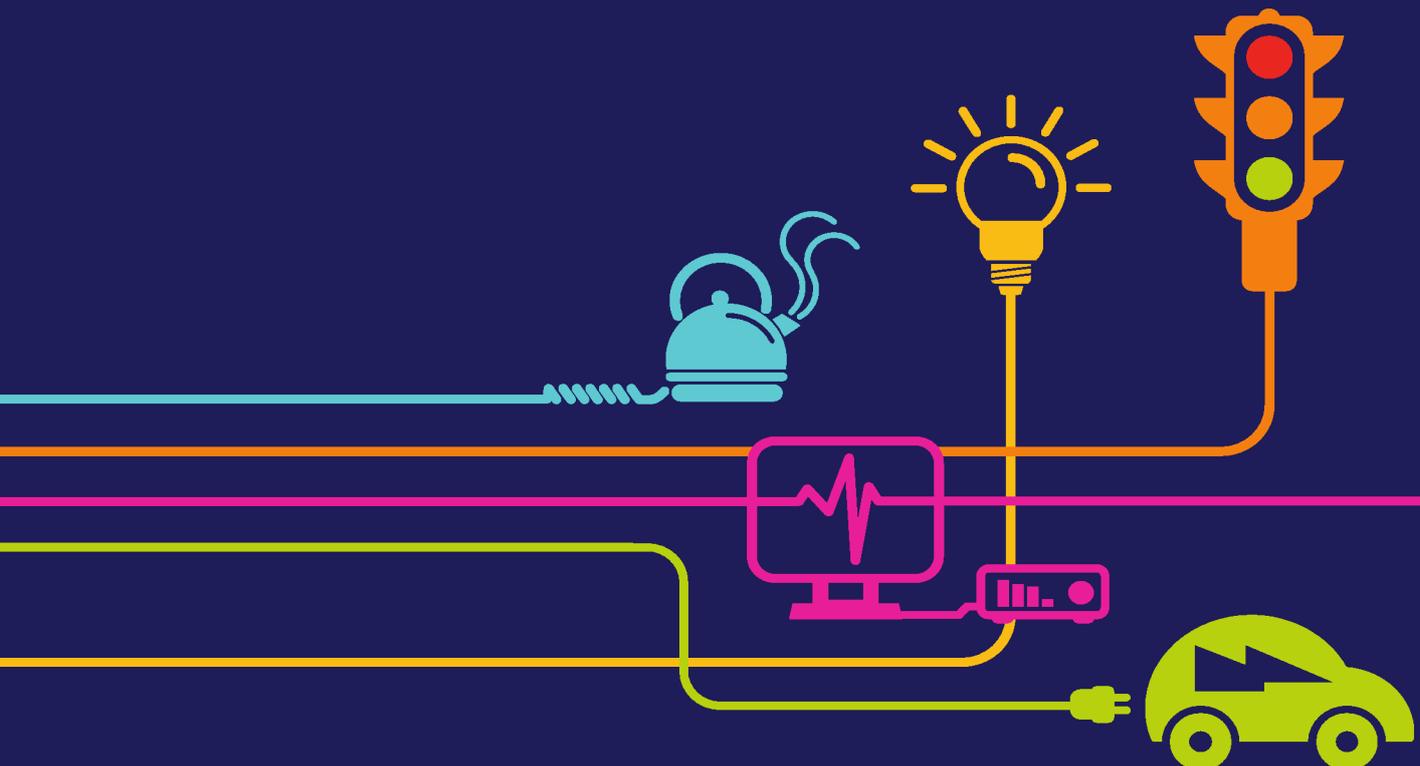


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Electric and Magnetic Fields Report

National Grid (North Wales Connection Project)

*Regulation 5(2)(q) of the Infrastructure Planning
(Applications: Prescribed Forms and Procedure) Regulations 2009*



North Wales Connection

Volume 5

5.25 Electric and Magnetic Fields Report

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1 INTRODUCTION

1.1 The applicant and an overview of the North Wales Connection Project

1.1.1 National Grid Electricity Transmission plc owns and operates the high voltage electricity transmission system in England and Wales. NG has a statutory duty to promote competition in the supply of electricity and is obliged to offer to connect to the system anyone who applies for a connection. Horizon Nuclear Power has applied to NG to connect a proposed new nuclear power station at Wylfa, Anglesey (Wylfa Newydd Power Station) to the system. The proposed power station is within a site already identified for this type of development in the UK government's National Policy Statement (NPS) EN-6 'Nuclear Power Generation'. NG is developing proposals for a connection (the Proposed Development) that would facilitate this generation and transmission by the contracted date of 2024 / 2025.

1.1.2 The Proposed Development consists of the following components:

- extension to the existing substation at Wylfa;
- sections of new 400 kV overhead line (OHL) between Wylfa substation and the Braint Tunnel Head House (THH) and Cable Sealing End Compound (CSEC) on Anglesey including modifications to parts of the existing 400 kV OHL between Wylfa and Pentir;
- Braint THH and CSEC on Anglesey;
- tunnel under the Menai Strait between the Braint THH and the Tŷ Fodol THH;
- Tŷ Fodol THH and CESC in Gwynedd;
- new section of 400 kV OHL between Tŷ Fodol THH and CSEC and Pentir Substation; and
- extension to the existing substation at Pentir.

1.1.3 The Proposed Development is situated within the administrative areas of Isle of Anglesey County Council (IACC) and Gwynedd Council, to whom application under the CoPA will be made as appropriate. A consistent approach will be applied to both Councils, where possible, through consultation and agreement.

1.1.4 In terms of the construction requirements of the Proposed Development, these consist of the following components:

- overhead line installation including new pylons;
- substation and connection works;

- shaft construction and tunnelling works;
- head house construction; and
- temporary construction compounds, access tracks, construction working areas and third party works that are required to construct the infrastructure listed above.

1.1.5 National Grid has prepared a series of plans and reports to explain its proposals to build the Project. The application has been submitted under the Planning Act 2008 (Ref.1) (known as an Application for development consent) which has been submitted to the Planning Inspectorate for review.

1.2 Purpose of this report

1.2.1 This report provides an assessment of the likely significant health and environmental effects of electric and magnetic fields (EMFs) associated with the construction, operation and decommissioning of the Project. A description of the Project is provided in paragraph 1.1.3.

1.2.2 National Grid has a very clear policy on EMFs, as set out in its Public Position Statement (Ref. 2) which states “...*In all our operations, as a minimum we comply with EMF regulations, guidelines or practices in force in the countries and different jurisdictions in which we operate*” and this policy would be applied to this Project. As is explained in more detail in Section 2 below, compliance with the relevant guidelines and practices in force in the UK ensures that there should be no significant health or environmental effects of EMFs. Therefore, it was proposed in the Scoping Report (Ref. 3) that the assessment of EMFs be scoped out of the Environmental Statement, (ES) which in accordance with the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009 (Ref. 4) (EIA Regulations 2009), is required to describe the “*likely significant effects of the development*”. It was instead proposed that comprehensive information about EMFs be provided in a separate report to be submitted alongside the ES.

1.2.3 The Scoping Opinion given in July 2016 (Ref. 5) states at paragraph 3.51 and 3.52:

“3.51 On the basis that evidence is provided demonstrating that the specifications for the overhead line, SECs and underground cable (including tunnel head housing) comply with regulatory thresholds, and that significant effects are unlikely the Secretary of State agrees that EMFs can be scoped out of the EIA. The Secretary of State welcomes the proposal to include a separate EMF document with the DCO application which will satisfy the requirements of NPS EN-5 and include evaluations of the EMFs that would be produced. This document should consider both the overhead transmission line and any cables that are undergrounded and should take into account the International Commission on Non-Ionizing Radiation Protection guidelines (1998), as detailed in NPS EN-5.

3.52 Similarly, the Secretary of State agrees that the electromagnetic compatibility (EMC) issues (ie interference with television or radio) can also be scoped out on the basis that the Applicant has obtained a Certificate of Conformity under the EMC Directive. However, the Secretary of State has been unable to locate Appendix B to the Scoping Report, which is stated to include this certificate; this should be provided within the ES to provide evidence of conformity. It would also be helpful to

demonstrate in the ES that the specification of the overhead line, SECs and underground cable proposed for the project meets the requirements of the EMC Directive.”

- 1.2.4 The Secretary of State and the Planning Inspectorate have previously accepted, for other nationally significant infrastructure proposals submitted by National Grid, that the required EMF information be provided in a separate report. National Grid is therefore following the same procedure for this project. This report constitutes the separate document covering EMFs, submitted alongside the ES.

1.3 Introduction to EMFs

- 1.3.1 Electric and magnetic fields and the electromagnetic forces they represent are an essential part of the physical world. Their sources are the charged fundamental particles of matter (principally electrons and protons). EMFs occur naturally within the body in association with nerve and muscle activity allowing these functions to take place. Humans also experience the natural static magnetic field of the Earth (to which a magnetic compass responds) and natural static electric fields in the atmosphere.
- 1.3.2 Electric and magnetic fields occur in the natural world, and people have been exposed to them for the whole of human evolution. The advent of modern technology and the wider use of electricity and electrical devices have inevitably introduced changes to the naturally occurring EMF patterns. Energised high voltage power-transmission equipment, along with all other uses of electricity, is a source of EMFs. The UK power system mainly uses alternating current (AC) so the fields that are produced are likewise alternating. The EMFs have the same frequency as the voltages and currents that produce them, which is 50 hertz (Hz) in the UK. The fields are described as power-frequency or extremely-low-frequency (ELF) EMFs, and exist in addition to the Earth's steady natural fields.
- 1.3.3 Electric fields depend on the operating voltage of the equipment producing them and are measured in volts per metre, symbol V/m. The operating voltage of most equipment is a relatively constant value. Electric fields are shielded by most common building materials, trees and fences, and diminish rapidly with distance from the source.
- 1.3.4 Magnetic fields are measured in microteslas, symbol μT , and depend on the electrical currents flowing, which vary according to the electrical power requirements at any given time. They are not significantly shielded by most common building materials or trees but do diminish rapidly with distance from the source.
- 1.3.5 This project comprises overhead lines, underground cables, substations, and cable sealing ends, at a voltage of 400kV. These are all assessed in detail in this report, but it can be noted here that above-ground equipment produces both electric and magnetic fields, but underground cables produce only a magnetic field, as the electric field is confined within the cable by the metallic sheath of the cable.
- 1.3.6 Electric and magnetic fields at 50Hz can cause induced currents to occur in the body, which, if high enough, can interfere with nerves. There are Government-

adopted exposure guidelines (discussed in Section 2 below), which are set to protect against these known or direct effects of EMF exposure. There are also 'indirect' effects that can occur as a result of exposure to EMFs and which are not explicitly covered by the exposure guidelines. Examples of indirect effects are interference with active implantable medical devices (AIMDs), and microshocks (discussed in paragraphs 2.9.1 to 2.11.1 below). The potential impact of both direct and indirect effects has been assessed using the guidance provided in National Policy Statement (NPS) EN-5 (Ref.6) and the codes of practice (discussed in Section 2 below).

- 1.3.7 Electric and magnetic fields at much higher frequencies than those generated by the electricity transmission system can be generated by other devices, e.g. radio, television transmissions and microwaves. These higher frequencies interact with objects and people in a rather different way to power frequencies, for example by heating of the body, so in scientific terms these are a different phenomenon, and it is important to make the distinction. Overhead lines produce EMFs at much lower frequencies and are sometimes referred to as "non-ionising" radiation.

2 POLICY AND LEGISLATION

2.1 Overview of policy

- 2.1.1 Whilst there are no statutory regulations in the UK that limit the exposure of the general public to power-frequency EMFs, responsibility for implementing appropriate measures for the protection of the public lies with the UK Government, which has a clear policy, restated in October 2009 and incorporated in NPS EN-5 (Ref. 6), on the exposure limits and other policies they expect to see applied. Practical details of how the policy is to be implemented are contained in a Code of Practice on Compliance (Ref.7) agreed between industry and Government.
- 2.1.2 Government in turn acts on the scientific advice from Public Health England (PHE), which has responsibility for advising on non-ionising radiation protection, including power-frequency EMFs. The National Radiological Protection Board (NRPB) had this responsibility until becoming part of the Health Protection Agency (HPA) on 1 April 2005, which in turn was replaced by PHE on 1 April 2013. This report refers to PHE, NRPB or HPA according to the name of the organisation at the time each statement was issued.
- 2.1.3 In 2004, following a recommendation by the then NRPB, the UK Government adopted exposure guidelines for the public published in 1998 by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) (Ref.8) in line with the terms of the 1999 European Union (EU) Recommendation (Ref.9) on public exposure to EMFs. In a Written Ministerial Statement in October 2009 (Ref. 10.; references to the Written Ministerial Statement encompass both the Statement itself and the detailed Response that the Statement introduced) the Government restated this policy of compliance with exposure limits and, acting on the recommendations of a stakeholder process, added, in relation to high voltage infrastructure, a single precautionary measure, a policy of optimum phasing of some overhead lines. "Optimum phasing" is an engineering measure that can be incorporated in the design of some overhead lines and which reduces the EMFs they produce, and is considered in detail in Section 6.2. The Government also
-

made clear in the Written Ministerial Statement that no other precautionary measures are appropriate for high voltage infrastructure.

- 2.1.4 These two policies, compliance with exposure limits plus optimum phasing, are the only ones applying to high voltage infrastructure. NPS EN-1 (Ref. 11) does not contain any provisions specific to EMFs. NPS EN-5 (Ref. 6) documents these policies and they are explained fully below.

2.2 National Policy Statement EN-5

As summarised above, Government has set out clear policies on control of EMF exposures in general. NPS EN-5 (Ref.6) gives clear guidance on the EMF requirements of all electricity infrastructure projects. The relevant paragraphs are summarised in Table 1, with a reference to where they are covered in this Report, and a summary of the conclusion.

Table 1: Summary of NPS EN-5 Requirements Relevant to EMF

Paragraph	Requirement	Section of this Report	Compliance Assessment
2.10.9	Before granting consent to an overhead line application, the Infrastructure Planning Commission (IPC)(replaced in 2012 by the Planning Inspectorate), should satisfy itself that the proposal is in accordance with the “Power Lines: Demonstrating compliance with EMF public exposure guidelines – a voluntary Code of Practice” published in February 2011 (Ref. 7), considering the evidence provided by the applicant and any other relevant evidence. It may also need to take expert advice from the Department of Health.	6	The Project has been designed and assessed in line with this Code of Practice. All of the EMFs produced, would comply with the Government adopted ICNIRP 1998 guidelines (Ref.8), as demonstrated in this report,

Paragraph	Requirement	Section of this Report	Compliance Assessment
2.10.10	Before granting consent to an overhead line application, the IPC should satisfy itself that the proposal is in accordance with the International Commission on Non-Ionizing Radiation Protection (ICNIRP) (1998) guidelines	6	The overhead line and all other assets associated with the Project are demonstrated in this report to comply with the Government adopted ICNIRP 1998 guidelines.
2.10.11	The Government has developed with industry a voluntary Code of Practice, "Optimum Phasing of high voltage double-circuit Power Lines – A Voluntary Code of Practice", published in February 2011 (Ref. 12) that defines the circumstances where industry can and will optimally phase lines with a voltage of 132kV and above. Applicant should demonstrate compliance with this.	6.2	The overhead line has been designed in compliance with the policy on optimum phasing as specified in the Code of Practice on Optimum Phasing, as demonstrated in this report.
2.10.14	The diagram at the end of Section 2.10 shows a basic decision tree for dealing with EMFs from overhead power lines to which the IPC can refer.	2.2 at Figure 1	This decision tree has been replicated at Figure 1 and forms the basis for the assessment of EMFs from the Project.

Paragraph	Requirement	Section of this Report	Compliance Assessment
2.10.15	<p>The applicant should have considered the following factors:</p> <ul style="list-style-type: none"> - Height, position, insulation and protection (electrical or mechanical as appropriate) measures subject to ensuring compliance with the Electricity Safety, Quality and Continuity Regulations 2002 	2.12 and 6.2	<p>The proposed overhead line has been designed to comply with the statutory requirements of the Electricity Safety, Quality and Continuity Regulations 2002 (Ref. 13). EMF requirements can, for some designs of overhead line, result in conductor clearances to ground (one of the requirements of these regulations) being increased but never reduced compared to the requirements of the Electricity Safety, Quality and Continuity Regulations 2002. The minimum conductor clearance information provided in this report demonstrates this compliance.</p>
	<ul style="list-style-type: none"> - That optimal phasing of high voltage overhead power lines is introduced wherever possible and practicable in accordance with the Code of Practice to minimise effects of EMFs; 	6.2	<p>The overhead line has been designed in line with the policy on optimum phasing as specified in the Code of Practice on Optimum Phasing.</p>
	<ul style="list-style-type: none"> - Any new advice emerging from the Department of Health relating to Government policy for EMF exposure guidelines. 	2.6	<p>This has been considered in the policy and legislation section of the current report, section 2, and all current advice has been used for the assessment. The assessment has been carried out against the current Government recommended EMF exposure guidelines and policies.</p>

Paragraph	Requirement	Section of this Report	Compliance Assessment
	<ul style="list-style-type: none"> - Where it can be shown that the line will comply with the current public exposure guidelines and the policy on phasing, no further mitigation should be necessary. 	6	<p>This report shows that the Project would be compliant with the current public exposure guidelines of ICNIRP 1998 and the policy on phasing using the principles in the Codes of Practice on Compliance and Optimum Phasing.</p>

2.2.1 As summarised above, Government has set out clear policies on control of EMF exposures in general. NPS EN-5 (Ref.6) gives clear guidance on the EMF requirements of all electricity infrastructure projects stating:

“2.10.9... Before granting consent to an overhead line application, the IPC should satisfy itself that the proposal is in accordance with the guidelines, considering the evidence provided by the applicant and any other relevant evidence.”

And

“2.10.11... Where the applicant cannot demonstrate that the line will be compliant ... with the exposure guidelines as specified in the Code of Practice on compliance, and with the policy on phasing as specified in the Code of Practice on optimal phasing then the IPC should not grant consent.”

2.2.2 A simplified route map for dealing with EMFs is provided in NPS EN-5 and is reproduced in Figure 1 : Simplified Route Map for Dealing with EMFs. Reproduced from NPS EN-5 (page 23) Figure 1.

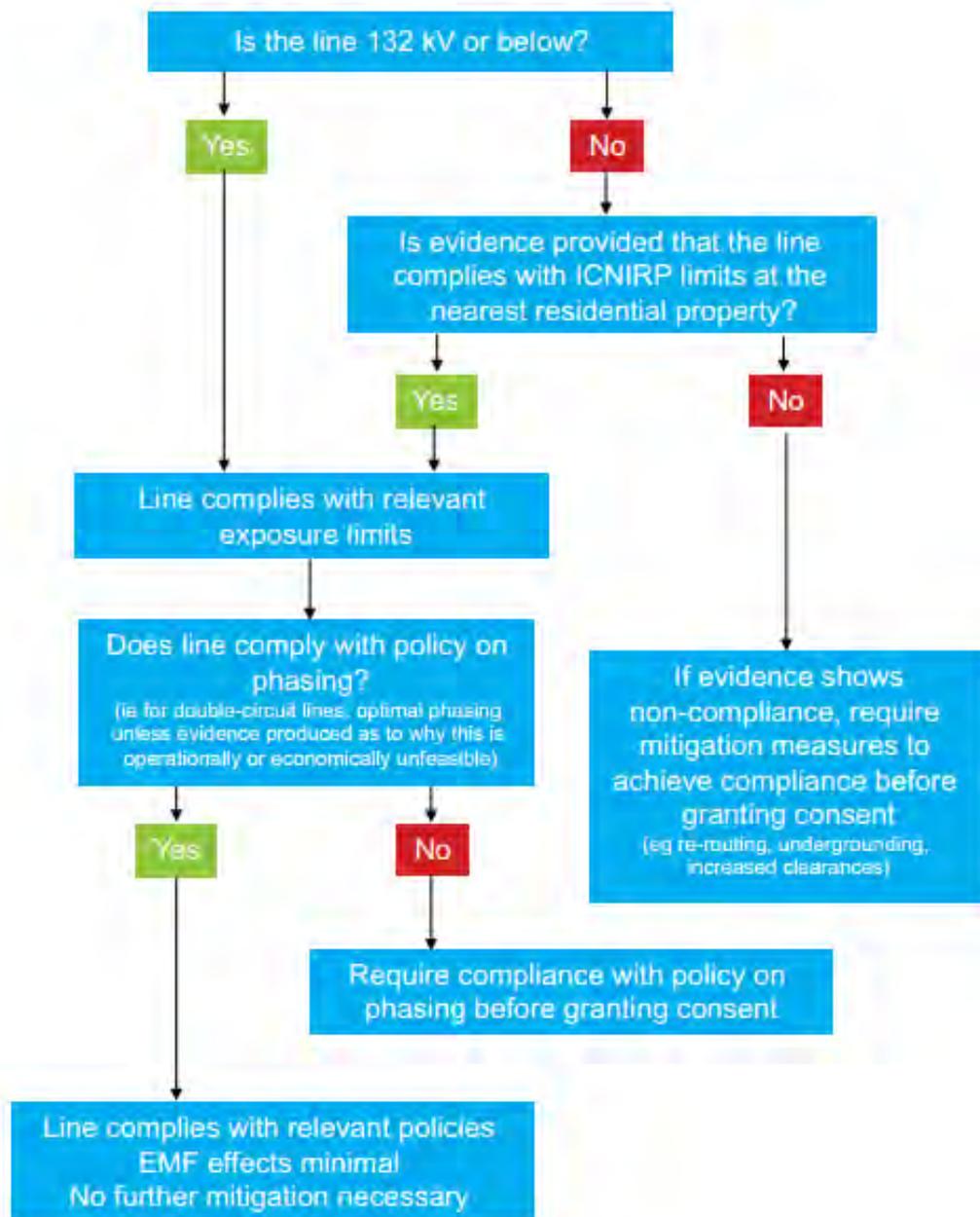


Figure 1 : Simplified Route Map for Dealing with EMFs. Reproduced from NPS EN-5 (page 23)

2.2.3 All relevant legislation, policies and guidance, including those contained within NPS EN-1 (Ref. 11) and EN-5 (Ref.6) have been reviewed and applied to this EMF assessment of the Project. These policies, guidance and legislation are explained and documented below including, for openness and transparency, a commentary of the science on which these have been based.

2.3 Public Exposure Limits

2.3.1 In March 2004 the then NRPB provided new advice to Government, replacing previous advice from 1993, and recommending the adoption in the UK of guidelines published in 1998 by the ICNIRP (Ref.8). The Government subsequently adopted

this recommendation, saying that limits for public exposures should be applied in the terms of the 1999 EU Recommendation (Ref. 9). This Government policy was subsequently set out more formally in the Written Ministerial Statement (Ref. 10) and incorporated into NPS EN-5 (Ref. 6). Table 2 below summarises the relevant values for power frequencies.

Table 2: Exposure Limits for Power Frequency EMFs

Public Exposure Levels	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

- 2.3.2 In recommending these levels, the NRPB considered the evidence for all suggested effects of EMFs. They concluded that the evidence for effects on the nervous system of currents induced by the fields was sufficient to justify setting exposure limits, and this is the basis of their quantitative recommendations (Ref.14). They concluded that the evidence for effects at lower fields, for example the evidence relating to childhood leukaemia, was not sufficient to justify setting exposure limits, but was sufficient to justify recommending that Government consider possible precautionary actions. Precautionary measures are considered in more detail below.
- 2.3.3 The EMF guidelines are documented in NPS EN-5 (Ref.6) and practical details of their application are given in the Code of Practice 'Power Lines: Demonstrating compliance with EMF public exposure guidelines – a voluntary Code of Practice' (Ref.7) published by the then 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.
- 2.3.4 The ICNIRP guidelines (Ref.8) are set so as to limit the currents induced in the body by external exposure to EMFs to below the threshold for those currents having any effects. These induced currents can be expressed as a current density and this is the quantity on which the guidelines are based. Specifically, the ICNIRP guidelines recommend that the general public are not exposed to levels of EMFs able to cause a current density of more than 2mA/m² within the human central nervous system, as shown in Table 2. This value of the induced current density is

described as the “basic restriction”. The 1999 EU Recommendation (Ref.9) uses the same basic restriction value as ICNIRP (Ref.8).

- 2.3.5 However, the basic restriction cannot be assessed directly, since *in-vivo* measurements of current density are not practicable. Instead, the external fields that have to be applied to the body to produce this current density are calculated by numerical dosimetry. Those calculations are normally performed for uniform fields, because this is the most onerous exposure condition; non-uniform fields produce lower induced currents.
- 2.3.6 Therefore, the ICNIRP guidelines also contain values of the external fields called “reference levels”. For the public, the reference level for electric fields is 5kV/m, and the reference level for magnetic fields is 100µT. The 1999 EU Recommendation (Ref.9) uses the same reference level values as ICNIRP (Ref.8).
- 2.3.7 In the ICNIRP guidelines and the EU Recommendation, the actual limit is the basic restriction. The reference levels are not limits, but are guides to when detailed investigation of compliance with the actual limit, the basic restriction, is required. If the reference level is not exceeded, the basic restriction cannot be exceeded and no further investigation is needed. If the reference level is exceeded, the basic restriction may or may not be exceeded.
- 2.3.8 The Code of Practice on Compliance (Ref.7) endorses this approach and gives the values of field corresponding to the basic restriction, stating:
- “The 1998 ICNIRP exposure guidelines specify a basic restriction for the public which is that the induced current density in the central nervous system should not exceed 2mA m^{-2} . The Health Protection Agency specify that this induced current density equates to uniform unperturbed fields of $360\mu\text{T}$ for magnetic fields and 9.0kV m^{-1} for electric fields. Where the field is not uniform, more detailed investigation is needed. Accordingly, these are the field levels with which overhead power lines (which produce essentially uniform fields near ground level) shall comply where necessary. For other equipment, such as underground cables, which produce non-uniform fields, the equivalent figures will never be lower but may be higher and will need establishing on a case-by-case basis in accordance with the procedures specified by HPA. Further explanation of basic restrictions, reference levels etc is given by the Health Protection Agency.”*
- 2.3.9 The Code of Practice on Compliance (Ref.7) also specifies the land uses where exposure is deemed to be potentially for a significant period of time and consequently where the public guidelines apply. These land uses are, broadly, residential uses and schools.
- 2.3.10 Therefore, if the EMFs produced by an item of equipment are lower than 9kV/m and 360µT, the fields corresponding to the ICNIRP basic restriction, the equipment is compliant with the ICNIRP guidelines and with PHE recommendations and Government policy. If the fields are greater than these values, the equipment is still compliant with Government policy if the land use falls outside the residential and other uses specified in the Code of Practice (Ref.7), and it may also still be compliant if the fields are non-uniform.

2.4 Occupational Exposure Limits

- 2.4.1 Occupational exposures to EMFs in England, Wales and Scotland are controlled by the Control of Electromagnetic Fields at Work Regulations 2016 (Ref.15) (CEFW Regulations), which implement a 2013 EU Directive (Ref.16). For power frequencies, these are based on a more recent ICNIRP publication, ICNIRP 2010 (Ref.17) rather than the ICNIRP 1998 (Ref.8) that is the basis for the public exposure limits.
- 2.4.2 The CEFW 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.
- 2.4.3 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 Project would be compliant with in all areas accessible to the public and to employees of third parties. Therefore all exposures from the Project would be compliant with the occupational exposure limits and employers need take no additional action specific to the Project in order to comply (the CEFW Regulations impose certain general duties on all employers which would apply regardless of the Project).
- 2.4.4 In some areas of the Project, accessible only to National Grid staff and to contractors of National Grid but not to the public or to employees of third parties, e.g. inside substation perimeter fences, higher field could be found that exceed the public exposure limits. National Grid has its own procedures for ensuring that staff do not exceed the occupational exposure limits in these areas.

2.5 Potential Future Changes to Exposure Limits

- 2.5.1 As discussed, current Government policy for public exposure is based on the limits from the 1998 ICNIRP Guidelines (Ref.8), in the terms of the 1999 EU Recommendation (Ref.9). In 2010, ICNIRP published new exposure guidelines (Ref. 17) for the range of frequencies including power frequencies. These new guidelines do not apply in the UK for public exposure unless and until Government decides to adopt them. This is clear in the Code of Practice on Compliance (Ref. 7):

“Current Government policy on electric and magnetic fields (EMFs) is that power lines should comply with the 1998 ICNIRP Guidelines on exposure to EMFs in the terms of the 1999 EU Recommendation, and this Code of Practice implements this policy. As and when either ICNIRP issue new Guidelines or the EU revise the Recommendation, it will be for Government to consider those changes and to decide whether to adopt them or not. If Government policy changes, this Code of Practice will also be changed accordingly, but until that happens, the present policy as reflected in this Code of Practice remains in force.” (page 2)

- 2.5.2 In fact, ICNIRP's intention in its new guidelines does not appear to be to make the guidelines either more or less onerous. It takes account of the most recent scientific developments but, having done so, the key scientific effects used as the basis for the guideline levels are essentially unchanged and the safety margins applied are broadly unchanged. The detailed values derived as basic restrictions and reference levels have changed, but this is principally a consequence of a different method of derivation, without representing any change in scientific thinking about the appropriate level of protection. National Grid's assessment is that the Project would in fact be compliant with those guidelines were they ever to be introduced.
- 2.5.3 More generally, if in the future there were other changes to the exposure limits or other policies in relation to EMFs, National Grid would have a duty to bring the whole transmission system, including the Project, into compliance with whatever new regime was introduced.

2.6 Scientific Evidence

- 2.6.1 As well as these established effects, over the past 30 years it has been suggested that exposure to power-frequency magnetic or electric fields of the magnitude encountered in the environment could be linked with various health problems, ranging from headaches to Alzheimer's disease and cancer. The most persistent of these suggestions relates to childhood leukaemia. A number of epidemiological studies have suggested a statistical association between the incidence of childhood leukaemia and the proximity of homes to power transmission and distribution equipment or the power-frequency magnetic-field strengths in the homes. However, no causal link has been established between cancer (or any other disease) and magnetic or electric fields and indeed there is no established mechanism by which these fields could cause or promote the disease.
- 2.6.2 The question of possible health effects of environmental power-frequency fields has been thoroughly reviewed in recent years by a number of national and international bodies. The principal such bodies that currently have authoritative relevance in the UK are the PHE (formerly the HPA, formerly the NRPB), the International Agency for Research on Cancer (IARC), the WHO, and the relevant official scientific advisory committee for the EU, until recently the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR).
- 2.6.3 When assessing the scientific evidence on EMFs, it is essential to consider all the evidence and to perform an overall assessment of the evidence, weighting each strand of evidence and each individual study as appropriate to its strengths and weaknesses. No single study can ever be conclusive (in either direction). Such reviews have been performed by the authoritative expert bodies, and it is those bodies that provide the most reliable conclusions, and on whose conclusions Government policy is based. The following are summaries of the conclusions of these relevant authoritative review bodies.

The National Radiological Protection Board/The Health Protection Agency/Public Health England

- 2.6.4 In 2004 the then NRPB published new “Advice on Limiting Exposure to Electromagnetic Fields (0-300GHz)” (Ref.14) and accompanied it with a “Review of the Scientific Evidence for Limiting Exposure to Electromagnetic Fields (0-300GHz)” (Ref.18). The former summarises epidemiological evidence as follows (page 15):

54 “In the view of NRPB, the epidemiological evidence that time-weighted average exposure to power frequency magnetic fields above 0.4µT is associated with a small absolute raised risk of leukaemia in children is, at present, an observation for which there is no sound scientific explanation. There is no clear evidence of a carcinogenic effect of ELF EMFs in adults and no plausible biological explanation of the association that can be obtained from experiments with animals or from cellular and molecular studies. Alternative explanations for this epidemiological association are possible: for example, potential bias in the selection of control children with whom leukaemia cases were in some studies and chance variations resulting from small numbers of individuals affected. Thus any judgements developed on the assumption that the association is causal would be subject to a very high level of uncertainty.

55 “Studies of occupational exposure to ELF EMFs do not provide strong evidence of associations with neurodegenerative diseases.....

56 “Studies of suicide and depressive illness have given inconsistent results in relation to ELF EMF exposure, and evidence for a link with cardiovascular disease is weak.

57 “The overall evidence from studies of maternal exposure to ELF EMFs in the workplace does not indicate an association with adverse pregnancy outcomes, while studies of maternal exposure in the home are difficult to interpret.

58 “Results from studies of male fertility and of birth outcome and childhood cancer in relation to parental occupational exposure to ELF EMFs have been inconsistent and unconvincing.

59 “All these conclusions are consistent with those of AGNIR (2001)¹.

60 “NRPB concludes that the results of epidemiological studies, taken individually or as collectively reviewed by expert groups, cannot currently be used as a basis for restrictions on exposure to EMFs.”

International Agency for Research on Cancer (IARC)

- 2.6.5 The IARC is an agency of the WHO. The IARC’s Unit of Carcinogen Identification and Evaluation has, since 1972, periodically published Monographs that assess the evidence as to whether various agents are carcinogenic and classify the agents accordingly. In June 2001, a Working Group met to consider static and ELF EMFs (Ref.19). Power-frequency magnetic fields were classified as “possibly

¹ A reference to the previous NRPB review of the science by its Advisory Group on Non-Ionising Radiation

carcinogenic", on the basis of "limited" evidence from humans concerning childhood leukaemia, "inadequate" evidence from humans concerning all other cancer types, and "inadequate" evidence from animals. Power-frequency electric fields were judged "not classifiable" on the basis of "inadequate" evidence from both humans and animals. These classifications are consistent with the conclusions reached by the NRPB.

World Health Organization

- 2.6.6 The WHO published an Environmental Health Criteria Monograph in 2007 on ELF EMFs (Ref.20), produced by a Task Group that met in 2005. This concluded, in part:

"Chronic effects

Scientific evidence suggesting that everyday, chronic low-intensity (above 0.3-0.4µT) power-frequency magnetic field exposure poses a health risk is based on epidemiological studies demonstrating a consistent pattern of increased risk for childhood leukaemia. Uncertainties in the hazard assessment include the role that control selection bias and exposure misclassification might have on the observed relationship between magnetic fields and childhood leukaemia. In addition, virtually all of the laboratory evidence and the mechanistic evidence fail to support a relationship between low-level ELF magnetic fields and changes in biological function or disease status. Thus, on balance, the evidence is not strong enough to be considered causal, but sufficiently strong to remain a concern.

A number of other diseases have been investigated for possible association with ELF magnetic field exposure. These include cancers in both children and adults, depression, suicide, reproductive dysfunction, developmental disorders, immunological modifications and neurological disease.

The scientific evidence supporting a linkage between ELF magnetic fields and any of these diseases is much weaker than for childhood leukaemia and in some cases (for example, for cardiovascular disease or breast cancer) the evidence is sufficient to give confidence that magnetic fields do not cause the disease."

Scientific Committee on Emerging and Newly Identified Health Risks

- 2.6.7 The Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) was, until 2016, the EU's designated source of expert scientific advice on EMFs (along with other issues). In March 2015 SCENIHR published its most recent report on EMFs, "Potential Health Effects of Exposure to EMF" (Ref. 21). The section of the abstract concerned with power-frequency fields states:

"Overall, existing studies do not provide convincing evidence for a causal relationship between ELF MF exposure and self-reported symptoms.

The new epidemiological studies are consistent with earlier findings of an increased risk of childhood leukaemia with estimated daily average exposures above 0.3 to 0.4 µT. As stated in the previous Opinions, no mechanisms have been identified and no support is existing from experimental studies that could explain these findings, which, together with shortcomings of the epidemiological studies prevent a causal interpretation.

Studies investigating possible effects of ELF exposure on the power spectra of the waking EEG are too heterogeneous with regard to applied fields, duration of exposure, and number of considered leads, and statistical methods to draw a sound conclusion. The same is true for behavioural outcomes and cortical excitability.

Epidemiological studies do not provide convincing evidence of an increased risk of neurodegenerative diseases, including dementia, related to power frequency MF exposure. Furthermore, they show no evidence for adverse pregnancy outcomes in relation to ELF MF. The studies concerning childhood health outcomes in relation to maternal residential ELF MF exposure during pregnancy involve some methodological issues that need to be addressed. They suggest implausible effects and need to be replicated independently before they can be used for risk assessment.

Recent results do not show an effect of the ELF fields on the reproductive function in humans.”

Conclusions from Reviews of Science

- 2.6.8 There is some scientific evidence suggesting that electric or, particularly, magnetic fields may have health effects at levels below the current UK exposure guidelines. The authoritative classification is that of the WHO, in 2001 (Ref.19) and reiterated in 2007 (Ref.20), that power-frequency magnetic fields are “*possibly*” a cause of cancer, specifically just of childhood leukaemia, with the evidence relating to any other health effect “*much weaker*”.

2.7 Precautionary Policies

- 2.7.1 The Government has addressed the uncertainty in the scientific evidence by adopting specified precautionary measures relating to various sources of EMFs.
- 2.7.2 The only specific precautionary measure that relates to high-voltage power lines or any other high-voltage transmission equipment is the policy of “optimum phasing”. “Phasing” is the order in which the conductors of the two circuits of double-circuit overhead lines are connected relative to each other, and certain phasing arrangements produce lower magnetic fields than others. This policy was introduced in the Written Ministerial Statement of 2009 (Ref.10) in response to a recommendation from the Stakeholder Advisory Group on ELF EMFs (SAGE) in its First Interim Assessment (Ref.22). The details are given in a second Code of Practice, ‘Optimum Phasing of High Voltage Double-Circuit Power Lines’ (Ref.12).
- 2.7.3 “Optimum phasing” is the phasing that produces the lowest magnetic fields to the sides of the line, taking account of the likely current flows in the line. **Paragraph 2.10.11** of NPS EN-5 mentions the February 2011 publication “Optimum Phasing of high voltage double-circuit Power Lines – A Voluntary Code of Practice”. This has now been replaced by a March 2012 edition with the same name and substantive content. The Code of Practice on Optimum Phasing (Ref.12) states that new overhead power lines should have optimum phasing where reasonable. It explains that it will normally be possible to achieve optimum phasing simply by choosing how to order the connections at the end of the overhead line, but that if achieving optimum phasing would either require an extra structure or would conflict with the requirements for power system stability, this would normally be “unreasonable” and is not required. The Code of Practice states that where necessary, “unreasonable”
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will be interpreted in terms of the cost-benefit analysis presented in the SAGE First Interim Assessment (Ref.22).

2.7.4 All the relevant scientific evidence on EMFs was considered fully in the process of establishing the exposure guidelines that apply in the UK. Those exposure guidelines together with the policy on optimum phasing (and other precautionary policies that relate only to low-voltage equipment) are considered by PHE and the Government to be the appropriate response to that evidence.

2.7.5 Government have specifically rejected the introduction of “corridors” around power lines on EMF grounds, stating of this option in the Written Ministerial Statement (Ref.10):

“The Government therefore considers this additional option to be disproportionate in the light of the evidence base on the potential health risks arising from exposure to ELF/EMF and has no plans to take forward this action.”

2.7.6 Having established that it is not Government policy to have restrictions on homes and schools near power lines, the Statement goes on to say (**paragraph 38**):

“It is central Government’s responsibility (rather than individual local authorities) to determine what national measures are necessary to protect public health.”

2.7.7 This makes it clear that Government has not introduced any restrictions (beyond those that may be created by the EMF exposure limits and the safety clearance distances) on constructing new power lines close to existing properties on grounds of safety or health risks, and neither is it appropriate for individual local authorities to do so.

2.7.8 In relation to undergrounding, the NPS EN-5 (Ref.6) states:

“2.10.12 Undergrounding of a line would reduce the level of EMFs experienced, but high magnetic field levels may still occur immediately above the cable. It is not the Government’s policy that power lines should be undergrounded solely for the purpose of reducing exposure to EMFs. Although there may be circumstances where the costs of undergrounding are justified for a particular development, this is unlikely to be on the basis of EMF exposure alone, for which there are likely to be more cost-efficient mitigation measures.”

2.7.9 Therefore, no additional measures or precautions are necessary or appropriate beyond the exposure limits and the policy on optimum phasing.

2.8 Pregnant women and other potentially sensitive subgroups

2.8.1 The scientific basis as given by the NRPB (now PHE) in their recommendation to Government for setting the public exposure limits lower than the occupational limits is not that the public in general need greater protection; it is that the public contains certain potentially sensitive subgroups, where EMF effects may occur at lower levels than in the population at large. One of those subgroups is pregnant women and the developing embryo (others include people with epilepsy or taking certain drugs).

2.8.2 Therefore, the potential extra sensitivity of pregnant women is already built in to the public exposure limits. No additional protective measures are required.

2.9 Microshocks

- 2.9.1 Under high-voltage overhead lines, conducting objects may become electrically charged if they are isolated from earth. If this charged object is then touched by a person at a different electrical potential, charge is transferred between the person and the object. When the person is very close to the object but before touching it, the voltage difference between the person and the object can be sufficient to cause the air in the gap to break down, and a small spark discharge occurs. This can be perceived by the person and is known as a microshock.
- 2.9.2 The size of a microshock depends on the size of the electric field, the sizes of the objects concerned, how well grounded or insulated they are, meteorological conditions, and the sensitivity of the skin. All of these factors determine the severity of the perception which can range from barely perceptible through to annoyance and in some rare circumstances even pain. Microshocks are similar to the static shocks that can occur by, for example, walking across a nylon carpet in dry weather. Microshocks have no known long-term health effects and any sensation is normally confined to the momentary spark discharge as contact is made or broken.
- 2.9.3 In a 2005 Information Sheet (Ref.23), HPA (now PHE) state:
“... on the basis of the available evidence, the direct effects of microshocks on the body are not considered capable of producing lasting harm. The response to some extent will depend on the sensitivity of the individual. Although the possibility of microshocks cannot be ruled out, in field strengths up to about 5kV m⁻¹ they are unlikely to be painful to the majority of people.”
- 2.9.4 Microshocks are indirect effects and as such are not directly covered by the quantitative exposure limit values that protect against direct effects of electric fields. The ICNIRP guidelines (Ref.8) do have a cautionary reference level of 5kV/m, but limiting exposure to 5kV/m is not considered the most appropriate way of dealing with microshocks. Reducing electric fields by changes to the design is possible, but will usually result in taller pylons, increasing the visual impact of the overhead line. As there is no threshold of electric field for preventing microshocks, the benefit of reducing the field to 5kV/m may be marginal. Rather than introducing an arbitrary limit the Code of Practice on Compliance (Ref.7) states:
“.....there is a suite of measures that may be called upon in particular situations, including provision of information, earthing, and screening, alongside limiting the field which should be used to reduce the risk to the public of indirect effects. In some situations, there may be no reasonable way of eliminating indirect effects, for instance where erecting screening would obstruct the intended use of the land.”
- 2.9.5 A separate Code of Practice on Microshocks, developed jointly by Industry and the then DECC, has been adopted (Ref. **Error! Reference source not found.**). This follows the principles for managing microshocks quoted above, but contains more details on the practical measures which can be taken.
- 2.9.6 The proposed overhead line has been designed to comply with the government exposure limit values for electric fields, ensuring 9kV/m is not exceeded, and in accordance with the Code of Practice on Microshocks, as demonstrated in Section 6.2 below. Some areas under the proposed overhead line would have electric fields which could potentially cause microshocks to occur if the particular set of circumstances required exists. National Grid will ensure that if microshocks are
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reported these will be investigated and mitigated where appropriate, following the provisions of the Code of Practice on Microshocks (Ref.24).

2.9.7 Microshocks will not occur for the tunnel, which produces no external electric fields.

2.10 Active Implantable Medical Devices

2.10.1 Electric and magnetic fields can affect Active Implantable Medical Devices (AIMDs), such as pacemakers, insulin pumps and Implanted Cardiac Defibrillators (ICDs), if the external field strength exceeds the immunity of the device. EMFs can induce voltages in the body which, if high enough, can potentially exceed the immunity of the device and temporarily affect its operation.

2.10.2 All modern AIMDs are expected to be immune from interference from electric and magnetic EMFs up to the reference levels for public exposure of the 1999 EU Recommendation (Ref.9) where the AIMD has been implanted and programmed in a standard manner. The reference levels at 50Hz are 100 μ T for magnetic fields and 5kV/m for electric fields. However, many AIMDs will have considerably higher immunity to external EMFs than the minimum requirements.

2.10.3 Specifically, the Active Implantable Medical Devices Directive (90/385/EEC) (Ref. 25) includes the following provision:

“Devices must be designed and manufactured in such a way as to remove or minimize as far as possible: ... risks connected with reasonably foreseeable environmental conditions such as magnetic fields, external electrical influences ...”

2.10.4 Neither National Grid nor the Medicines and Healthcare Products Regulatory Agency (MHRA) are aware of any instance of a patient with a modern, correctly fitted AIMD experiencing any interference from the electricity transmission system.

2.10.5 The Project would be capable of producing electric and magnetic fields which, while still compliant with the public exposure limits, are in excess of the reference levels for public exposure. Therefore, in theory, some interference of EMFs with AIMDs could possibly occur. However, some existing National Grid overhead lines and underground cables are likewise theoretically capable of producing fields that exceed the public reference levels, and as noted above neither the MHRA or National Grid are aware of any instance of electricity transmission infrastructure interfering with a correctly fitted modern AIMD such as a pacemaker or ICD. The risk of any interference occurring is not significant in practice for the following reasons:

- 1) While manufacturers have to ensure that AIMDs are immune up to the reference levels for public exposure, many modern AIMDs will be immune to EMFs considerably in excess of these levels; and
- 2) the maximum EMFs from an overhead line or underground cable as calculated for assessing compliance with the exposure limits represent a worst-case scenario, chosen to demonstrate that exceeding the exposure guidelines is not possible. However, typically, the overhead line or underground cable would produce EMFs 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 EMFs at ground level, with the minimum clearance found only in a limited area towards the middle of certain spans.

2.10.6 Thus, there is considerable confidence in saying that, based on the absence of reported incidents and on the typical EMF exposures that would occur on a daily basis, transmission assets do not appear to interfere with AMIDs in practice. The risk of any interference occurring is assessed as being negligible and does not constitute a significant effect.

2.10.7 This is confirmed in NPS EN-5 (Ref.6), at **Section 2.10.7**, which states that:

“The Department of Health’s Medicines and Healthcare Products Regulatory Agency (MHRA) does not consider that transmission line EMFs constitute a significant hazard to the operation of pacemakers.”

2.11 Farming, Flora and Fauna

2.11.1 No effects of EMFs on farming, flora and fauna are expected.

2.11.2 The NPS for Electricity Networks Infrastructure (EN-5) (Ref.6) in Part 2, **Section 2.10.8** states:

“There is little evidence that exposure of crops, farm animals or natural ecosystems to transmission line EMFs has any agriculturally significant consequences.”

2.12 The Electricity Safety, Quality and Continuity Regulations 2002

2.12.1 NPS EN-5 (Ref.6, paragraph 2.10.10) refers to the Electricity Safety, Quality and Continuity Regulations 2002 (Ref.13) which set out the minimum height, position, insulation and protection specifications at which conductors can be strung between pylons to ensure safe clearance of objects. Regulation 17(2) and Schedule 2 require the clearances set out in Table 3.

Table 3: The Electricity Safety, Quality and Continuity Regulations 2002 – Minimum Height above Ground of Overhead Lines

Nominal Voltages	Over Roads (m)	Other Locations (m)
Exceeding 66kV but not exceeding 132kV	6.7	6.7
Exceeding 132kV but not exceeding 275kV	7	7
Exceeding 275kV but not exceeding 400kV	7.3	7.3

- 2.12.2 The minimum conductor clearance information for the Project is provided in section 6.2 which demonstrates compliance with these requirements.

2.13 Summary of Policy and Legislation

- 2.13.1 The EMF policies applying to high-voltage electricity equipment comprise compliance with the exposure guidelines, as set out in the Code of Practice on Compliance; the policy on optimum phasing, as set out in the Code of Practice on Optimum Phasing; and the policy on indirect effects expressed in the Code of Practice on Microshocks; but no other policies.
- 2.13.2 NPS EN-5 (Ref.6) explicitly applies these policies to applications for consent for new electricity connections such as the Project. If a proposed overhead line or, where relevant, underground cable, substation etc. complies with these, there are no grounds in relation to EMFs not to grant consent.

3 ELECTROMAGNETIC COMPATIBILITY

- 3.1.1 Electromagnetic compatibility (EMC) is controlled by EU Directive 2014/30/EU (Ref.26) (the EMC Directive) which replaced Directive 2004/108/EC (Ref.27) on 20 April 2016. These Directives are enacted in UK law by Regulations. The current Regulations are the 2016 Regulations (Ref. 28), which are based on the 2014 Directive.
- 3.1.2 The requirements of the EMC Directive are that the electromagnetic disturbance that an apparatus generates should not exceed a level allowing radio and telecommunication equipment and other apparatus to operate as intended; and that the apparatus itself has an adequate level of intrinsic immunity to electromagnetic disturbance to enable it to operate as intended.
- 3.1.3 Permanent, fixed infrastructure of the type owned and operated by National Grid is covered by specific provisions in the EMC Directive relating to “fixed installations”.
- 3.1.4 Article 6 of the 2014 Directive (Ref. 26) requires conformity with Annex 1, Part 2 of that Directive, which in turn requires that “*A fixed installation shall be installed applying good engineering practices....*” in order to avoid EMC problems.
- 3.1.5 The main potential source of interference from transmission systems such as the proposed Project arises from radio frequency (RF) emissions caused by corona discharge from overhead lines and substations (underground cables do not in general produce any significant radio-frequency emissions). Corona discharge results from the high voltages on the surface of conductors particularly in wet conditions where water droplets can concentrate the electric field; it is recognisable by the characteristic crackling sound. RF emissions and corona levels are limited by designing to National Grid’s technical specifications which include BS5049-3 (Ref.29), along with other equipment specific standards such as BS EN60437 (Ref.30) for the insulators on the pylons. Thus National Grid’s Transmission System applies good engineering practices and meets the essential requirements detailed in Annex 1 of the EMC Directive.
- 3.1.6 This was initially documented and certified under the provisions of the EMC Directive then in force, the 1989 Directive 89/336/EEC (Ref.31), by creating a Technical Construction File (TCF) for the National Grid transmission system. The

TCF is based on a combination of extensive on-site testing (overhead lines and substations) and examination of National Grid's technical specifications, policies and standards to ensure that RF noise and corona are adequately addressed. The on-site surveys showed that there were no significant emission problems to address; and equipment technical specifications and policies ensured equipment was designed in accordance with British Standards to limit RF noise and corona. Using the rationale of the TCF it was determined that the National Grid system meets the essential requirements of the EMC Directive. A Certificate of Conformity was issued by Hursley EMC Services (the Competent Body) and is provided at **Appendix A** to this document.

- 3.1.7 The subsequent EMC Directive, 2004/108/EC (Ref.27), and the current EMC Directive 2014/30/EU (Ref.26), no longer use the terminology of a TCF and Certification. However, the essential requirements of the Directives have not changed, and the content of the TCF remains a valid method of documenting compliance with the EMC Directive.
- 3.1.8 The Project would contain electrical equipment that is the same as or similar to that tested by on-site measurements documented in the TCF, and would also be designed to the same technical specifications.
- 3.1.9 Occasionally, radio interference is reported from equipment on the National Grid system. The most likely cause of such interference is equipment that has been damaged or degraded while in operation. This sort of occurrence is normally addressed during routine maintenance. Interference reports are extremely rare but where interference is reported it will be investigated and remedial action will be taken to mitigate interference where it is appropriate to do so.
- 3.1.10 Given that the provisions of the current EMC Directive are met through using good engineering practice and applying the relevant technical standards, and that the EMC performance of this system has been certificated as compliant by a Competent Body following appropriate on-site testing, the Project would present no issues with TV or radio interference under normal operating conditions.

3.2 Effects on magnetic compasses

- 3.2.1 Magnetic compasses, whether traditional magnetic needle designs or alternatives such as fluxgate magnetometers, operate from the Earth's magnetic field, and are susceptible to any perturbation to the Earth's magnetic field by other sources.
 - 3.2.2 This is a potential issue with direct current (DC) conductors or cables, which produce a static magnetic field that perturbs the geomagnetic field. However, there are no DC cables proposed for use in the Project and no DC fields could be produced.
 - 3.2.3 The magnetic fields produced by this Project would be 50Hz fields. These oscillate far too quickly for a magnetic compass needle to be affected. Fluxgate magnetometers are capable of responding to 50Hz fields, but, when used as a compass, always have filtering to eliminate unwanted frequencies including 50Hz. They can cease working correctly if saturated by a high-enough field, but the field required are orders of magnitude higher than would be produced by the Project.
 - 3.2.4 Therefore, the Project would have no significant effect on magnetic compasses.
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4 ASSESSMENT METHODOLOGY

- 4.1.1 The assessment considers the EMFs produced from the electricity assets associated with the Project. Each asset is assessed including the cumulative impacts on existing assets.

4.2 Study Area

- 4.2.1 The EMFs produced by the electrical assets of the Project would have a given magnitude at a given distance from the asset. Therefore, the Study Area of the assessment includes all areas around the assets where the EMFs could potentially be significant, such that the assessment is asset-specific rather than location-specific. Therefore, any changes in alignment that could occur within the Order Limits or Limits of Deviation proposed for the Project would not alter the assessments presented here. This ensures that the equipment would be compliant with exposure guidelines irrespective of the Project's exact location within the Order Limits or Limits of Deviation.

4.3 Predicted Field Levels

- 4.3.1 The magnetic field produced by a current in an individual conductor falls with distance from the conductor. Where there is more than one current forming part of one or more electrical circuits, there is also partial cancellation between the magnetic fields produced by the individual currents, and that cancellation generally becomes more complete as the distance increases. Overall, the magnetic field is highest at the point of closest approach to the conductors and falls quite rapidly with distance. Similarly, there is partial cancellation between the electric fields produced by the voltages on individual conductors, and the electric field is usually highest at the point of closest approach to the conductors and falls quite rapidly with distance.
- 4.3.2 For sources of field with a simple, defined geometry, such as overhead lines or underground cables, calculations are the best way of assessing fields and are acceptably accurate. The calculations of fields presented here follow the provisions specified in the Code of Practice on Compliance (Ref.7) and were performed using specialised computer software that has been validated against direct measurement (Ref.32).
- 4.3.3 By contrast, due to the complex physical arrangement of electrical equipment, the EMFs produced by an electrical substation or sealing-end compound are not readily calculable. However, the highest field levels at and outside the perimeter of a substation are usually those produced by the overhead lines entering the substation. The fields produced by equipment within the substation are generally smaller and decrease with distance more quickly than fields generated by overhead lines.
- 4.3.4 Since field strengths are constantly varying, they are usually described by reference to an averaging calculation known as the "root mean square" or RMS. Future mention of power-frequency field strengths in this chapter refer to the RMS amplitude of the power-frequency modulation of the total field, which is the conventional scientific way of expressing these quantities.

- 4.3.5 To assess compliance with exposure limits, the Code of Practice on Compliance (Ref.7) specifies that the maximum fields the overhead line is capable of producing should be calculated using the following conditions:
- 1) electric fields: for nominal voltage and design minimum clearance;
 - 2) magnetic fields: for the highest rating that can be applied continuously in an intact system (i.e. including ratings which apply only in cold weather, but not including short-term ratings or ratings which apply only for the duration of a fault elsewhere in the electricity system) and design minimum clearance; and
 - 3) electric and magnetic fields: for 1m above ground level, of the unperturbed field, taking account of the correct wire type and bundle size, taking account of the basic pylon geometry for the design of overhead line in question, but ignoring variations in conductor spacing at angle pylons etc, of the 50Hz component ignoring harmonics, ignoring zero-sequence currents and voltages and currents induced in the ground or earth wire, and using the infinite-straight-line approximation.
- 4.3.6 The same provisions apply, where relevant, to assessing the fields from underground cables.
- 4.3.7 Therefore, the calculations for the Project were performed using worst-case conditions including minimum conductor clearances for overhead lines. The circuits are unlikely to operate at this maximum rating routinely, resulting in lower typical magnetic fields on a day to day basis.
- 4.3.8 Electric fields (but not magnetic fields) are readily perturbed by conducting objects, including, for example, buildings, fences and trees. The fields calculated here are unperturbed fields, as specified by the Code of Practice on Compliance (Ref.7). These give a valid indication of the size of any electric-field related phenomena over the area concerned, but the local value, close to a source of perturbation, would vary. In practice, perturbations within or to the sides of buildings and other fixed objects usually act so as to reduce, not increase, the electric field. Fields inside any buildings are generally much reduced. However, the Code of Practice (Ref.7) specifies that it is acceptable to demonstrate compliance by reference to the unperturbed fields.
- 4.3.9 As an alternative to calculations, the Code of Practice on Compliance (Ref.7) specifies that there are certain classes of equipment which inherently produce fields below the guideline levels, and can be assumed to comply without producing case-by-case specific assessments of the field. Substations are one such type of equipment:

“The Energy Networks Association will maintain a publicly-available list on its website of types of equipment where the design is such that it is not capable of exceeding the ICNIRP exposure guidelines, with evidence as to why this is the case. Such types of equipment are likely to include:

- overhead power lines at voltages up to and including 132kV*
- underground cables at voltages up to and including 132kV*
- substations at and beyond the publicly accessible perimeter*

Compliance with exposure guidelines for such equipment will be assumed unless evidence is brought to the contrary in specific cases.” (page 4)

- 4.3.10 The Energy Networks Association's publicly available list can be found on the National Grid EMF website (<http://www.emfs.info/compliance/public/>). This confirms that substations (that do not contain a static var compensator) and sealing end compounds, such as those proposed or that would be extended by the Project, are within the class of equipment which are regarded as inherently compliant without the need for case-by-case specific assessments.

4.4 Combining fields from different sources

- 4.4.1 When more than one source of EMFs are present, such as two different overhead lines or an overhead line and an underground cable, the field from each source is calculated separately, and it is then necessary to combine the two individual fields to obtain the resulting field.
- 4.4.2 Because of the physical properties of EMFs, specifically that they are what is known as "vectors" not "scalars", (i.e. direction as well as magnitude is relevant), the magnitudes of the EMFs from two different sources do not simply add together. The addition of EMFs from different sources is complex, but has the general effect that, when the field from one source is larger than the other, the larger field dominates, with the smaller field making only a small difference to the resulting field.

4.5 Assessment of Effects

- 4.5.1 The Project would be assessed as having a significant effect if non-compliance with the EMF exposure limits was demonstrated, using the principles set out in the Code of Practice on Compliance (Ref.7). Conversely, as specified in NPS EN-5 (Ref.6), if the Project complies with the exposure limits and with the policies on phasing (Ref.12) and microshocks (Ref.24), EMF effects would be assessed as not significant and no mitigation would be necessary.

5 BASELINE ENVIRONMENT

- 5.1.1 The Project would be located within a mixture of primarily rural and semirural areas, which accommodate existing electrical assets. All equipment that generates, distributes or uses electricity produces EMFs. The UK power frequency is 50Hz which is the principal frequency of the EMFs produced.
- 5.1.2 Electric and magnetic fields 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 μ T 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 100V/m in fine weather.
- 5.1.3 As detailed earlier in this Report, the Earth's natural fields are static, and the power system produces alternating fields. In homes in the UK 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 μ T with an average of approximately 0.05 μ T, normally arising from currents in the low voltage distribution circuits that supply

electricity to homes. 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 μ T for electric razors and hair dryers, 800 μ T for vacuum cleaners, and 50 μ T for washing machines. The electric field in most homes is in the range 1-20V/m, rising to a few hundred V/m close to appliances (Ref.33).

5.1.4 Along or close to much of the proposed overhead line element of the Project there is an existing 400kV overhead line. There are also overhead lines operated by the Distribution Network Operator at 132kV and lower voltages in the area which produce EMFs. The fields produced by these specific lines depend on the loads carried and will be different for different lines and at different times but would all be within the exposure limits. Magnetic and electric fields for typical loads that overhead lines such as these carry are shown in **Figure 2** and Figure 3. Note that, in general, the typical load for a 400kV line is usually taken as 500A. However, during the period when the Wylfa Magnox power station was generating, and the power was exported on the existing 400kV line, the typical load carried by this particular line would have been 700A, slightly higher than for 400kV lines in general. The magnetic fields corresponding to both currents are shown on the graph. Wood-pole distribution lines are represented by a 33kV design. The cumulative effect of the fields from the existing and the proposed new line are considered separately below.

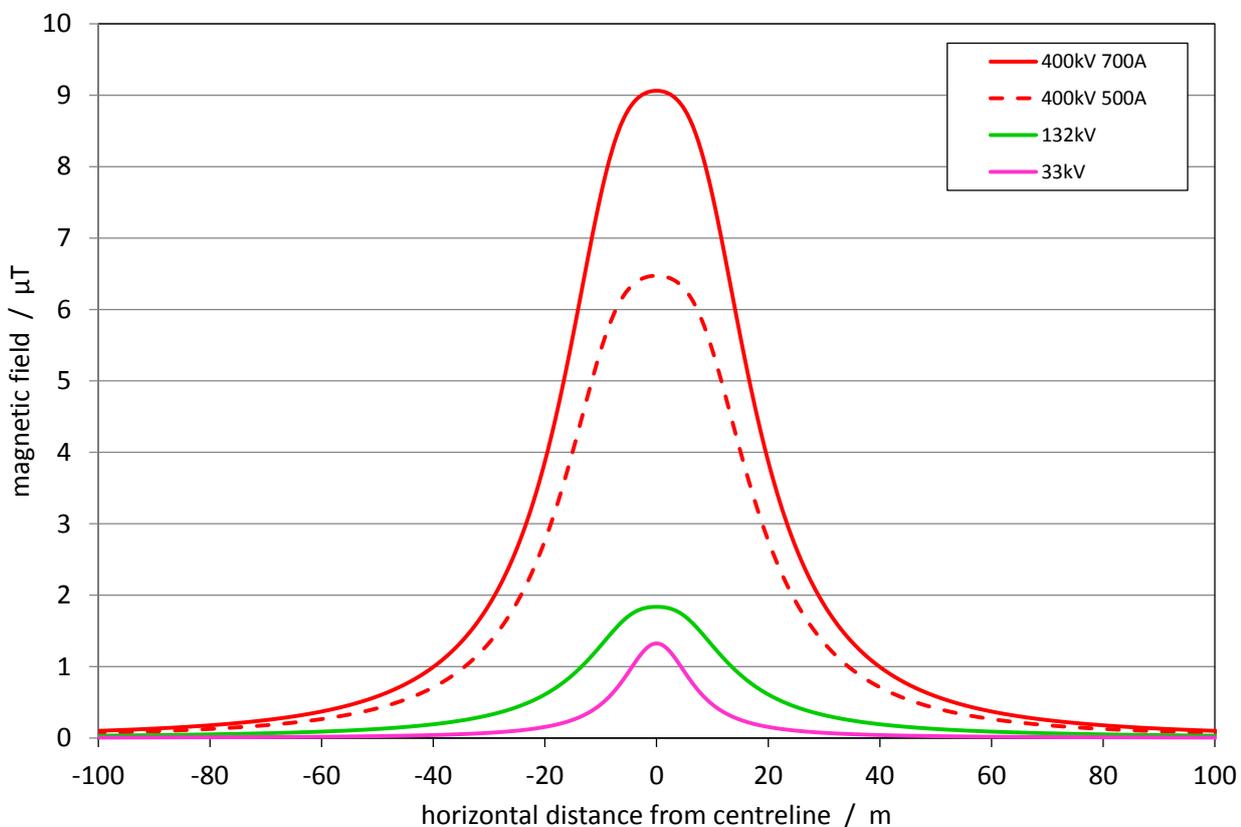


Figure 2: Typical magnetic fields from existing overhead lines

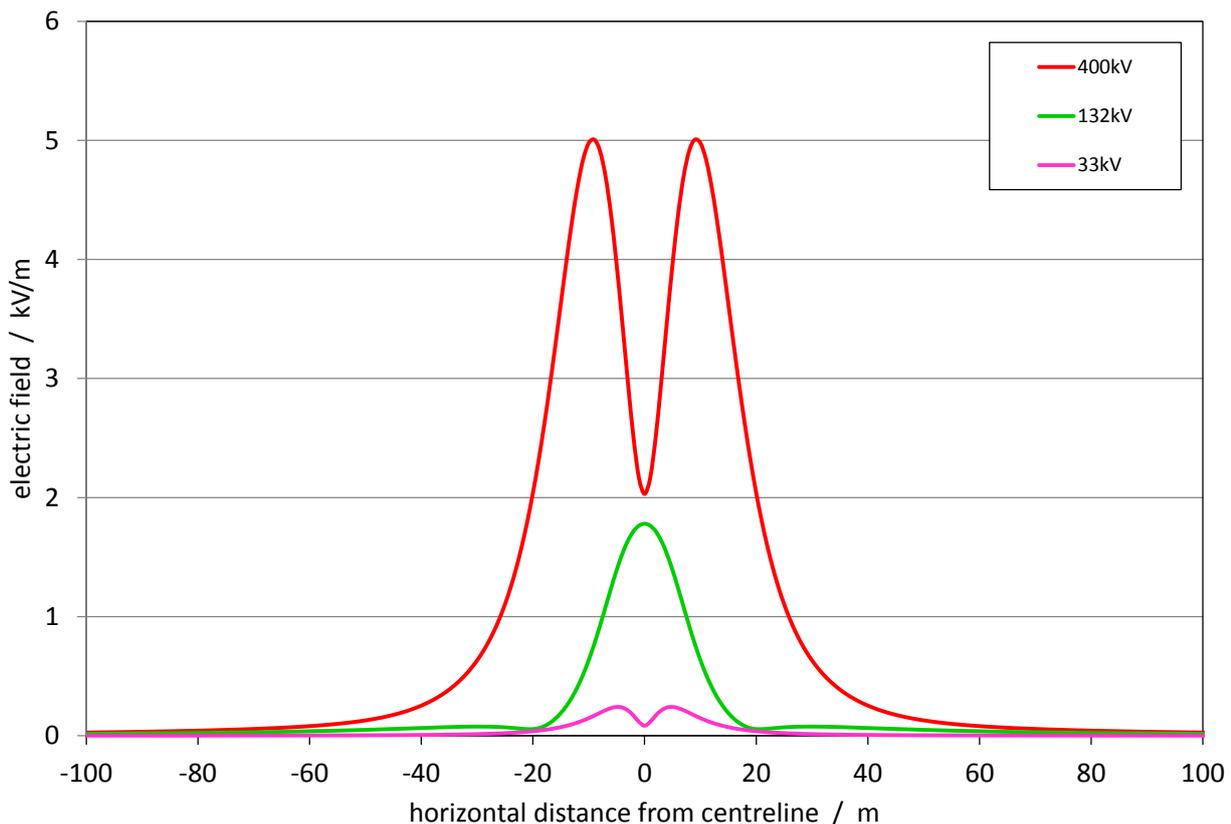


Figure 3 : Typical electric fields from existing overhead lines

5.1.5 Since Wylfa Magnox Power Station ceased generating, the existing line has typically carried only the relatively low level of electricity demand on Anglesey, so loads on the line are currently typically well below typical loads and the loads carried in the past. This means that, at present, the typical magnetic fields from the existing line are likewise well below these values.

6 PREDICTION AND ASSESSMENT OF THE SIGNIFICANCE OF THE POTENTIAL EFFECTS

6.1 Construction Effects

6.1.1 During construction and prior to energisation, transmission equipment would not produce any significant EMFs. Therefore construction effects are not considered further.

6.2 Operational Effects – overhead line

Predicted field from proposed new 400kV overhead line

6.2.1 The detailed assessments that follow are based on the DCO Application design of overhead line. This is a particular design of traditional lattice pylon, known as the

“L12”, with a shorter length of a low-height L12 variant, both with a particular set of conductors, known as “Twin Redwood”. Additional calculations, not presented here, have been performed to ensure that any alternative that might be used would also be compliant.

- 6.2.2 All spans would have a minimum conductor design clearance to ground of 8.1m, although in many cases this would be higher.
- 6.2.3 Calculations have been performed for two different conditions. Firstly, for purposes of assessing compliance with the exposure limits under worst-case conditions, the calculations have been performed for the maximum field the overhead line would be capable of producing, i.e. specifically for the rating of the overhead lines. Secondly, as extra information not required for assessing compliance, calculations have also been performed for what is considered to be a likely typical load in the line in the future. All calculations were performed in accordance with the conditions set out in the Code of Practice on Compliance (Ref. 7).
- 6.2.4 Sections of the new line that is the subject of this application will be connected to sections of the existing line, such that the resulting two connections from Pentir to Wylfa each comprise a mixture of existing line and new line. The ratings of these two connections will be different: that for the eastern route (to be known then as 4ZA), utilising the existing 400kV overhead line over the Menai Strait, will be determined by the overhead lines themselves, whereas that for the western route (to be known as 4AP), which includes the proposed new tunnel under the Menai Strait, will be determined by the cables used for the underground section. Calculations for the maximum field produced by both connections are presented here. For the typical fields, the typical scenario will be that the power being exported from Wylfa Newydd divides equally between the connections, and hence the typical fields are the same for both connections. (There are scenarios in which the load does not divide evenly in this way, but this equal division will be typical.)
- 6.2.5 Electric fields do not depend on the current and hence do not depend on the rating. The electric fields, both maximum and typical, will be the same for both overhead lines.
- 6.2.6 The results of these calculations are illustrated in Figure 4 (for magnetic fields) and Figure 5 (for electric fields). The relevant rating, the winter pre-fault continuous rating, is 1500 mega-volt-amperes or MVA which equates to 2165A for the western connection, and 2650MVA which equates to 3820A for the eastern connection. The calculated EMFs are presented for the overhead line carried on conventional pylons (the majority of the route) and on low-height pylons (for a short length of the route on the approach to the underground section on the western connection).
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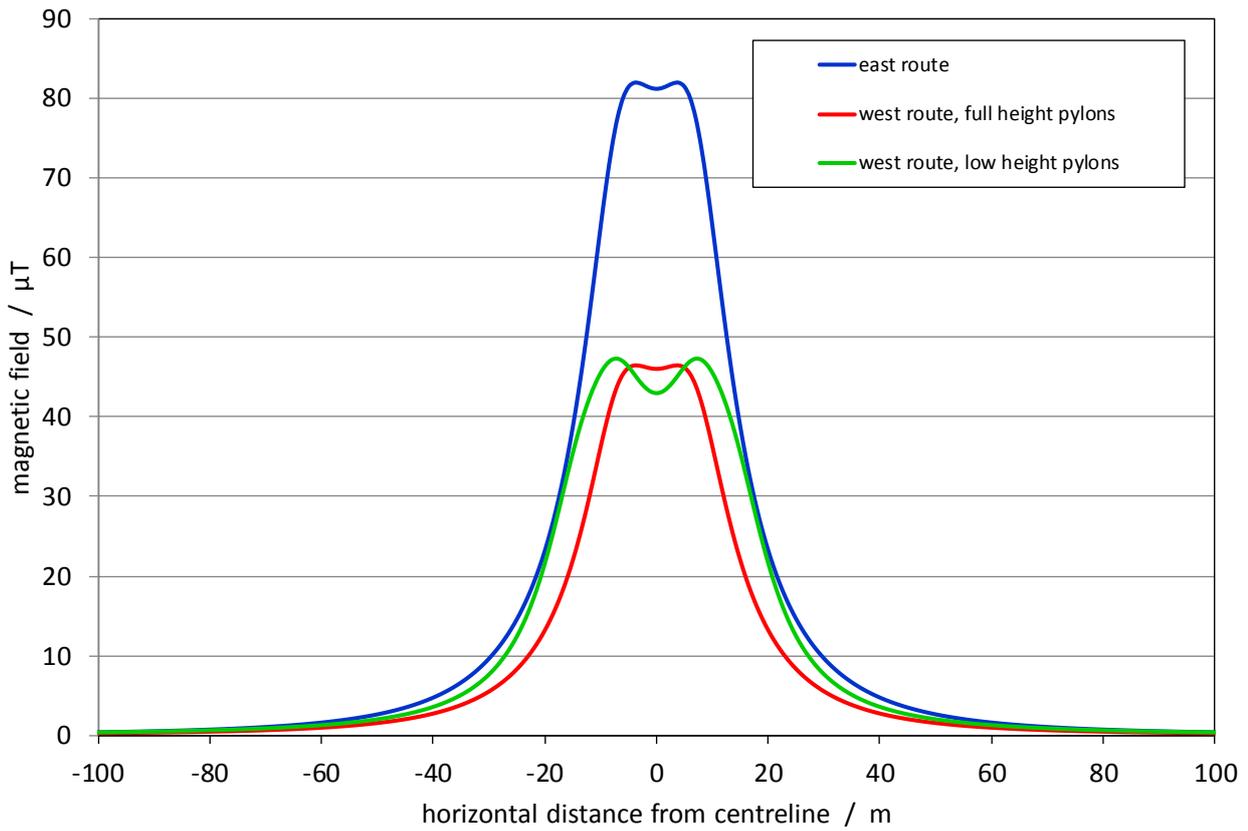


Figure 4 : Maximum magnetic fields from each proposed 400kV overhead line

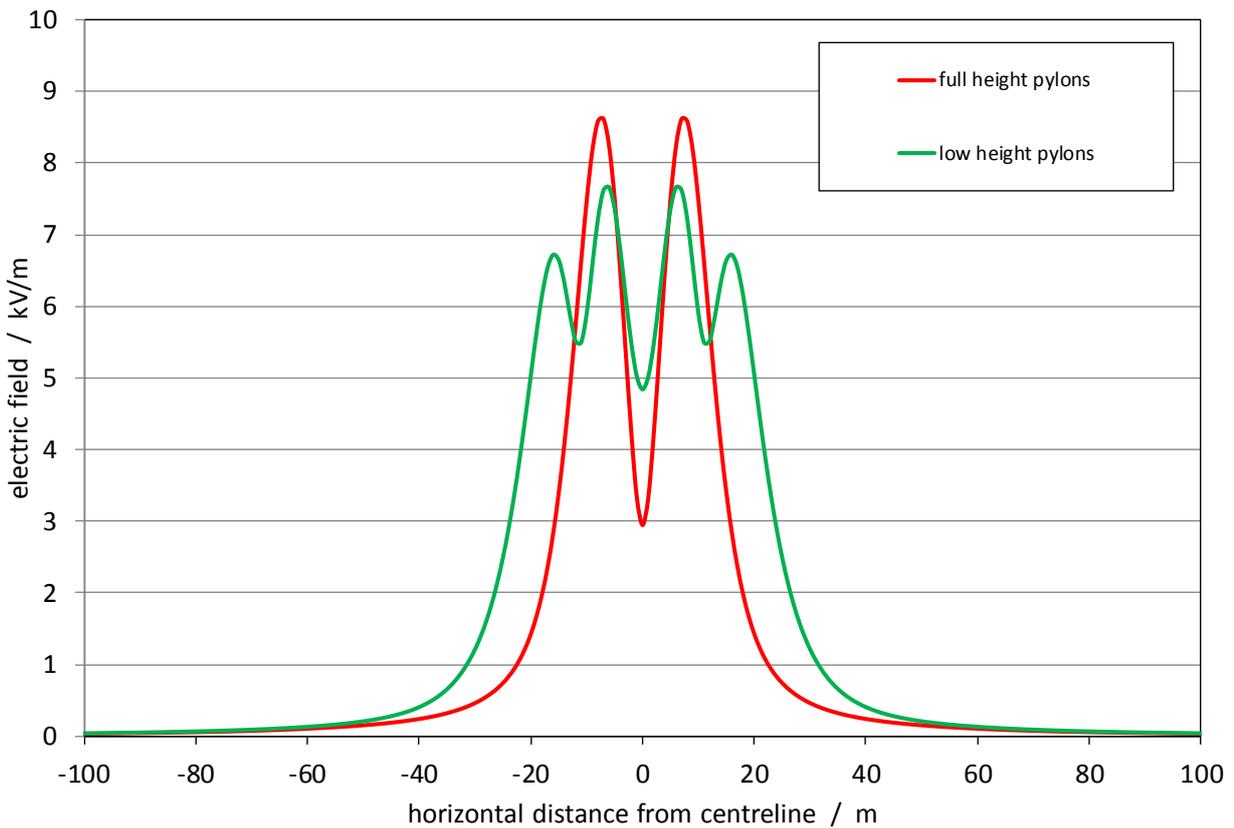


Figure 5 Maximum electric fields from each proposed 400kV overhead line

6.2.7 The results presented above are for the maximum field each overhead line would be capable of producing (i.e. the rating level) as specified in the Code of Practice on Compliance (Ref.7). Under normal conditions, the overhead lines would carry lower loads and therefore produce lower magnetic fields. Typical clearances above ground would also be higher than the minimum clearances assumed for the previous calculations, which would reduce both the electric and magnetic fields. Typical, as opposed to maximum, magnetic and electric fields from the proposed 400kV overhead lines for the standard-height pylons are shown in Figure 6 and Figure 7.

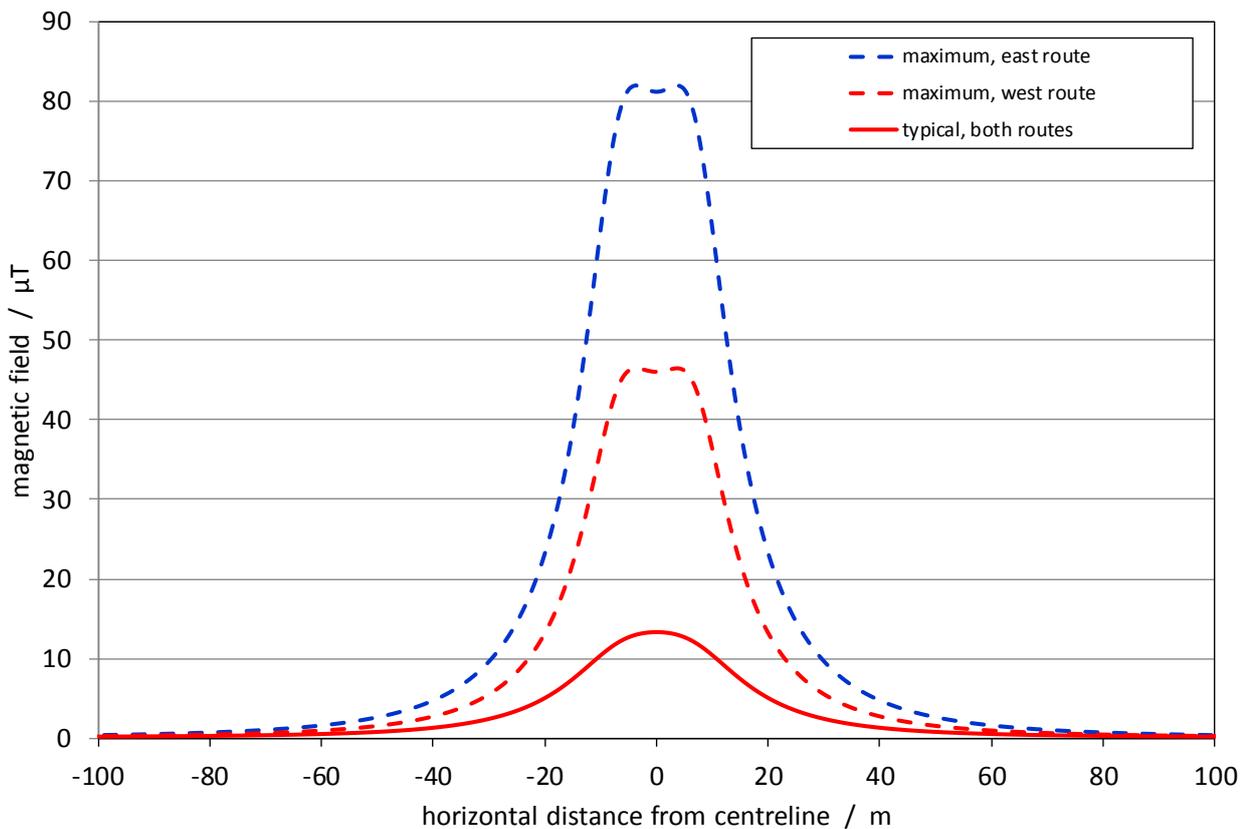


Figure 6 : Typical magnetic fields from each proposed 400kV overhead line

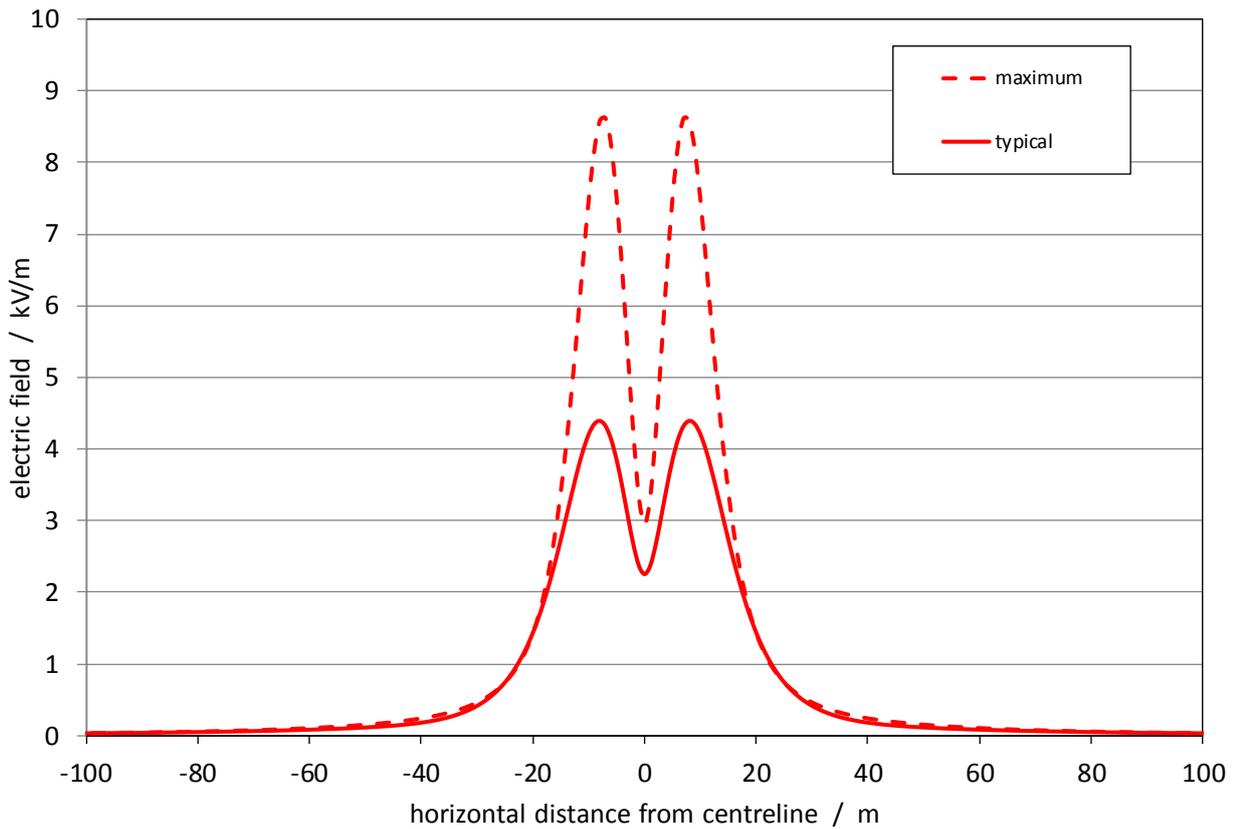


Figure 7: Typical electric fields from each proposed 400kV overhead line

6.2.8 The maximum fields from the various overhead lines are summarised in Table 4.

Table 4: Summary of calculated maximum fields for proposed overhead lines

Voltage	400kV	
Height above ground of calculation	1m	
Ground clearance of lowest conductors	8.1m	
Pylon and Conductor type	L12 full height Twin Redwood	L12 low height Twin Redwood

Phasing	Transposed (optimum for conventional pylons)		Optimum for low-height pylons
Route	west	east	west
Rating (per circuit)	1500MVA =2165A	2650MVA =3820A	1500MVA =2165A
Maximum fields produced by the proposed overhead line:			
electric field	8.61kV/m	8.61kV/m	7.66kV/m
magnetic field	46.5 μ T	82.0 μ T	47.4 μ T
Exposure limits for general public			
electric field	9kV/m		
magnetic field	360 μ T		

Compliance with Policy on Phasing

- 6.2.9 The 400kV overhead line has been designed with transposed phasing meaning that it is optimally phased as set out in the Code of Practice on Optimum Phasing (Ref.12). The two circuits 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 to the sides of the line. This applies to both of the resulting routes.
- 6.2.10 The phasing of the L12 pylons determines the phasing of the L12 low-height pylons, because it is only possible to transition from full-height to low-height pylons in one sequence whilst preserving electrical clearances. Phasing is inherently less effective at reducing magnetic fields for low-height designs than for full-height designs of pylons. However, it so happens that the resulting phasing for the low-height pylons is also the optimum that can be achieved with low-height pylons.

Combined effects with existing 400kV line

- 6.2.11 For much of the route, the proposed new overhead line would be parallel to the existing 400kV overhead line (albeit noting that due to the 'swap overs' or transpositions, the new line and existing line will be sometimes one way round and sometimes the other). The standard distance between the two parallel overhead lines would be 80m. Therefore, it is necessary to consider the combined field from the two overhead lines.

- 6.2.12 As explained in section 4.4, because of the physical properties of EMFs, specifically that they are “vectors” not “scalars”, EMFs from two different sources do not simply add together. The addition of EMFs from different sources is complex, but has the general effect that, when the field from one source is larger than the other, the larger field dominates, with the smaller field making only a small difference to the resultant field.
- 6.2.13 This is illustrated in Figure 8, which shows the calculated typical magnetic field from each of the two overhead lines, 80m apart, individually, compared to the combined field from the two overhead lines. It can be seen that, to the sides of the overhead lines, where the field from the closer overhead line is larger than that from the farther and consequently dominates the resultant field as explained above, the combined field is indeed very little different from the field from the closer line only. Similar principles apply to electric fields and to fields calculated for maximum conditions rather than for typical conditions.

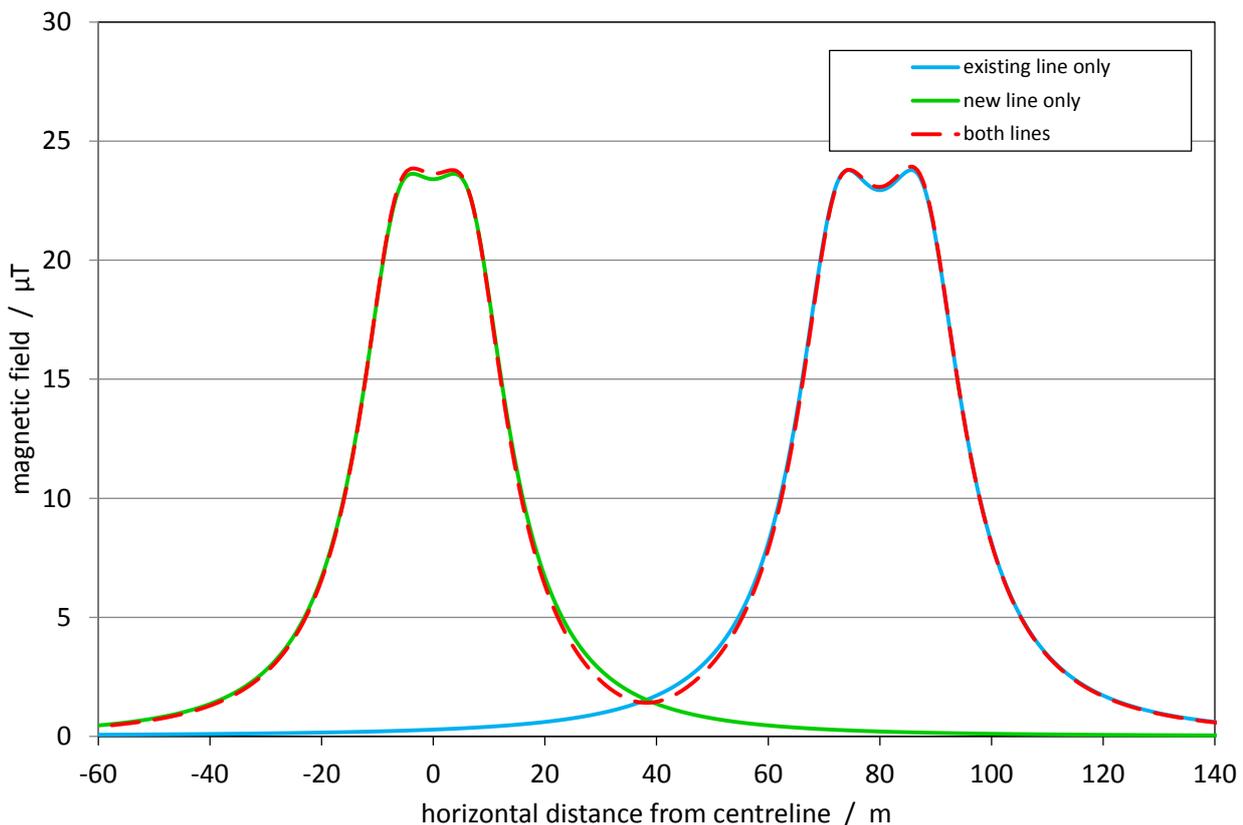


Figure 8 Combining magnetic fields from parallel overhead lines

- 6.2.14 The exact difference that the field from the existing overhead line makes to the maximum field underneath the proposed new line (or vice versa) depends on specifics of relative phasing and loads (Figure 8 has been calculated for just one specific set of conditions, but is representative of other possible specific conditions). However, in general, it is not expected to be more than around a percent. These small differences are not enough to affect the assessment of compliance for the proposed new overhead line.

Overhead Lines – Assessment

- 6.2.15 The maximum calculated magnetic field from either of the 400kV overhead lines resulting from this proposal, calculated according to the Code of Practice on Compliance, is 82.0 μ T. The maximum calculated electric field is 8.61kV/m. The respective exposure limits for the general public are 360 μ T and 9kV/m. Therefore the maximum EMFs produced by the proposed overhead lines would be less than the relevant public exposure limits (allowing for the effect with other overhead lines). Thus, the proposed overhead lines would meet the relevant exposure limits, the ICNIRP general public guidelines (Ref.8) in the terms of the EU Recommendation (Ref.9). They would also comply with the Government policy on phasing, and there are no other restrictions on grounds of EMFs, health or safety applying to power lines.
- 6.2.16 The assessment presented above shows that the maximum value of the fields produced by the proposed 400kV overhead lines would be compliant with the relevant exposure limits in Table 2, even directly under one of the overhead lines. There is no minimum lateral distance from the overhead line required in order to achieve compliance. Therefore, assessment of compliance is not dependent on: the exact routing of the overhead line; the exact location of the nearest existing residential property to the overhead line; the nearest proposed property already granted planning permission; or the nearest property that might in future be granted planning permission, because the field from the overhead line is compliant everywhere, not just compliant outside a specified distance.
- 6.2.17 However, 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.

6.3 Operational Effects – substations and cable sealing end compounds

- 6.3.1 As explained above, substations and cable sealing-end compounds are treated, according to the Code of Practice on Compliance (Ref.7), as inherently compliant with the exposure limits. The highest fields around them are usually from any overhead lines entering them and not from equipment within the substation or sealing-end compound itself. This compliance includes tunnel headshafts and headhouses and any lengths of underground cable making connections within the overall boundary of the substation or cable sealing-end compound.

6.4 Operational Effects – underground cables

Electric fields

- 6.4.1 Underground cables produce no external electric field because of the metallic sheath.

Magnetic fields – cable within the tunnel

The proposed new 400kV connection from Anglesey to Gwynedd would comprise cables within a tunnel beneath the Menai Strait. As the cables in the tunnel would be relatively deep beneath the ground or water level, the magnetic fields they

produce at the surface would be much lower than for the overhead line. The field when the cables are operating at their rating is presented in Figure 9 for the likely minimum depth of the tunnel (40m, below the water level of the Menai Straights) and for the likely maximum depth below the local ground level (100m, at the Gwynedd end of the tunnel).

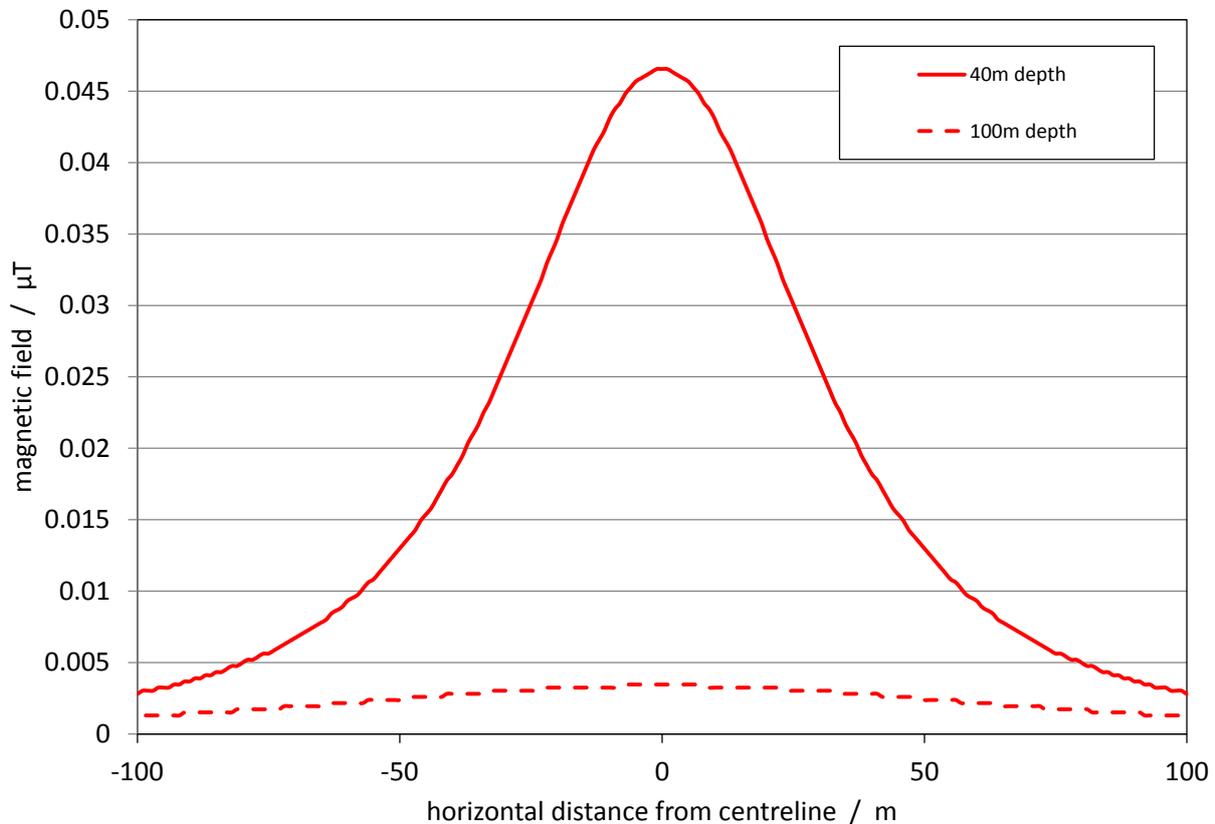


Figure 9 : Maximum magnetic field from 400kV cable within the tunnel for minimum and maximum depths

Compliance of underground cables with exposure limits

6.4.2 The maximum field is $0.05\mu\text{T}$, therefore the maximum magnetic field from the tunnel is below the relevant exposure limit and therefore the cables and surrounding tunnel is compliant.

6.5 Decommissioning Effects

6.5.1 When the equipment is de-energised and decommissioned no EMFs would be produced. Therefore this is not considered further.

7 MITIGATION

7.1.1 No mitigation measures are necessary as the Project has been demonstrated to comply with the current exposure limits for the general public and the policy on

phasing as detailed in NPS EN-5 (Ref.6). If these requirements are met NPS EN-5 states that “*no further mitigation should be necessary.*”

8 RESIDUAL EFFECTS

8.1.1 The Project has been demonstrated to comply with the current public exposure guidelines and the policy on phasing as detailed in NPS EN-5 (Ref.6). If these requirements are met NPS EN-5 states that “*EMF effects are minimal.*”

9 CUMULATIVE EFFECTS

9.1.1 The combined EMFs from the proposed new connection and, the existing 400kV overhead lines in the area were assessed above.

9.1.2 In addition, the electric and magnetic fields from the proposed overhead line can combine with the EMFs already present from other sources such as appliances, domestic and industrial wiring, etc. However the largest source of fields are typically from electricity transmission and distribution infrastructure. The way in which fields from different sources combine with each other is complex. The relative power flows, voltage and the relative phasing of each electrical asset would affect the direction of the fields from each asset and whether they add or subtract with one another. The cumulative field could increase or decrease depending on the specific conditions, but it would only be a slight effect either way. Therefore, the cumulative impact of all of the components of the Project and any interactions with other developments which produce lower EMFs would not be significant.

9.1.3 It is National Grid’s and the electricity industry’s policy to ensure that all electrical assets comply with Government exposure limits and policies. As all of the components of the proposed Project will comply with these exposure limits, the cumulative impacts would not be significant.

10 CONCLUSIONS

10.1.1 Government, acting on the advice of authoritative scientific bodies, has put in place appropriate measures to protect the public from EMFs. These measures comprise compliance with the relevant exposure limits, and one additional precautionary measure, optimum phasing, applying to high voltage power lines. This policy is incorporated in NPS EN-5 (Ref.6).

10.1.2 The assets associated with the Project would be fully compliant with the Government policy. Specifically, all the EMFs produced would be below the relevant exposure limits, and the proposed overhead lines would comply with the policy on optimum phasing. Therefore there would be no significant EMF effects resulting from the Project.

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Appendix A –

Certificate of Conformity

Technical Certificate 05R110 issued by
Hursley EMC Services Ltd

*Appointed by the Secretary of State for Trade and Industry
as a UK EMC Competent Body*



**HURSLEY
EMC
SERVICES**

TECHNICAL CERTIFICATE

PRODUCT TITLE: NGT Electricity Transmission Network

MANUFACTURED BY: National Grid Transco (NGT) plc

Manufacturers Address: NGT House, Warwick Technology Park, Gallows Hill,
Warwick CV34 6DA UK

Applicants Name: Mr Jon Carlton, of NGT plc.

Product Description: The NGT Electricity Transmission Network (consisting of some 14,000 Km of high voltage supply lines) is the high voltage electricity transmission system in England and Wales.

Technical Statement: The Technical Construction File (TCF), "NGT Electricity Transmission Network" (dated 2005), describes the general construction, conformity procedures and EMC test rationale for the Electricity Network. This Technical Construction File, in so far as is technically viable, is based on testing to international standards, specifically EN50121-2:2000 and CISPR 18 for emissions. These standards were used as the most suitable guide for the emissions testing in lieu of any other practical or harmonized product related standards. Given the size of the equipment, testing was performed in-situ at several representative sites and is therefore an approximation to the standards. The results of the tests applied and described in the test reports along with the EMC detail supplied in the TCF indicate that the product complies with the standards. Taking into consideration the technical rationale provided in the TCF and the results of the site measurement reports, Hursley EMC Services is satisfied the TCF does demonstrate compliance with the essential protection requirement of EC Directive 89/336. NGT operates a certified ISO 9001 quality management system covering both the operation and installation procedures for the Electricity Network. Due to its size and nature along with quality procedures used for installations the NGT Electricity Transmission Network would seem inherently immune to normal EMC phenomena.

This route to compliance with respect to the provisions of EC Directive 89/336 is in accordance with section 42(c) of the UK Statutory Instrument 1992 No 2372 (The Electromagnetic Compatibility Regulations). This application and certificate applies only to the NGT Electricity Transmission Network for the UK as described in the Technical Construction File.

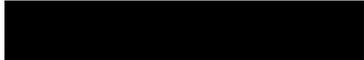
COMPETENT BODY CONFORMITY STATEMENT

Hursley EMC Services Ltd. certifies that the National Grid Transco plc TCF demonstrates that the NGT Electricity Transmission Network conforms to the protection requirements of European Council Directive 89/336 and its amendments. This directive is on the approximation laws of the Member States relating to electromagnetic compatibility.

Signed:


Rob St John James
EMC Technical Manager

Approved:


Ian Kenney
EMC Quality Manager

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