Chapter 16
Other Issues

Contents

16	**Other Issues**	**1**
	Introduction	1
	Electric and Magnetic Fields	1
	Dust	2

Figures

Figure 16.1: Dust Sensitive Receptors

Appendices

Appendix 16.1: Electric and Magnetic Fields Report

16 Other Issues

Introduction

16.1 This chapter presents the findings of the likely significant construction and operational effects of the proposed Kendoon to Tongland 132 kilovolt (kV) Reinforcement Project ('the KTR Project') on electric and magnetic fields (EMF) and dust. Details of which are provided in **Chapter 4: Development Description** and **Chapter 5: Felling, Construction, Operational Maintenance and Decommissioning**. National Grid completed the assessment of EMF effects and LUC completed the assessment of dust effects. A detailed assessment of the likely effects associated with EMFs is provided in **Appendix 16.1: Electric and Magnetic Fields Report**.

16.2 Planning policies of relevance to this assessment are provided in **Chapter 6: Planning Policy Context**.

16.3 As noted in **Chapter 3: Approach to the EIA**, the assessment recognises the distinction between:

- Embedded mitigation: items that are embedded through the design of the KTR Project and which are assumed to be in place as an integral part of the KTR Project; and
- Additional mitigation: items that are further required to mitigate the likely adverse effects of the KTR Project and which will be implemented to avoid, reduce or offset these effects.

Electric and Magnetic Fields

Introduction

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

16.5 The proposed overhead lines (OHLs) that form part of the KTR Project are a source of both EMF[1]. The electric field generated by an OHL is mainly dependent on the voltage of the line and remains more or less constant once the OHL is operational. The magnetic field will vary depending on the current flowing in the conductors. The EMFs produced by an OHL will be highest directly under the line and will rapidly decrease at increasing distance from the line.

16.6 EMFs are only produced when an OHL is energised with current flowing. As these effects are associated with OHLs once they are operational, potential effects during construction are not assessed as no EMFs will be produced.

16.7 EMFs 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, 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) e.g. implantable cardiac pacemakers, and microshocks. The potential impact of both direct and indirect effects has been assessed using the guidance provided in a range of code of practice documents (including the exposure guidelines) that are set out in Section 2 of **Appendix 16.1**.

Assessment Methodology

16.8 The detailed assessment methodology and the existing conditions are set out in Section 2 of **Appendix 16.1**. Each line is assessed on its design (i.e. L4, L7, or Trident) rather than geographic location as OHLs need to be in close proximity to one another to produce a combined effect. The OHL closest to the receptor will be the dominant and most relevant source. The values and assessment below therefore represents the KTR Project connections individually and in combination.

Operational Effects

16.9 As a result of the routeing process and design strategy, the KTR Project lines have been routed away from residences and other sensitive land uses where possible.

16.10 The double circuit OHL (the steel towers) have been designed with transposed phasing meaning that it is optimally phased as set out in the Code of Practice on Optimum Phasing[i]. 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 all of the double circuit OHLs. Transposed phasing does not apply to single circuit OHLs (the wood poles).

16.11 For context, the typical background levels of EMFs in residences are between 1-20 volts per metre (V/m) and 0.01-0.2 microtesla (μT), respectively. Exposure limits are set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) general public guidelines[ii] which are in response to the EU Recommendation on public exposure to EMFs[iii].

16.12 To assess compliance with exposure limits, the Code of Practice on Compliance specifies that the maximum fields an OHL is capable of producing should be calculated for certain specified conditions. All calculations were performed at maximum circuit rating and minimum clearance representing a worst-case scenario.

16.13 The maximum calculated magnetic field from the 132kV OHLs of the KTR Project, calculated according to the Code of Practice on Compliance[iv], is 39.43μT. The maximum calculated electric field is 2.88kV/m. The respective exposure limits for the general public are 360μT and 9kV/m. Therefore, the maximum EMFs produced by the proposed OHLs would be less than the relevant public exposure limits. The effects associated with EMFs for the KTR Project are therefore **not significant**.

Cumulative Effects

16.14 The EMFs from the proposed OHLs can combine with the EMFs already present from other sources, such as appliances, domestic and industrial wiring, etc. However, the largest source of EMFs is 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 powerline would affect the direction of the fields from each line 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.

16.15 Due to the complex physical arrangement of electrical equipment, EMFs produced by electrical substations and sealing-end compounds are not readily calculable. However, the highest field levels at and outside the perimeter of a substation are usually those produced by the OHLs entering the substation. The fields produced by equipment within the substation are generally smaller and decrease with distance more quickly than fields generated by OHLs. Therefore, the cumulative impact of all of the components of the KTR Project and any interactions with other developments which produce EMFs, including Glenlee Substation Extension, would be **not significant**.

16.16 It is SP Energy Networks' (SPEN) and the electricity industry's policy to ensure that all powerlines comply with Government exposure limits and policies. As all of the components of the KTR Project will comply with these exposure limits, the cumulative impacts are therefore **not significant**.

Summary of Effects

16.17 The OHLs associated with the KTR Project would be fully compliant with Government policy. Specifically, all the EMFs produced would be below the relevant exposure limits, and the proposed OHLs would comply with the policy on optimum phasing. Therefore, EMF effects resulting from the KTR Project would be **not significant**. **Table 16.1** summarises the likely effects of the KTR Project on EMF exposure.

[1] It should be noted that the 11 kV OHLs which are proposed to be undergrounded as part of the P-G via K Connection are considered in the *Department of Energy and Climate Change (2012) Power Lines: Demonstrating compliance with EMF public exposure guidelines. A voluntary Code of Practice* as a type of equipment that is inherently compliant with Government exposure limits due to the design. Evidence for demonstration of compliance with Government exposure guidelines for insert voltage kV cables is maintained at: http://www.emfs.info/compliance/public/.

Table 16.1: Summary of EMF Effects

Predicted Effect (for each individual connection)	Significance	Mitigation	Significance of Residual Effect
Electric Field Exposure	Not Significant	None	Not Significant
Magnetic Field Exposure	Not Significant	None	Not Significant

Dust

Introduction

16.18 The impact of dust on sensitive receptors during construction activities can result in temporary effects if unmanaged. For example, nuisance effects such as soiling of buildings can, if present over a long period of time, affect human health. Activities likely to result in dust being produced during construction of the KTR Project include earthworks (e.g. earth moving and excavation), material handling (e.g. stockpiling and loading/unloading vehicles), natural causes, e.g. wind blowing on stockpiles and uncovered vehicles, material transport and traffic on unsurfaced roads, and the movement of dirty vehicles.

Assessment Methodology

Desk Based Research and Data Sources

16.19 The assessment has been informed by the following data sources:

- OS AddressBase data (in relation to the location of residential properties); and
- Site specific GIS information, including details of the existing electricity network and the location of sensitive receptors.

Field Survey

16.20 The assessment has been desk based, drawing on knowledge of the KTR Project Study Area and surveys undertaken as part of the EIA; therefore no additional field surveys were undertaken.

Legislation and Guidance

16.21 The dust assessment has been informed by the following guidance:

- Design Manual for Roads and Bridges (DMRB), Volume 11 Environmental Assessment, Section 3 Environmental Assessment Techniques, Part 1, HA207/07 Air Quality[v]; and
- Planning Advice Note (PAN) 50: Controlling the Environmental Effects of Surface Mineral Workings[vi].

Study Area

16.22 The assessment of dust effects during construction has been undertaken for receptors within 200m of proposed construction activities in accordance with accepted good practice using a risk-based approach as detailed further below.

Assessing Significance

Sensitivity

16.23 The risk-based approach to assessing dust effects has been based on the likelihood of dust emissions causing nuisance. This includes assessing effects such as soiling of buildings and the potential for effects on human health, with the aim of determining the level of mitigation which may be required, to ensure that any potential effects are minimised. The DMRB states that dust generated during construction should be mitigated and that the locations of 'sensitive receptors' within 200m of construction activities should be identified and mitigation measures to reduce dust effects applied. As such, all receptors within 200m of potential dust generating sources have been considered as potential receptors. 'Sensitive receptors' can include housing, schools, hospitals and designated species.

Magnitude

16.24 Effect magnitude has been determined through consideration of the potential dust raising activities during construction:

- High magnitude: earthworks (e.g. earth moving and excavation), material handling (e.g. stockpiling and loading/unloading vehicles), and natural causes, e.g. wind blowing on stockpiles and uncovered vehicles.
- Medium magnitude: material transport and traffic on un-surfaced roads.
- Low magnitude: movement of dirty vehicles.

16.25 Professional judgement is used to consider how receptor sensitivity and effect magnitude combine to affect potential receptors. Effects which are predicted to have an adverse effect on the amenity of the receptor or on human health are considered significant in the context of the EIA Regulations.

Scope of the Assessment

Effects Assessed in Full

16.26 As noted above, construction activities can result in temporary effects such as soiling of buildings which if unmanaged over a long period of time can cause nuisance effects as well as effects on human health. The potential effect of dust on sensitive receptors within 200m of construction activities within the site boundary is therefore assessed in full.

Effects Scoped Out

16.27 On the basis of the desk-based survey work undertaken, the professional judgement of the EIA team, experience from other relevant projects and policy guidance or standards, the following areas have been 'scoped out' of detailed assessment:

- Dust effects during operation of the new OHLs of the KTR Project: during operation there will be limited dust raising maintenance activities being undertaken and transport will be limited.
- Dust effects on ecological receptors and designations as dust has not been scoped into the ecology assessment. Pristine blanket bog communities are habitats where significant effects could arise from dust impacts, however these habitats are not found within the Study Area. The peat habitats identified in the Study Area are fragmented/isolated, heavily modified and their ecological importance is limited to the 'Study Area' level and are very unlikely to be significantly affected by dust. Effects on other ecological receptors are not considered likely.
- There are no hospitals, GP surgeries and schools within the 200m Study Area, therefore these are scoped out of the assessment.
- The removal of the existing N and R routes has been scoped out from this assessment on the basis that the activities required to facilitate removal of the towers will have limited dust raising potential. In addition, access for tower removal will be undertaken using low ground pressure plant and vehicles to avoid the requirements for stone roads where possible.
- **Chapter 13: Traffic and Transport** states that dust effects associated with temporary construction traffic is not assessed on the basis that the KTR Project will be accessed via a number of geographically distinct roads and access points.

Existing Conditions

16.28 There are 103 residential properties within 200m of the KTR Project (see **Figure 16.1**) and these are therefore judged to be potential receptors of dust emissions from the associated construction works and construction traffic movements. **Table 16.2** identifies the number of residential properties within 200m of each connection of the KTR Project infrastructure.

Table 16.2: Dust Receptors

Receptor	Connection					
	P-G via K	C-K	E-G	G-T	BG Deviation	Total*
Residential properties	45	16	15	57	11	102

* Total does not sum as some receptors are located within the 200m of more than one connection.

Assessment of Effects: Individual Connections

16.29 The dust sensitive receptors in **Table 16.2** could be affected by the construction of the new site access and the movement of vehicles as they transport equipment and goods to site. The level and distribution

of dust emissions will vary according to factors such as the duration of dust-generating activity and weather conditions.

16.30 Dust emitting activities generally respond well to appropriate dust control measures and these are set out in **Appendix 5.2: Embedded and Additional Mitigation and Monitoring Measures** and include:

- ensuring all loads which will enter the site are covered where practicable;
- enforcing an appropriate speed limit; and
- making use of netting screens for construction activities within 200m of both receptors.

16.31 These good practice measures are part of the mitigation embedded through the KTR Project design process. With adherence to these good practice measures, the predicted magnitude of the temporary dust effects will be minimised and associated dust effects for each of the individual connections of the KTR Project will be **not significant**.

Proposed Mitigation

16.32 No additional mitigation (beyond the adoption of embedded mitigation measures noted above and detailed further in **Appendix 5.2**) is required for dust management.

16.33 As noted in **Chapter 5** in partnership with SPEN, the appointed contractors will be required to maintain close liaison with local community representatives, landowners and statutory consultees throughout the construction period. This is likely to include circulation of information about ongoing activities, particularly those that could potentially cause disturbance and nuisance, including effects of dust. A telephone number will be provided and persons with appropriate authority to respond to calls and resolve any problems made available.

Residual Effects

16.34 The predicted residual effect of the KTR Project on dust receptors remains **not significant**.

Assessment of Effects: KTR Project as a Whole

16.35 A number of residential properties fall within 200m of more than one connection and this is shown in **Table 16.3** below.

Table 16.3: Residential properties that fall within 200m of more than one connection

Receptor	Connection							
	P-G via K only	P-G via K & G-E	P-G via K, G-E, BG & G-T	P-G via K & KC	G-T only	G-T & BG	G-T, BG & G-E	G-E only
Residential properties	24	2	7	16	46	2	2	4

16.36 Residential properties that fall within more than one connection may be exposed to greater dust effects. However, the adoption of good practice measures outlined above will ensure that dust is minimised such that **no significant effects** are predicted for dust for the KTR Project as a Whole.

Cumulative Effects

16.37 With the exception of the proposed Glenlee Substation Extension, there are no cumulative schemes identified on **Figure 3.1** that lie within 200m of the construction activities associated with the KTR Project. As noted above, dust generally settles locally, and there are no properties in close enough proximity to the KTR Project as well as other planned developments for cumulative effects to occur.

16.38 There are ten properties located within 200m of the KTR Project and the proposed Glenlee Substation which could be potential receptors of dust emissions from onsite construction works from both projects. These properties are listed below, all of which are located off the minor road from the U2S adjacent to the existing Glenlee substation:

- Carville;
- Dunston;
- Tummel;
- Rannoch;
- Tarbert;
- Navar;
- Maree;
- Orrin;
- Garry; and
- Black Bank.

16.39 A detailed assessment of potential effects of dust has not been undertaken for the Glenlee Substation Extension. The combined dust effect for the KTR Project and the Glenlee Substation will be temporary and both projects will be subject to good practice measures to control dust as noted above. As such, **no significant** cumulative effects are anticipated.

Further Survey Requirements and Monitoring

16.40 As noted above, liaison with potentially affected residents will be undertaken by SPEN and the appointed contractors, and a telephone number will be made available for members of the public to report any disturbance or issues therefore no further mitigation, survey or monitoring is proposed.

Summary of Effects

16.41 **Table 16.4** summarises the predicted effects of the KTR Project.

Table 16.4: Summary of Effects for Dust

Predicted Effects	Significance	Proposed Mitigation	Residual Effects
Dust	Not Significant	None	Not Significant

[i] Department of Energy and Climate Change (2012). Optimum Phasing of high voltage double-circuit Power Lines. A voluntary Code of Practice, London.
[ii] International Commission on Non Ionising Radiation Protection (1998). Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields. Health Physics, 74 (4), p.494.
[iii] European Union 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). Brussels.
[iv] Department of Energy and Climate Change (2012). Power Lines: Demonstrating compliance with EMF public exposure guidelines. A voluntary Code of Practice. London.
[v] Design Manual for Roads and Bridges (DMRB), Volume 11 Environmental Assessment Techniques, Part 1, HA207/07 Air Quality
[vi] The Scottish Executive (1996), PAN 50: Controlling the Environmental Effects of Surface Mineral Working

KTR Project
EIA Report

Figure 16.1.1: Dust Sensitive Receptors

Polquhanity terminal tower

Kendoon substation

Carsfad substation

Earlstoun substation

Glenlee substation

- Polquhanity sealing end and terminal tower
- Substation and hydro electricity generating station
- Polquhanity to Glenlee via Kendoon
- Carsfad to Kendoon
- Earlstoun to Glenlee
- BG route deviation
- Glenlee to Tongland
- 200m from KTR Infrastructure (not including NR route removal)
- KTR infrastructure

Dust Receptors

- Residential properties within 200m of construction activity

0 2.5 5 km

Map Scale @ A3: 75,000

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CB:JN EB:nunn_j LUCGLA FIG16-01_6120-002_KTR_Dust_SensitiveReceptors 30/07/2020

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Figure 16.1.2: Dust Sensitive Receptors

Substation and hydro electricity generating station

Glenlee to Tongland

200m from KTR Infrastructure (not including NR route removal)

KTR infrastructure

Dust Receptors

Residential properties within 200m of construction activity

Tongland substation

0 2.5 5 km

Map Scale @ A3: 75,000

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CB:JN EB:nunn_j LUCGLA FIG16-01_6120-002_KTR_Dust_SensitiveReceptors 30/07/2020

Appendix 16.1

Electric and Magnetic Fields Report

nationalgrid

Kendoon to Tongland 132kV Reinforcement Project

Electric and Magnetic Fields Report

Appendix 16.1

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Table of Contents

1 INTRODUCTION 5
1.1 The Applicant and an Overview of the Kendoon to Tongland 132kV Reinforcement Project 5
1.2 Purpose of this Report 5
1.3 Introduction to EMFs 5
2 POLICY AND LEGISLATION 5
2.1 Overview of policy 5
2.2 UK Government - National Policy Statement EN-5 6
2.3 Public Exposure Limits 8
2.4 Occupational Exposure Limits 9
2.5 Potential Future Changes to Exposure Limits 9
2.6 Scientific Evidence 9
2.7 Precautionary Policies 11
2.8 Pregnant Women and other Potentially Sensitive Subgroups 12
2.9 Microshocks 12
2.10 Active Implantable Medical Devices 12
2.11 Farming, Flora and Fauna 13
2.12 The Electricity Safety, Quality and Continuity Regulations 2002 13
2.13 Summary of Policy and Legislation 13
2.14 Effects on Magnetic Compasses 13
3 ASSESSMENT METHODOLOGY 13
3.2 Study Area 13
3.3 Predicted Field Levels 14
3.4 Combining Fields from Different Sources 15
3.5 Assessment of Effects 15
4 BASELINE ENVIRONMENT 15
5 PREDICTION AND ASSESSMENT OF THE SIGNIFICANCE OF THE POTENTIAL EFFECTS 15
5.1 Construction Effects 15
5.2 Operational Effects – Overhead Lines 15
6 MITIGATION 18
7 RESIDUAL EFFECTS 18
8 CUMULATIVE EFFECTS 18
9 CONCLUSIONS 18

1 INTRODUCTION

1.1 The Applicant and an Overview of the Kendoon to Tongland 132kV Reinforcement Project

1.1.1 Scottish Power Energy Networks (SPEN) Limited, owns and operates the high voltage electricity transmission system in central and southern Scotland.

1.1.2 The Kendoon to Tongland 132kV Reinforcement Project ('the KTR Project') involves the replacement, modernisation and reinforcement of the existing 132kV network within Dumfries and Galloway. This will involve constructing 5 replacement lines, namely:

- a new 132kV double circuit steel tower overhead line, of approximately 10.6km in length, between Polquhanity (approximately 3km north of the existing Kendoon substation) and the existing Glenlee substation (via Kendoon substation);
- a new 132kV single circuit wood pole overhead line, of approximately 2.6km in length, between Carsfad and Kendoon;
- a new 132kV single circuit wood pole overhead line, of approximately 1.6km in length, between Earlstoun and Glenlee;
- a new 132kV double circuit overhead line deviation of the existing BG route, at Glenlee substation approximately 1km in length; and
- a new 132kV double circuit steel tower overhead line, of approximately 32.5km in length, between Glenlee and Tongland.

1.1.3 The KTR Project also involves the removal of the existing 132kV overhead lines between Polquhanity, Kendoon, Carsfad, Earlstoun, Glenlee and Tongland ('N' and 'R' routes). This will involve the decommissioning of around 43km of existing overhead line infrastructure.

1.1.4 In terms of the construction requirements of the KTR Project, these consist of the following components:

- overhead line installation including new steel towers and wood poles;
- substation works;
- felling of woodland, temporary construction compounds, quarries, access tracks, and construction working areas.

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 and operation of the KTR Project as described above.

1.2.2 There is a Code of Practice agreed between the Energy Networks Association and the Government (Ref.2), which specifies how EMF compliance will be determined. Among many other details, it states that for some equipment, compliance will be demonstrated on a case-by-case basis. But for other equipment, which always complies with the current exposure limits, the industry will not have to demonstrate compliance on a case-by-case basis. 132kV lines such as the ones proposed for the KTR project fall into the category of "always complies" and do not require a specific assessment.

1.3 Introduction to EMFs

1.3.1 EMFs 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 EMFs 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 The Electric fields generated by powerlines are dependent on the voltage they operate at 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 EMFs 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 effect of both direct and indirect effects has been assessed using the guidance provided in the codes of practice (discussed in Section 2 below).

1.3.6 EMFs at much higher frequencies than those generated by the electricity transmission system can be generated by other devices, e.g. radio and 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 this distinction. Overhead lines produce EMFs at much lower frequencies than televisions, microwaves and other common electrical devices and are sometimes referred to as "non-ionising" radiation.

2 POLICY AND LEGISLATION

2.1 Overview of policy

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 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.1), 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.2) agreed between industry and Government.

2.1.3 The UK 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. PHE exercise radiological protection functions across the whole of the UK, including Scotland. 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.

2.1.4 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.3) in line with the terms of the 1999 European Union (EU) Recommendation (Ref.4) on public exposure to EMFs. In a Written Ministerial Statement in October 2009 (Ref.5); 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 5.2. The Government also made clear in the Written Ministerial Statement that no other precautionary measures are appropriate for high voltage infrastructure.

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

2.2 UK Government - National Policy Statement EN-5

2.2.1 As summarised above, the UK Government has set out clear policies on control of EMF exposures in general. NPS EN-5 (Ref.1) 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 determining body, 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.2), 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 KTR 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.3), as demonstrated in this report.
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 lines associated with the KTR Project are demonstrated in this report to comply with the Government adopted ICNIRP 1998 guidelines.

[1] Department of Energy and Climate Change. National Policy Statement for Electricity Network Infrastructure (EN-5). London: The Stationary Office, 2011.

[2] Department of Energy and Climate Change. Power Lines: Demonstrating compliance with EMF public exposure guidelines. A voluntary Code of Practice. London, 2012.

[3] International Commission on Non Ionising Radiation Protection. Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields. Health Physics, 1998, 74 (4), p.494.

[4] European Union Council. 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). Brussels, 1999.

[5] Department of Health. Government response to the stakeholder advisory group on extremely low frequency electric and magnetic fields (ELF EMFs) (SAGE) recommendations. 2009. (Online) Available from http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_107124

[6] Department of Energy and Climate Change. Overarching policy statement for electricity (EN-1). London: The Stationary Office, 2011.

Paragraph	Requirement	Section of this Report	Compliance Assessment
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.7) 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 lines have 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 determining authority 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 KTR Project.
2.10.15	The applicant should have considered the following factors: - 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**	The proposed overhead lines have been designed to comply with the statutory requirements of the Electricity Safety, Quality and Continuity Regulations 2002. 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.
	- 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**	The overhead lines have been designed in line with the policy on optimum phasing as specified in the Code of Practice on Optimum Phasing.
	- Any new advice emerging from the Department of Health relating to Government policy for EMF exposure guidelines.	**2.6**	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.
	- Where it can be shown that the lines will comply with the current public exposure guidelines and the policy on phasing, no further mitigation should be necessary.	**6**	This report shows that the KTR 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.

2.2.2 As summarised above, the UK Government has set out clear policies on control of EMF exposures in general. NPS EN-5 (Ref.1) gives clear guidance on the EMF requirements of all electricity infrastructure projects.

2.2.3 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)**Figure 1**.

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

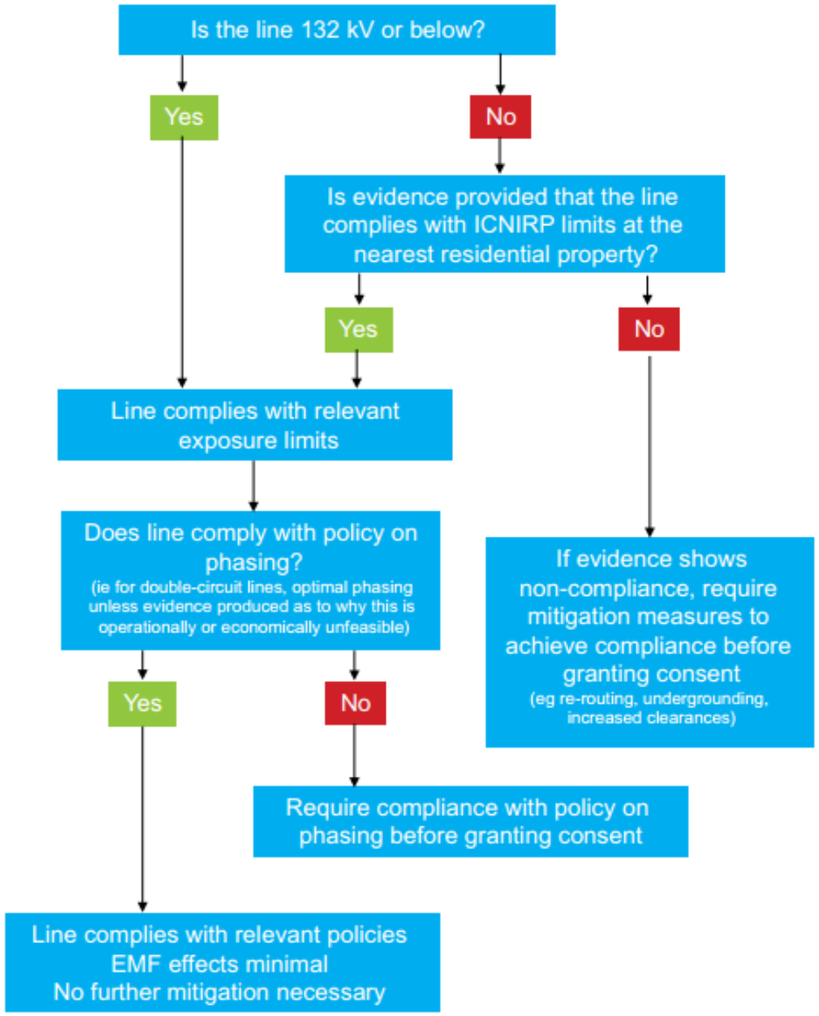


Figure 1 : Simplified Route Map for Dealing with EMFs

2.2.4 All relevant legislation, policies and guidance, including those contained within NPS EN-1 (Ref. 6) and EN-5 (Ref. 1) have been reviewed and applied to the EMF assessment of the KTR 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. 3). The Government subsequently adopted this recommendation, saying that limits for public exposures should be applied in the terms of the 1999 EU Recommendation (Ref. 4). This Government policy was subsequently set out more formally in the Written Ministerial Statement (Ref. 5)

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. 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. 1) 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. 2) 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. 3) 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/m^2 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. 4) uses the same basic restriction value as ICNIRP (Ref. 3).

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.3) uses the same reference level values as ICNIRP (Ref.3).

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.2) 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 360μT 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. 2) 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.2), 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.8) (CEFW Regulations), which implement a 2013 EU Directive (Ref.9). For power frequencies, these are based on a more recent ICNIRP publication, ICNIRP 2010 rather than the ICNIRP 1998 (Ref.3) 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 KTR Project would be compliant with in all areas accessible to the public and to employees of third parties. Therefore all exposures from the KTR Project would be compliant with the occupational exposure limits and employers need take no additional action specific to the KTR Project in order to comply (the CEFW Regulations impose certain general duties on all employers which would apply regardless of the KTR Project).

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.3), in the terms of the 1999 EU Recommendation (Ref.4). In 2010, ICNIRP published new exposure guidelines 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. 2):

> *"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. SP Energy Networks assessment is that the KTR 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, SP Energy Networks would have a duty to bring the whole transmission system, including the KTR 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

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

[9] 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

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. 10) and accompanied it with a 'Review of the Scientific Evidence for Limiting Exposure to Electromagnetic Fields (0-300GHz)' (Ref.10). 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).

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. 11). Power-frequency magnetic fields were classified as "*possibly 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.12), 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

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

[11] Working Group on the Evaluation of Carcinogenic Risks to Humans. Non-ionizing radiation, Part 1: Static and extremely low-frequency (ELF) electric and magnetic fields. (Monographs on the Evaluation of Carcinogenic Risks to Humans, 80). Lyon, IARC, 2002.

[12] World Health Organisation, Environmental Health Criteria Monograph No 238 on Extremely Low Frequency Fields, 2007. (Online) Available from http://www.who.int/peh-emf/publications/elf_ehc/en/index.html

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. 13). 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."

[13] Scientific Committee on Emerging and Newly Identified Health Risks SCENIHR (2015), Potential Health Effects of Exposure to EMF, http://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_041.pdf

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. 12) and reiterated in 2007 (Ref. 13), 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.5) in response to a recommendation from the Stakeholder Advisory Group on ELF EMFs (SAGE) in its First Interim Assessment (Ref.14). The details are given in a second Code of Practice, 'Optimum Phasing of High Voltage Double-Circuit Power Lines' (Ref.**Error! Bookmark not defined.**).

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. **Error! Bookmark not defined.**) 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" will be interpreted in terms of the cost-benefit analysis presented in the SAGE First Interim Assessment (Ref. 14).

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. 5):

"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."

[14] Stakeholder Advisory Group on ELF EMF. SAGE First Interim Assessment. 2007. (Online) Available from http://www.emfs.info/NR/rdonlyres/39CDF32F-4E2E-AD30 -A2B0006B8ED5/0/SAGEfirstinterimassessment.pdf

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.1) 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 and other subgroups 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.15), 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. 2) 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. 2) 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. 16). 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 5.2 below. The calculated electric fields for all overhead line designs will be below 5 kV/m reducing significantly the risk of microshocks occurring. SP Energy Networks will ensure that if microshocks are reported these will be investigated and mitigated where appropriate, following the provisions of the Code of Practice on Microshocks (Ref. 16).

2.10 Active Implantable Medical Devices

2.10.1 EMFs 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.

[15] Health Protection Agency. Application of ICNIRP Exposure Guidelines for 50 Hz Power Frequency Fields. 2005. (Online) Available from: http://www.hpa.org.uk/web/HPAweb&HPAwebStandard/HPAweb_C/1195733805036

[16] Department of Energy and Climate Change. Power lines: Control of microshocks and other indirect effects of public exposure to electric fields. A voluntary Code of Practice. London, 2013.

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. 4) where the AIMD has been implanted and programmed in a standard manner. The reference levels at 50Hz are 100µT 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. 17) 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 The Medicines and Healthcare Products Regulatory Agency (MHRA) are not aware of any instance of a patient with a modern, correctly fitted AIMD experiencing any interference from the electricity transmission system.

2.10.5 Thus, there is considerable confidence in saying that, based on the absence of reported incidents and on the calculated EMF exposures being below the public reference levels, overhead power lines 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.

2.10.6 This is confirmed in NPS EN-5 (Ref. 1), 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; the NPS for Electricity Networks Infrastructure (EN-5) (Ref.1) 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 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 KTR Project is provided in section 5.2 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.1) explicitly applies these policies to applications for consent for new electricity connections such as the KTR 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.

2.14 Effects on Magnetic Compasses

2.14.1 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.

2.14.2 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 KTR Project and no DC fields could be produced.

2.14.3 The magnetic fields produced by the KTR Project would be 50Hz fields. These oscillate 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 KTR Project.

2.14.4 Therefore, the KTR Project would have no significant effect on magnetic compasses.

3 ASSESSMENT METHODOLOGY

3.1.1 The assessment considers the EMFs produced from the overhead lines comprising the KTR Project.

3.2 Study Area

3.2.1 The EMFs produced by the overhead lines of the KTR Project would have a given magnitude at a given distance from the line. Therefore, the Study Area of the assessment includes all areas around the overhead lines where the EMFs could potentially be significant, such that the assessment looks at the overhead line design

[17] Council Directive 90/385/EEC of 20 June 1990 on the approximation of the laws of the Member States relating to active implantable medical devices. Brussels, 1990.

rather than the specific location. Therefore, any changes in alignment that could occur within the 50m Infrastructure Location Allowance (ILA) proposed for the KTR Project would not alter the assessments presented here. This ensures that the equipment would be compliant with exposure guidelines irrespective of the KTR Project's operational location within the ILA.

3.3 Predicted Field Levels

3.3.1 The magnetic field produced by a current in an individual conductor reduces 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 closest 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.

3.3.2 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. 2) and were performed using specialised computer software that has been validated against direct measurement (Ref. 18).

3.3.3 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.

3.3.4 Since field strengths are constantly varying, they are usually described by reference to an averaging calculation known as the "root mean square" or RMS. Subsequent references to 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.

3.3.5 To assess compliance with exposure limits, the Code of Practice on Compliance (Ref. 2) 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 steel tower or wood pole geometry for the design of overhead line in question, but ignoring variations in conductor spacing at angle towers/poles 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.

3.3.6 The same provisions apply, where relevant, to assessing the fields from underground cables.

3.3.7 Therefore, the calculations for the KTR 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.

3.3.8 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. 2). 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. 2) specifies that it is acceptable to demonstrate compliance by reference to the unperturbed fields.

3.3.9 As an alternative to calculations, the Code of Practice on Compliance (Ref. 2) 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)

3.3.10 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 KTR Project, are within the class of equipment which are regarded as inherently compliant without the need for case-by-case specific assessments.

[18] J. Swanson, Magnetic fields from transmission lines: Comparison of calculations and measurements, IEE Proceedings.-Generator Transmission Distribution, 1995, 142 (5), p481.

3.4 Combining Fields from Different Sources

3.4.1 When more than one source of EMFs is 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.

3.4.2 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.

3.5 Assessment of Effects

3.5.1 The KTR 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. 2). Conversely, as specified in NPS EN-5 (Ref.1), if the KTR Project complies with the exposure limits and with the policies on phasing (Ref.**Error! Bookmark not defined.**) and microshocks (Ref. 16), EMF effects would be assessed as not significant and no mitigation would be necessary.

4 BASELINE ENVIRONMENT

4.1.1 The KTR Project is located within a mixture of primarily rural and semirural areas, which accommodate existing electrical overhead lines and substation. The UK power frequency is 50Hz which is the principal frequency of the EMFs produced.

4.1.2 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 50µT 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.

4.1.3 As detailed above, 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 – 0.2µT with an average of approximately 0.05µT, 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 2000µT for electric razors and hair dryers, 800µT for vacuum cleaners, and 50µT 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.

5 PREDICTION AND ASSESSMENT OF THE SIGNIFICANCE OF THE POTENTIAL EFFECTS

5.1 Construction Effects

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

5.2 Operational Effects – Overhead Lines

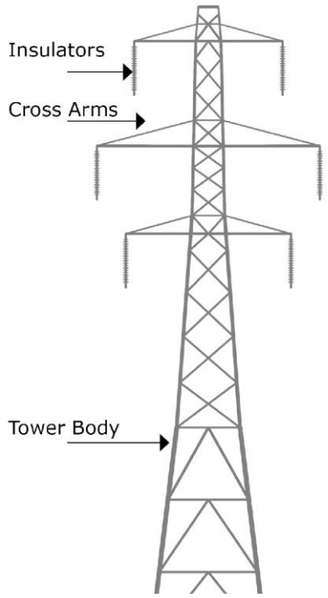
Predicted Field from Proposed New 132kV Overhead Line

5.2.1 The detailed assessments that follow are based on the designs of the KTR Project overhead lines, comprising the design of traditional steel lattice towers, known as the “L7C”, with a conductor known as Upas, “L4M” with a conductor known as “Sycamore” and a “Trident” wood pole line with a conductor known as “Poplar”. All spans have a minimum conductor design clearance to ground of 6.7m, although in many cases this would be higher.

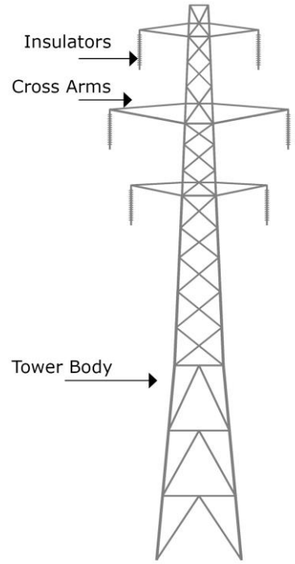
5.2.2 Electric fields do not depend on the current and hence do not depend on the rating. The electric fields, both maximum and typical, will be the same for both types of overhead lines (i.e. those supported on steel towers and wood poles).

5.2.3 The results of these calculations are illustrated in Figure 2, 4 and 6 (for magnetic fields) and Figures 3, 5 and 7 (for electric fields). The relevant rating, the winter pre-fault continuous ratings are:

Tower Type	Conductor system	OHL Pre-Fault Continuous Rating
L7(C)	2 x UPAS	405 MVA
Trident	1 x Poplar	116 MVA
L4M	1 x Sycamore	166 MVA



L7(C)



L4(M)

Trident

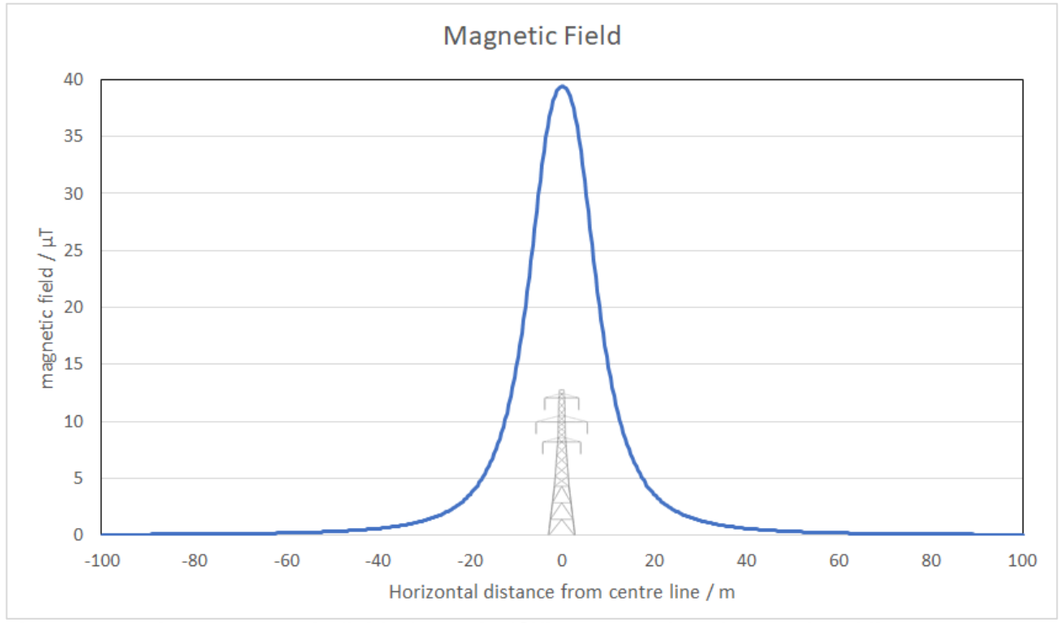


Figure 2: Maximum magnetic fields from "L7(C)" proposed 132kV overhead line

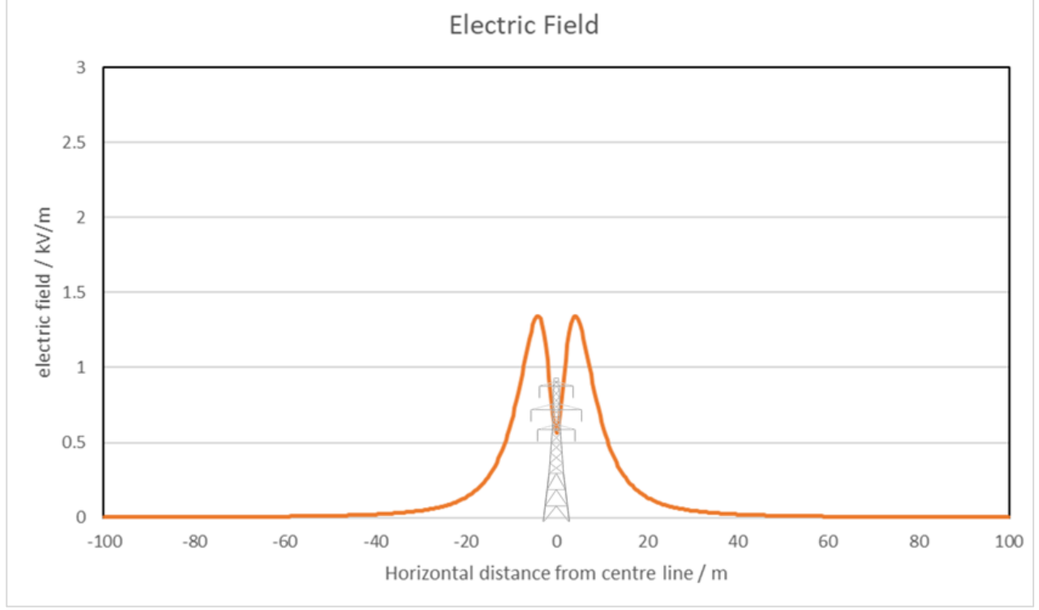


Figure 3: Maximum electric fields from "L7(C)" " proposed 132kV overhead line

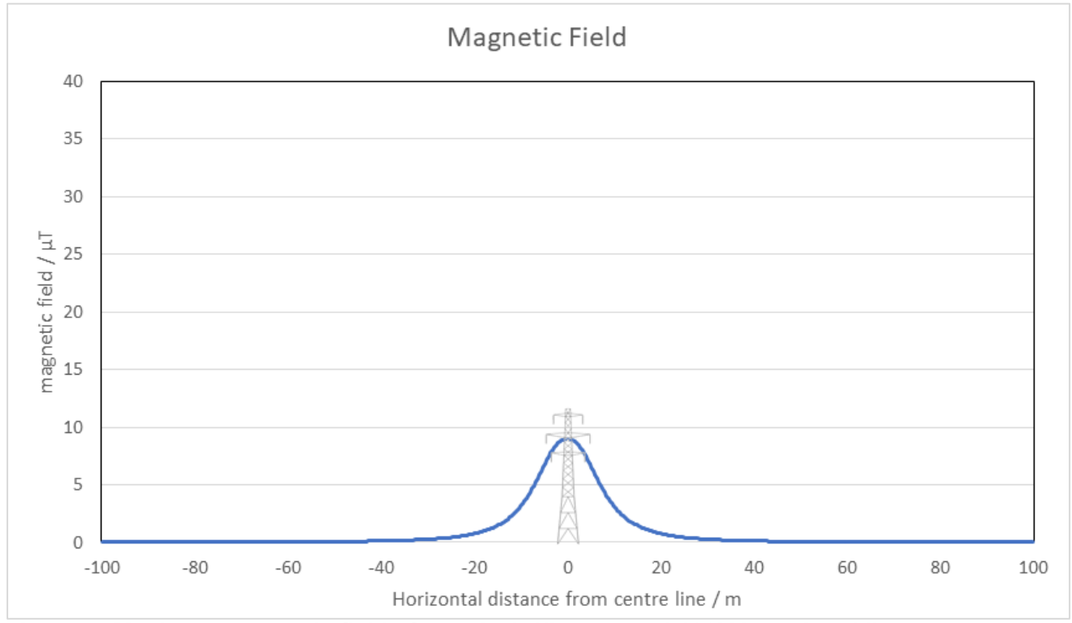


Figure 4: Maximum magnetic fields from "L4(M)" proposed 132kV overhead line

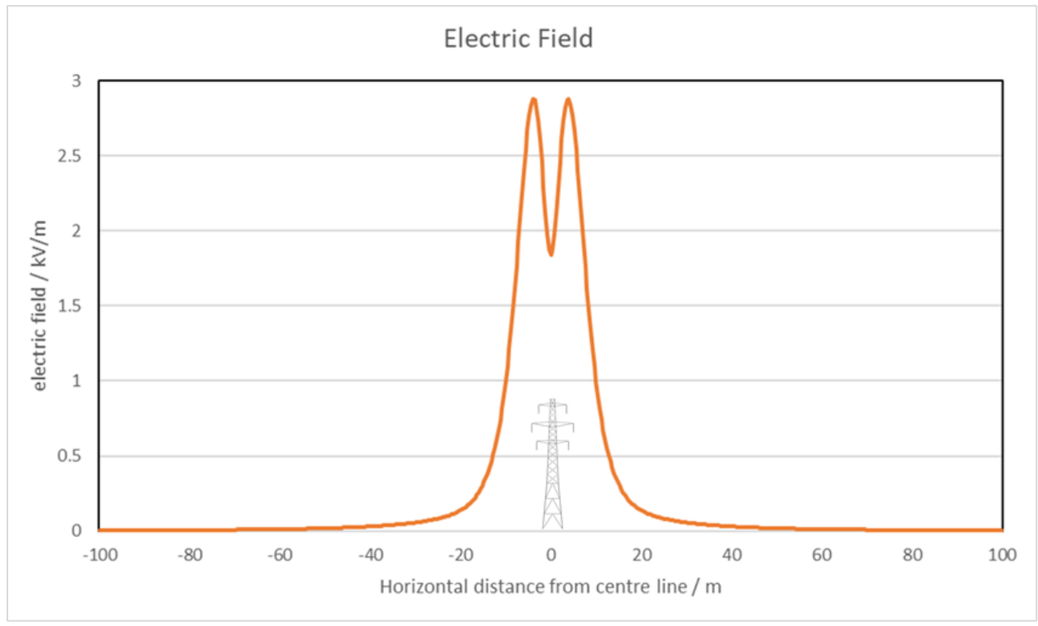


Figure 5: Maximum electric fields from "L4(M)" proposed 132kV overhead line

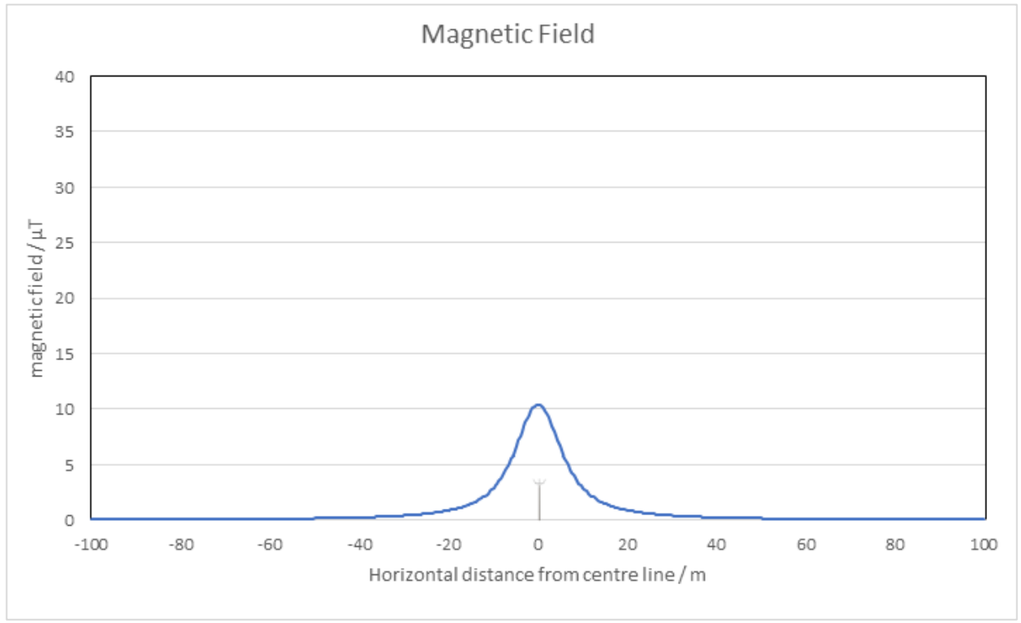


Figure 6: Maximum magnetic fields from "Trident" proposed 132kV overhead line

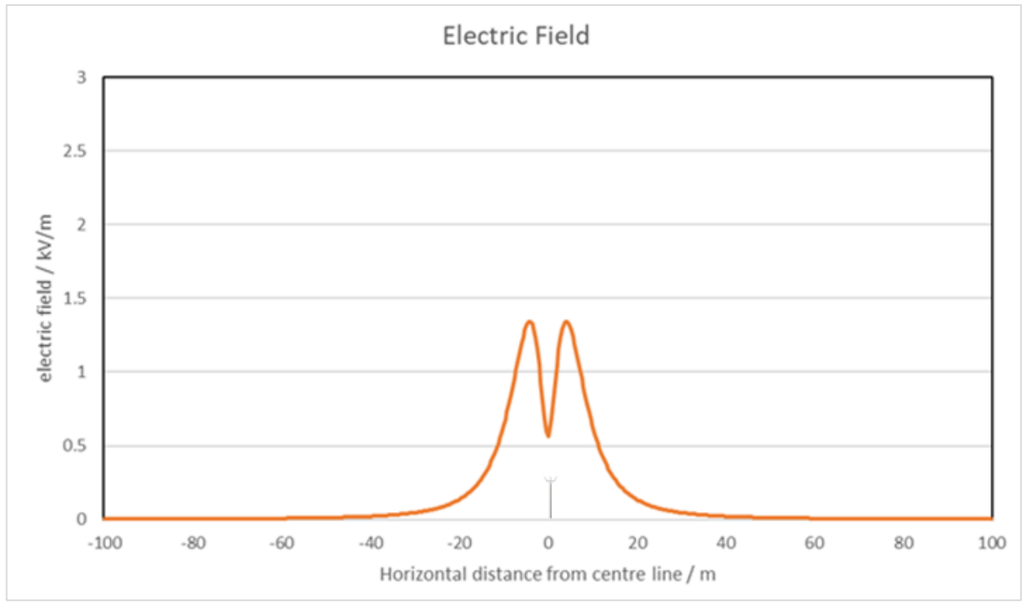


Figure 7: Maximum electric fields from "Trident" proposed 132kV overhead line

5.2.4 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	132kV		
Height above ground of calculation	1m		
Ground clearance of lowest conductors	6.7m		
Phasing	Transposed (optimum for conventional pylons)		
Pylon and Conductor type	L7(C) 2x300mm² AAAC "UPAS"	L4(M) 1x250mm² AAAC "Sycamore"	Trident 1x200mm² AAAC "Poplar"
Rating (per circuit)	405MVA	166MVA	116MVA
Maximum fields produced by the proposed overhead line:			
electric field	2.42kV/m	2.88kV/m	1.34kV/m
magnetic field	39.43µT	8.98µT	10.36µT
Exposure limits for general public			
electric field	9kV/m		
magnetic field	360µT		

Compliance with Policy on Phasing

5.2.5 The 132kV double circuit overhead lines have been designed with transposed phasing meaning that it is optimally phased as set out in the Code of Practice on Optimum Phasing (Ref.**Error! Bookmark not defined.**). 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 all of the resulting double circuit routes.

Overhead Lines – Assessment

5.2.6 The maximum calculated magnetic field from the 132kV overhead lines comprising the KTR Project, calculated according to the Code of Practice on Compliance, is 39.43µT. The maximum calculated electric field is 2.88kV/m. The respective exposure limits for the general public are 360µT and 9kV/m. Therefore, the maximum EMFs produced by the proposed overhead lines would be less than the public exposure limits of 360µT and 9kV/m. Thus, the proposed overhead lines would meet the relevant exposure limits, the ICNIRP general public guidelines (Ref. 3) in the terms of the EU Recommendation (Ref.4). 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. On this basis, the effects are **not** considered to be significant.

5.2.7 The assessment presented above shows that the maximum value of the fields produced by the proposed 132kV overhead lines, individually and in combination, 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 to achieve compliance. Therefore, assessment of compliance is not dependent on: the exact routeing 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.

5.2.8 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 MITIGATION

6.1.1 No mitigation measures are necessary as the KTR 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.1). If these requirements are met NPS EN-5 states that "*no further mitigation should be necessary."*

7 RESIDUAL EFFECTS

7.1.1 The KTR Project has been demonstrated to comply with the current public exposure guidelines and the policy on phasing as detailed in NPS EN-5 (Ref. 1). If these requirements are met NPS EN-5 states that "*EMF effects are minimal."* On this basis, the effects are **not** considered to be significant.

8 CUMULATIVE EFFECTS

8.1.1 The EMFs 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 EMFs is 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 powerline would affect the direction of the fields from each line 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 KTR Project and any interactions with other developments which produce EMFs would not be significant.

8.1.2 It is SPEN's and the electricity industry's policy to ensure that all powerlines 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.

9 CONCLUSIONS

9.1.1 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. 1).

9.1.2 The powerlines associated with the KTR Project would be fully compliant with 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 individual connections comprising the KTR Project, the KTR Project as a Whole and cumulatively with other developments.