voltalia

Technical Appendix 15.2: EMF Assessment

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PAGERPOWER
Urban & Renewables

High-Level Electromagnetic Field Assessment

Voltalia UK Limited

Springfield Solar

April 2025





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Job Reference:	14381A
Author:	Vijayatha Vijayaraghavan
Telephone:	01787 319001
Email:	vijayatha@pagerpower.com

Reviewed By:	Ayda Yates; Danny Scrivener
Email:	ayda@pagerpower.com; danny@pagerpower.com

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Stour Valley Business Centre, Brundon Lane, Sudbury, CO10 7GB

T:+44 (0)1787 319001 E:info@pagerpower.com W: www.pagerpower.com

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EXECUTIVE SUMMARY

Report Purpose

Pager Power has been retained to assess the potential electromagnetic fields (EMF) generated by electrical equipment within a fixed ground-mounted solar photovoltaic development with respect to safe levels for human exposure. The Proposed Development is located near Oldhamstocks, East Lothian, Scotland, and will consist of underground power cables, overhead powerlines, transformers, photovoltaic (PV) inverters and a distribution substation[1].

Emissions

All electrical equipment emits electric and magnetic radiation. Power cables produce both electric and magnetic fields, which can potentially affect human health. Radiation from underground cables is generally less than radiation from overhead powerlines because emissions from adjacent conductors within a cable tend to cancel each other out. When assessing the impacts of overhead power lines, it is important to consider the impact of both electric and magnetic fields. Underground cables generally cause a negligible electric field above ground but can cause a significant magnetic field, which is dependent on the current in the conductors.

Standards in the UK

The UK Policy on public exposure limits to EMF radiation is designed to comply with the 1998 International Commission on the Non-Ionizing Radiation Protection (ICNIRP) guidelines in terms of the 1999 EU Recommendation. In 2010, ICNIRP produced new guidelines, but these have not been incorporated into UK Policy. The public exposure limits in UK policy define reference levels for electric and magnetic fields. Where field levels exceed these reference levels in significantly occupied spaces, further investigation is warranted. Further information can be found in Section 3 of this report.

Assessment Conclusions - 33kV Underground Cables

The maximum magnetic field produced by the proposed 33kV underground cables is predicted to be 1.0 micro-Tesla. The magnetic field levels are, therefore, below the reference level from the public exposure limits in UK policy.

This value correlates to a human being 1m agl, directly above the cable, and therefore, the magnetic fields will be further diminished due to any lateral separation distances between the cables and any dwelling.

When considering the cumulative magnetic fields of the proposed underground cables and existing overhead powerlines (worst-case), the minimum exposure limits directly above the cable are still maintained.

[1] The maximum voltages for underground cables, transformers/PV inverters and the distribution substation have been assumed to account for a worst-case scenario in the absence of a finalised electrical design of the site.

Assessment Conclusions - 400kV Overhead Powerlines

The maximum magnetic field produced by the existing 400kV overhead powerlines is predicted to be 81.942 micro-Tesla. The magnetic field value is, therefore below the reference level from the public exposure limits in UK policy. This value correlates to a human 1m agl, directly above the cable.

The maximum electric field produced by the existing 400kV overhead powerlines is predicted to be 10.642kV/m. The electric field levels are, therefore, above the reference level from the public exposure limits in UK policy. To minimise risks associated with prolonged exposure to electromagnetic fields generated by the existing overhead powerlines, it is recommended that a 15m standoff distance is retained to ensure that dwellings and workplaces are at a safe distance from the powerlines. This standoff distance helps limit potential risks from prolonged exposure to electromagnetic fields generated by the powerlines.

When considering the cumulative magnetic fields at 0m from the proposed underground cables and existing overhead powerlines (worst-case), the exposure limits are still maintained. When considering the cumulative electric fields at 0m from the proposed underground cables and existing overhead powerlines (worst-case), the exposure limits are exceeded but can still be met with the recommended clearance distance of 15m.

The two residential dwellings are situated approximately 400 and 670 meters away from the nearest overhead power line, which is well beyond the minimum clearance distance. Consequently, the maximum electric field strength at the dwellings will be less than 0.136 kV/m, and the maximum magnetic field strength will be less than 2.145 microteslas.

Assessment Conclusions - Distribution Substations, Transformers, and PV Inverters

The most significant sources of radiation other than the cables and powerlines are the eight transformers/PV inverters positioned across the Proposed Development, as well as the distribution substation.

The electrical equipment associated with the transformers and PV inverters should be 'CE' marked (Conformité Européene, or European Conformity marking), and/or 'UKCA' marked (UK Conformity Assessed). CE and UKCA markings indicate that a product has been assessed by the manufacturer and determined to meet the safety, health, and environmental protection requirements of the European Union and the United Kingdom, respectively. CE marking requirements were adopted and extended indefinitely in Great Britain until the UK left the EU in 2020. From 1 January 2021, the UKCA mark started to replace the CE mark for goods sold within Great Britain, and the CE mark has continued to be required for goods sold in Northern Ireland. The CE marking should ensure that electrical and electronic equipment does not generate, or is not unintentionally affected by, electromagnetic disturbance.

The transformers and PV inverters are also predicted to produce fields at a lower level than that of underground cables because the equipment is typically housed in protective enclosures. Therefore, no significant impacts associated with the proposed conversion units are predicted.

Overall Conclusions

Levels of electromagnetic radiation from the underground cables and overhead powerlines are predicted to be below ICNIRP reference levels for magnetic fields, even when assuming maximum radiation is being experienced from the proposed underground cables and the existing overhead powerlines. However, electric field levels from the existing overhead powerlines are predicted to be above ICNIRP reference levels, and an approximately 15m minimum horizontal clearance distance is recommended for workplaces and dwellings where there is a risk of prolonged exposure.

Radiation from the substation, transformers and PV inverters will be even less significant because the equipment is predicted to be housed in protective enclosures and the substation, transformers, and PV inverters will be UKCA/CE marked, meaning they should not generate or be affected by electromagnetic disturbance.

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ABOUT PAGER POWER

Pager Power is a dedicated consultancy company based in Suffolk, UK. The company has undertaken projects in 61 countries internationally.

The company comprises a team of experts to provide technical expertise and guidance on a range of planning issues for large and small developments.

Pager Power was established in 1997. Initially, the company focus was on modelling the impact of wind turbines on radar systems. Over the years, the company has expanded into numerous fields including:

- Renewable energy projects;
- Building developments;
- Aviation and telecommunication systems.

Pager Power prides itself on providing comprehensive, understandable, and accurate assessments of complex issues in line with national and international standards. This is underpinned by its custom software, longstanding relationships with stakeholders and active role in conferences and research efforts around the world.

Pager Power's assessments withstand legal scrutiny, and the company can provide support for a project at any stage.

1 INTRODUCTION

1.1 Purpose of the Study

Pager Power has been retained to assess the potential electromagnetic fields (EMF) generated by electrical equipment within a fixed ground-mounted solar photovoltaic development with respect to safe levels for human exposure. The Proposed Development is located near Oldhamstocks, East Lothian, Scotland, and will consist of underground power cables, overhead powerlines, transformers, photovoltaic (PV) inverters and a distribution substation[2].

1.2 Proposed Development Site Layout

Figure 1 on the following page shows the Site Layout[3] for the Proposed Development.

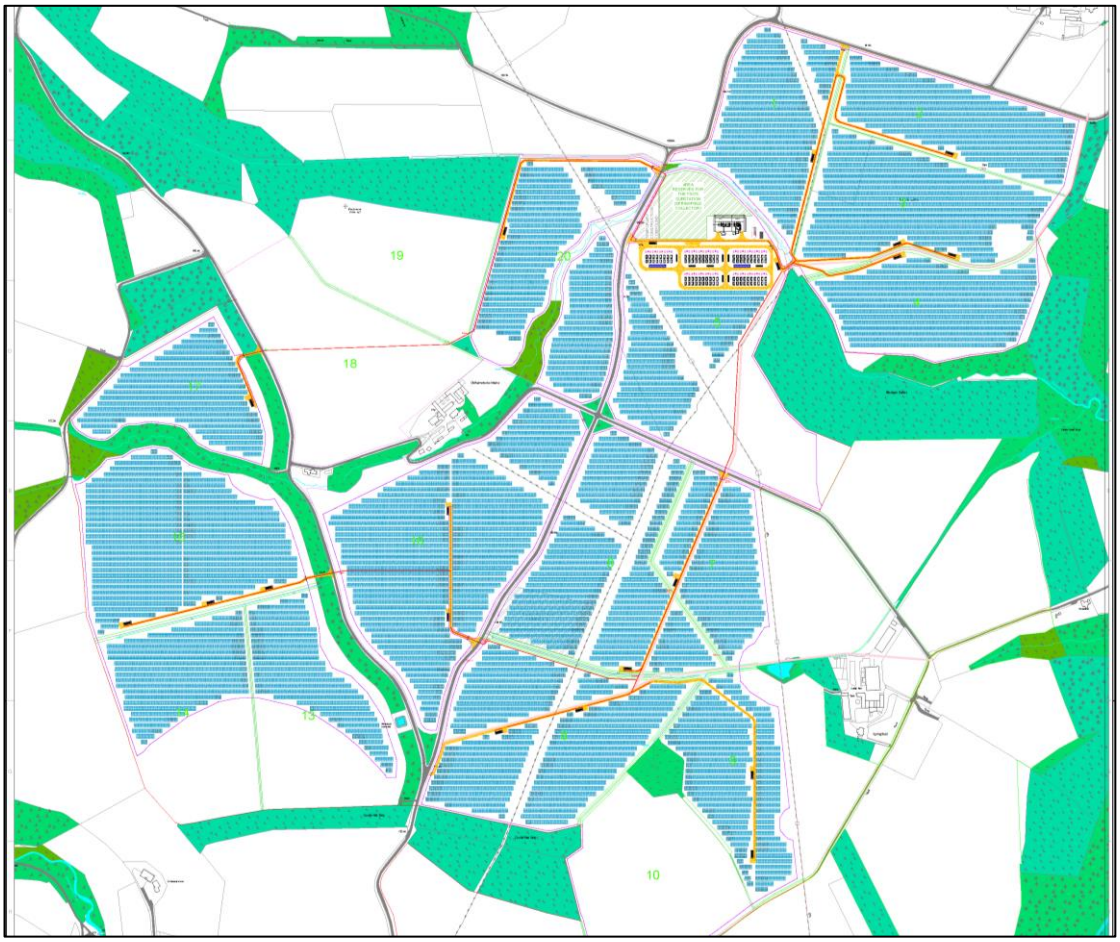

Figure 1 Proposed Development Site Layout

[2] The maximum voltages for underground cables, transformers/PV inverters and the distribution substation have been assumed to account for a worst-case scenario in the absence of a finalised electrical design of the site.
[3] Source: GFE01-DV-AS--GEN_IMP-01-10.pdf [cropped].

1.3 Dwellings

The public exposure levels of potential electric and magnetic fields are assessed for two Residential Dwellings as shown in Figure 2 below.

Figure 2 *Assessed Dwelling locations*

1.4 Assessed Infrastructure

The known locations of assessed infrastructure are shown in Figure 3 on the following page:

- 400kV existing overhead powerlines (*light blue line*);
- 11kV Overhead Line (*purple line*);
- Battery Container and Power Control System (*yellow polygon*);
- 132 kV Distribution Network Operator (DNO) Substation (*black polygon*);
- Transformer Centre (*circular icons*);
- Proposed transformers (*square icons*).

Additional information highlighted in Figure 3 includes the proposed 33kV underground cable lines (orange line) and the red line boundary of the development. Furthermore, the underground cables have been included in Figure 3, but there is no finalised electrical design of the Proposed Development; however, these have still been assessed while considering a worst-case scenario in Section 4.1.

More detailed sections are shown within the technical assessment sections of this report. Figure 3 is intended to provide an overview of the environment and infrastructure.

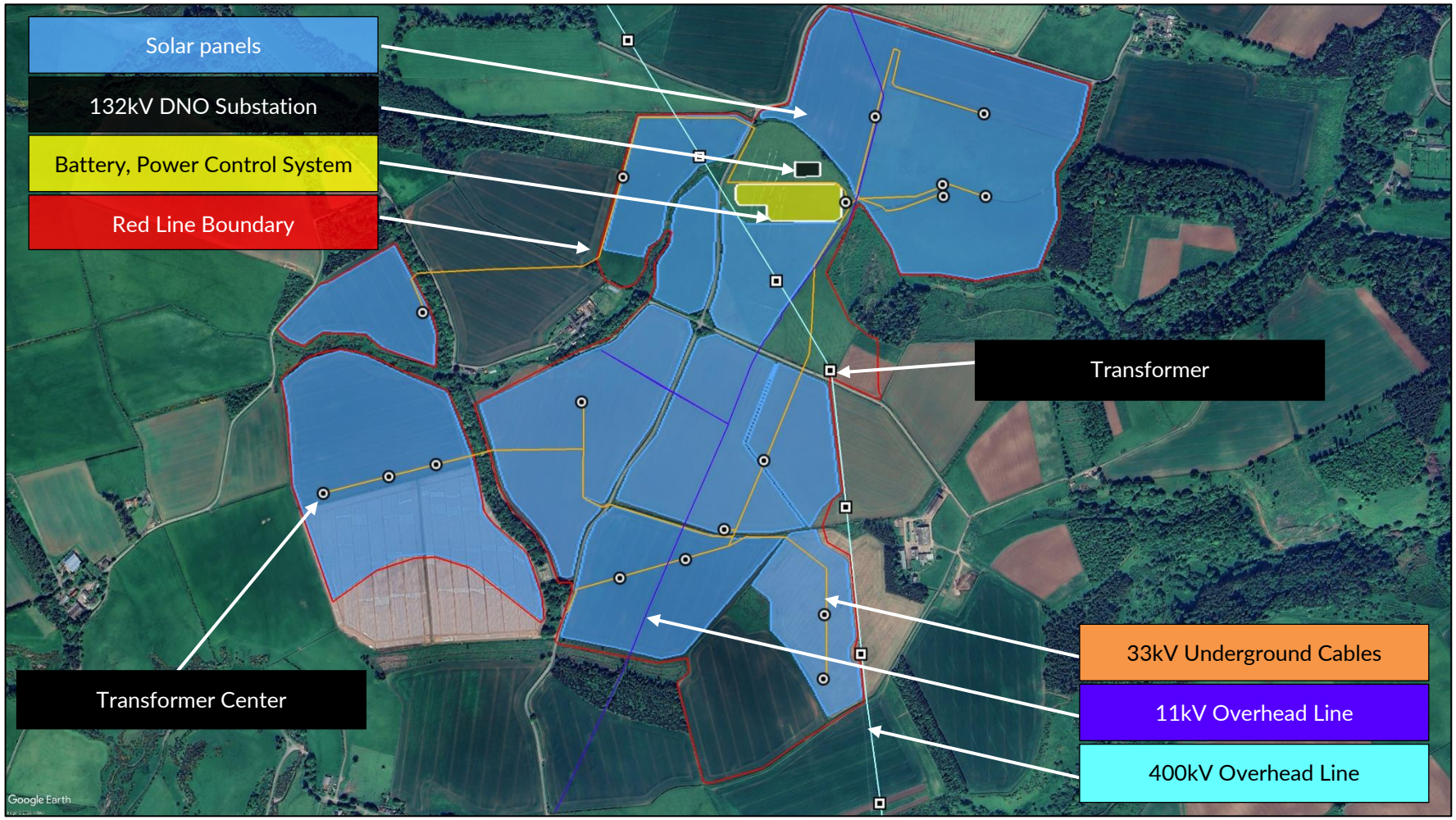

Figure 3 *Assessed infrastructure locations*

2 TECHNICAL BACKGROUND

2.1 Emissions

All electrical equipment emits electric and magnetic radiation. Power cables produce both electric and magnetic fields, which can potentially affect human health. Radiation from underground cables is generally less than radiation from overhead lines because emissions from adjacent conductors within a cable tend to cancel each other out. When assessing the impacts of overhead powerlines, it is important to consider the impact of both electric and magnetic fields.

Underground cables generally cause a negligible electric field above ground but can cause a significant magnetic field, which is dependent on the current in the conductors.

2.2 Electromagnetism

The movement of an electric charge causes electric and magnetic fields to be produced in the space surrounding the charge. Human exposure to such fields can cause health problems if persistent and/or they are of high strength. The magnitude of the effects is dependent on both the field strength and the exposure time.

2.3 Health Concerns – Potential Effects

The potential effects on human health caused by time-varying magnetic fields, such as those generated by AC[4] cables, are due to induced current on functions of the central nervous system. There are various international bodies which provide maximum safe exposure levels to time-varying electromagnetic fields.

Various sources of information relating to safe exposure levels have been reviewed as part of this study. The UK Policy on public exposure limits to EMF radiation is designed to comply with the 1998 ICNIRP (International Commission on the Non-Ionizing Radiation Protection) guidelines in terms of the 1999 EU Recommendation. In 2010 ICNIRP produced new guidelines, but these have not been incorporated into UK Policy. The public exposure limits in UK policy define reference levels for electric and magnetic fields. Where field levels exceed these reference levels in significantly occupied spaces, further investigation is warranted.

Another relevant resource consulted is the EMFs.info[5] webpage, where the UK electricity industry has collected relevant studies on safe limits on exposure in the UK and elsewhere in the world. The relevant sections are analysed in the next chapter.

[4] Alternating Current

[5] Last Accessed: March 2024: https://emfs.info/.

2.4 Radiation from Home Electrical Equipment

The World Health Organization (WHO) publishes data regarding electromagnetic fields including the following typical levels for home electrical equipment, shown in Table 1 below.

Appliance	Electric field strength (Volts per metre)	Magnetic field strength (micro-Tesla) (at 1 metre)
Hair Dryer	80	0.01 – 7
Iron	120	0.12 – 0.3
Vacuum Cleaner	50	2 – 20
Refrigerator	120	0.01 – 0.25
Television	60	0.04 - 2

Table 1 *Typical emissions from home electrical equipment*

2.5 Radiation Reduction with Distance

Radiation levels reduce with distance, which means, for example, the typical magnetic field from a vacuum cleaner reduces from 800 micro-Tesla to 2 micro-Tesla when the separation distance increases from 3 centimetres to 100 centimetres.

This means radiation levels from the cables, powerlines, substations, transformers, and PV inverters will tend to reduce with distance in any direction – including towards a receptor.

3 EMFS.INFO

3.1 Overview

The Electricity Networks Association[6] provides a comprehensive overview of EMFs and the issues associated with these on their webpage. Regarding health issues caused by EMFs they state the following:

However, there are suggestions that magnetic fields may cause other diseases, principally childhood leukaemia, at levels below these limits. The evidence for this comes from epidemiology studies, which have found a statistical association - an apparent two-fold increase in leukaemia incidence, from about 1 in 24,000 per year up to 1 in 12,000 per year, for the children with the top half percent of exposures. The evidence is strong enough for magnetic fields to be classified by the World Health Organization as "possibly carcinogenic". But because these studies only show statistical associations and do not demonstrate causation, and because the evidence from the laboratory is against, the risk is not established, it remains only a possibility.

3.2 Exposure limits in the UK

As set out in the previous section, the limits in the UK come from the 1998 ICNIRP guidelines. The original guidance in 1999 specified:

i) Basic Restrictions

These are the levels at which radiation is potentially harmful to humans. This is a current density[7] given in mA m^{-2} (milliamps per metre squared).

ii) Reference Level (Investigation Level)

Provided for practical exposure assessment purposes to determine whether the basic restrictions are likely to be exceeded. Compliance with the reference level will ensure compliance with the relevant basic restriction.

iii) Field Actually Required

This is the field strength at which the basic restriction is likely to be exceeded.

The values for the above stated in the ICNIRP 1998 paper are shown in Table 2 on the following page. These are the public exposure values, not the occupational exposure values – the former is more conservative than the latter by a factor of five.

[6] This is an industry body for the companies which run the UK and Ireland's energy networks. The group comprises 14 members including National Grid.

[7] Current density is the amount of electric current flowing through a unit area.

ICNIRP 1998 – Public Exposure Limits				
Basic Restriction (mA m^{-2})	Magnetic Fields Reference Level (µT)	Electric Fields Reference Level (kV m^{-1})	Magnetic Field Actually Required (µT)	Electric Field Actually Required (kV m^{-1})
2	100	5	360	9

Table 2 *ICNIRP Exposure Limits 1998*

The reference levels in Table 2 will be considered within this analysis.

3.3 Height Above Ground Used for Testing Compliance

EMFS.info specifically states the following with regard to the height to be used to test compliance:

The standard height for measuring fields, especially from power lines, is 1 m above ground level … This isn't just because it's a convenient round number, it's because roughly half way up the height of a standing person is actually the height that gives the best approximation to the induced current in the body.

3.4 Safe Levels – Summary

The values of interest are those shown in Table 2 above. Effectively, this means that in locations of significant exposure time, such as residences, levels should be below:

- 100 micro-Tesla (µT) (magnetic fields);
- 5kV m^{-1} (electric fields).

Values exceeding the limits above, at one metre above ground level (agl), would suggest that further investigation is required.

4 TECHNICAL ASSESSMENT

4.1 Field Levels – Underground Cables

Field-level data from various cable configurations have been sourced from EMFS.info. The data below and on the following page show the magnetic fields for 33kV cables, which represent the maximum assumed voltage for underground cables in the Proposed Development, considering a worst-case scenario[8]. The relevant charts for the magnetic fields are shown in Figure 4 below. Table 3 provides the associated indicative numerical values at set distances.

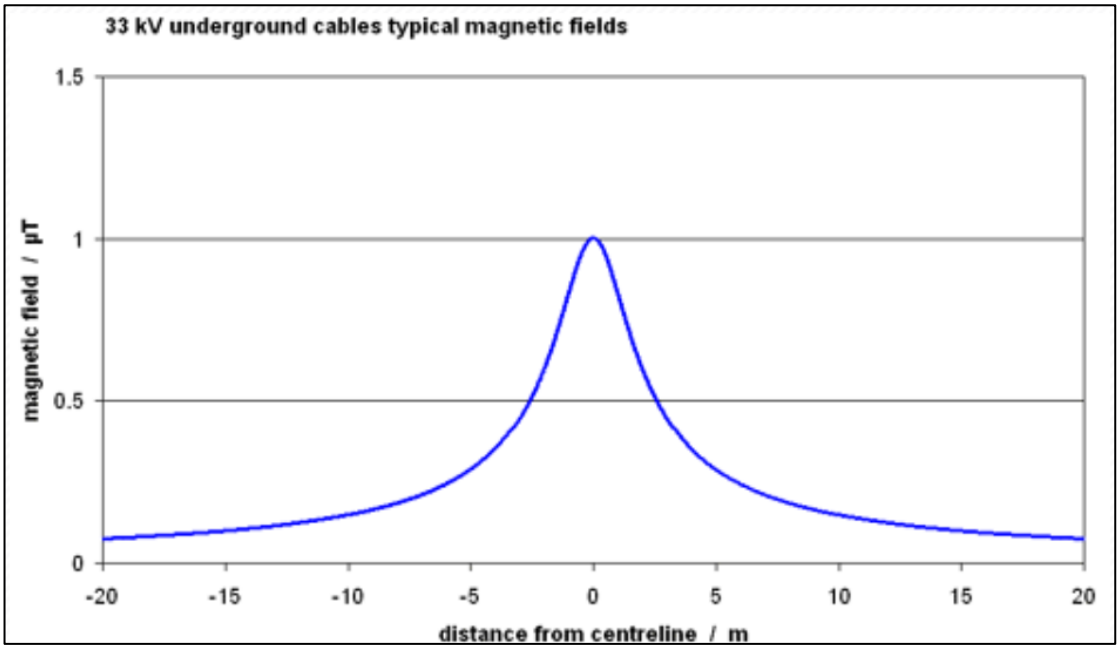

Figure 4 *Typical magnetic fields associated with 33kV underground cable*

Distance from Centreline (m)	Magnetic Field (single 33 kV cable at 1m depth)
0	1.00 micro Teslas
5	0.29 micro Teslas
10	0.15 micro Teslas
20	0.07 micro Teslas

Table 3 *Typical magnetic field levels for an underground 33kV cable (source: EMFS.info)*

[8]It has been confirmed by the developer via email dated 19/02/2025 that the maximum voltage of the proposed underground cables is 33kV.

4.2 Field Levels – Overhead Powerlines

Field-level data has been sourced from EMFS.info. The data below and on the following pages shows magnetic and electric fields for a 400kV overhead powerline in an L12 lattice pylon design, which is typical in the UK, with the minimum ground clearance and the highest allowed loads. This gives the maximum magnetic and electric fields and, therefore, provides a conservative assessment.

The relevant chart for the maximum magnetic field is shown in Figure 5 below, and the relevant chart for the maximum electric field is shown in Figure 6 on the following page. Tables 4 and 5 provide the associated indicative numerical values at set distances.

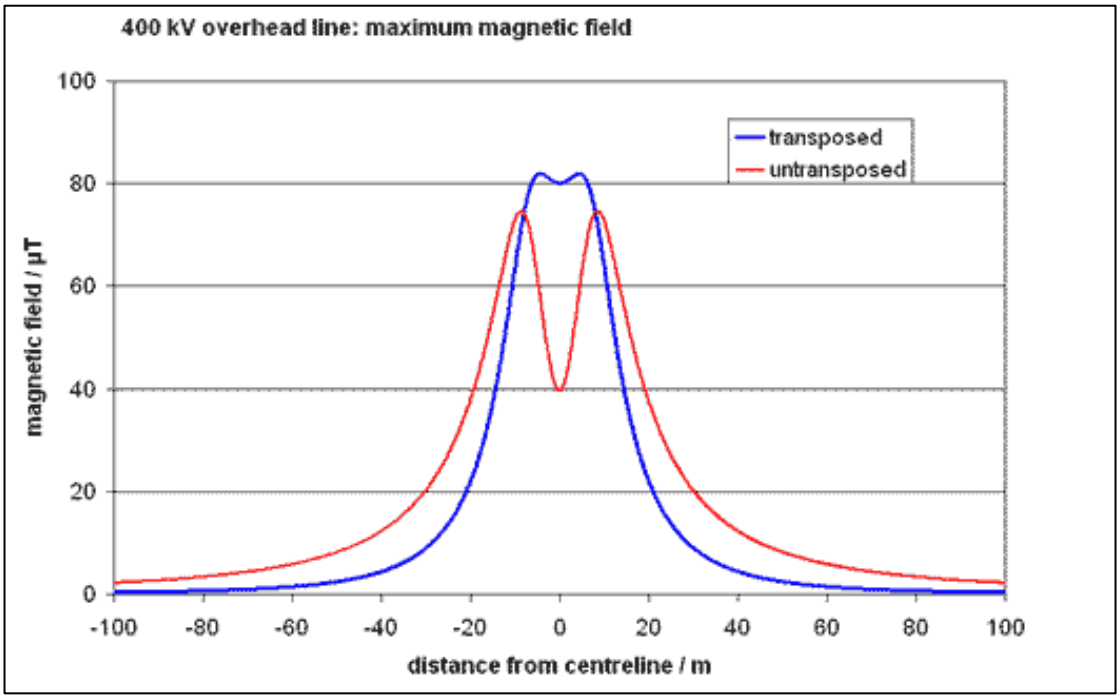

Figure 5 *Maximum magnetic fields associated with 400kV overhead powerline*

Distance from Centreline (m)	Magnetic Field (L12 lattice pylon design with 7.6m ground clearance and the highest allowed loads)
0	81.942 micro-Tesla
10	72.818 micro-Tesla
25	22.103 micro-Tesla
50	8.148 micro-Tesla
100	2.145 micro-Tesla

Table 4 *Maximum magnetic field levels for an overhead 400kV powerline (source: EMFS.info)*

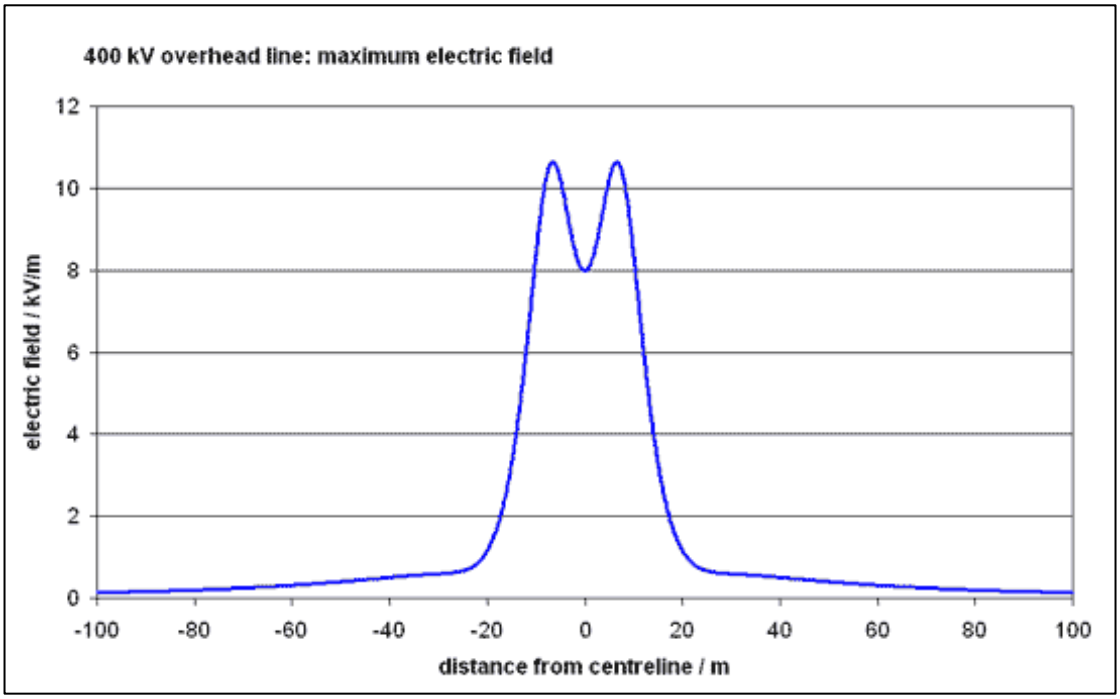

Figure 6 *Maximum electric fields associated with 400kV overhead cable*

Distance from Centreline (m)	Electric Field (L12 lattice pylon design with 7.6m ground clearance and the highest allowed loads)
0	10.642 kV/m
10	8.410 kV/m
25	0.669 kV/m
50	0.404 kV/m
100	0.136 kV/m

Table 5 *Maximum electric field levels for an overhead 400kV cable (source: EMFS.info)*

4.3 Recommended Minimum Clearance Distances

The recommended minimum clearance distances for different categories of cable based on the public exposure limits previously referenced in this report for magnetic and electric fields are presented in Table 6 on the following page.

The dataset provided maximum values and typical values for the configurations that have been evaluated – in all cases, the 'maximum' option has been chosen where possible in order to remain conservative.

Type of Line	Recommended minimum Clearance Distance (m)	Estimated Maximum Magnetic Field (micro-Tesla)	Estimated Maximum Electric Field (kV/m)
33kV underground cable	None	1.0 (below 100 limit)	-
400kV overhead powerline	Approximately 15m	81.942 (below 100 limit)	10.642 (above 5 limit)

Table 6 *Recommended minimum clearance distances for the different sources*

This shows that clearance distances are not required for any proposed underground cables. The table highlights that the fields produced by the cables are significantly below the acceptable exposure limit, and significant effects upon health are not predicted.

Additionally, the estimated maximum magnetic field produced by the overhead powerline is significantly below the acceptable exposure limit, and significant health effects are not predicted.

The estimated maximum electric field produced by the overhead powerline surpasses the acceptable exposure limits specified in Table 2. A minimum clearance distance of approximately 15 meters is recommended for the 400kV overhead powerline to reduce the maximum electric field to below the reference exposure.

This recommendation specifically addresses public exposure limits for human health, and the minimum clearance distance is with reference to human activity. Therefore, workplaces and dwellings should be situated no closer than 15m horizontally to the overhead powerlines to limit prolonged exposure. This standoff distance helps reduce potential risks from electromagnetic fields generated by the powerlines.

4.4 Radiation from Other Sources

The most significant sources of radiation other than the cables and powerlines are the eight transformers/PV inverters positioned across the Proposed Development, as well as the distribution substation. The proposed locations are shown in Figure 2 in Section 1.3.

The electrical equipment associated with the transformers and PV inverters should be 'CE' marked (Conformité Européene, or European Conformity marking), and/or 'UKCA' marked (UK Conformity Assessed). CE and UKCA markings indicate that a product has been assessed by the manufacturer and determined to meet the safety, health, and environmental protection requirements of the European Union and the United Kingdom, respectively. CE marking requirements were adopted and extended indefinitely in Great Britain until the UK left the EU in 2020. From 1 January 2021, the UKCA mark started to replace the CE mark for goods sold within Great Britain, and the CE mark has continued to be required for goods sold in Northern Ireland. The CE marking should ensure that electrical and electronic equipment does not generate, or is not unintentionally affected by, electromagnetic disturbance.

Additionally, the electromagnetic fields generated by substation equipment typically do not extend beyond the substation boundaries. The strongest fields often originate from overhead power lines and underground cables connected to the substation. Similarly, the transformers and PV inverters are also predicted to produce fields at a lower level than that of underground cables and overhead powerlines because the equipment is housed in a protective enclosure.

4.5 Comparative Assessment

The maximum magnetic field produced by appliances such as vacuum cleaners can reach up to 20 micro-Tesla. It would follow that appliances with larger voltages would produce fields at a higher level; however, the 33kV underground cables do not produce larger fields.

The maximum magnetic field produced by the proposed underground cables is 1.00 micro-Tesla. In comparison to the household appliances previously mentioned, these values are significantly lower and are within the acceptable exposure limits. The substation, transformers and PV inverters will produce magnetic fields at levels lower than the underground cables, thus, lower than the household appliances previously mentioned.

The maximum electric field produced by larger household appliances such as refrigerators is 0.12kV/m and, as mentioned above, the maximum magnetic field produced by appliances such as vacuum cleaners can reach up to 20 micro-Tesla. While the overhead powerlines generate stronger magnetic and electric fields compared to household appliances, it is crucial to consider the recommended clearance buffer of 15 meters for human activity. This safety measure mitigates exposure to these fields, ensuring acceptable exposure limits.

4.6 Cumulative Effects

When assessing the cumulative effects of electromagnetic fields, the worst case is based upon the addition of source A and source B; however, it is important to note that this is only true for magnetic fields that are exactly in line. When the electromagnetic fields are not in line, the sum of these is less than ‘A+B’.

For the purpose of this assessment, the worst case has been calculated i.e. based upon ‘A+B’. When adding the magnetic fields of the proposed underground cables and the existing overhead powerlines, the resultant is 82.942 micro-Tesla, which is still significantly less than the exposure limit. Although the resultant electric field of the proposed underground cables and the existing overhead powerlines is 10.642 kV/m, this can be reduced according to the recommended clearing distance. As discussed in Section 4.4, the substation, transformers, and PV inverters produce smaller magnetic fields than that of the underground cables and overhead powerlines; thus, considering all sources of radiation, the cumulative magnetic and electric fields are still significantly below the acceptable exposure limits.

The cumulative effects are not significantly impacted by the use of household items. Electrical household appliances will add to the overall exposure of electromagnetic fields; however, these levels will still remain below the recommended exposure limit due to the lower voltages of the appliances and are not used constantly, providing only a temporary addition to the resultant electromagnetic field levels.

5 CONCLUSIONS

5.1 Assessment Conclusions - 33kV Underground Cables

The maximum magnetic field produced by the proposed 33kV underground cables is predicted to be 1.0 micro-Tesla. The magnetic field levels are, therefore, below the reference level from the public exposure limits in UK policy.

This value correlates to a human being 1m agl, directly above the cable, and therefore, the magnetic fields will be further diminished due to any lateral separation distances between the cables and any dwelling.

When considering the cumulative magnetic fields of the proposed underground cables and existing overhead powerlines (worst-case), the minimum exposure limits directly above the cable are still maintained.

5.2 Assessment Conclusions - 400kV Overhead Powerlines

The maximum magnetic field produced by the existing 400kV overhead powerlines is predicted to be 81.942 micro-Tesla. The magnetic field value is, therefore below the reference level from the public exposure limits in UK policy. This value correlates to a human 1m agl, directly above the cable.

The maximum electric field produced by the existing 400kV overhead powerlines is predicted to be 10.642kV/m. The electric field levels are, therefore, above the reference level from the public exposure limits in UK policy. To minimise risks associated with prolonged exposure to electromagnetic fields generated by the existing overhead powerlines, it is recommended that a 15m standoff distance is retained to ensure that dwellings and workplaces are at a safe distance from the powerlines. This standoff distance helps limit potential risks from prolonged exposure to electromagnetic fields generated by the powerlines.

When considering the cumulative magnetic fields at 0m from the proposed underground cables and existing overhead powerlines (worst-case), the exposure limits are still maintained. When considering the cumulative electric fields at 0m from the proposed underground cables and existing overhead powerlines (worst-case), the exposure limits are exceeded but can still be met with the recommended clearance distance of 15m.

The two residential dwellings are situated approximately 400 and 670 meters away from the nearest overhead power line, which is well beyond the minimum clearance distance. Consequently, the maximum electric field strength at the dwellings will be less than 0.136 kV/m, and the maximum magnetic field strength will be less than 2.145 microteslas.

5.3 Assessment Conclusions - Distribution Substations, Transformers, and PV Inverters

The most significant sources of radiation other than the cables and powerlines are the eight transformers/PV inverters positioned across the Proposed Development, as well as the distribution substation.

The electrical equipment associated with the transformers and PV inverters should be 'CE' marked (Conformité Européene, or European Conformity marking), and/or 'UKCA' marked (UK Conformity Assessed). CE and UKCA markings indicate that a product has been assessed by the manufacturer and determined to meet the safety, health, and environmental protection requirements of the European Union and the United Kingdom, respectively. CE marking requirements were adopted and extended indefinitely in Great Britain until the UK left the EU in 2020. From 1 January 2021, the UKCA mark started to replace the CE mark for goods sold within Great Britain, and the CE mark has continued to be required for goods sold in Northern Ireland. The CE marking should ensure that electrical and electronic equipment does not generate, or is not unintentionally affected by, electromagnetic disturbance.

The transformers and PV inverters are also predicted to produce fields at a lower level than that of underground cables because the equipment is typically housed in protective enclosures. Therefore, no significant impacts associated with the proposed conversion units are predicted.

5.4 Overall Conclusions

Levels of electromagnetic radiation from the underground cables and overhead powerlines are predicted to be below ICNIRP reference levels for magnetic fields, even when assuming maximum radiation is being experienced from the proposed underground cables and the existing overhead powerlines. However, electric field levels from the existing overhead powerlines are predicted to be above ICNIRP reference levels, and an approximately 15m minimum horizontal clearance distance is recommended for workplaces and dwellings where there is a risk of prolonged exposure.

Radiation from the substation, transformers and PV inverters will be even less significant because the equipment is predicted to be housed in protective enclosures and the substation, transformers, and PV inverters will be UKCA/CE marked, meaning they should not generate or be affected by electromagnetic disturbance.

PAGERPOWER

Urban & Renewables

Pager Power Limited
Stour Valley Business Centre
Sudbury
Suffolk
CO10 7GB

Tel: +44 1787 319001 **Email:** info@pagerpower.com **Web:** www.pagerpower.com