# Technical Report – Electric and Magnetic Fields

Virya Energy

Yanco Delta Wind Farm
15 September 2022

# Executive summary

Virya Energy is proposing to construct, operate and maintain the Yanco Delta Wind Farm (the Project). Approval is sought under Division 4.7 of Part 4 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act) and Part 9, Division 1 of *the Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Project would involve the construction, operation and maintenance of a wind farm with up to 208 wind turbine generators (WTGs), a battery energy storage system (BESS) and associated electrical infrastructure. The generating capacity of the wind farm is approximately 1,500 megawatts (MW).

This electric and magnetic fields (EMF) assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) relating to potential hazards and risks associated with EMF and will assist the Minister for Planning to make a determination on whether or not to approve the Project. This assessment provides an assessment of potential EMF impacts of the Project and outlines proposed management measures.

## Assessment methodology

The EMF assessment has considered and documented any health issues having regard to the latest advice of the National Health and Medical Research Council and has identified potential hazards and risks associated with electric and magnetic fields. Moreover, an assessment has been performed against the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields, with demonstration and application of the principles of prudent avoidance implemented.

## Overview of EMF impacts

The EMF assessment has identified multiple sources of EMF within the Project area. These sources include the WTGs, underground cables, overhead power lines, substations, BESS and overhead transmission line.

At this stage of the Project, limited information is available to determine the applicable EMF levels associated with the majority of the high voltage equipment. Where information regarding the high voltage installations is available, a preliminary EMF assessment has been performed using CDEGS and SESEnviroPlus software.

The underground cables have been modelled in the HIFREQ module of CDEGS, and the overhead power lines and transmission line have been modelled in SESEnviroPlus, to calculate the electric and magnetic fields generated by these electrical assets. The EMF levels associated with the underground cables and overhead power lines within the Project are below the ICNIRP reference levels.

The electric field strength under the 330 kV and 500 kV transmission line options is above the ICNIRP reference level but below the limit derived by detailed dosimetric calculations, as reported by TransGrid for the Project Energy Connect EIS. It is further noted that the electric field strength (EFS) generated by the 330 kV transmission line option is below the 5 kV/m ICNIRP reference level 17 m from the centre of the line.

Similarly, the EFS generated by the 500 kV transmission line option is below the 5 kV/m ICNIRP reference level 21 m from the centre of the line. The EFS levels should therefore be below the ICNIRP reference levels within a typical transmission line easement width. The closest sensitive receiver to the proposed transmission line is a dwelling 2.6 km from the transmission line easement. At this distance from the transmission line, the measured electric field strength from any of the proposed transmission lines would be much lower than the ICNIRP reference levels.

The WTGs are proposed to be capable of generating up to 8 MW. Given the location of the high voltage equipment associated with WTGs is located over 100 m above ground level, and based on field measurements reported by various studies, the worst case EMF levels produced by the WTGs at 1 m above ground level would be much lower than the ICNIRP reference levels.

The Australian design standard for HV installations, AS2067, requires that the detailed substation design complies with the ICNIRP reference levels both inside and outside the substation. The EMF associated with the substations has therefore not been assessed at this early stage of the Project but would be assessed in detail during the design stages to verify compliance with the requirements of AS 2067. The EMF requirements specified in AS 2067 would also apply to these future installations.

## Management measures

The expected EMF levels from the Project would comply with the relevant Australian and international standards and guidelines. As such, mitigation measures have not been considered in the assessment however prudent avoidance measures would be considered in the detailed design of the Project.

## Conclusion

The EMF levels generated by the Project has been assessed as compliant with the applicable Australian and international standards and guidelines, specifically the ICNIRP reference levels, within and at the perimeter of the Project area using both calculations and references to published test data for comparable infrastructure. The only significant source of electric field levels would be the outdoor substation equipment and the aerial 330 kV and 500 kV transmission line however EFS levels associated with these transmission line options only exceed the ICRNIRP reference levels within the transmission line easement.

Prudent avoidance measures to further reduce public exposure to EMF generated by the Project will be considered as part of the detailed design process.

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# Glossary and terms

| Term | Definition |
|---|---|
| AAAC | All Aluminium Alloy Conductor |
| ACSR | Aluminium Conductor Steel Reinforced |
| ARPANSA | Australian Radian Protection and Nuclear Safety Agency |
| AS | Australian Standard |
| EF | Electric Field |
| EIA | Environmental Impact Assessment |
| ELF | Extremely Low Frequency |
| EMF | Electric and Magnetic Fields |
| EPA | Environmental Protection Authority |
| HF | High Frequency |
| ICNIRP | International Commission on Non-ionizing Radiation Protection |
| IEEE | Institute of Electrical and Electronic Engineers |
| MF | Magnetic Field |
| MFD | Magnetic Flux Density |
| MFS | Magnetic Field Strength |
| pu | Per Unit |
| RMS | Root Mean Square |
| UHF | Ultra High Frequency |
| VHF | Very High Frequency |
| WHO | World Health Organisation |

# 1. Introduction

## 1.1 Background

Virya Energy is proposing to construct, operate and maintain the Yanco Delta Wind Farm (the Project). Approval is sought under Division 4.7 of Part 4 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act) and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Project would involve the construction, operation and maintenance of a wind farm with up to 208 wind turbine generators (WTGs), a battery energy storage system (BESS) and associated electrical infrastructure including overhead power and transmission lines. The generating capacity of the wind farm is approximately 1,500 megawatts (MW). The Project would be located within the South-West Renewable Energy Zone (REZ), 10 km north-west of the town of Jerilderie, within the Murrumbidgee Council and Edward River Council Local Government Areas (LGAs) (refer to **Figure 1-1**).

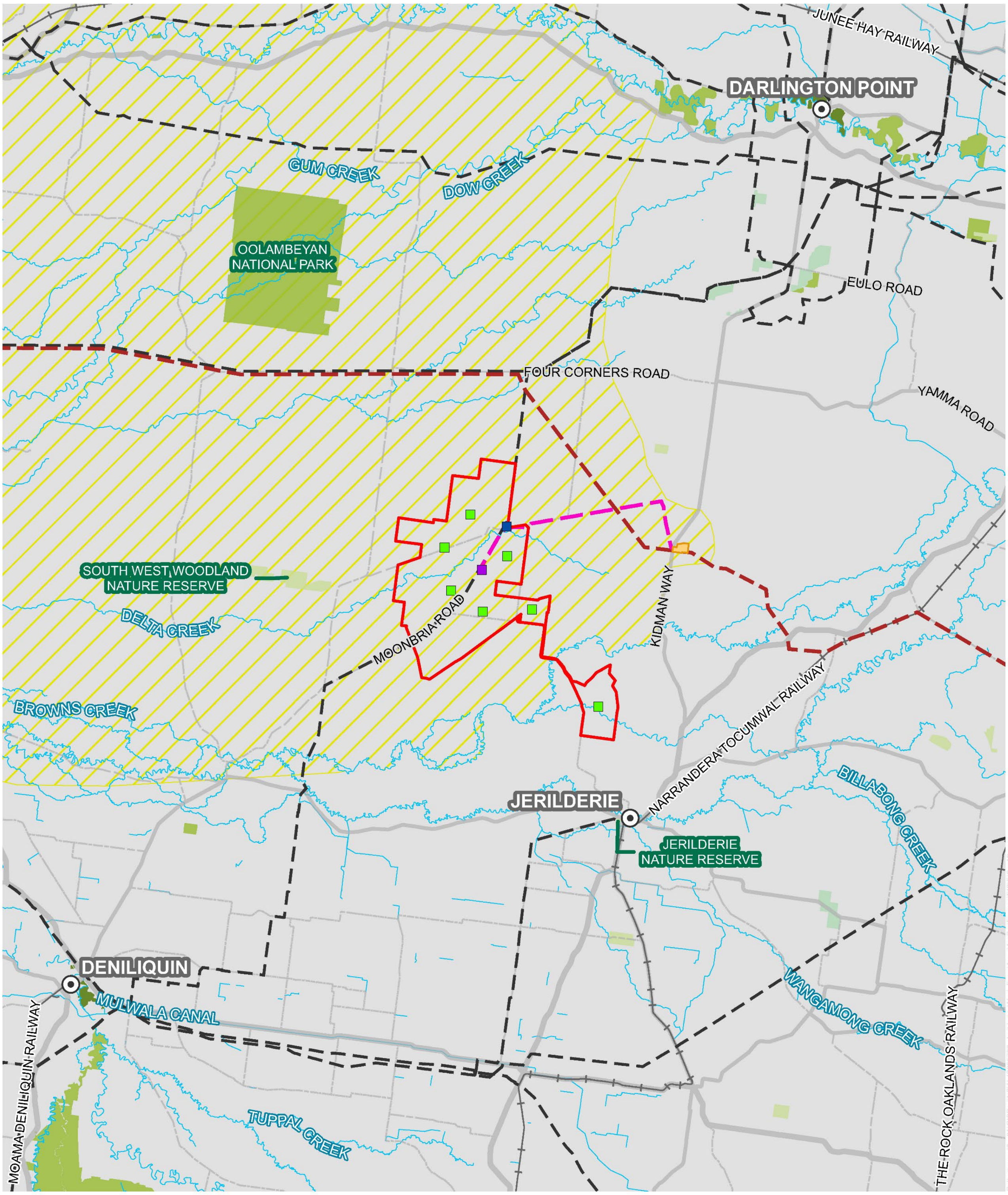
The Project area is defined as the property boundaries of Project landowners (i.e. landowners that have entered into agreements with Virya Energy to have WTGs or associated infrastructure on their properties).

## 1.2 Project description

The Project would include the following key features:

- Up to 208 WTGs to a maximum tip height of 270 metres
- Generating capacity of approximately 1500 MW
- BESS, approximately 800 MW/800 megawatt hours (MWh) (type yet to be determined)
- Permanent ancillary infrastructure, including operation and maintenance facility, internal roads, hardstands, underground and overhead cabling, wind monitoring masts, central primary substation and up to eight collector substations
- Temporary facilities, including site compounds, laydown areas, stockpiles, gravel borrow pit(s) and concrete batch plants.

An indicative Project layout is provided in **Figure 1-2**.




Project area
Substation / Battery - Option 1
Substation / Battery - Option 2
Collector substation
Proposed transmission line
Project EnergyConnect

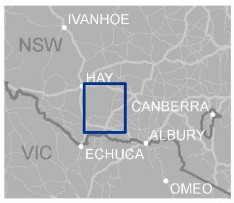
Indicative South West Renewable Energy Zone
Transgrid's Dinawan Terminal Station

Railway
Major waterways
Existing electricity transmission line
Road
National Park
Nature Reserve
Regional Park
State Forest

0 10 20 km

1:650,000 at A4

GDA 1994 MGA Zone 55




Data sources

Jacobs 2022
Department of Customer Service 2020

**Figure 1-1 Regional context of the Project**

Jacobs NSW Spatial | Buildings & Infrastructure | Eastern Asia Pacific | www.jacobs.com

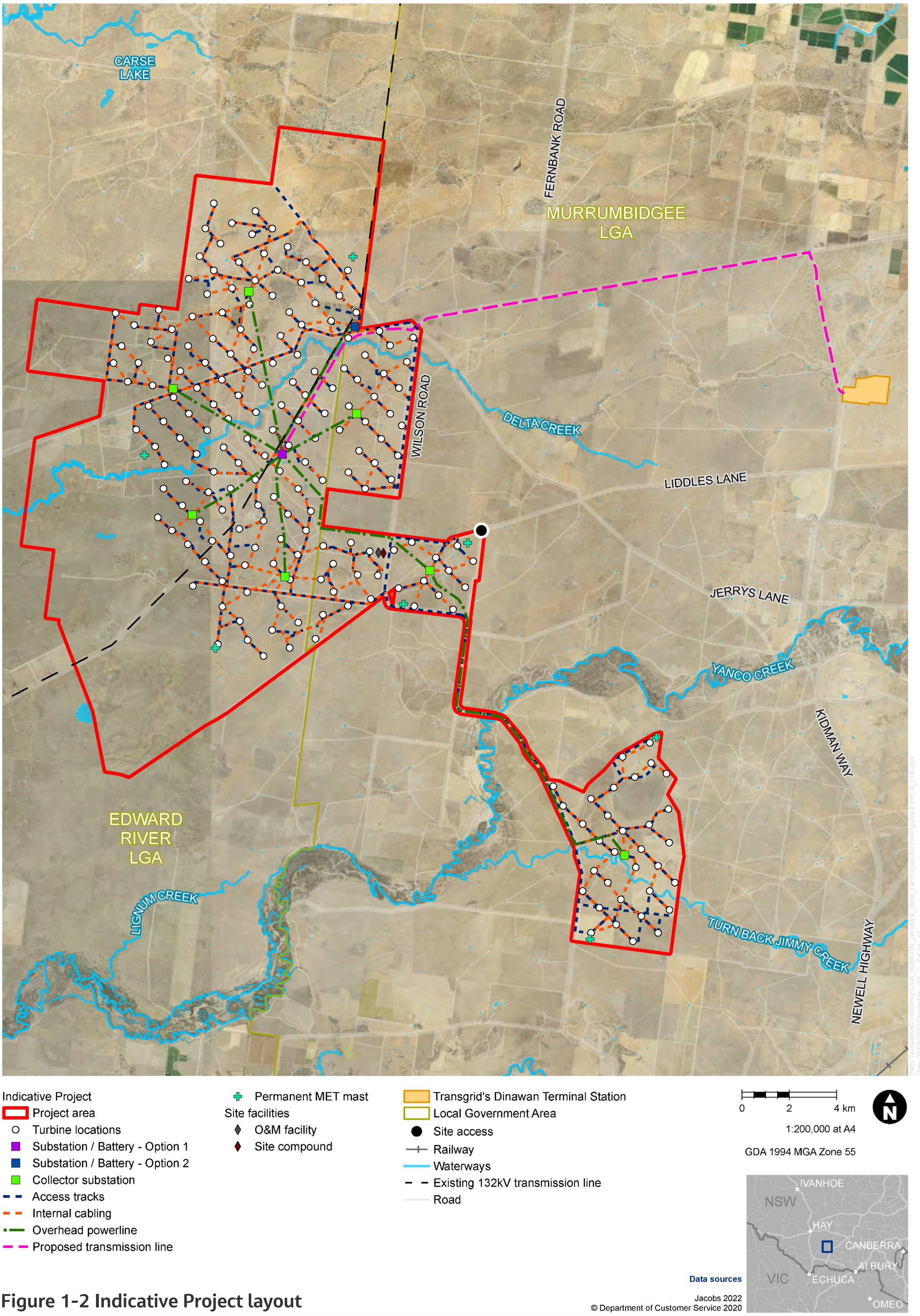



**Figure 1-2 Indicative Project layout**

## 1.3 Secretary's Environmental Assessment Requirements

This assessment forms part of the environmental impact statement (EIS) for the Project. The EIS has been prepared under Division 4.7 of the EP&A Act. This assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) (SSD-41743746) relating to potential hazards and risks associated with electric and magnetic fields (EMF) and will assist the Minister for Planning to make a determination on whether or not to approve the Project.

**Table 1-1** outlines the SEARs relevant to this assessment along with a reference to where these are addressed.

**Table 1-1 SEARs relevant to EMF impacts**

| Secretary's requirement | Where addressed in this report |
|---|---|
| Hazards and Risks – including: | |
| ▪ Health – consider and document any health issues having regard to the latest advice of the National Health and Medical Research Council, and identify potential hazards and risks associated with electric and magnetic fields (EMF) and demonstrate the application of the principles of prudent avoidance, including an assessment against the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines for limiting exposure to Time-varying Electric, Magnetic and Electromagnetic Fields | Potential hazards and risks are EMF are described in **Chapter 3**.<br>Potential health issues are discussed in **Chapter 3**, which takes into consideration latest advice.<br>Application and assessment of the principles of prudent avoidance is discussed in **Chapter 6**. |

## 1.4 Structure of this report

The structure and content of this report are outlined in **Table 1-2**.

**Table 1-2 Structure and content**

| Chapter | Description |
|---|---|
| **Chapter 1**<br>Introduction | Outlines key elements of the Project, SEARs and the structure of this report (this Chapter) |
| **Chapter 2**<br>Legislative and policy context | Provides an outline of the statutory context, including applicable legislation and planning policies |
| **Chapter 3**<br>Assessment methodology | Provides a description of the assessment methodology for this assessment |
| **Chapter 4**<br>Potential EMF impacts | Presents the outcomes of the operational impact assessment |
| **Chapter 5**<br>Cumulative impacts | Presents the qualitative assessment of potential cumulative operational EMF impacts with other projects near the Project |
| **Chapter 6**<br>Environmental management measures | Presents the management measures applicable for the Project |
| **Chapter 7**<br>Conclusion | Summarises the findings of this report |

| Chapter | Description |
| --- | --- |
| **References** | Provides details of external resources used |
| **Appendix A**<br>Additional information | Provides calculation plots that has been used to inform this assessment |

# 2. Legislative and policy context

## 2.1 Standards and guidelines

The World Health Organisation (WHO) recognises two international extremely low frequency (ELF) EMF exposure guidelines:

- The Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz to 100 kHz) (International Commission on Non-Ionising Radiation Protection, 2010)
- IEEE Standard C95.1- Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0Hz to 300GHz (Institute of Electrical and Electronics Engineers, 2019).

These guidelines apply to the general public in all areas (i.e., not just under or adjacent to transmission lines) and no distinction is made in the guidelines as to the duration of exposure for the general public.

There are currently no national guidelines or regulations in Australia for ELF electric and magnetic fields. The Australian Radiation Laboratory, on behalf of the National Health and Medical Research Council (NHMRC), published the "*Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields*" in December 1989 as part of its Radiation Health Series, No. 30 (RHS30).

ARPANSA (Australian Radiation Protection and Nuclear Safety Agency) is the national Commonwealth government of Australia's regulatory agency tasked with protecting Australians from both ionising and non-ionising radiation. ARPANSA's Radiation Health Committee agreed at its 24 June 2015 meeting that it would withdraw the existing NHMRC RHS30 guideline on ELF EMF exposure and recognised that the International Commission on Non-Ionizing Radiation Protection (ICNIRP) 2010 Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1 Hz – 100 kHz) are consistent with ARPANSA's and the RHC's understanding of the scientific basis for the protection of people from exposure to ELF EMF.

# 3. Assessment methodology

The following chapter provides an introduction to EMF, in conjunction with providing a description of potential health impacts, and the applicable exposure reference levels. In the following chapter, **Chapter 4**, these reference levels are compared to calculated values of EMF produced by the electrical assets associated within the Project (where information is available at this stage of the Project). The EMF values calculated by modelling have been performed in the HIFREQ module of CDEGS software, and SESEnviroPlus software.

## 3.1 Introduction to EMF

Electro Magnetic Fields are invisible, physical fields that surround electrical charges and exert forces on all charged particles in the field. All electrical and electronic equipment and appliances that are powered by electrical charges produce EMF. Some equipment and appliances also intentionally and unintentionally radiate electromagnetic fields (e.g. intentional emissions from a radio transmit antenna and the microwaves that heat food in a microwave oven). Most generated fields fluctuate between minimum and maximum peaks at a fixed rate per second, known as the frequency of emission. The EMF generated by a given source is characterised by the magnitude and frequency of the fields.

Both the voltages and currents associated with WTG, central primary substation (two current options), the current collector system, transmission lines and underground cables in this study oscillate between minimum and maximum values at an ELF of 50 cycles per second (i.e., 50 Hz) and are referred to collectively as Alternating Current (AC). The Root Mean Square (RMS) of the oscillating voltage and current produced by the windfarm is used as a measure of how much electrical power is generated by the windfarm and injected into the transmission network. The voltages associated with the Project are kept within a tight band by the operator. There is therefore little fluctuation in the RMS electric field level. The currents and associated magnetic fields associated with the windfarm are likely to fluctuate over a wide range due to changes in demand for electrical power on the network and changing weather conditions.

The ELF and EMF that people are exposed to in and around the windfarm, above an underground cable and under a transmission line are non-ionising fields in that they do not have enough energy to ionize atoms or molecules in the human body. The fields are strongest near the conductors and decrease exponentially with increasing distance away from the conductors.

### 3.1.1 Electric fields

The voltages that are applied to aerial transmission line conductors generate electric fields in the air gaps between the conductors and the ground. In underground cables, the metal screen that surrounds the cable's core contains the electric field within the cable, shielding all areas surrounding the cables from the electric field. Typical building construction materials such as brick, steel and wood provide shielding against electric fields.

The Electric Field Strength (EFS) is measured in volts per meter (V/m). The large electric fields associated with high voltage electrical infrastructure are typically expressed in kilovolts per meter (kV/m), with 1 kV/m = 1,000 V/m.

### 3.1.2 Magnetic fields

The electrical currents that flow in the aerial line conductors and underground cable cores generate magnetic fields near the conductors. The metallic cable screens in underground cables and typical building materials do not provide any significant shielding of the ELF magnetic fields which are able to penetrate through the materials.

Magnetic fields are normally measured in Gauss (G) or Tesla (T) and are commonly expressed in units of milligauss (mG) or microtesla (μT), with 10 mG = 1 μT.

### 3.1.3 Typical values

Typical, measured electric and magnetic field levels associated with everyday electrical and electronic equipment are summarised below in **Table 3-1**. The magnetic field strength levels have been sourced from ARPANSA measurements, and the electric field strength levels have been sourced from Transpower New Zealand Ltd measurements.

**Table 3-1 Measured EMF levels associated with everyday electrical and electronic equipment and appliances**

| EMF Source | Typical Range of Magnetic Field Strength (μT) | Typical Range of Electric Field Strength (kV/m) |
|---|---|---|
| Electric stove | 0.2 to 3 | 0.07 to 0.1 |
| Refrigerator | 0.2 to 0.5 | - |
| Electric kettle | 0.2 to 1 | - |
| Toaster | 0.02 to 0.2 | - |
| Television | 0.02 to 0.2 | - |
| Personal computer | 0.2 to 2 | - |
| Electric blanket | 0.5 to 3 | 0.058 to 0.6 |
| Hair dryer | 1 to 7 | 0.3 to 0.8 |
| Pedestal fan | 0.02 to 0.2 | - |
| Substation fence | 0.1 to 0.8 | - |
| Distribution line – under the line | 0.2 to 3 | 0.06 to 0.01 |
| Distribution line – 10 m from line | 0.05 to 1 | - |
| Transmission line – under the line | 1 to 20 | 0.003 to 4.1 |
| Transmission line – edge of easement | 0.2 to 5 | - |

## 3.2 Human health

### 3.2.1 Short term effects

Extremely low frequency electric and magnetic fields induce internal electric fields and current within the human body. The WHO states that exposure to high magnetic field levels (well above 100 μT) can cause nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system. Established biological effects caused by acute exposure to high field strengths include:

- The sensation of flashes of light caused by induced electric currents stimulating the retina (Magneto-phosphene effect)
- Micro-shocks – a sensation caused by a small electric spark discharge or arc when a person touches a metallic object that is electrically earthed.

### 3.2.2 Long term effects

Extensive scientific research into possible biological effects associated with exposure to extremely low frequency electric and magnetic fields at lower levels (i.e. non-acute exposure but higher than background levels) has been undertaken since the 1970's.

Most of this research indicates that the exposure normally encountered in the environment, including in the vicinity of power lines, does not pose a risk to human health[1]. However, there have been epidemiological studies that have reported a possible association between increased rates of childhood leukaemia and prolonged exposure to ELF magnetic fields. This exposure was at levels less than the exposure limits but larger than levels that are typically encountered in the household environment. It is noted that an identified association does not necessarily indicate a cause-effect relationship and that ARPANSA has concluded, on the balance of the published research, that the possible association reported in some research is not supported by laboratory or animal studies and that no credible theoretical mechanism has been proposed (i.e. no biological effect has been put forward that can validate a possible association between EMF exposure and the identified health effect). Overall, the evidence related to a possible association between childhood leukaemia and prolonged exposure to magnetic fields is not strong. Research is currently continuing in this area.

Other adverse health effects of magnetic field exposure, including cancers in adults and mental health conditions, have also been studied. The WHO concluded that the scientific evidence supporting an association between extremely low frequency magnetic field exposure and other adverse health effects is much weaker than that for childhood leukaemia.

Based on limited evidence, the International Agency for Research on Cancer (IARC) published a monograph that prudently classifies ELF magnetic fields as "possibly carcinogenic to humans[2]" (Group 2B[3]) and ELF electric fields as "not classifiable to carcinogenicity" (Group 3).

### 3.2.3 Active implantable medical devices

Active implantable medical devices (AIMDs), such as cardiac pacemakers and defibrillators, may be sensitive to ELF magnetic field exposure at levels close to the ICNIRP reference levels. There are many models and manufacturers of AIMDs. The more recently developed AIMDs have been designed to be immune to electric and magnetic fields in accordance with various design standards (e.g., EN 45502 for AIMDs and EN50527 series for pacemakers, implantable cardioverter-defibrillators, and spinal cord stimulators). Only a small proportion of AIMDs have been found to be sensitive to magnetic fields levels near to the ICNIRP public reference levels. There have been no known instances of adverse effects on users with correctly fitted pacemakers near powerlines.

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[1] Source: Australian Radiation Protection and Nuclear Safety Agency: (https://www.arpansa.gov.au/understanding-radiation/radiation-sources/more-radiation-sources/electricity)

[2] List of classifications by the IARC monographs can be found in: https://monographs.iarc.who.int/list-of-classifications

[3] IARC publishes independent assessment by international experts of the carcinogenic risks posed to humans by a variety of agents, mixtures and exposures. These agents, mixtures and exposures are categorised into 4 groups, namely:

- Group 1 – the agent is carcinogenic to humans – 121 agents are included in the group, including asbestos, tobacco and UV radiation
- Group 2A – the agent is probably carcinogenic – 89 agents are included in the group, including lead compounds and creosotes
- Group 2B – the agent is possibly carcinogenic to humans – 319 agents are included in the group, including gasoline and dry cleaning
- Group 3 – the agent is not classifiable as to carcinogenicity – 500 agents are included in this group, including caffeine and tea

### 3.2.4 Reference levels and limits

The ICNIRP guidelines define general public exposure as the exposure of individuals of all ages and of varying health statuses to electric and magnetic fields. These guidelines specify basic restrictions and reference levels, rather than limits. The basic restrictions for ELF EMF are limits set for electric fields internal to the human body, and in different body tissues. Relating these internal field levels within body tissues to external fields generated by high voltage equipment is a complex undertaking requiring detailed dosimetry analysis. ICNIRP has therefore also defined reference levels, which relate to external, measurable field levels that equate to internal field levels within body tissues that are below the basic restrictions. However, the ICNIRP reference levels are defined only for generic EMF sources and not the field distributions that are specific to high voltage equipment such as underground cables and overhead transmission lines. They also include conservative safety factors that account for statistical variability in the general population and uncertainty in the calculation method.

The reference levels specified in the ICNIRP guidelines are defined as the spatial average of the area occupied by a person's body. As such, the reference levels are compared to measured levels at 1 m above the normal standing surface of a person under or near the line.

**Table 3-2 ICNIRP EMF reference levels and AIMD limits**

| Exposure Scenario | Electric Field Strength (kV/m) | Magnetic Field Strength (µT) |
|---|---|---|
| General Public – all areas | 5 | 200 |
| Active Implantable Medical Devices | 5 | 100 |

# 4. Potential EMF impacts

## 4.1 Wind turbine generators

The datasheet of the proposed WTG indicates that the minimum tower height would be 115 m. This height corresponds to the centre point of the nacelle. The nacelle would contain the main transformer, low voltage switchgear, and converters. The high voltage switchgear is located at the bottom of the WTG. The main sources of magnetic fields from the WTG would be from the current carrying cables and the power transformer. Given that the transformer is located at a minimum height of 115 m above ground level and that the low voltage cables that carry the highest current are contained within the nacelle at the same height, the magnetic flux density at the base of the WTG, to which the public may be exposed, would be from the high voltage cables only. The metallic screens of these cables would shield the public from electric fields.

EMF measurements in the vicinity of WTG installations have been reported in various studies. The measured EMF in and around three operational Vesta V90 50 Hz 3 MW WTGs is reported in 'Study of Physical Factors Emitted by Wind Power Generators in the Environment' (Israel et al, 2011). The measurements were taken at 20 cm, 120 cm, and 180 cm above ground level and at 2 m and 3 m from the base of the tower and above the 33 kV cable trench. Similarly, magnetic field measurements in and around 15 Vesta 60 Hz 1.8 MW WTGs were reported in 'Measuring Electromagnetic Fields (EMF) Around Wind Turbines in Canada: Is There a Human Health Concern?' (McCallum et al, 2014). The measurements were taken along 500 m traverses from the base of the WTG and also above the 27.5 kV collector cables.

The reported EMF measurements in and around the WTGs are summarised in **Table 4-1**. It is noted that that the WTGs associated with the Project have been specified as 8 MW units. As such, the EMF levels associated with the proposed installations may be up to 4.5 times the magnitude of the reported measurements. These worst case EMF levels would be much lower than the ICNIRP reference levels.

**Table 4-1 EMF windfarm field measurements**

| Study | Measured Electric Field Strength (kV/m) | Measured Magnetic Flux Density (µT) |
|---|---|---|
| Vesta V90 50 Hz 3 MW [1] | $1.44 \times 10^{-3}$ | 0.133 – 0.225 |
| Vesta 60 Hz 1.8 MW [2] | - | 0.3 - 0.9 |

## 4.2 Underground cables

The High Voltage (HV) collector network for the Project would comprise underground 33 kV or 66 kV cables. The worst-case EMF levels at 1 m above ground level above 33 kV cables were calculated in the HIFREQ module of CDEGS for the specified WTG number and size. The results are summarised in **Table 4-2**. The 33 kV cables will produce the worst case magnetic field density at 1 m above ground level compared to the 66 kV cable option. Both the calculated electric field strength and magnetic field density levels generated by the underground 33 kV cables are much lower than the ICNIRP reference levels. The calculation plots are included in **Appendix A**.

**Table 4-2 Calculated EMF levels above the underground 33 kV collector cables**

| HV Equipment | Calculated Maximum Electric Field Strength (kV/m) | Calculated Maximum Magnetic Flux Density (µT) |
|---|---|---|
| 33 kV Underground Cable | $2.4\times 10^{-6}$ | 8 |

## 4.3 Overhead lines

Overhead lines are proposed to connect the collector substations to the central primary substation. The overhead lines connecting the current collector substations to the main substation are proposed to be either 66 kV or 132 kV. The 132 kV option is considered to be the worst-case option from an electric field perspective and the 66 kV option is the worst-case from a magnetic field perspective; therefore, both options have been modelled. The maodelling has been performed in SESEnviroPlus.

The transmission line connecting the central primary substation to the TransGrid Dinawan Terminal Station is proposed to be operated at 330 kV or 500 kV. This is consistent with TransGrid's proposed Project Energy Connect line. The EIS for Project Energy Connect is publicly available online and provides the minimum clearance to ground for TransGrid's proposed 330 kV and 500 kV transmission lines. These minimum ground clearance values have been considered in this EMF assessment. They are slightly larger than the minimum ground clearances specified in AS/NZS 7000.

TransGrid also performed dosimetric analyses of the internal electric fields generated inside the human body to determine what magnitude of external electric field will induce an internal electric field strength equal to that of the ICNIRP basic restriction for the public. The derived electric field limit derived by detailed calculation of the transmission line EMF was 7.8 kV/m for a 330 kV transmission line and 9.1 kV/m for a 500 kV transmission line, defined at 1 m above ground level.

Tower geometries for the 66 kV, 132 kV, 330 kV, and 500 kV transmission line options for the Project have not yet been confirmed. Generic 330 kV and 500 kV tower geometries for an assumed single circuit transmission line have been considered for this EMF assessment. All EMF calculations were done for 1.1 pu voltage and maximum windfarm capacity. The calculated EMF levels at 1 m above ground level are summarised in **Table 4-3**. The calculated magnetic field levels are below the ICNIRP reference levels for all transmission line options. The EFS under the 330 kV and 500 kV transmission line options is above the ICNIRP reference level but below the limit derived by detailed dosimetric calculations, as reported by TransGrid for the Project Energy Connect EIS. It is further noted that the EFS generated by the 330 kV transmission line option is below the 5 kV/m ICNIRP reference level 17 m from the centre of the line. Similarly, the EFS generated by the 500 kV transmission line option is below the 5 kV/m ICNIRP reference level 21 m from the centre of the line. The EFS levels should therefore be below the ICNIRP reference levels within a typical transmission line easement width.

The closest sensitive receiver to the proposed transmission line is a dwelling 2.6 km from the transmission line easement. At this distance from the transmission line, the measured electric field strength from any of the proposed transmission lines would be much lower than the ICNIRP reference levels. The CDEGS calculation plots are included in **Appendix A**.

**Table 4-3 Calculated maximum EMF levels from overhead lines**

| Voltage Level (kV) | Calculated Maximum Electric Field Strength (kV/m) | Calculated Maximum Magnetic Flux Density (µT) |
|---|---|---|
| 66 | 0.84 | 41 |
| 132 | 2.32 | 33 |
| 330 | 7.06 | 69 |
| 500 | 9.10 | 36 |

## 4.4 Substations

A central primary substation (two options are presently under consideration) and multiple collector substations are proposed within the Project area. These substations are current collector substations that collect the power generated by the WTGs and connect to one central primary substation. This central primary substation is the interface between the Project and the transmission network. Substations are large and complex sources of electric and magnetic fields. However, as was the case for transmission lines, the field strengths drop off quickly with distance from the source. The Australian design standard for HV installations, AS2067, requires that the detailed substation design complies with the ICNIRP reference levels both inside and outside the substation. The EMF associated with the substations has therefore not been assessed at this early stage of the Project but would be assessed in detail during the design stages to verify compliance with the requirements of AS 2067. The EMF requirements specified in AS 2067 would also apply to these future installations, including the BESS installation.

The closest sensitive receiver (Host Landowner) is located more than 2 km from the nearest proposed substation. At this distance from the substation(s), the electric and magnetic fields from any of the proposed operating voltages would be much lower than the ICNIRP reference levels.

# 5. Cumulative impacts

The electric and magnetic fields generated by the WTGs, overhead lines, and underground cables are expected to be below the ICNIRP reference levels at 1 m above ground level inside and outside of the Project area, even with the conservative assumptions considered in this assessment. There is the potential for cumulative EMF impacts at 1 m above ground level at interface points in the Project, specifically where the overhead 330/500 kV transmission line terminates to the central substation. The risk of cumulative impacts can be mitigated in the detailed design of the electrical infrastructure for the Project by ensuring during the detailed design stages that compliance with the requirements of AS 2067 are met.

The cumulative EMF impacts on the Project due to other windfarms in the area are expected to be negligible based on the minimum required distance between adjacent windfarm boundaries and infrastructure contained therein. However, where adjacent windfarms may share transmission line easements, the parallelism between transmission line conductors from different circuits will have a cumulative effect within, and in the vicinity of, the easement(s). These cumulative effects shall be quantified during the detailed design stage or once the transmission line easements have been confirmed. Phase arrangements for each circuit can be selected to minimise these cumulative effects.

# 6. Environmental management measures

It has been determined in this study that the expected EMF levels from the Project would comply with the relevant Australian and international standards and guidelines. As such, mitigation measures have not been considered in the assessment.

## 6.1 Prudent avoidance

Energy Networks Australia (ENA) is the national industry body for Australia's energy networks. It is ENA's position that its members design and operate their electricity generation, transmission, and distribution systems in compliance with the ICNIRP guidelines and to continue following an approach consistent with the concept of prudent avoidance.

Prudent avoidance is part of a precautionary approach built on the understanding that whilst adverse health effects from EMF's have not been established, based on findings of science reviews conducted by credible authorities, the possibility of a cause-effect relationship cannot be ruled out.

Prudent avoidance encompasses measures that can be implemented at no, or very low cost, provided that it does not unduly compromise other issues. Therefore, whilst the anticipated EMF levels from the Project will comply with the requirements of the relevant Australian and international standards and guidelines, the following prudent avoidance measures listed in **Table 6-1** would be considered in the detailed design of the Project.

**Table 6-1 Prudent avoidance measures applicable to the Project**

| Reference | Description | Responsibility | Timing |
|---|---|---|---|
| EMF1 | The phase spacing of overhead conductors (including transmission line and substation bus equipment) will be reduced where practicable to increase the degree of magnetic cancellation and reduce associated EMF levels. The design will also ensure that the reduction in phase spacing does not result in unacceptable levels of audible noise and radio frequency interference from the transmission line and substations where practicable. | Contractor | Detailed Design |
| EMF2 | The phase-to-ground separation associated with transmission line will be increased where practicable to reduce the electric field strength and magnetic flux density at 1 metre above ground level. | Contractor | Detailed Design |
| EMF3 | Underground cables will be arranged in close trefoil or multicore cable arrangement where practicable. This will maximise the magnetic field cancellation and minimises the magnetic flux density level at 1 metre above ground level. | Contractor | Detailed Design |
| EMF4 | Consideration will be given to the location of substation equipment with respect to the perimeter fence. For example, equipment that generates significant magnetic fields, such as air-core reactors associated with harmonic filters, will not be placed close to publicly accessible areas where practicable. | Contractor | Detailed Design |

# 7. Conclusion

The magnetic field levels generated by the wind farm infrastructure has been assessed as compliant with the applicable Australian and international standards and guidelines, specifically the ICNIRP reference levels, within and at the perimeter of the Project area using both calculations and references to published test data for comparable infrastructure. Prudent avoidance measures to further reduce public exposure to magnetic fields generated by the windfarm will be considered as part of the detailed design process.

The only significant source of electric field levels would be the outdoor substation equipment and the aerial 330 kV and 500 kV transmission line options that connect the windfarm to the TransGrid Dinawan Terminal Station. The EFS levels associated with these transmission line options may exceed the ICRNIRP reference levels within the line easement only. Dosimetric analysis conducted by TransGrid for comparable 330 kV and 500 kV transmission line options for the Project Energy Connect EIS has demonstrated that the EFS levels within the easement would comply with the ICNIRP basic restrictions.

# References

M. Israel, P. Ivanova and M. Ivanova (2013) “Study of Physical Factors Emitted by Wind Power Generators in the Environment,” The Environmentalist, vol. 31, no. 2, pp. 161-168, June 2011.

L. C. McCallum, M. L. Whitfield Aslund, L. D. Knopper, G. M. Ferguson and C. A. Ollson (2014) “Measuring Electromagnetic Fields (EMF) Around Wind Turbines in Canada: Is There a Human Health Concern?,” Environmental Health, vol. 13, no. 9, 2014.

# Appendix A. Additional information

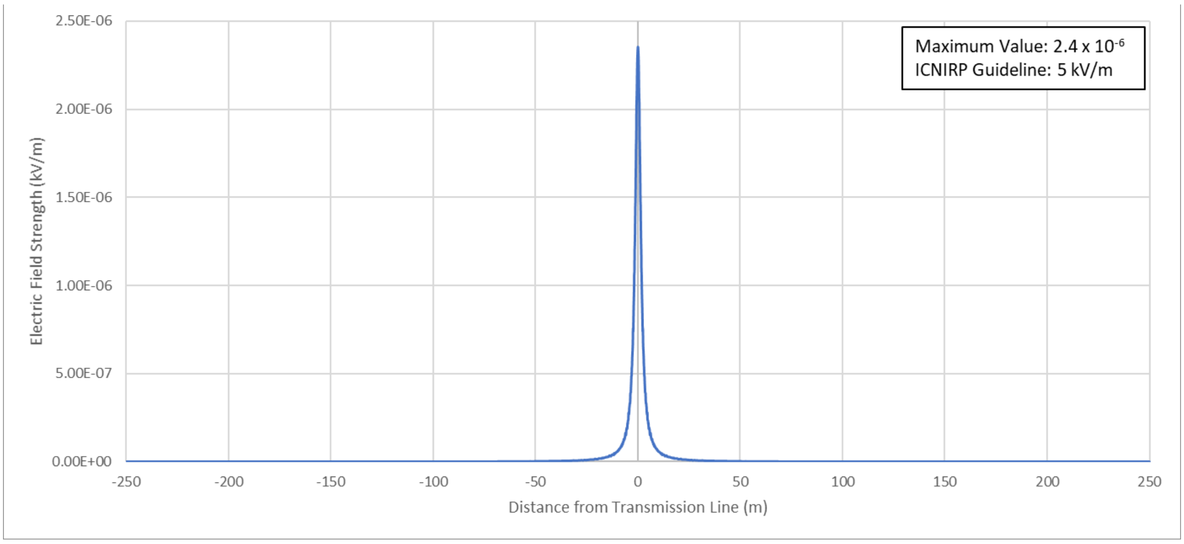


**Figure A-1 Calculated electric field strength at 1 m above ground above a 33 kV cable (1.1 p.u. voltage)**

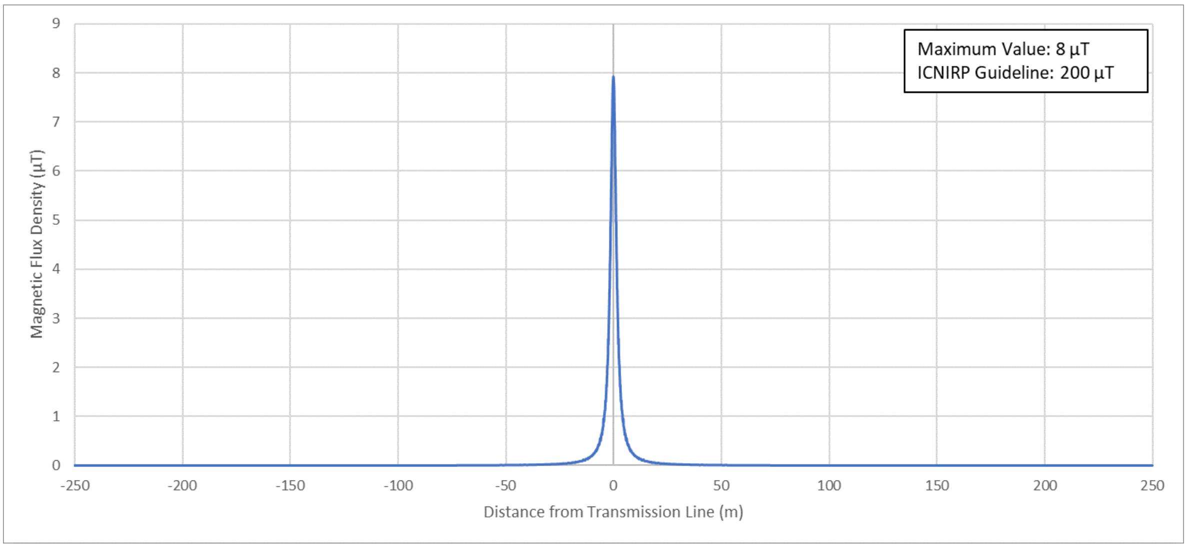


**Figure A-2 Calculated magnetic flux density at 1 m above ground above a 33 kV cable**

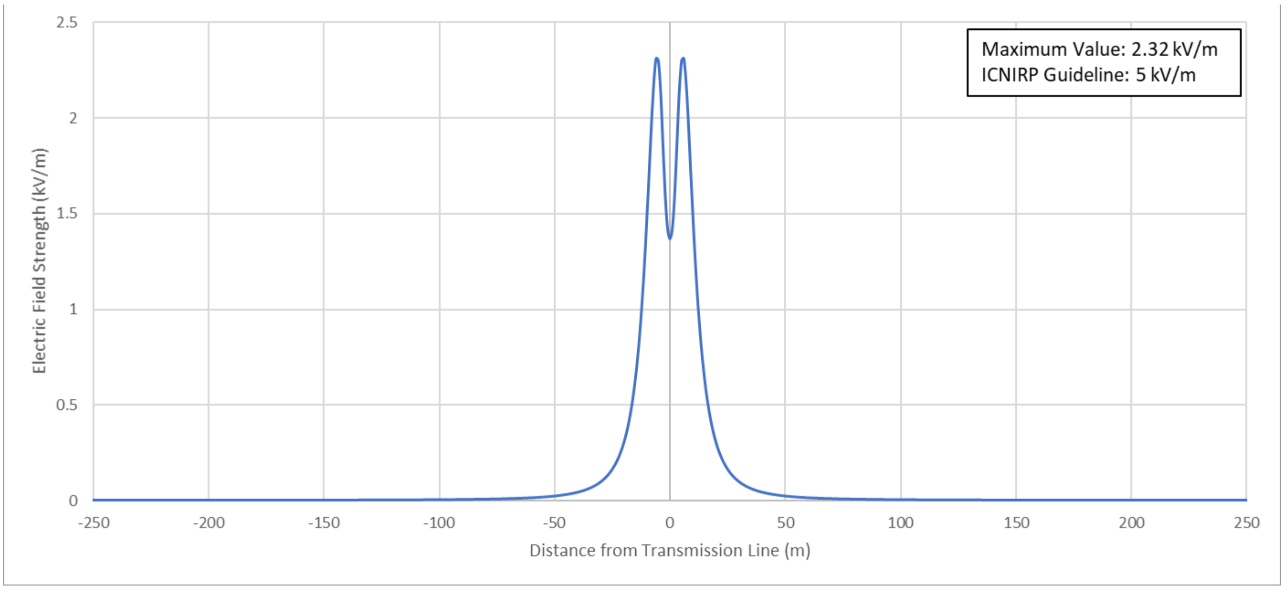


**Figure A-3 Calculated electric field strength at 1 m above ground below a 132 kV transmission line (1.1 p.u. voltage)**

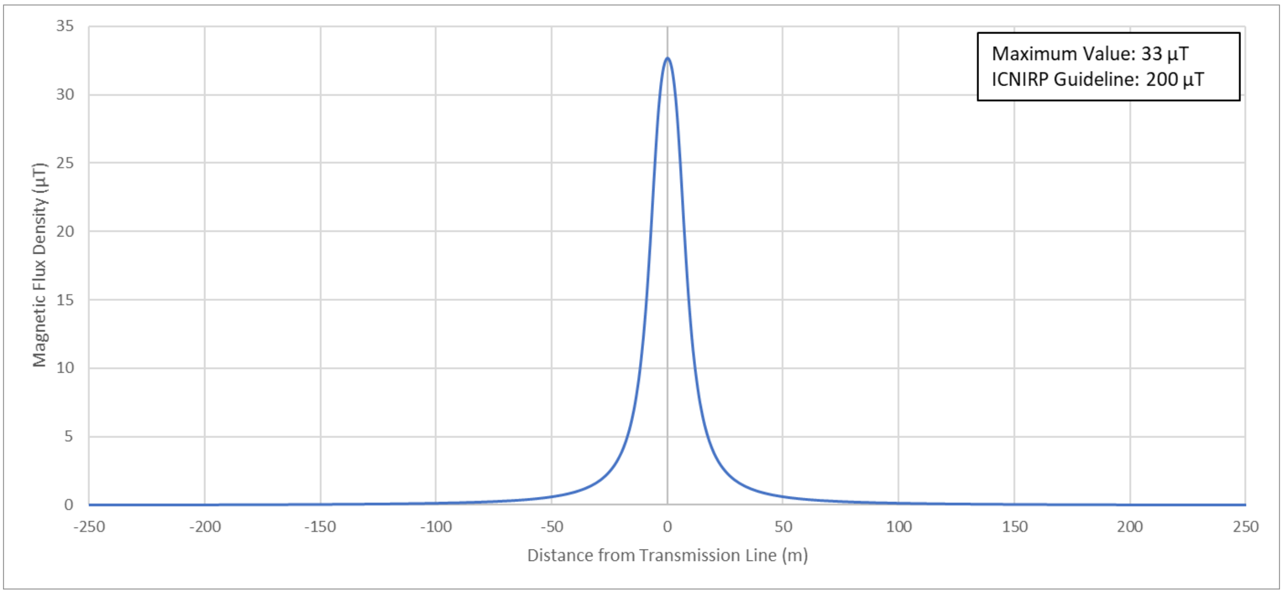


**Figure A-4 Calculated magnetic flux density at 1 m above ground below a 132 kV transmission line**

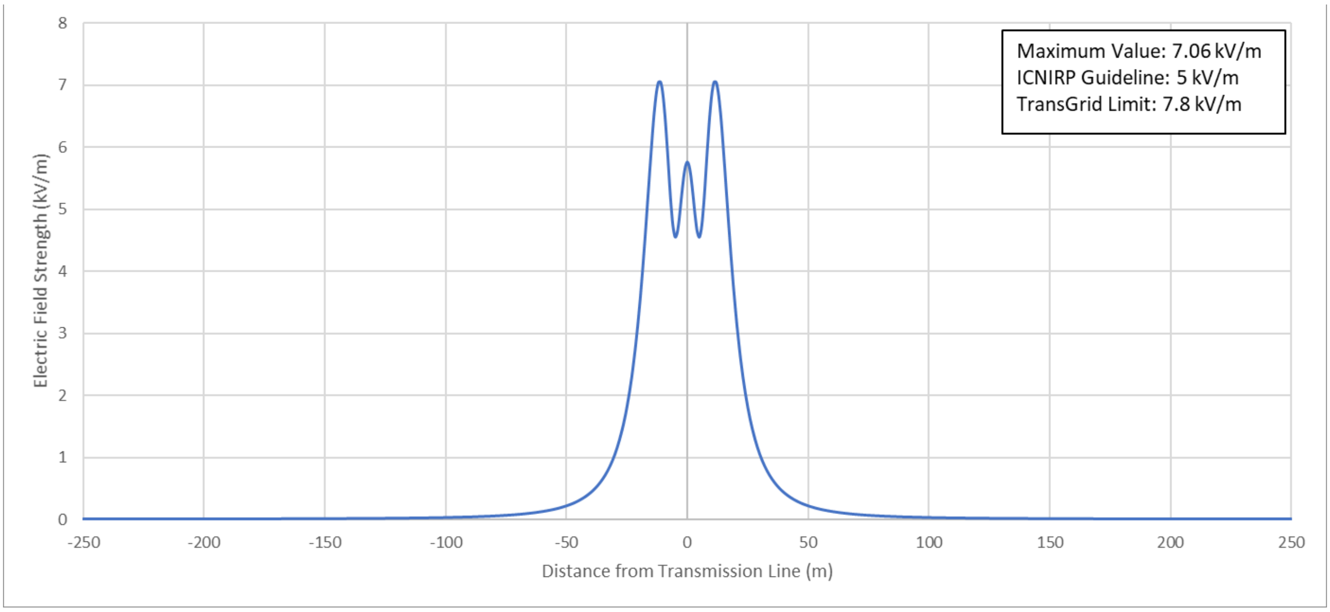


**Figure A-5 Calculated electric field strength at 1 m above ground below a single circuit 330 kV transmission line strung at TransGrid's minimum clearance-to-ground (1.1 p.u. voltage)**

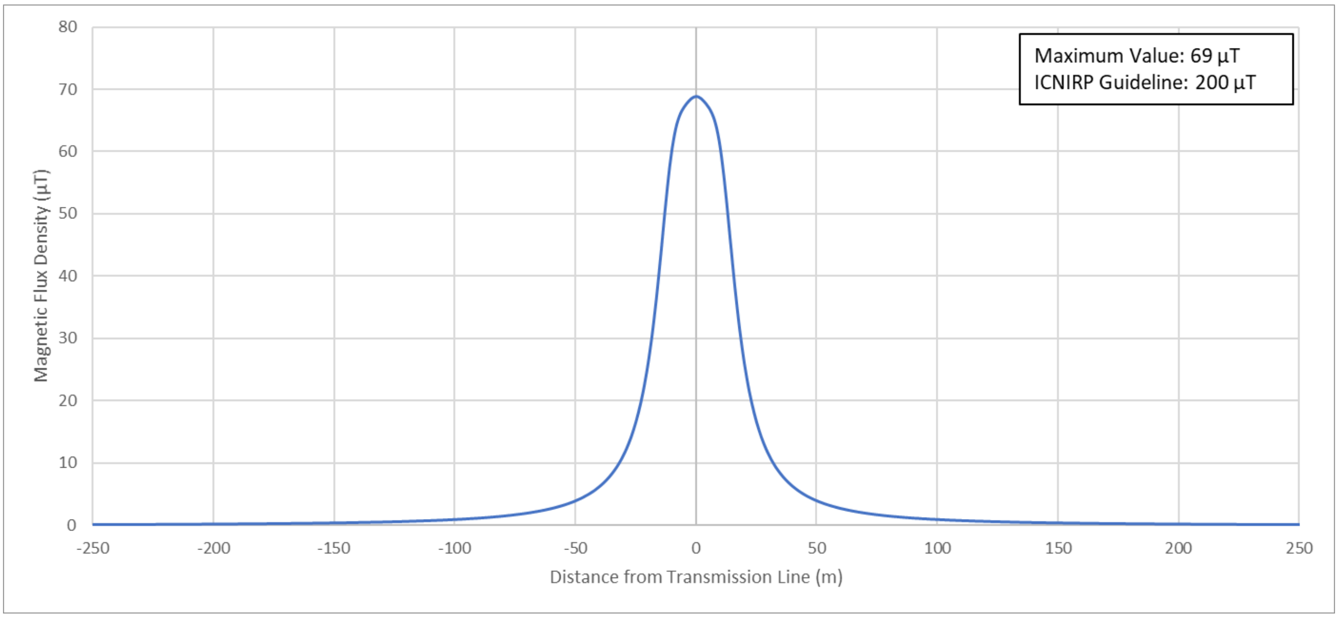


**Figure A-6 Calculated magnetic field strength at 1 m above ground below a single circuit 330 kV transmission line strung at TransGrid's minimum clearance-to-ground (1.1 p.u. voltage)**

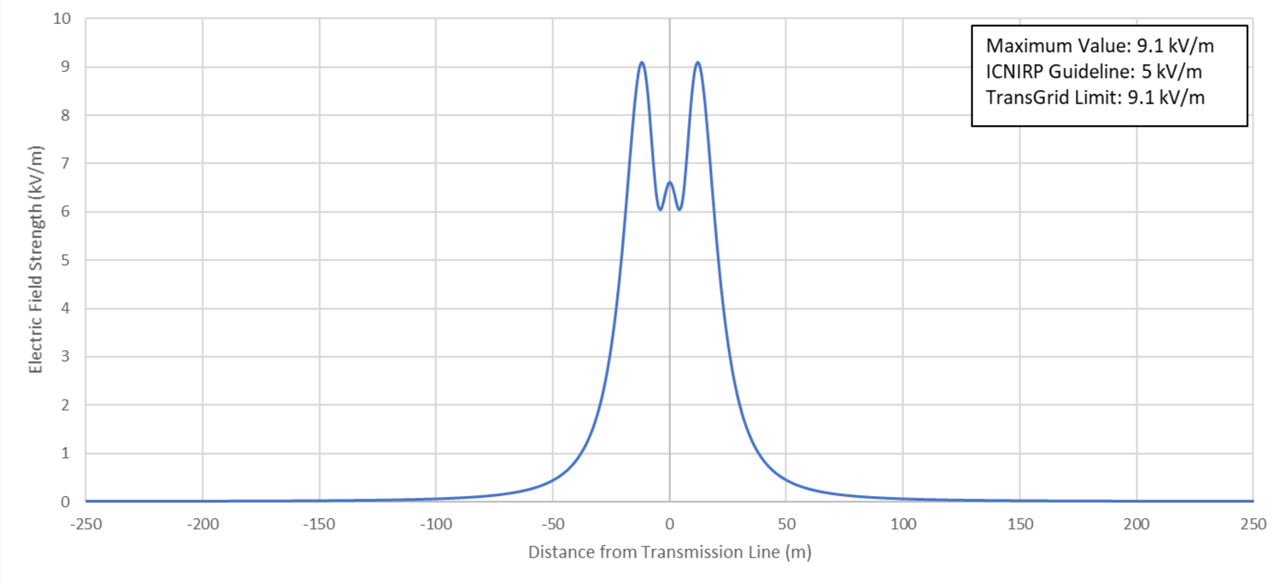


**Figure A-7 Calculated electric field strength at 1 m above ground below a single circuit 500 kV transmission line strung at TransGrid's minimum clearance-to-ground (1.1 p.u. voltage)**

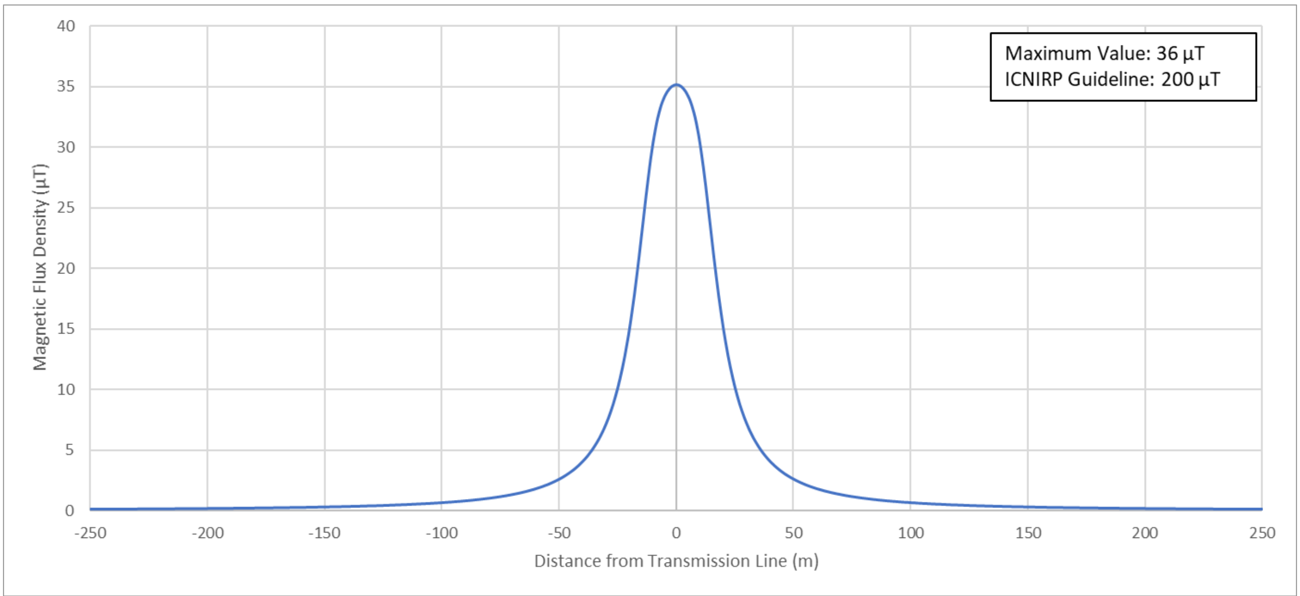


**Figure A-8 Calculated magnetic field strength at 1 m above ground below a single circuit 500 kV transmission line strung at TransGrid's minimum clearance-to-ground (1.1 p.u. voltage)**