# Appendix O

# EMF Assessment

# Newcastle Power Station

## Transmission Line: Electric and Magnetic Fields (EMF) Assessment

**AGL**

Reference: 503269

Revision: 1

2019-05-08

Bringing ideas to life

# Document control record

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| Document control | | | | | | |
|---|---|---|---|---|---|---|
| **Report title** | | Transmission Line: Electric and Magnetic Fields (EMF) Assessment | | | | |
| **Document code** | | | **Project number** | | 503269 | |
| **Client** | | AGL | | | | |
| **Client contact** | | | **Client reference** | | | |
| **Rev** | **Date** | **Revision details/status** | **Author** | **Reviewer** | **Verifier** (if required) | **Approver** |
| 0 | 2019-03-04 | Initial Draft | P.Flanagan | C Boyle | | M Hicks |
| 1 | 2019-05-08 | Initial Issue | P.Flanagan | C Boyle | | M Hicks |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| **Current revision** | | **1** | | | | |

| Approval | | | |
|---|---|---|---|
| Author signature | | Approver signature | |
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| Title | Principal Electrical Engineer | Title | Associate |

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# Summary


AGL Energy Limited (AGL) proposes to develop a power station at Tomago in the Newcastle area of NSW to provide approximately 250 megawatts (MW) of firming capacity to the National Electricity Market (NEM).

It is proposed to connect the power station to the NSW transmission system via a short section of 132kV line to TransGrid's Tomago 132kV switching station. Aurecon has been engaged to undertake an Electric and Magnetic Field (EMF) assessment of the transmission line connection as part of the overall environmental impact assessment of the power station.

In summary, Aurecon's findings are:

### Magnetic fields

- Whether in isolation, or in combination with the existing 132 and 330kV transmission lines, the highest predicted contribution of the proposed 132kV line to the magnetic field environment is predicted to be 11% of the ICNIRP Guideline Reference Level of 2000 milligauss (mG).
- At the edge of the proposed easement, 15 metres from the line, the highest predicted magnetic field contribution is 3% of the ICNIRP Guideline Reference Level.
- Notwithstanding the line's proximity to the existing 132 and 330kV lines, there is little interaction with their magnetic fields, except at the undercrossings, where the field contribution from the proposed line will dominate the existing fields from the adjacent lines. The resulting magnetic fields are expected to remain well below 15% of the ICNIRP Guideline Reference Level.

### Electric fields

- Whether in isolation, or in combination with the existing 132 and 330kV transmission lines, the contribution of the proposed 132kV line to the electric field environment is predicted to be less than 30% of the ICNIRP Guideline Reference Level of 5000 Volts/metre. In practice, due to shielding by vegetation etc, the actual electric field is likely to be considerably less than that predicted.
- The proposed line is not expected to cause any material increase to the existing electric field where it crosses under the existing lines.

### Prudent avoidance

As the route of the proposed line is not frequented, there will be no prolonged human exposure and, accordingly, it is unnecessary to seek any further technical measures to reduce the magnetic fields.

# 1 Project overview

## 1.1 Background

AGL Energy Limited (AGL) proposes to develop a power station at Tomago, in the Newcastle area of NSW to provide approximately 250 MW of firming capacity to the National Electricity Market (NEM).

It is proposed to connect the power station to the NSW transmission system via a short (approximately 570 metres) section of 132kV line to TransGrid's Tomago 132kV switching station. The design of the 132kV line is constrained by the need to cross under three existing transmission lines and, accordingly, although a vertical[1] phase arrangement is feasible for the first span (from the pole immediately outside the power station switchyard to the edge of the TransGrid easement) and the conductors of the second span can "roll" from vertical at one end to horizontal at the other, a horizontal arrangement will be necessary for the remaining spans to achieve the required clearances at the under crossings.

Aurecon has been engaged to undertake an EMF assessment of the transmission line connection as part of the overall environmental impact assessment of the power station.

## 1.2 Scope

The scope of Aurecon's assessment is to encompass the following:

- Provision of a brief description of EMF in relation to human health;
- Performance of calculations of the electric and magnetic fields for the proposed line at 1m above ground level, extending up to 30m on each side of the centreline and covering the range of conductor configurations proposed for the line;
- An assessment of the compliance of the anticipated field levels with the relevant national and international EMF guidelines;
- An assessment of compliance of the proposed line with precautionary and prudent avoidance principles as defined in the relevant guidelines; and
- Preparation of a report covering the EMF assessment.

[1] *A vertical phase arrangement results in lower magnetic fields than other configurations.*

## 1.3 Route description and existing EMF environment

The proposed route of the 132kV line is shown in Figure 1-1.


**Figure 1-1 Proposed route of the 132kV line**

It can be seen from Figure 1-1 that, although the 132kV line length is short, two TransGrid double-circuit, steel tower lines and one Ausgrid pole line need to be undercrossed to reach the TransGrid switching station. These lines are also sources of EMF.

Approximately 20% of the proposed route is located within a TransGrid easement, which accommodates the two steel tower lines. The remaining 80% of the proposed route crosses vacant land, half of which is immediately adjacent to the TransGrid easement. A further quarter of the proposed route is immediately outside the 132kV switching station where an Ausgrid 132kV line is also undercrossed. Accordingly, the proposed line route is already subject to substantial EMF sources and, apart from where it is proposed to cross Old Punt Road, is unlikely to be encountered by members of the public.

# 2 Overview of electric and magnetic Fields

## 2.1 General description

Whenever electrical equipment is in service, it produces an electric field and a magnetic field. The electric field is associated with the voltage of the equipment and the magnetic field is associated with the current (amperage). In combination, these fields cause energy to be transferred along electric wires. Being related to voltage, the electric fields associated with high voltage equipment remain relatively constant over time, except where the operating voltage changes. Conversely, being related to current, the magnetic field strength resulting from an electrical installation varies continually with time as the load on the equipment varies.

The electric and magnetic fields associated with electrical equipment, whilst interrelated, are not dependent on each other and as such can exist independently.

Further detail on electric and magnetic fields can be found in Appendix A.

## 2.2 Electric and magnetic fields and health

Health effects from electric and magnetic fields at magnitudes much higher than those encountered in everyday life have been established. In addition, the possibility of adverse health effects due to the much lower EMFs associated with electrical equipment has been the subject of extensive research throughout the world for more than 40 years. To date, adverse health effects due to fields of the levels normally associated with electrical infrastructure, have not been established. However, due to a body of epidemiological evidence, the possibility that such effects may exist has not been ruled out. Further discussion on this can be found in Appendix B.

## 2.3 Health guidelines

Since late 2015, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), has adopted the international guideline published by the International Commission on Non-Ionising Radiation Protection (ICNIRP) in 2010. The “Reference Levels” set out in the guideline, which are well above the levels normally associated with electrical equipment, are derived from the levels at which interactions with the central nervous system are established, with a safety factor applied and a further adjustment to simplify compliance measurement. Details of the current ICNIRP guideline “Reference Levels” for electric and magnetic field exposure can be found in Appendix C.

These “Reference Levels” have been used as the principal assessment criteria for this assignment and are reproduced in Table 2-1. It should be noted that these criteria are independent of duration of exposure.

**Table 2-1 ICNIRP Guideline Reference Levels (General Public)**

| Parameter | Reference Level |
|---|---|
| Electric Field | 5,000 Volts per metre (V/m) |
| Magnetic Field | 2,000 milligauss (mG) |

## 2.4 Prudent avoidance

Given the inconclusive nature of the science regarding EMF at levels commonly associated with electrical equipment and human health, it is widely considered that a prudent approach is the most appropriate response under the circumstances. Prudent Avoidance is a precautionary concept developed to address the possibility of health effects from prolonged exposure to field levels much lower than those for which effects have been established. Under this approach, subject to modest cost and reasonable practicality, the owners of electric power infrastructure should design their facilities to reduce the intensity of the fields they generate in frequented areas where prolonged[2] exposure is possible. Further general discussion on this subject can be found in Appendix D and the implications for this assessment are discussed in Section 5.2.

[2] *In this context, prolonged exposure is taken as the time-weighted average exposure, measured over a period of months or years, rather than days or weeks.*

# 3 Input information and aspects of field predictions

## 3.1 Input information

The input data required for the calculations on which this assessment is based has been obtained from the designers of the proposed 132kV line or the owners of the existing lines, as appropriate, and is summarised below:

- Design details of the proposed 132kV line structures
- Aerial views showing the relative locations of the proposed line and the adjacent existing 132 and 330kV lines
- An indicative run-time profile for the power station, as shown in Table 3-1.

**Table 3-1 Indicative run-time profile**

| Season | Average Run time (hrs/day) | Peak Run time (hrs/day) |
|---|---|---|
| Spring | 0 | 24 |
| Summer | 5 | 24 |
| Autumn | 0 | 24 |
| Winter | 8 | 24 |
| (average) | 3.25 | 24 |
| Annual Run-hours | 1186 | 8760 |
| Capacity Factor | 14% | 100% |

- Advice to assume the typical power station output when running to be 250MW.
- 12 months' records of loadings on in the existing 132 and 330kV lines (provided by TransGrid and Ausgrid)
- Other electrical data regarding the various lines

## 3.2 Approach

The following approach has been adopted in undertaking this assignment:

- To gain a comprehensive understanding of the magnetic field contribution of the proposed line, the predicted EMF levels associated with the various sections of the proposed route have been modelled separately as follows:
  - The first span of line from the power station, where the conductors are in vertical configuration
  - The two spans of line which run parallel to the TransGrid easement have been modelled separately, taking into account the configuration of the conductors on the proposed line and the contribution of the TransGrid lines
  - The contribution to the EMF levels within the existing easements where the proposed line undercrosses the existing lines have also been addressed

- The intermittent nature of the power station's "run time" profile is taken into account in the overall assessment.
- As noted in Appendix B, while EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields. Accordingly, the magnetic fields are addressed in more detail.

## 3.3 Assumptions for modelling

The following assumptions have been made in undertaking the EMF modelling:

- In calculating line currents, the reactive power requirements under the National Electricity Rules have been applied to derive a power factor of 0.93. This gives a line load of 269 MVA.
- As the individual spans of the proposed 132kV line are short and the sags are not great, the design minimum clearances have been adopted for modelling purposes.[3]
- As much of the proposed line route is in proximity to existing lines, their interaction may influence the resulting fields. Material influences are reflected in the modelling results.
- The loadings in the existing transmission lines have been taken as the time-weighted average values, derived from comprehensive load records provided by TransGrid and Ausgrid.
- The loadings used for modelling are summarised in **Table 3-2**.

**Table 3-2 Line loadings used for modelling**

| Line | Line Load (MVA) | Corresponding Amps |
|---|---|---|
| Proposed 132kV Line | 269 | 1176 |
| TransGrid 330kV SCN 95 | 253 | 443 |
| TransGrid 330kV SCN 82 | 443 | 774 |
| TransGrid 132kV SCN 9C5 | 10 | 43 |
| TransGrid 132kV SCN 96F | 13 | 55 |
| Ausgrid 132kV line | 20 | 88 |

- The influence of the Ausgrid 132kV lines exiting the 132kV switching station will not exceed the range of field levels in proximity to the TransGrid lines and need not be modelled separately.

[3] *This is a conservative (worst case) assumption.*

# 4 Field characterisation

## 4.1 Approach

Based on the available design and loading information, the magnetic fields in the vicinity of the proposed 132kV line have been modelled using in-house software which applies well established physics and has been in use for more than 20 years. The software has been extensively validated against other commercial and public domain packages.

The electric fields have been estimated based on extensive measurements around similar lines over many years.

In all cases, the fields cited apply at a height of 1m above ground, in accordance with international practice.

## 4.2 Magnetic field results

The results obtained from the magnetic field modelling are shown in the following sections in the form of profiles indicating the magnetic fields along a line at right angles to the proposed 132kV overhead conductors. As the proposed 132kV line is parallel to existing transmission lines in two of the five spans, the contribution of the adjacent line has the potential to influence the total field. Where material, the extent of such influence will be seen in the profiles for the sections which parallel the TransGrid easement. In all cases the profiles are as seen by an observer looking along the line towards the power station.

### 4.2.1 First span from power station

The calculated magnetic field in the first span, which extends from the power station to the western edge of the TransGrid easement, is shown in Figure 4-1.

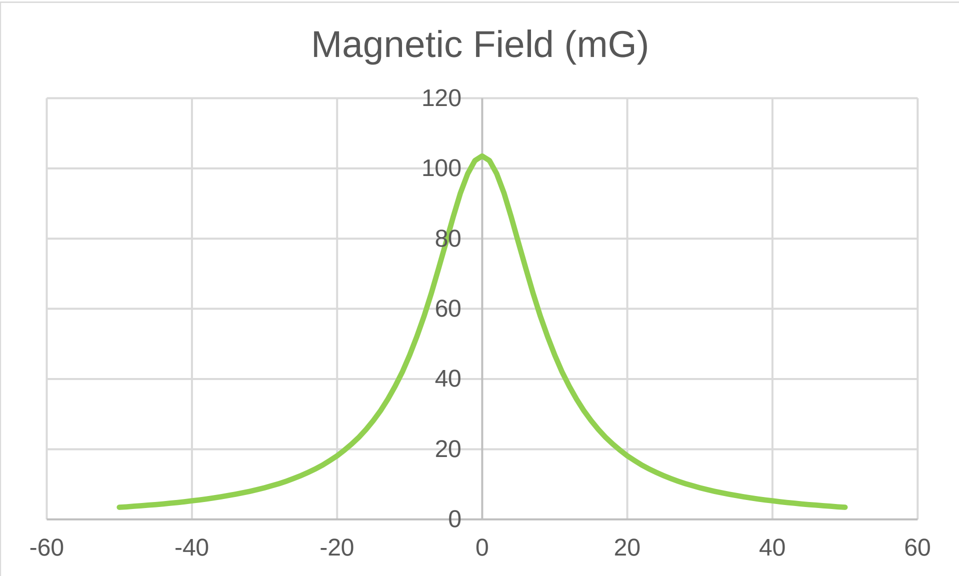


**Figure 4-1 Calculated magnetic field profile - first span from power station**

It can be seen from Figure 4-1 that, with the power station running, the predicted magnetic field directly under the proposed 132kV line is 104mG, decreasing to 28mG at the edge of the proposed easement, 15 metres away in either direction.

### 4.2.2 Mid-span along western edge of TransGrid easement

The calculated magnetic field in the span along the western edge of the TransGrid easement is shown in Figure 4-2.

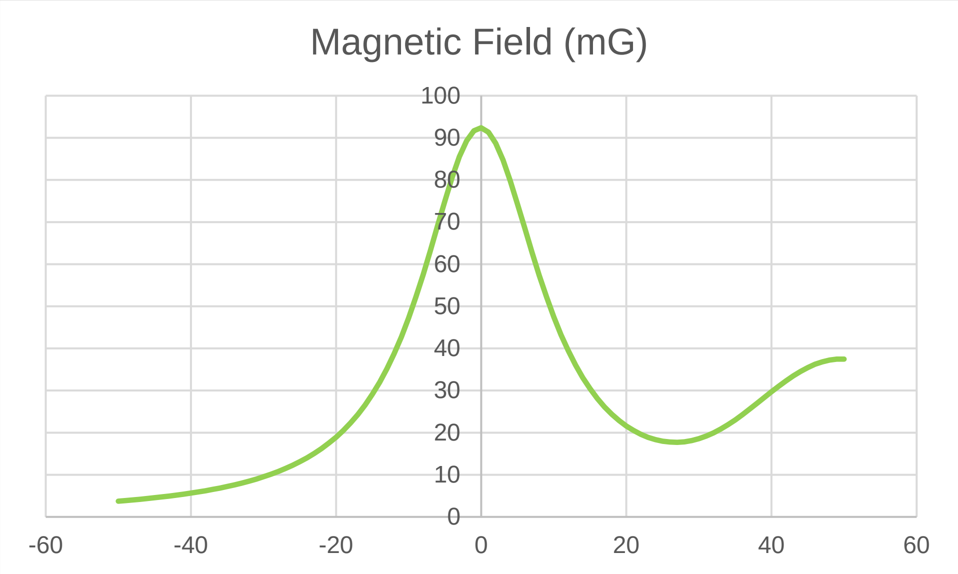


**Figure 4-2 Calculated magnetic field profile - mid-span along western edge of TransGrid easement**

It can be seen from Figure 4-2 that, when the power station is running, the predicted magnetic field directly under the proposed 132kV line is 92mG. At the edge of the proposed easement, 15 metres west of the proposed line, the predicted field is 29mG.

At the edge of the TransGrid easement, 15 metres east of the proposed line, the predicted magnetic field is 30mG, reflecting a minor contribution at that point from the TransGrid lines. The magnetic field directly beneath the TransGrid 330kV lines can be seen towards the right-hand side of Figure 4-1Figure 4-2.

### 4.2.3 Span along eastern edge of TransGrid easement

The calculated magnetic field in the span along the eastern edge of the TransGrid easement is shown in Figure 4-3. It can be seen that, when the power station is running, the predicted magnetic field directly under the proposed 132kV line is 221mG. At the edge of the proposed easement, 15 metres on either side of the proposed line, the predicted field is 60mG.

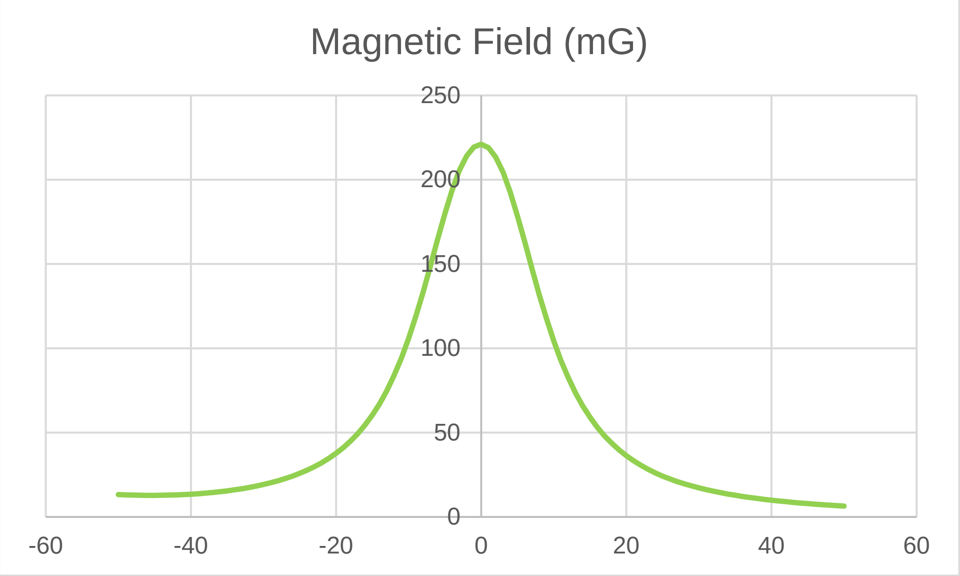


**Figure 4-3 Calculated magnetic field profile - span along eastern edge of TransGrid easement**

### 4.2.4 Span along northern edge of 132kV switching station and undercrossing spans

The calculated magnetic field contribution of the proposed line in the spans undercrossing the TransGrid and Ausgrid lines is shown in Figure 4-4.

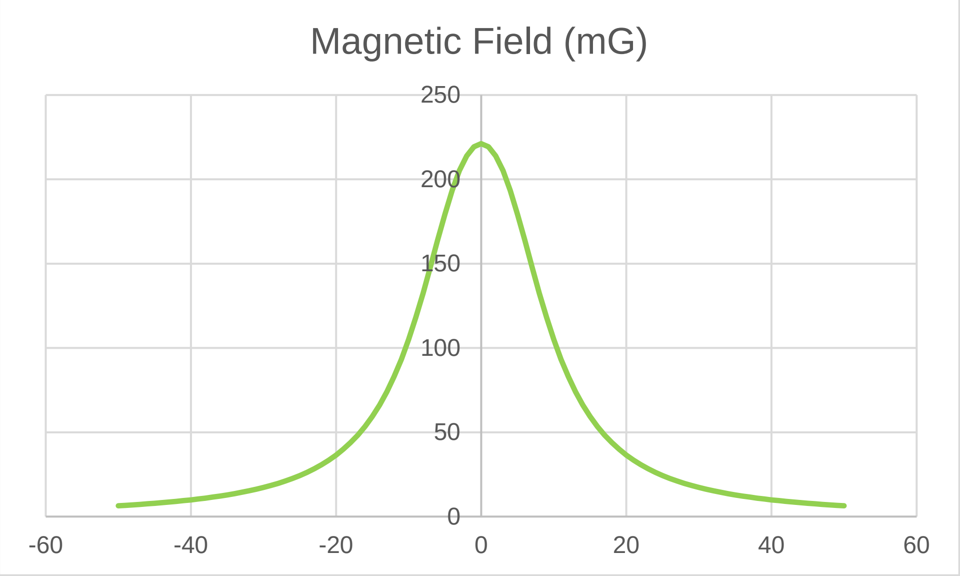


**Figure 4-4 Calculated magnetic field contribution in** span **along northern edge of 132kV switching station and in undercrossing spans**

It can be seen from Figure 4-4 that, when the power station is running, the predicted magnetic field contribution of the proposed 132kV line is 219mG directly beneath it. 15 metres away in either direction, the predicted field is 59mG.

This field will interact with the contributions from the existing TransGrid and Ausgrid lines in a complex way, being higher in some parts of the undercrossing and lower in others. Due to the currents to be carried by the proposed 132kV line being much higher than those carried by the existing lines, and the relatively low ground clearances necessitated by the need to pass under them, when the proposed power station is running, the fields under the existing lines at the undercrossings will be dominated by those from the proposed line.

## 4.3 Magnetic fields experienced in everyday life

In considering the fact that the magnetic fields associated with the proposed line are quite localised and, due to the line's location on vacant land, are unlikely to be experienced by people, other than intermittently, it is useful to recognise that life in the modern world involves moving from one source of magnetic fields to another. To put this into perspective, the Energy Networks Association has published a series of typical magnetic field levels associated with particular appliances and infrastructure at normal user distance. These are set out in Table 4-1.

**Table 4-1 ELF magnetic field levels associated with appliances and infrastructure[4]**

| Appliances | Typical Measurement (mG) | Range of Measurements (mG) |
|---|---|---|
| Electric Stove | 6 | 2 – 30 |
| Refrigerator | 2 | 2 – 5 |
| Electric Kettle | 3 | 2 – 10 |
| Toaster | 3 | 2 – 10 |
| Television | 1 | 0.2 – 2 |
| Personal Computer | 5 | 2 – 20 |
| Electric Blanket | 20 | 5 – 30 |
| Hair Dryer | 25 | 10 – 70 |
| Pedestal Fan | 1 | 0.2 – 2 |
| Substation<br>- Substation Fence | 5 | 1 – 8 |
| Distribution Line<br>- Under Line<br>- 10m Away | 10 | 2 – 30<br>0.5 – 10 |
| Transmission Line<br>- Under Line<br>- Edge of Easement | 20<br>10 | 10 – 200<br>2 – 50 |

From the above range of fields, it can be seen that when the power station is generating, the predicted magnetic field contributions associated with the proposed 132kV line are at the upper end of the range of fields normally encountered around transmission lines. However, this finding is tempered by the facts that the line will only operate, on average, for 14% of the time and the proposed route is not in a frequented area. Human interaction with the line's magnetic fields will mainly be confined to the occupants of passing traffic on old Punt Road and will be transitory in nature.

## 4.4 Electric field results

The electric fields directly beneath the proposed line are predicted to range between 1100 and 1500 Volts/ metre, decreasing to 500 Volts/metre 15 metres away. As the electric field produced by a power line is dependent on the line's voltage, the contribution of the existing 330kV lines to the electric field is more significant than for the magnetic field. The electric field directly beneath the existing 330kV lines is expected to be in the range from 3000 to 4500Volts/metre and, from the existing 132kV lines, 1200 to 1800 Volts/metre. The proposed line is not expected to cause any material increase to the existing electric field where it crosses beneath the existing lines.

[4](Source: Energy Networks Association)

# 5 Compliance with EMF guidelines and prudent avoidance principles

## 5.1 Compliance with health guidelines

### 5.1.1 Magnetic fields

Whether in isolation, or in combination with the existing 132 and 330kV transmission lines, the contribution of the proposed 132kV line to the magnetic field environment is predicted to be well within the ICNIRP Guideline Reference Level of 2000mG.

With the power station operating at full load[5]:

- Directly beneath the proposed line, the highest predicted magnetic field contribution is 11% of the ICNIRP Guideline Reference Level.
- At the edge of the proposed easement, 15 metres from the line, the highest predicted magnetic field contribution is 3% of the ICNIRP Guideline Reference Level.

Notwithstanding the line's proximity to the existing 132 and 330kV lines, there is little interaction with their magnetic fields, except at the undercrossings where the field contribution from the proposed line will dominate the existing fields from the adjacent lines but the resulting magnetic fields are expected to remain well below 15% of the ICNIRP Guideline Reference Level.

### 5.1.2 Electric fields

Whether in isolation, or in combination with the existing 132 and 330kV transmission lines, the contribution of the proposed 132kV line to the electric field environment is predicted to be less than 30% of the ICNIRP Guideline Reference Level of 5000 Volts/metre. In practice, due to shielding by vegetation etc, the actual electric field is likely to be considerably less than that predicted.

The proposed line is not expected to cause any material increase to the existing electric field where it crosses beneath the existing lines.

## 5.2 Assessment against prudent avoidance principles

As noted in Section 2.4, given the inconclusive nature of the science, it is considered that, in the circumstances, a prudent/precautionary approach continues to be the most appropriate response to health concerns regarding EMF. Under this approach, the operators of electricity infrastructure should design their facilities to reduce the intensity of the magnetic fields they generate, and locate them to minimise the fields that people, especially children, encounter over prolonged periods, provided this can be readily achieved without undue inconvenience and at reasonable expense, and be consistent with good engineering and risk minimisation practice.

In this context, it is noted that the route of the proposed line is only 570 metres (approximately) long and its design is already heavily constrained by the need to undercross three existing transmission lines. Most significantly, the route is not frequented by people and, accordingly, there will be no prolonged human exposure. Accordingly, it is unnecessary to seek any further technical measures to reduce the magnetic fields associated with the proposed line.

[5] *It is relevant, again, to note that, given its role of providing firming capacity to the National Electricity Market (NEM), for most of the time, the power station will not be operating.*

# 6 Conclusions

Based on Aurecon's modelling of the electric and magnetic fields likely to be associated with the proposed 132kV power line, the following conclusions may be drawn:

## 6.1 Magnetic fields

- Whether in isolation, or in combination with the existing 132 and 330kV transmission lines, the highest predicted contribution of the proposed 132kV line to the magnetic field environment is predicted to be 11% of the ICNIRP Guideline Reference Level of 2000mG.
- At the edge of the proposed easement, 15 metres from the line, the highest predicted magnetic field contribution is 3% of the ICNIRP Guideline Reference Level.
- Notwithstanding the line's proximity to the existing 132 and 330kV lines, there is little interaction with their magnetic fields, except at the undercrossings where the field contribution from the proposed line will dominate the existing fields from the adjacent lines. The resulting magnetic fields are expected to remain well below 15% of the ICNIRP Guideline Reference Level.

## 6.2 Electric fields

- Whether in isolation, or in combination with the existing 132 and 330kV transmission lines, the contribution of the proposed 132kV line to the electric field is predicted to be less than 30% of the ICNIRP Guideline Reference Level of 5000 Volts/metre. In practice, due to shielding by vegetation etc, the actual electric field is likely to be considerably less than that predicted.
- The proposed line is not expected to cause any material increase to the existing electric field where it crosses under the existing lines.

## 6.3 Prudent avoidance

As the route of the proposed line is not frequented, there will be no prolonged human exposure and accordingly, it is unnecessary to seek any further technical measures to reduce the magnetic fields.

# 7 References[6]

1. Electric and Magnetic Fields: What we know: Energy Networks Association, June 2006, March 2016.

[6] *Further references are cited at the end of each Appendix.*

# Appendices

# Appendix A
# General description of electric and magnetic fields

The electric and magnetic fields associated with electrical equipment, whilst interrelated, are not dependent on each other and can exist independently. The electric field is associated with the voltage of the equipment and the magnetic field is associated with the current (amperage). In combination, these fields cause energy to be transferred along electric wires.

An **electric field** is a region where electric charges experience an invisible force. The strength of this force is related to the voltage, or pressure, which forces electricity along wires. Electric fields are strongest closest to their source, and their strength diminishes rapidly with distance from the source, in much the same way as the warmth of a fire decreases with distance. Many common materials – such as brickwork or metal – block electric fields, so they are readily shielded and, for all practical purposes, do not penetrate buildings. They are also shielded by human skin, such that the electric field inside a human body will be at least 100,000 times less than the external field. (Ref A-1) Being related to voltage, the electric fields associated with HV aerial lines and electrical substations remain relatively constant over time, except where the operating voltage changes.

A **magnetic field** is a region where magnetic materials experience an invisible force produced by the flow of electricity (known as electric current and measured in Amperes). The strength of a magnetic field depends on the size of the current and decreases as distance from the source increases. The magnetic field strength resulting from an electrical installation varies continually with time and is affected by a number of factors including:

- The total electric load
- The size and nature of the equipment
- The design of the equipment
- The layout and electrical configuration of the equipment and its interaction with other equipment

While electric fields are blocked by common materials, this is not the case with magnetic fields. This is why locating equipment in enclosures or underground will eliminate any external electric field but not the magnetic field.

Alternating electric and magnetic fields are produced by any electric wiring or equipment carrying alternating current (AC). This current does not flow steadily in one direction but oscillates backwards and forwards at a frequency[7] of 50Hz and hence the fields produced by AC systems oscillate at the same frequency. This frequency falls into a range referred to as **extremely low frequency** (ELF), so the electric and magnetic fields are referred to as ELF fields.

**Electromagnetic Radiation**

It is not uncommon for the ELF EMF associated with electrical equipment to be confused with electromagnetic radiation (EMR). The fact that, in many jurisdictions, agencies which regulate the various forms of EMR are also involved in the setting of guidelines/standards for EMF tends to add to this confusion.

Electromagnetic radiation is a term we use to describe the movement of electromagnetic energy through the propagation of a wave. This wave, which moves at the speed of light in a vacuum, is composed of electric and magnetic waves which oscillate (vibrate) in phase with, and perpendicular

[7] *Frequency is a measure of the number of times per second a wave oscillates or vibrates. The most common unit of measurement of frequency is the Hertz (Hz) where 1 Hz is equal to 1 cycle per second.*

to, each other. This is in contrast to EMF, where the electric and magnetic components are essentially independent of one another.

Electromagnetic radiation is classified into several types according to the frequency of its wave; these types include (in order of increasing frequency): radio waves, microwaves, terahertz radiation, infra-red radiation, visible light[8], ultraviolet radiation, X-rays and gamma rays. Whereas EMR causes energy to be radiated outwards from its source e.g. light from the sun or radio-frequency signals from a television transmitter, EMFs cause energy to be transferred along electric wires.

In the context of EMF and health, the distinction between EMF and EMR is addressed by the New Zealand Ministry of Health in its public information booklet "Electric and Magnetic Fields and Your Health" (Ref A-2) as follows:

*"The electric and magnetic fields around power lines and electrical appliances are not a form of radiation. The word "radiation" is a very broad term, but generally refers to the propagation of energy away from some source. For example, light is a form of radiation, emitted by the sun and light bulbs. ELF fields do not travel away from their source, but are fixed in place around it. They do not propagate energy away from their source. They bear no relationship, in their physical nature or effects on the body, to true forms of radiation such as x-rays or microwaves."*

**References**


A-1. World Health Organisation: Environmental Health Criteria Vol. 238: Extremely low frequency fields. (2007).

A-2. New Zealand Ministry of Health: Electric and Magnetic Fields and Your Health. (2008).


[8] *Visible light is a group (spectrum) of frequencies which can be sensed by the eyes of humans and various other creatures.*

# Appendix B
# Overview of EMF and health

Research into EMFs and health is a complex area involving many scientific disciplines – from biology, physics and chemistry to medicine, biophysics and epidemiology. Many of the health end points of interest to researchers are quite rare. In this context, it is well accepted by scientists that no study considered in isolation will provide a meaningful answer to the question of whether or not EMFs can contribute to adverse health effects. In order to make an informed conclusion from all of the research, it is necessary to consider the science in its totality. Over the years, governments and regulatory agencies around the world have commissioned independent scientific review panels to provide such overall assessments.

**Extremely Low Frequency (ELF) Fields**

The possibility of adverse health effects due to the ELF EMFs at levels commonly associated with electrical equipment has been the subject of extensive research throughout the world. To date, while adverse health effects have not been established, the possibility that they may exist cannot be ruled out.

While EMFs involve both electric and magnetic components, electric fields are relatively constant over time, are readily shielded and, in the health context, are generally no longer associated with the same level of interest as magnetic fields. Nevertheless, high electric field strengths, such as those associated with high voltage equipment in major substations can approach a level at which "nuisance shocks" can occur and this phenomenon needs to be managed. Magnetic fields are not readily shielded, are more ubiquitous and remain the subject of some debate. Accordingly, much of the remainder of this section is directed towards magnetic fields.

The most recent scientific reviews by authoritative bodies are reassuring for most potential health end points. However, statistical associations[9] between prolonged exposure to elevated magnetic fields and childhood leukaemia have persisted. This led the International Agency for Research on Cancer (IARC) (Ref. B-1) in 2002 to classify magnetic fields as a "possible carcinogen" [10].

The fact that, despite over 30 years of laboratory research, no mechanism for an effect has been established, lends weight to the possibility that the observed statistical associations reflect some factor other than a causal relationship. This point is made in the 2001 report of the UK National Radiological Protection Board's (NRPB) Advisory Group, chaired by eminent epidemiologist, the late Sir Richard Doll (Ref. B-2)

> *"in the absence of clear evidence of a carcinogenic effect in adults, or of a plausible explanation from experiments on animals or isolated cells, the evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children" (page 164)*

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[4] *It should be noted that a statistical association does not necessarily reflect a cause and effect relationship.*

[5] *IARC publishes authoritative 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 5 groups, namely:*

- *Group 1 – the agent is carcinogenic to humans – 118 agents are included in the group, including asbestos, tobacco and ultraviolet radiation*
- *Group 2A – the agent is probably carcinogenic – 79 agents have been included in this group, including diesel engine exhaust, creosotes and PCBs*
- *Group 2B – the agent is possibly carcinogenic to humans – 290 agents have been included in this group, including coffee, gasoline, lead, nickel, petrol engine exhaust and extremely low frequency magnetic fields*
- *Group 3 – the agent is not classifiable as to carcinogenicity – 501 agents have been included in this group, including caffeine, coal dust, extremely low frequency electric fields and static electric and magnetic fields*

**References**

B-1. World Health Organisation, International Agency for Research on Cancer, Lyon, France: IARC Monographs on the evaluation of carcinogenic risks to humans. Non-Ionising Radiation Part 1: Static and Extremely Low Frequency (ELF) Electric and Magnetic Fields. (2001)

B-2. National Radiological Protection Board, (UK), ELF Electromagnetic Fields and the Risk of Cancer, Report of an Advisory Group on Non-Ionising Radiation, Chairman, Sir Richard Doll, NRPB Vol. 12 No. 1, 2001.

- *Group 4 – the agent is probably not carcinogenic to humans – only 1 agent (caprolactam) has been included in this group.*

# Appendix C
# Health guidelines

## Health Guidelines for Extremely Low Frequency Electric and Magnetic Fields

The World Health Organisation recognises two international EMF/Health guidelines:

- the Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz) produced by the International Commission on Non-Ionising Radiation Protection (ICNIRP) Ref C-1), and
- the, IEEE Standard C95.1, produced by the International Committee on Electromagnetic Safety, Institute of Electrical and Electronics Engineers (IEEE) in the USA.

In July 2015, the relevant Australian regulator (ARPANSA) officially adopted the more conservative of the above two, the ICNIRP 2010 Guidelines, in full, stating:

> *"The ICNIRP ELF guidelines are consistent with ARPANSA's understanding of the scientific basis for the protection of the general public (including the foetus) and workers from exposure to ELF EMF." (Ref. C-2)*

In line with the regulator's advice, Aurecon has applied the current international ICNIRP guideline reference levels to this assessment.

The reference levels[11] for both electric and magnetic fields contained in the current ICNIRP guidelines are summarised in the table below

**ICNIRP Guideline Reference Levels**

| Parameter | ICNIRP 2010 Reference Levels |
|---|---|
| Electric Fields – General Public | 5kV/m |
| Electric Fields – Occupational | 10kV/m |
| Magnetic Fields – General Public | 2,000mG |
| Magnetic Fields – Occupational | 10,000mG |

In applying the guidelines, it is to be noted that, unlike earlier versions, the various limits are now independent of duration of exposure.

In applying the ICNIRP Guideline, it is also important to recognise that the numerical limits, e.g. 2,000 mG, are based on established health effects. In ICNIRP's fact sheet on the guidelines (Ref. C-3), it notes that:

> *"It is the view of ICNIRP that the currently existing scientific evidence that prolonged exposure to low frequency magnetic fields is causally related with an increased risk of childhood leukaemia is too weak to form the basis for exposure guidelines. Thus, the perception of surface electric charge, the direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes are the only well-established adverse effects and serve as the basis for guidance."*

[11] *The "Reference Levels" set out in the guideline are derived from the levels at which interactions with the central nervous system are established, with a safety factor applied and a further adjustment to simplify compliance measurement.*

Being based on established biological effects (which occur at field levels much higher than those normally encountered in the vicinity of electrical equipment), the (numerical) exposure limits in the guidelines and standards cannot be said to define safe limits for possible health effects, should these exist, from magnetic fields at levels normally encountered in the vicinity of electrical equipment.

It is in this context that precautionary measures for ELF magnetic fields such as “Prudent Avoidance” have arisen (see Appendix D).

### References

C-1 International Commission on Non-Ionising Radiation Protection (2010: Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1Hz to 100kHz): Health Physics 99(6):818-836; (2010).

C-2 ARPANSA: Extremely Low Frequency Electric and Magnetic Fields – 2015, accessed 10 May 2016.

C-3. ICNIRP Fact Sheet on the guidelines for limiting exposure to time-varying electric, and magnetic fields (1Hz-100kHz) published in Health Physics 99(6): 818-836; 2010, accessed 10 May 2016, < http://www.icnirp.org/cms/upload/publications/ICNIRPFactSheetLF.pdf>.

# Appendix D
# Prudent avoidance

## Extremely Low Frequency Magnetic Fields

Regarding the potential health effects from ELF magnetic fields, while compliance with the relevant guideline is important in protecting people from established health effects, it does not necessarily address possible health effects, should they exist, from fields at levels normally encountered in the vicinity of electrical equipment. The possibility of such effects has been comprehensively studied over several decades worldwide but, to this day, there is no clear understanding of how ELF electric or magnetic fields at low levels could pose a threat to human health.

Since the late 1980s, many reviews of the scientific literature have been published by authoritative bodies. There have also been several inquiries such as those by Sir Harry Gibbs in NSW (Ref. D-1) and Professor Hedley Peach in Victoria (Ref. D-2). These reviews and inquiries have consistently found that:

- Adverse health effects have not been established for fields at levels commonly found around electrical equipment and infrastructure.
- The possibility cannot be ruled out
- If there is a risk, it is more likely to be associated with the magnetic field than the electric field

Both Sir Harry Gibbs and Professor Peach recommended a policy of prudence or prudent avoidance, which Sir Harry Gibbs described in the following terms:

> *"… [doing] whatever can be done without undue inconvenience and at modest expense to avert the possible risk …"*

In 1999, the (US) National Institute of Environmental and Health Sciences (NIEHS) (Ref. D-3) found:

> *"In summary, the NIEHS believes that there is weak evidence for possible health effects from ELF-EMF exposures, and until stronger evidence changes this opinion, inexpensive and safe reductions in exposure should be encouraged." (page 38)*

The practice of 'prudent avoidance' has been adopted by the (Australian) Energy Networks Association (ENA) and most Australian power utilities.

The World Health Organisation has also addressed the notion of prudence or precaution on several occasions, including in its 2007 publication Extremely low frequency fields. Environmental Health Criteria, Vol. 238 (Ref. D-4), which states:

> *"…the use of precautionary approaches is warranted. However, it is not recommended that the limit values in exposure guidelines be reduced to some arbitrary level in the name of precaution. Such practice undermines the scientific foundation on which the limits are based and is likely to be an expensive and not necessarily effective way of providing protection."*

It also states:

> *"Provided that the health, social and economic benefits of electric power are not compromised, implementing very low-cost precautionary procedures to reduce exposure is reasonable and warranted."*

Given the inconclusive nature of the science, it is considered that a prudent approach continues to be the most appropriate response in the circumstances. Under this approach, subject to modest cost and reasonable convenience, power utilities and transport authorities should design their facilities to reduce the intensity of the fields they generate, and locate them to minimise the fields that people, especially children, encounter over prolonged periods. While these measures are prudent, it cannot be said that they are essential or that they will result in any benefit.

In the Australian context, ENA's position, as adopted in their EMF Management Handbook (Ref. D-5), states:

> *"Prudent avoidance does not mean there is an established risk that needs to be avoided. It means that if there is uncertainty, then there are certain types of avoidance (no cost / very low cost measures) that could be prudent."*

It also states:

> *"Both prudent avoidance and the precautionary approach involve implementing no cost and very low cost measures that reduce exposure while not unduly compromising other issues."*

**References**

D-1. Gibbs, Sir Harry, Chairman, Inquiry into Community Needs and High Voltage Transmission Line Development, Submission to the NSW Government, February 1991.

D-2. Peach HG, Bonwick WJ and Wyse T (1992). Report of the Panel on Electromagnetic Fields and Health to the Victorian Government (Peach Panel Report). Melbourne, Victoria: September 1992.

D-3. National Institute of Environmental Health Sciences, National Institutes of Health, (USA), NIEHS report on health effects from exposure to power-line frequency electric and magnetic fields, NIH Publication No. 99-4493, 1999.

D-4. World Health Organisation: Environmental Health Criteria Vol. 238: Extremely low frequency fields. (2007).

D-5. Energy Networks Association: EMF Management Handbook. (2016).

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