RICHARD CROOKES CONSTRUCTIONS

# MULGOA RISE PUBLIC SCHOOL

## EXTREMELY LOW FREQUENCY (ELF) ELECTROMAGNETIC FIELDS/ENERGY (EME) IMPACT ASSESSMENT

NOVEMBER 2021

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ENGINEERING GROUP

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ENDEAVOUR ENERGY PADMOUND SUBSTATION EME IMPACT ASSESMENT REPORT (VER.1.0)

PROJECT NO. PS114A
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| Prepared by: | Richard Saliba | 09/11/2021 | |

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# 1 INTRODUCTION

Traca Group Pty Ltd was commissioned by Richard Crookes Constructions to prepare this report for the assessment of the impact of Extremely Low Frequency (ELF) Electromagnetic Fields/Energy (EME) associated with the existing Endeavour Energy 315kVA Padmound Substation (No. 29097) to be upgraded to 1000kVA on the proposed education development at Forestwood Drive, Glenmore Park.

The existing Endeavour Energy Padmount Substation to be upgraded is located on Darug Ave, upon the grounds of which the proposed Mulgoa Rise Public School is proposed to be built.

The new proposed development along 1-23 Forestwood Drive, Glenmore Park is a multi-level Pre-school consisting of 2 levels of teaching and administration spaces. The power for this development will be provided from a 1 x 1000kVA 11kV/433V padmount substation located on the Darug Avenue site boundary, with the Main Switch Room approximately 15m away, outside the School building.


**Figure 1 - Site Plan**

# 2 EXECUTIVE SUMMARY

The report specifies the calculations carried out and recommendations provided for Electromagnetic Energy (EME) or Electromagnetic Fields (EMF) measures to be taken at the proposed Mulgoa Rise Public School Building.

We have used Ausgrid's EGN 423: EMF Calculator to determine the Magnetic Flux Density (uT) at various distances from the 1000kVA Padmount Substation. As shown below;

*Results shown for a loading of*
*1450 Amps*

| *Distance* | *uT* |
|---|---|
| 0m | 35.235 |
| 1m | 3.654 |
| 2m | 1.624 |
| 3m | 1.015 |
| 4m | 0.5945 |
| 5m | 0.377 |
| 6m | 0.145 |
| 7m | 0.0725 |
| 8m | Negligible |
| 9m | Negligible |
| 10m | Negligible |
| 11m | Negligible |
| 12m | Negligible |
| 13m | Negligible |
| 14m | Negligible |
| 15m | Negligible |
| 16m | Negligible |
| 17m | Negligible |
| 18m | Negligible |
| 19m | Negligible |
| 20m | Negligible |

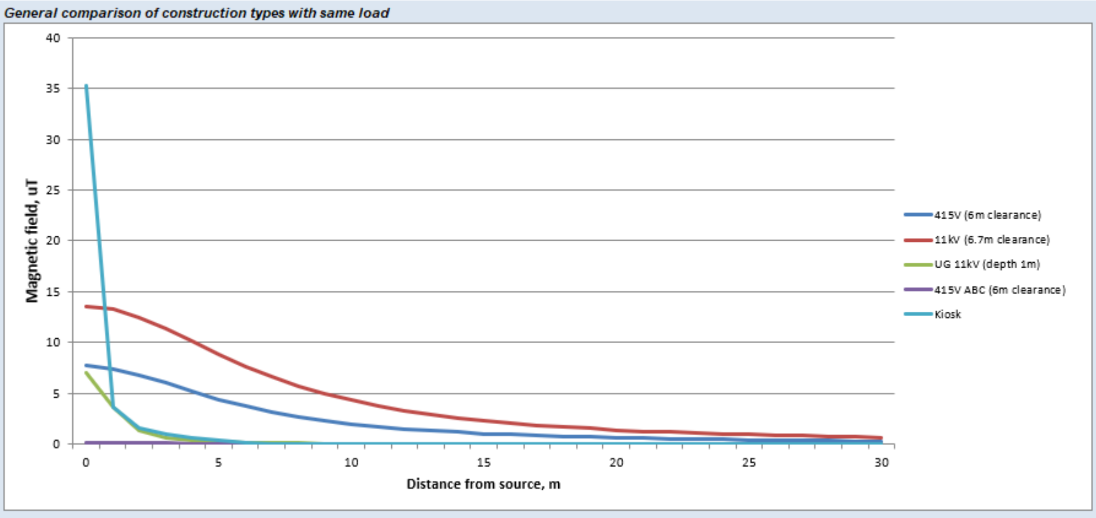


**Figure 2 - Ausgrid's EGN 423: EMF Calculator Results**

Section 11 of the referenced report provides consideration to the precautionary principles as defined by the ARPANSA EMF Standard. A summary of the findings and recommendations are below.

There will be no issues with magnetic field mitigation with regard to the Endeavour Energy Padmount substation, as it is at least 7m away from the building and the field strength is less than 4mG at a distance of 5m from the Padmount location.

This report confirms that EME generating equipment within the proposed design complies with all applicable standards, regulations and guidelines, including the National Health & Medical Research Council's Interim Guidelines on the limits of exposure to 50/60Hz electric and magnetic fields (1989).

# 3 APPROACH

This report addresses the following issues in relation to extremely low frequency (ELF) 50Hz, magnetic interference at the proposed development site:

a. Electrical and magnetic fields.

b. Units of measurement and conversion factors.

c. Sources of ELF magnetic field.

d. Australian Standards:
   - Australian electrical and electronic equipment electromagnetic immunity standards.
   - Australian magnetic storage facility standards.
   - Australian human exposure standards.

e. Magnetic field effect on normal functioning of computers.

f. Assessment of ELF magnetic interference specific to the site.

# 4 ELECTRICAL AND MAGNETIC FIELDS

Everyone is exposed to some form of electromagnetic fields (EMF – often incorrectly referred to as electromagnetic radiation) of different frequencies from many natural and man-made sources in our environment. Electromagnetic fields consist of electric and magnetic waves travelling together at the speed of light. In recent years, the general public has become increasingly concerned about the potential adverse effects of exposure to electric and magnetic fields at extremely low frequency (ELF).

Extremely low frequencies are defined as the frequency range from 0-300Hertz (Hz). At these low frequencies, electric and magnetic fields act independently and can be separately measured.

Exposures to these fields arise mainly from the transmission and use of electrical energy at the frequencies of 50/60 Hz. This report is particularly concerned with the 50Hz frequency as this is the frequency established for the electrical power supply throughout Australia.

Electricity generates electrical and magnetic fields as a natural consequence of the use and distribution of power supply electricity.

Electric and magnetic fields are strongest closest to the source and diminish very quickly with an increase in distance from the source. Electric fields are proportional to the source voltage and can be shielded by common materials such as wood, masonry and metal. Magnetic fields are proportional to the source current and easily pass through these common materials. As such this report will concentrate on issues associated with magnetic fields.

Magnetic fields are produced by electric current. The flow of electrical current through metal conductors produces an electromagnetic field. The magnetic field is created around the supply cable and the equipment when it is operating. This is a major but not exclusive source of electromagnetic fields.

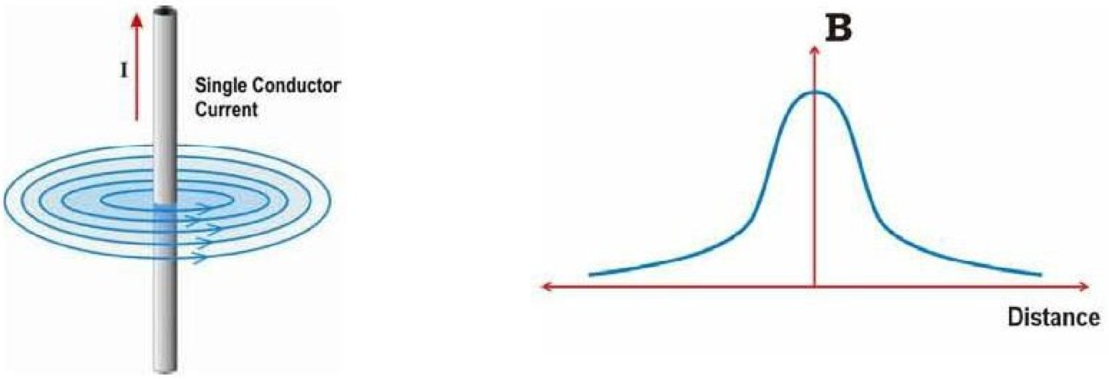


**Figure 1. Reduction of magnetic field strength, B, with distance from conductor source**

Other sources of electromagnetic fields include radio waves, 3-phase lines, unbalanced currents, currents in earthing systems, proximity of power installations and railway tracks & presence of harmonics in the neutral line. The magnetic fields pass undiminished through earth, concrete and most building materials and are expensive to shield.

Some electrical and electronic equipment is sensitive to and will malfunction in environments of elevated magnetic field. The most common example is interference with cathode ray tube (CRT) video display monitors.

A document issued by The National Health and Medical Research Council in their document “Interim guidelines on limits of exposure to 50/60 Hz electric and magnetic fields” provides magnetic field limits for occupational and general public categories.

The sources of magnetic fields in commercial buildings include power supply and distribution equipment, power consumption equipment and other less obvious sources such as structural steel beams or metallic cable trays.

This report outlines the issues of extremely low frequency (ELF) 50Hz, magnetic interference. The report discusses the relevant Australian Standards that exist and then outlines the available pre-emptive options for mitigating the effects of ELF magnetic interference.

# 5 UNITS OF MEASUREMENT AND CONVERSION FACTORS

Electric fields are measured as electric field strength (Volts per metre, V/m). Magnetic fields are measured as magnetic field strength (Ampere per metre, A/m) or as magnetic flux density -microTesla (µT) or milliGauss (mG).

| Quantity | SI Unit (International system of units) |
|---|---|
| Magnetic flux | Weber, Wb |
| Magnetic field strength | Ampere per metre, A/m |
| Magnetic flux density | Weber per sq. metre or Tesla, T |
| Magnetic flux density | Gauss, G see note 1. |

Note: Gauss is not an official SI unit and Standards Australia deprecates its use. However, in Australia magnetic flux density is commonly described in one of two distinct units, microTesla (µT) or milliGauss (mG), where 1 µT = 10 mG.

# 6 SOURCES OF ELF MAGNETIC FIELD

All electric currents generate electromagnetic fields. Man-made external sources include installations associated with the transport of electricity, such as power lines and underground cables, open type and indoor transmission and distribution substations or large indoor LV switchboards.

The sources of magnetic fields in commercial buildings can be grouped into three general categories:

1. Power supply and distribution equipment;
2. Power consumption equipment;
3. Incidental sources.

## 6.1 POWER SUPPLY AND DISTRIBUTION EQUIPMENT

a. Substation inside buildings:
   - transformers
   - busbars
   - isolator, circuit breakers, switches
   - HV incoming and LV outgoing cables

b. LV switchrooms
   - switchboards
   - single and three phase conductors
   - bus duct
   - neutral and earth wires
   - incoming and outgoing cables

c. LV distribution
   - distribution boards
   - single and three phase conductors
   - earth wires
   - single and three phase power and lighting cables
   - earth wires

d. UPS systems and diesel generator electrical distribution

## 6.2 POWER UTILISATION EQUIPMENT

a. air conditioning plant

b. lights (fluorescent, incandescent and low voltage)

c. lifts

d. fans

e. electric heaters

f. hot water units
g. refrigerators
h. office equipment (computers, printers, facsimile machines)
i. workshop equipment
j. security, intercom and communication equipment driven by AC power

## 6.3 INCIDENTAL SOURCES

a. metallic air conditioning duct
b. metallic pipes
c. structural beams
d. steel reinforcement of concrete beams, slabs and panels
e. metallic cable trays

# 7 AUSTRALIAN STANDARDS

## 7.1 AUSTRALIAN ELECTROMAGNETIC IMMUNITY STANDARDS FOR ELECTRICAL AND ELECTRONIC APPARATUS

Australian/New Zealand Standard AS/NZS 61000.6.1:2006 (R2016) which outlines test specifications requirements. The objective of this Standard is to provide designers, manufacturers and testers of equipment incorporating electrical or electronic operation with methods of test for ascertaining immunity to electromagnetic disturbance. The test specifications outlined are as follows:

- 3 A/m (37.5mG) for all equipment
- 1 A/m (12.5mG) for cathode ray tube (CRT) display based equipment

## 7.2 RECOMMENDED LIMITS ON HUMAN EXPOSURE TO EXTREMELY LOW FREQUENCY (ELF) MAGNETIC FIELDS

There are currently no Australian standards regulating human exposure to 50 Hz magnetic fields.

In Australia, the organisation responsible for setting health guidelines is the National Health and Medical Research Council (NHMRC). In November 1989, the NHMRC adopted the guidelines set out by the World Health Organisation (WHO) and the International Radiation Protection Association (IRPA). As such the IRPA guidelines where published under the NHMRC and released the document “Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields (1989) – Radiation Health Series No.30”. These guidelines are aimed at preventing immediate health effects resulting from exposure to these fields.

As this publication is over 10 years old, NHMRC has passed responsibility for review of this publication to the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

In December 2006, ARPANSA released the Draft Radiation Protection Standard for Exposure Limits to Electric and Magnetic Fields 0 Hz - 3 kHz taking into account the latest scientific research. This new draft standard relates to EMF of extremely low frequency (ELF) such as those found around an electricity network. The draft standard has public exposure limits similar to the NHMRC guidelines.

Following public comment this Draft Standard was expected to be finalised and implemented in 2008. The ARPANSA Draft Standard has not been ratified to date.

Human exposure limits are defined for occupation and general public categories as follows:

### 7.2.1 OCCUPATIONAL

The guidelines recommend that 'Basic Restrictions' for continuous occupational exposure during the working day should be limited to rms magnetic flux densities not greater than 500 µT (5000mG).

Controlled activity' exposure for up to one hour per workday should not exceed a magnetic flux density of 1,500µT (15,000mG). When restricted to body area other than the head, exposures up to 1,800 µT (18,000mG) can be permitted. Occupational exposure is permitted only after the appropriate risk management and control regimes are in force.

Note that employed people are to be regarded as members of the general public unless their employer chooses to designate them as needing to work in an environment where ELF controls are necessary.

### 7.2.2 GENERAL PUBLIC

The guidelines recommend that 'Basic Restrictions' for members of the general public should not be exposed on a continuous basis to unperturbed rms magnetic flux densities exceeding 100 µT (1000mG). This restriction applies to areas in which members of the general public might reasonably be expected to spend a substantial part of the day.

'Controlled activity' exposures are to be limited to magnetic flux densities between 100 µT (1000mG) and 300 µT (3,000mG) (rms) and must have appropriate signage to alert the public to the area affected by the magnetic field.

General public exposure is less controlled and in many cases the general public are unaware of their exposure to ELF fields. Moreover, individual members of the general public may be continuously exposed and cannot reasonably be expected to take precautions to minimise or avoid exposure. These considerations are the basis for the application of more stringent exposure restrictions for the general public than for the occupationally exposed population.

Measures for the protection of the general public who may be exposed to ELF due to their proximity to high ELF sources must include the following:

a. Determination of the boundaries of areas where general public exposure limits levels may be exceeded.
b. Restriction of public access to those areas where the general public exposure limits may be exceeded.
c. Appropriate provision of warning signs or notices.

d. Notification to the competent authority, as required, in the event of the exposure exceeding the relevant limits.

e. Minimising, as appropriate, ELF and magnetic field exposure provided this can be readily achieved without undue inconvenience and at reasonable expense. Any such precautionary measures should follow good engineering and risk minimisation practice. Planning practice and relevant codes of practice should also be followed. Precautionary measures should be proportional to the risk. (e.g. where children are involved).

Note that the previous ARPANSA Guidelines 1989 stated: "Exposures to magnetic flux densities between 100 µT (1000mG) and 1000 µT (10,000mG) (rms) should be limited to a few hours per day. When necessary, exposures to magnetic flux densities in excess of 1000 µT (10,000mG) should be limited to a few minutes per day."

### 7.2.3 CHILDREN

The guidelines recommend that 'Basic Restrictions' for continuous exposure for children to avoid all risk of leukaemia should be limited to rms magnetic flux densities not greater than 0.4 µT (4mG).

Typical magnetic field measurements and ranges associated with various appliances and power lines.

| | Typical Measurements (mG) | Range of Measurements (mG) |
|---|---|---|
| Stove | 6 | 2-30 |
| PC | 5 | 2-20 |
| TV | 1 | 0.2-2 |
| Electric Blanket | 20 | 5-30 |
| Hair Dryer | 25 | 10-70 |
| Refrigerator | 2 | 2-5 |
| Toaster | 3 | 2-10 |
| Kettle | 3 | 2-10 |
| Fan | 1 | 0.2-2 |
| Distribution Line (under the line) | 10 | 2-20 |
| Transmission line | | |
| under line | 20 | 10-200 |
| edge of easement | 10 | 2-50 |

***Measurements taken at normal user distance.***

Localised EMF's may also be encountered in specific situations such as near substations, underground cables or specialised electrical equipment, or at elevated locations near lines. Note that the strengths of EMF's decrease rapidly with distance from the source.

# 8 HEALTH EFFECTS OF EXTRA LOW FREQUENCY (ELF) MAGNETIC FIELDS

Human studies have consistently shown that there is no evidence that prolonged exposure to weak electric fields, such as those found in the home or in most work places, result in adverse health effects. There is no evidence that these fields cause immediate, permanent harm.

Exposure to magnetic fields at levels commonly found in the environment is not a proven health risk. The Australian radiation health authorities do not regard the chronic exposure to 50Hz electric and magnetic fields at the levels commonly found in the environment as a proven health risk. Current studies do not allow authorities to decide whether there is a specific magnetic field strength above which chronic exposure is dangerous or compromises human health. At this stage, any action to reduce the exposure must rest with the individual.

Electromagnetic fields interact with the human body by inducing electric fields and currents in them. The exposure to these fields at levels normally found in the environment produces lower fields and currents than those that are naturally occurring within the human body.

Many Australian Electricity Authorities have a ‘Prudent Avoidance’ policy which includes taking reasonable steps to limit field exposures from new facilities by locating and operating electrical installations prudently within the latest Australian health guidelines.

‘Prudent avoidance’ has been defined in an Australian context by the former Chief Justice of the High Court of Australia, Sir Harry Gibbs as “doing what can be done without undue inconvenience and at modest expense to avert the possible risk to health from exposure to new high voltage transmission facilities. In practical terms, this means designing new transmission and distribution facilities having regard to their capacity to produce EMF, and siting them having regard to the proximity of houses, schools and the like.”

# 9 DESIGN CONSIDERATIONS FOR NEW INSTALLATIONS AND ELF MAGNETIC FIELD MITIGATION OPTIONS

In general, extremely low frequency (ELF) 50Hz, magnetic interference is not addressed in the design and installation of building electrical distribution systems. However, experience has shown that if magnetic interference is subsequently found to exceed the minimum sensitivity, then the cost of rectification is much more costly than if the magnetic interference were accounted for during initial design.

Magnetic fields can be readily and accurately modelled and predicted for relatively simple sources such as a balanced three phase cables. However, limitations arise when attempting to model a multitude of sources such as transformers, switchgear, busbars and cables that are randomly oriented in three dimensional space. Moreover, the maximum expected load of each circuit, the degree of phase in-balance and harmonic content for each circuit group, the current of the neutral conductor and the geometry of the electrical circuit groups across cable trays cannot be accurately estimated. Such inaccuracy may result in addition of fields produced simultaneously by various sources at a particular point in space.

Therefore, the best possible approach currently available is to use recognised and commonly accepted design practices and recommendations based on experience and where possible use modelling techniques as support to that approach.

There are three basic approaches to ELF magnetic interference mitigation:

1. Maximise the distance between the source of the field and the sensitive device or area.
2. Maximise natural cancellation of magnetic fields in conductors.
3. Shield the sensitive device, source or area.

In many situations, a combination of these elements can be used to achieve the desired results.

## 9.1 MAXIMISE THE DISTANCE

Frequently, the most cost effective means to reduce ELF magnetic field strength in an area is to increase the distance between the sensitive device or area and the source of the interference. Magnetic fields fall off quickly with distance.

The strength of a magnetic field decreases with distance as a function of the source type. From single conductor sources, magnetic field strengths decrease directly proportional to the distance from the source (1/D). From multiple conductor sources, magnetic field strengths decrease as the square of the distance ($1/D^2$). And, from coils or loops, magnetic field strengths decrease as the cube of the distance ($1/D^3$).

If the source of the magnetic fields cannot be moved, then possibly the sensitive equipment or area can. An option is to redesignate the use of the area potentially affected by elevated magnetic fields. In buildings where space is not an issue, an office area can be converted into storage room, because of its sensitivity to elevated magnetic fields.

When space is more of a commodity however, downgrading prime office space may be undesirable and ultimately expensive in lost utility and possibly lost revenue.

## 9.2 MAXIMISE NATURAL CANCELLATION OF MAGNETIC FIELDS IN CONDUCTORS

Field strength reduction may be attained by ensuring cable configurations are constructed to enhance natural field cancellation. Methods include:

a. Using busbar configurations with minimum allowable clearances between phases and between phases and neutral bus.

b. Using three phase cables in preference to three single phase cables.

c. Using trefoil configuration of phases.

d. Avoiding phase by phase groupings of single core cables in parallel circuits.

e. Distributing all single phase electrical loads evenly between three phases of the main supply cables.

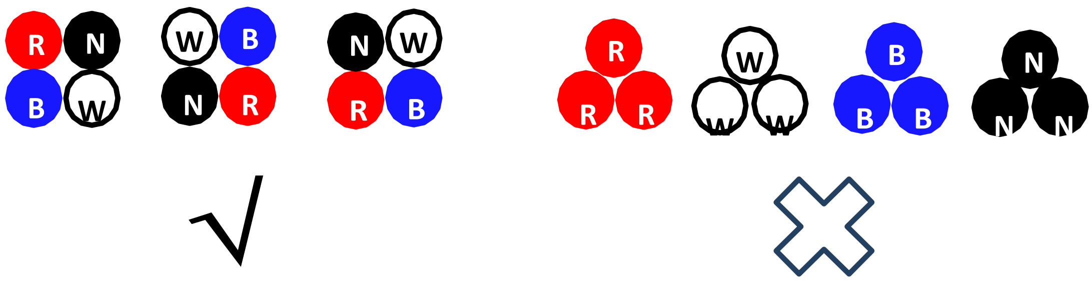


Figure 2. Low EMF cable group arrangement for circuit of parallel single-core conductors

## 9.3 SHIELD THE SENSITIVE DEVICE, SOURCE OR AREA

A shield refers to a magnetic enclosure that either partially or completely encloses electrical and electronic equipment.

There are two purposes a shield can serve:

a. To shield the affected device from radiated emission external to the product from causing interference in the product.

b. To shield the affected source or area to prevent electrical and electronic equipment within the area from radiating electromagnetic fields outside the area.

Shielding serves to reflect or absorb radiation depending on the source of the radiation and the purpose of the shielding.

### 9.3.1 SHIELDING THE AFFECTED DEVICE

The affected device may be a computer monitor that may be susceptible to ELF magnetic fields. External magnetic fields may impinge upon the monitor's internal magnetic fields and disrupt the electron beam as it writes to the screen. Monitor shields create a path for the magnetic fields around the monitor rather than through it, thus enabling the electron beam to perform uninterrupted.

### 9.3.2 SHIELDING THE AFFECTED SOURCE OF AREA

In those instances where equipment shielding is not an acceptable option, either the magnetic field source or the affected area can be shielded.

Frequently, large scale shielding such as shielding applied to an area such as a substation, can be shielded least expensively as part of a new building construction.

However, shielding of large sources as the entire substation is a very expensive option. It should only be used if all other less expensive options are not viable. In some locations, shielding of the affected rooms is a more economical solution than shielding the source itself. In general shielding of the affected equipment or a small area of office space can be much more effectively and economically achieved than shielding of large and complex sources such as substations.

# 10 SHIELDING AGAINST EXTRA LOW FREQUENCY (ELF) MAGNETIC FIELD

## 10.1 SHIELDING EFFECTIVENESS

Shielding effectiveness (Se) is measured in decibels (dB) and is calculated as:

$SE_{dB} = 20 \log_{10}(H_o/H_1)$

Where $H_o$ – magnetic field strength without shield
$H_1$ – magnetic field strength with shield

It should be noted that the shielding effectiveness could be much less than that theoretically predicted.

## 10.2 SHIELDING MATERIALS

Shielding is usually constructed from various grades of steel or other special material. The steel is supplied in sheets or rolls and is of different sizes and thicknesses. A shield of the required thickness can be constructed from thin sheets of the same material. The shield can also be constructed from layers of different materials with different physical properties such as a combination of materials with high permeability (high absorption loss – hot rolled steel) and high conductivity (high reflection loss and high conductivity for induced currents).

The effective values for cold rolled steel and hot rolled silicon steel are in the order of 180 and 1500 respectively. It is important to use a material that will provide the required screening effectiveness.

High permeable materials such as mumetal require annealing after machining and tend to be high cost materials. On the basis of cost and overall shielding effectiveness, steel is probably the most useful material.

The use of mumetal (an alloy with 80% Ni, 4% Mo & Fe) for shielding is very expensive due to the basic cost of the metal sheets, their cutting to size and annealing. Bending, cutting, drilling or any mechanical shock of the annealed mumetal will degrade its characteristics. Shielding of a single substation with mumetal may cost up to $300,000 and as such mumetal is only recommended for applications where it can be used in small quantities such as shielding of computer screens.

Steel can be used as an effective shielding material. High permeable steel such as used in electrical machines can be effectively used as an inexpensive shielding material. The common trade name of this silicon steel is ‘lycore’.

## 10.3 PRACTICAL ASPECTS OF SHIELDING

An example, typical shielding solution may consist of several layers of high permeability metal, with each layer being 3 mm thick plates with individual sheets butt-jointed and overlapping. The installed shield is to be earthed with a minimum 10mm$^2$ earthing cable from the earth connection of the main switchboard to the shielding system.

As shielding is usually constructed from plates or sheets of the selected material, it is important to account for the effect of discontinuity and joints on its overall effectiveness. Any gaps or holes in a shield will reduce its effectiveness. Consideration should also be given to the increased field level at the edge of the material due to “edge effects”.

Other aspects of shielding that should be accounted for are as follows:

a. Sheets are manufactured in lengths as long is practical to minimise joints in the sheets. Any gaps or holes in a shield reduce its effectiveness.
b. Provision of adequate heat dissipation. Heat may be produced by the shield due to induction currents or by the electrical equipment it is designed to shield.
c. Derating of cables and other conductors surrounded by a shield
d. Provision of noise suppression. It is not uncommon that a shielding plate or an enclosure if operating in a relatively strong magnetic field environment will vibrate with the frequency of the induced current.

# 11 SPECIFIC ELF MAGNETIC FIELD IMPACT ASSESSMENT

In line with the 'prudent avoidance' policy, maintaining the ELF magnetic field levels below the threshold limitations for the general public and occupational health guidelines are a necessary objective. A secondary objective is to identify areas of electronic equipment use and to mitigate ELF magnetic fields if necessary to maintain electronic equipment operation.

## 11.1 PADMOUNT SUBSTATION

These specific design measures are in reference to the proposed Endeavour Energy Padmount Substation which is intended to be located adjacent to the property boundary of the proposed school development.

The assumption has been made that consumers mains cabling between the proposed Padmount Substation and the Site Main Switchboard will be run in conduits underground for bottom entry into the Site Main Switchboard in the switch room, approximately 15m away from the substation as shown in Figure 1 Site Plan.

The primary sources of ELF magnetic fields are summarised as being electrical equipment of high current carrying capacity in close proximity to areas sensitive to human health, specifically identified as the following:

a. Substation Low Voltage Transformers.
b. Substation Low Voltage Switchboard.
c. Substation High Voltage Cabling.
d. Customer Main Switchboards.
e. Consumers Mains Cabling.

The primary sources of ELF magnetic fields which are considered to represent high magnetic field levels of interest for specific assessment, based on the proposed Padmount Substation location, have been identified on Figure 1 identifies the proposed location of the Padmount Substations. These drawings identify the estimated maximum ELF magnetic field densities that may be achieved under peak current loading of the equipment. The density values identified on the sketch drawing are based on modelling of the proposed Padmount substation derived from our previous experience in taking field measurements of similar substations, switchboards and cabling arrangements.

The effects of the proposed Padmount substations, on the adjacent areas of the building have been considered and calculated.

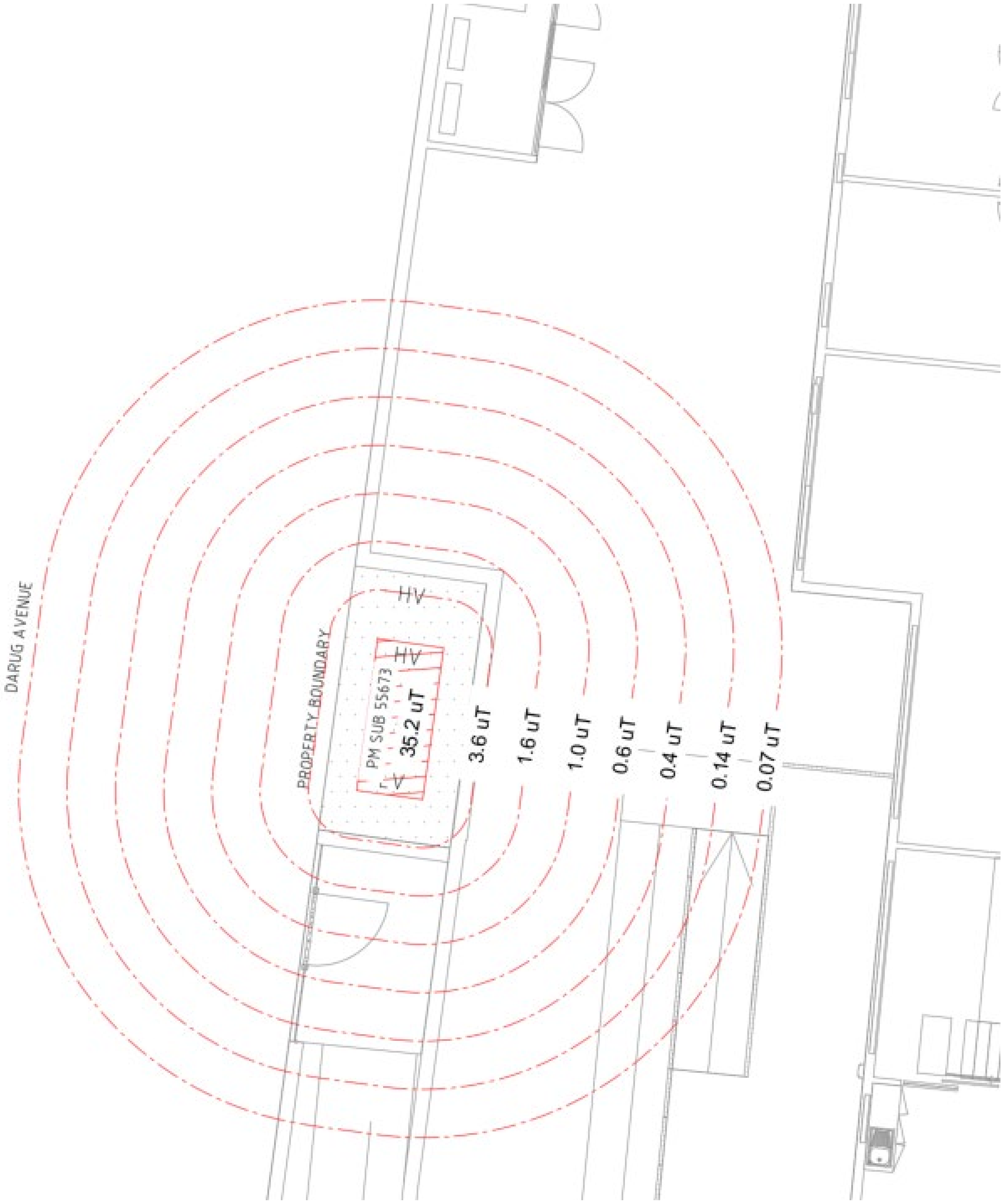


**Figure 3 – Calculated Contours of EMF Magnetic Fields Density from known sources for proposed Padmount Substation – Plan View**

## 11.2 SPECIFIC HUMAN HEALTH EXPOSURE ASSESSMENT

### 11.3.2 PADMOUNT SUBSTATION

We have used Ausgrid's EGN 423: EMF Calculator to determine the Magnetic Flux Density (uT) at various distances from the 1000kVA Padmount Substation. As shown below;

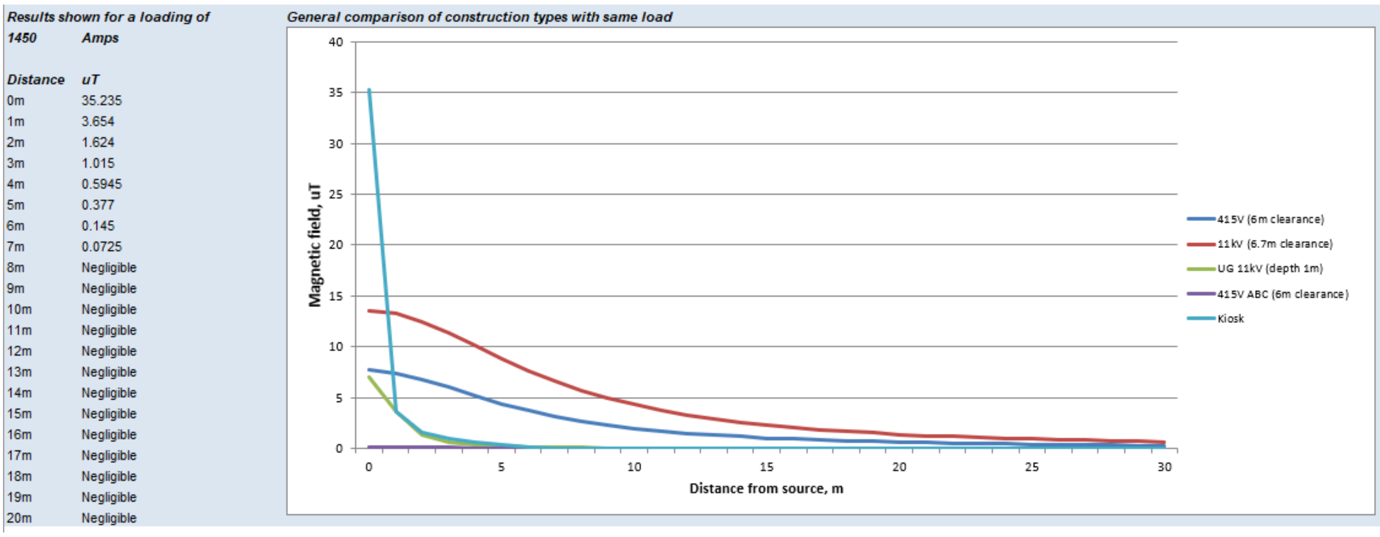


**Figure 4 - Ausgrid's EGN 423: EMF Calculator Results**

The minimum distance to the adjacent spaces and the primary sources are as follows:

| | | |
|---|---|---|
| a. | Substation Transformers | 7m (to building on Ground Level) |
| b. | Substation Low Voltage Switchboard | 6.5m (to building on Ground Level) |
| c. | Consumers Mains | 6.5m (to building on Ground Level) |

The resultant estimated maximum ELF magnetic flux density derived at the adjacent spaces, as derived from the source:

| | | |
|---|---|---|
| a. | Substation Transformers | below 0.7mG (0.07µT) (to building on Ground Level) |
| b. | Substation Low Voltage Switchboard | below 0.7mG (0.07µT) (to building on Ground Level) |
| c. | Consumers Mains | below 1mG (0.1µT) (to building on Ground Level) |

#### 11.3.2.1 SUBMAIN CABLING

Another area where higher levels of ELF magnetic flux density exist is within the electrical submain risers. These risers are generally located in the core sections of the building away from the occupied spaces. Layout of the cables within these risers can greatly affect the ELF magnetic flux density, either positively or negatively. Generally, the submains in the risers closest to the occupied spaces will have a maximum current of 300A and in most cases much less. The estimated maximum ELF magnetic flux density, derived 1m away from the cables, would be less than 25mG (2.5µT).

#### 11.3.2.2 GENERAL

Darug Avenue, which is accessible by the public, will be directly adjacent to the substation transformers and is estimated at 350mG magnetic flux density which is below the 1,000mG threshold limitation for the General Public. Therefore, there is no risk.

As described earlier, simple magnetic fields can be readily and accurately modelled and predicted for relatively simple sources such as a balanced three phase cables. However, there is a significant inaccuracy when attempting to model a multitude of sources such as transformers, switchgear, busbars and cables that are randomly oriented in three dimensional space which may result in addition of fields produced simultaneously by various sources at a particular point in space.

While the estimated ELF magnetic field density values above are the expected maximum values for individual primary sources under full load conditions, which is a limited period occurrence, the mutual addition of the multiple primary sources may produce a resultant ELF magnetic field density higher than those estimated in this report.

With this in mind, it is clear that the ELF magnetic fields generated by the substations will not exceed the 1,000mG (100µT) threshold for General Public exposure even during peak load periods, and hence the risk of continuously exceeding the exposure limitation in the outdoor spaces surrounding the substations is low and unlikely. However, the Padmount Substation for the school site is located in close proximity to the building proposed, which represents the highest levels for ELF magnetic fields generated but is still below 4mG.

The occurrence of the peak current carrying period of the substation will occur during the day, when the school is occupied, for the hottest summer days. School buildings typically exhibit an average loading of 60% peak during the majority of the school day. Note that the ELF magnetic field strength is directly proportional to the electrical current.

The provision of magnetic field mitigation becomes a 'Prudent Avoidance' approach, where it is known that a significant ELF magnetic field density will exist and is likely to be below the ARPANSA guidelines for the threshold limitation for the General Public which may only be exceeded during the building peak load periods.

The installation of local shielding for magnetic field mitigation would not be required, provided that the other field mitigation methods described in Section 11.5 of this report are applied to the design of the building.

It should be noted that design measures for field mitigation may not be controlled after installation and changes may cause the magnetic field density to be higher than the estimated values stated in this report. For example, balanced loading across all three phases is dependent on the electrical services fit out throughout the building and can result in unbalanced loads. It is imperative that the design mitigation measures are maintained for the life of the building.

## 11.5 PRUDENCE AVOIDANCE METHODS

### 11.5.1 SPECIFIC DESIGN MEASURES WITHIN THE SUBSTATION AND MAIN SWITCH ROOM

Within Padmount substations the following design measures have already been incorporated to mitigate the ELF magnetic field effects:

a. The substation and main switchroom have located transformers, LV switchboards, busduct, heavy current cables and other potentially large sources of magnetic field in such a manner as to minimise ELF Magnetic Fields.

b. Use space in proximity to the substation and similar ELF sources that is the space above, below and around its perimeter, for storage, passageways where electronic equipment susceptible to ELF fields will not be located.

The configuration of the Substation Low Voltage switchboard has busbars and a configuration mandated by Endeavour Energy regulations and cannot be modified to reduce the associated ELF magnetic field.

### 11.5.2 SPECIFIC DESIGN MEASURES WITHIN THE SCHOOL PREMISES

The following additional mitigation measures which can be effectively implemented shall also be considered for reduction of the ELF magnetic field effects, if not already incorporated:

a. When designing a system of busbars for the Main Switchboards choose minimum allowable clearances between phases and between phases and neutral bus.

b. Locate all cable trays as far as possible from the substation or switchroom ceiling and walls that separate it from the dedicated office space or other space which is sensitive to ELF magnetic fields.

c. Use metallic encased busway for submains where possible.

d. Where possible use three phase cables in preference to three single phase cables.

e. Use trefoil configuration of phases to minimise the magnetic field.

f. Avoid phase by phase groupings of single core cables in parallel circuits.

g. Avoid any wiring which may result in large physical separation between the phase and neutral conductors.

h. Ensure that the total return current flows in a return cable that shares the same route with the active conductor which conducts the forward current.

i. Aim to distribute all single phase electrical load evenly between three phases of the main supply cables.

j. For larger submains, where practical, use smaller sized multiple conductors per phase rather than a single larger sized conductor.

The application of general ELF mitigation measures will eliminate the requirement for direct ELF shielding in the vicinity of the substation.

# 12 CONCLUDING ASSESSMENT OF ELF MAGNETIC INTERFERENCE MITIGATION

The EME/EMF assessment presented in this report the impact of the proposed Padmount Substation onto the new Mulgoa Rise Public School building development.

There will be no issues with magnetic field mitigation with regard to the Padmount substation, as it is at least 7m away from the proposed building edge and the field strength is less than 4mG at a distance of 5m from the Padmount location.

The proposed Endeavour Energy Padmound Substation at Mulgoa Rise Public School will be compliant to the relevant electromagnetic fields standards which has been confirmed through the evaluation and compliance assessment in this report. The Padmount substation will be located at such a distance inside the boundary fence that the EME risk posed to the general public is deemed negligible. The Padmount Substation design will also be reviewed and approved by Endeavour Energy against the relevant guidelines prior to construction.

# 13 BIBLIOGRAPHY

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# APPENDIX A

## AUSGRID EGN 423 : EMF CALCULATOR

# EGN 423: EMF Calculator

*Version 4.1 - 4 July 2018*

## 11 kV, 415 V power lines and kiosks

**NOTE ON GUIDELINES**

- ARPANSA currently recommends compliance with the ICNIRP 2010 guidelines and these have a public exposure level of 200uT.

**NOTES ON PRUDENT AVOIDANCE**

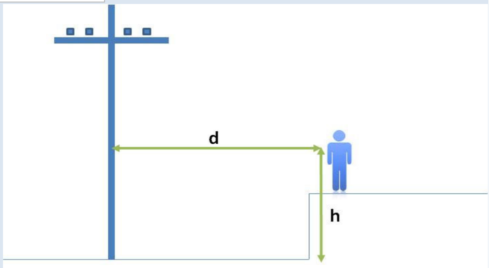
- Ausgrid's policy includes "taking reasonable steps to limit field exposures from new facilities by locating and operating our electrical installations prudently within current health guidelines as established by Australian health authorities"
- Measures to reduce EMF should be used if they are effective, can be implemented at low cost and do not compromise other factors.
- Prudent avoidance does not operate in isolation, but rather is one of many issues that need to be given due consideration.
- There is no scientific basis for the adoption of arbitrary low exposure limits or setbacks.
- Where field levels are consistent with typical background levels (0.1-0.2uTG) then the potential for further reductions is limited.
- Undergrounding for reasons of EMF alone is clearly outside the scope of prudent avoidance due to the additional cost.
- The results below are indicative only and in most cases will be sufficient to demonstrate the application of prudent avoidance.
- Prudent avoidance is about considering ways to reduce exposure, not accurately predicting the fields at any particular point.

**INSTRUCTIONS**

Use the EMF calculator to predict the magnetic field from the installation at the nearest receiver.

STEP 1: Indicate the type of installation.
STEP 2: Indicate the load (current) in Amps that the installation will be carrying. Use the calculation in the 'VA to Amp calcs' worksheet to determine the Amps based on the voltage and VA.
STEP 3: Using the diagram as a guide, determine the perpendicular distance (d) from the installation to the nearest receiver.
STEP 4: Determine the height (h) of the nearest receiver above the ground. ***Not relevant for kiosks.***

| | | | |
|---|---|---|---|
| Source | Kiosk | | STEP 1 |
| Load used for calculation (use LV Amps for kiosk) | 1450 | Amps | STEP 2 |
| Perpendicular distance from power line, **d** | 8m | | STEP 3 |
| Height above ground, **h** *(kiosk results only for 1m)* | 0m | | STEP 4 |
| **Magnetic field at (d, h)** | Negligible | uT | Answer |




***If the above answer is above typical background levels (0.1-0.2uT) then consider prudent avoidance (see notes above)***

***Magnetic field reduction considerations (hover over cell for examples)***

Overhead distribution
Underground distribution
Distribution substations

***Results shown for a loading of***
***1450 Amps***

| ***Distance*** | ***uT*** |
|---|---|
| 0m | 35.235 |
| 1m | 3.654 |
| 2m | 1.624 |
| 3m | 1.015 |
| 4m | 0.5945 |
| 5m | 0.377 |
| 6m | 0.145 |
| 7m | 0.0725 |
| 8m | Negligible |
| 9m | Negligible |
| 10m | Negligible |
| 11m | Negligible |
| 12m | Negligible |
| 13m | Negligible |
| 14m | Negligible |
| 15m | Negligible |
| 16m | Negligible |
| 17m | Negligible |
| 18m | Negligible |
| 19m | Negligible |
| 20m | Negligible |

***General comparison of construction types with same load***