



8 January 2013

Belrose Residential Electromagnetic Field Impact Assessment

1. INTRODUCTION

The proposed residential sub-division on Ralston Avenue in Belrose, west of the existing large electrical substation, is a low density proposal of traditional housing lots, approximately 161 in number.

The 330kV/132kV electrical substation, which is owned and operated by TranGrid, is one of the major transmission substations for provision of electricity supply to greater Sydney.

The proposed residential subdivision is located to the west of the substation ground.

The purpose of this study is: to:

- To assess the level of electromagnetic field emission from the existing substation into the area proposed for residential subdivision
- To compare the results of such assessment with the national and international guidelines and standards for safe human exposure to such fields
- To compare the results of such assessment with limits set out in the Australian standard for interference free operation of electrical and electronic equipment commonly used in residential and commercial premises.

2. MEASUREMENTS OF ELECTROMAGNETIC FIELD

The existing Belrose 330kV/132kV substation is an open air substation and is located between Ralston Avenue to its south and Wyatt Avenue to its north.

It is occupying an area of land approximately 390m long (the longest distance between the eastern and western perimeter fences) and 230 m wide.

The substation is equipped with three 3x1-phase 330kV/132kV oil-filled transformers, two sets of 200 MVar, 330kV capacitor banks and a large number of air insulated switchgear with interconnecting busbars both on its 330kV and 132kV sides.

The incoming supply is provided by two 330kV overhead transmission lines approaching the substation from the north (see Photo #1 below). The electric power is converted by the substation transformers from 330kV to 132kV and then sent out from the substation by three dual circuit 132kV overhead lines (six overhead feeders) and by additional six 132kV underground cables.

The substation contains two separate switchyards, the 330kV switchyard and the 132kV switchyard.

The plan view of the substation with marking of its major electrical plant and incoming and outgoing power lines is shown in Fig.1 below.



Fig.1 Belrose 330kV/132kV TransGrid Substation



Photo #1 *Two 330kV transmission lines and one 132kV sub-transmission line approaching the substation from the north.*

The area proposed for the residential subdivision is shown to the left of the substation.

The letters A to G in Fig.1 are marking the locations where the electromagnetic field was measured either near the substation fence or at various lateral distances away from the substation fence. The later are indicated by white colour arrows.

The electromagnetic field emitted from substations contains two separate components: the electric field and the magnetic field. The electric field is due to the voltage on wires, while the magnetic field is due to the electric current flowing through these wires.

The electric field exists in the space between an energised wire and the grounded object or the ground itself. It also exists in the space between two or more wires energised at different potentials in respect to each other.

The magnetic field is present around an energised wire only if it conducts the electrical current. For example, the electric cord of a table lamp, if plugged into a power point, will be energised at 240 V and hence, there will be an electric field between its active and neutral wires. However there will be no magnetic field around the cord unless the light switch is turned on and the electric current flows through the wires of the cord.

The higher the voltage between the wires the proportionally higher is the electric field in the space between them. The higher is the current in the wires the proportionally higher is the magnetic field produced by these wires.

The power frequency electric and magnetic fields are measured by two different instruments.

The power frequency electric field, which is measured under the power lines and inside and outside the substations, is commonly measured and reported in units of kV/m, while the magnetic field is commonly measured and reported in units of milliGauss (mG) or microTesla (μ T). [$1 \mu\text{T} = 10 \text{ mG}$].

The measurements were carried out on Thursday, the 8th of November, starting from 12:10pm and finishing at 1:30 pm.

The electric field meter that was used in the survey was **Model 111**, Made by the Electric Field Measurement Company in USA with the following technical specification:

Measuring range	10.0 V/m – 100kV/m, (9 ranges)
Resolution	1% of the full scale in each range
Accuracy Error	$\pm 3\%$
Frequency Response	50-500Hz
Calibration Frequency	50Hz

The magnetic field measurements were made using the hand-held **HMI-1 EMF Magnetic Field Survey Meter** with the following technical characteristics:

Number of axes	3
Measuring range	0.1-6000mG
Resolution	0.1mG
Accuracy Error	$\pm(2\% + 1 \text{ digit})$
Frequency Response	50-1000Hz
Calibration Frequency	50Hz
Measurement type	true RMS

The HMI-1 meter is equipped with three orthogonally oriented sensors to measure and display the root-mean-square (r.m.s.) value of the low frequency magnetic flux density in units of *milliGauss (mG)*. The meter measures and displays the r.m.s. value of each of the three vector components from which it calculates and displays on its LCD screen the resultant magnetic flux density.

As per the standard procedure for measurements of 50 Hz electric and magnetic fields for assessment of human exposure all measurements were made at 1m above the ground in outdoor areas or above the floor inside buildings.

It should be noted that the electric field can be well shielded by non-conductive materials including trees, rocks, all type of building materials including glass, etc. As the area around the substation western side is covered by relatively high trees and shrubs, the electric field near the substation perimeter fences was small, rarely exceeding 0.02 kV/m.

The only location where the electric field was relatively high was below the 330kV wires in the space between the substation's northern perimeter fence and the first two 330kV power line support towers (this location is to the right of letter "G" in Fig.1). The highest electric field directly below the outer phase of the 330kV line was 2.1 kV/m and it was 1.16 kV/m measured below the middle phase of the power line.

The results of the electric and magnetic field measurements in different locations near the substation perimeter fence (see Fig.1) are summarised in the table below:

Location	Electric Field (kV/m)	Magnetic Field (mG)	Comments
A	0.01 kV/m	2.1 mG	
B	0.01 kV/m	1.5 mG	
C	0.01 kV/m	1.1 mG	
D	0.02 kV/m	4.7 mG	
E	0.02 kV/m	3.4 mG	
F	0.6 kV/m	6.0 mG	Near 330kV line

The ground in the westerly direction from the substation, especially along its northern halve, was rising up at approximately 10°-12° angle and it was covered by vegetation.

Measurements of the electric field in all locations near the western perimeter fence of the substation, which are well covered by trees and toll shrubs, resulted in very low readings that are similar to the readings one can made in residential streets of Sydney below high voltage (11kV) distribution lines.

On the other hand the magnetic field is not affected by non-metallic objects, such as trees and shrubs and all non-metallic building materials.

Since the proposed residential subdivision is located to the west of the substation western perimeter fence, it is interesting to ascertain the rate of the EMF reduction with distance away from the substation fence.

The results of the magnetic field measurements made at 1m intervals in the directions shown in Fig.1 by arrows (dashed lines) and marked by letters D, F and G are presented in graphical form as profiles in Fig.2 below.

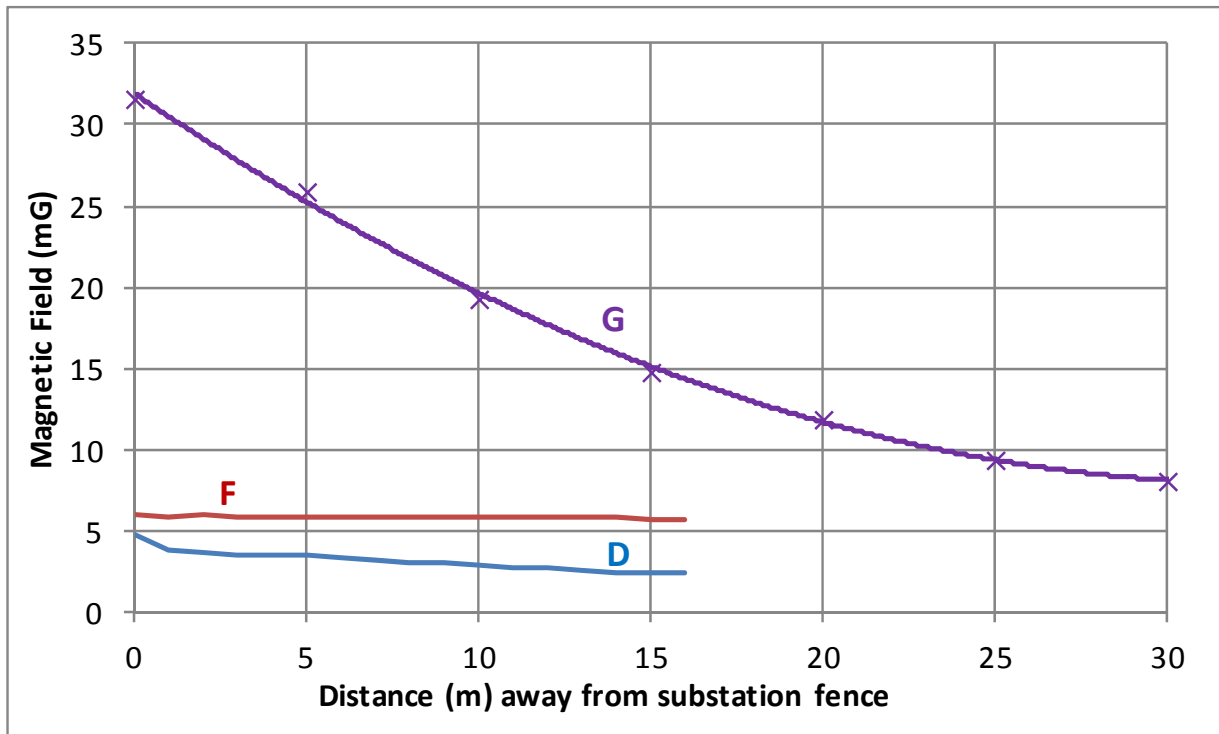


Fig.2 Magnetic field profiles measured at 1m above ground

Looking at the graphs in Fig.2 above the following should be noted:

- The line of the measurements in the direction of arrow “F” in Fig.1 is parallel to the west-most incoming 330 kV transmission line and is approximately 37m away, in the horizontal plane, from its closest conductor. Since the EMF profile along line F is flat it means that the main source of that EMF is the transmission line and not the substation. This was somewhat puzzling as it was expected that the main contributing sources of EMF in this area would be the air-core reactors of the two 200 MVAR 330 kV capacitor banks. However, the measurements clearly demonstrated that the reactors were not in service at the time of our EMF measurements. This was confirmed by TransGrid, the owner and operator of this substation
- The line of the measure in the direction of arrow “G” in Fig.1 is running across the incoming 330kV transmission lines. The zero point on the distance axis for this EMF profile was located directly below the west-most phase conductors of the transmission line located closer to the proposed subdivision.
- the EMF at lateral distances away from the substation perimeter fence in the direction towards the proposed residential subdivision is relatively small considering the size of the substation and the current carrying capacity of its equipment. The EMF readings taken near this substation were not higher than if the readings would be made in an average suburban street with houses supplied by electricity from an overhead distribution line.

Several comments should be made about the two capacitor bank installations located in the north-western corner of the substation (see Fig.1).

2.1 EMF from Two 200 MVAR 330kV Capacitor Banks

There are two, 3-phase 200MVAR 330kV Capacitor Bank installations and associated equipment located in the north-western corner of the substation ground (see Photo #2 below). These are de-tuned to 225Hz Capacitor Bank installations each consisting of the following equipment::

- Three sets of capacitors interconnected to form one 3-phase 200MVAR Capacitor Bank.
- Three single phase tapped de-tuned reactors. Each approximately 2.2m in diameter and 3m high erected on insulators at approximately 0.5m above the ground.
- Three single phase capacitor unbalanced current transformers.
- Three single phase surge arresters.
- High voltage connections.

The Capacitor Bank installation is separated from the rest of the substation by high fence.



Photo #2 **200 MVAR, 330kV Capacitor Bank installation with air-core reactors (gray colour cylinders) shown on the left and the capacitor stacks in front of the picture**

Based on the TranGrid advice, the two Capacitor Banks are rarely switched on and the two units are almost newer in operation concurrently. Presently and based on the long-term trend for the electricity demand within the area supplied by this substation, it is unlikely that the capacitor banks will be operating for more than few days each year and only during the peak of the electricity demand within the greater Sydney.

As the capacitor banks are rarely in service and, hence, the EMF emission from them cannot be easily measured while on site, it was necessary to model and calculate the magnetic field emission from these units and their potential impact onto the proposed residential subdivision.

Our EMF modelling and calculations revealed that if one out of two 200 MVAR capacitor banks is in service, then the highest EMF outside the substation perimeter fence at the location marked by letter “F” in Fig.1 would be in the order of 130 mG reducing to 25 mG at a distance of 5m away from the fence, while at the location marked by letter “E” in Fig.1 the

EMF near the substation fence would be 45 mG reducing to 10 mG at a distance of 5m away from the fence.

3. EMF AND HEALTH

3.1 IRPA Guidelines

In 1989, the International Radiation Protection Association (IRPA) approved interim EMF human exposure guidelines prepared by its International Non-Ionising Radiation Committee. In the same year these guidelines were adopted as the interim guidelines by the National Health and Medical Research Council of Australia (NHMRC). The guidelines recommended the following limits:

Exposure	Magnetic Flux Density
<u>Occupational</u> Whole working day Short term For limbs	0.5 mT (=5,000 mG) 5.0 mT (= 50,000 mG) 25.0 mT (=250,000 mG)
<u>General public</u> Up to 24 hours per day Few hours per day	0.1 mT (=1,000 mG) 1.0 mT (=10,000 mG)

Notes:

- IRPA guidelines were developed "*primarily on established or predicted health effects produced by currents induced in the body by external [EMFs]*".
- The guidelines were based on limiting current densities induced in the head and trunk by continuous exposure to 50/60 Hz electric and magnetic field to no more than about 10 mA/m².
- Immediately observable minor biological effects have been reported in human studies in respect to induced current densities between 1 and 10 mA/m²
- The occupationally exposed population consists of adults exposed under controlled conditions in the course of their duties, who should be trained to be aware of potential risks and to take appropriate precautions.

The NHMRC guidelines state that: "*The occupationally exposed population consists of adults exposed under controlled conditions in the course of their duties, who should be trained to be aware of potential risks and to take appropriate precautions*". Based on this definition, the occupational exposure limits should only be applicable to skilled and trained workers who are directly involved with operation and maintenance of EMF emitting equipment and installations and who know how to limit the severity and duration of exposure to the power frequency electric and magnetic fields.

Concerns about inadequacies of IRPA guidelines were summarised in Gibbs Report in 1991:

Since the guidelines proceed on the basis that "adverse human health effects from exposure to ELF electric fields at strengths normally encountered in the environment or the workplace have not been established", it is apparent that they are not intended to provide protection against any adverse health effect that may be caused by such exposure, and they would not do so. The levels of exposure recommended are many times greater than the levels at which it has been suggested that the fields may create a risk.

3.2 ICNIRP Guidelines

In 2010 the International Commission on Non-Ionising Radiation Protection (ICNIRP) published the new "Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)". The new document replaced the last version of the guidelines previously published in 1998.

The principal limitation of the guidelines is stated in the "BASIS FOR LIMITING EXPOSURE" section as follows:

Induction of cancer from long-term EMF exposure was not considered to be established, and so these guidelines are based on short-term immediate health effects such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conducting objects, and elevated tissue temperatures resulting from absorption of energy during exposure to EMF.

The guidelines state that:

Epidemiological studies have found that everyday chronic low intensity power frequency magnetic field exposure is associated with an increased risk of childhood leukaemia. However, laboratory studies have not supported this association and a causal relationship between magnetic fields and childhood leukaemia or any other long term effect has not been established. The absence of established causality is the reason why the epidemiological results have not been addressed in the basic restrictions. ICNIRP is well aware that these epidemiological results have triggered concern within the population in many countries. It is ICNIRP's view that this concern is best addressed within the national risk management framework.

The table below contains the ICNIRP reference levels for occupational and general public exposure to time-varying electric and magnetic fields.

Frequency range	E-field strength (kV/m)	Magnetic flux density (T)
Occupational exposure		
1 Hz - 8 Hz	20	0.2/f
8 Hz - 25 Hz	20	$2.5 \times 10^{-2}/f$
25 Hz - 300 Hz	$5 \times 10^2/f$	1×10^{-3}
300 Hz - 3 kHz	$5 \times 10^2/f$	0.3/f
3 kHz – 100 MHz	1.7×10^{-1}	1×10^{-4}
General public exposure		
1 Hz - 8 Hz	5	$4 \times 10^{-2}/f^2$
8 Hz - 25 Hz	5	$5 \times 10^{-3}/f$
25 Hz – 50 Hz	5	2×10^{-4}
50 Hz - 400 kHz	$2.5 \times 10^2 /f$	2×10^{-4}
400 Hz - 3 kHz	$2.5 \times 10^2 /f$	$5 \times 10^{-2}/f$
3 kHz – 10 MHz	8.3×10^2	2.7×10^{-5}

Notes: a) $1 \mu\text{T} = 10 \text{ mG}$
b) f - is the frequency of EMF in units given in the first column of the table.

From the ICNIRP table the maximum EMF exposure limit at the power frequency of 50Hz is $200 \mu\text{T}$ or 2000 mG.

3.3 Other References

On the 18 December 1995 the Senate Economics References Committee released its report to the Senate on the proposed Eastlink transmission line project linking the electricity grids of New South Wales and Queensland. The committee's findings on the electromagnetic fields health effects are similar to those of the 1991 Gibbs Report. The Committee's Report states:

"In the light of... conflicting evidence, and because it is not possible scientifically to prove a negative, the Committee is unable to totally dismiss that there may be adverse (health) effect. Similarly the Committee is unable to conclude that a definite link between power lines and adverse effects on human health exists and thus that any new policy recommendations need to be made. However, the Committee is able to conclude that simply the fear of detrimental health effects, whether real or imaginary, is in itself having an impact on lives of some individuals. The Committee

takes a similar stand to that of Gibbs Report. The Committee agrees that, as a minimum policy or until evidence suggests otherwise, the concept of 'prudent avoidance' should continue to be practised by government and power authorities..."

There have been a number of reported cases around the world where power transmission and distribution companies relocated or modified their existing electrical installations on the basis of perceived health risk associated with exposure to the power frequency magnetic fields, even though the levels were much smaller than the recommended by the NHMRC and ICNIRP safe exposure limits. Notwithstanding this the level at which such relocations or modifications are warranted is not established and consideration should be given to the net potential benefit that may be gained from such actions.

Over the last few years there have been many magnetic field surveys conducted within commercial and residential buildings in Australia and overseas. As a result of these surveys it can be concluded that the background level of magnetic field in a typical office or home environments is generally within the range of 0.5 – 3 mG. The EMF levels that can be measured along the streets in residential areas can typically range from 0.5 mG to 18 mG.

Some household electrical appliances can produce the EMF in the range of 5 mG to 70 mG. For example, an average electric hair dryer can typically emit the EMF of 25 mG, while an electric stove may emit the field in the range of 2 mG to 30 mG and the personal desk-top computer can emit the EMF in the range of 2 mG to 20 mG.

There is no irrefutable scientific evidence of the adverse health effect from the power frequency magnetic fields. Nor there is evidence to categorically dismiss its adverse health effect. It was not yet established, if a cumulative effect of relatively low field strengths may have some biological effect. It is also not known if even an intermittent exposure to the EMF may cause an adverse health effect and should be avoided.

In May 1999, the Director of the US National Institute of Environmental Health Sciences (NIEHS) tabled a report to the US Congress on "Health Effects from Exposure to Power-line Frequency Electric and Magnetic Fields".

A conclusion of the NIEHS report was:

"that ELF-EMF exposure cannot be recognised at this time as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In my opinion, the conclusion of this report is insufficient to warrant aggressive regulatory concerns. However, because everyone in the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is warranted, such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposure.

"While the support from individual studies is weak, the epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of a small, increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia".

"mechanistic studies and the animal toxicology literature, failed to demonstrate any consistent pattern across studies although sporadic findings of biological effects have been recorded. No indication of increased leukemias in experimental animals has been observed."

In February 1, 2000, the Swiss Bundesrat (Upper House) has enacted an "Ordinance Concerning Protection from Non-Ionising Radiation (NISV)" which sets a 10 mG exposure limit for power lines and other exposure sources affecting "sensitive use locations", including any room in a building which is "regularly occupied for significant period of time" and children's playgrounds.

An Explanatory Report issued by the Swiss Federal Office for the Environment, Forestry and Agriculture explains that these "precautionary" measures are needed because biological effects have been documented from EMF exposures below the ICNIRP limits, and because there is uncertainty about the possible harmful consequences of lower level exposures. The Report specifically points to the NIEHS Working Group recommendation that power frequency EMF be considered as "possible carcinogenic."

Early in 2001 the Advisory Group on Non-Ionising Radiation (AGNIR) to the UK National Radiological Protection Board has published a report on power frequency electromagnetic fields and the risk of cancer.

In assessing the results of all Residential Exposure studies conducted around the world the report states that:

"... relatively heavy average exposure of 0.4 μ T (4 mG) or more are associated with doubling of the risk of leukaemia in children under 15 years of age. The evidence, however, is not conclusive."

The main conclusion of the report is:

"Laboratory experiments have provided no good evidence that extremely low frequency electromagnetic fields are capable of producing cancer, nor do human epidemiological studies suggest that they cause cancer in general. There is, however, some epidemiological evidence that prolonged exposure to higher levels of power frequency magnetic fields is associated with a small risk of leukaemia in children. In practice, such levels of exposure are seldom encountered by the general public in the UK. 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 epidemiological evidence is currently not strong enough to justify a firm conclusion that such fields cause leukaemia in children. Unless, however, further research indicates that the finding is due to chance or some currently unrecognised artefact, the possibility remains that intense and prolonged exposure to magnetic fields can increase the risk of leukaemia in children."

In 2002 the International Agency for Research on Cancer (IARC) classified the power frequency magnetic fields as a *possible carcinogen*. [Ref.: (IARC), I.A.f.R.o.C. (2002). *Non-ionizing radiation, Part 1: static and extremely low-frequency (ELF) electric and magnetic fields*. Vol. 80. IARC Monogr Eval Carcinog Risks Hum.]

A recently conducted in the USA study of the effect of magnetic fields on the risk of miscarriage resulted in the following conclusion *"...prenatal maximum magnetic field exposure above a certain level (possibly around 16 mG) may be associated with miscarriage risk. The association was stronger for early miscarriages (<10 weeks of gestation) and among "susceptible" women with multiple prior foetal losses or subfertility."* [Re: Epidemiology 2002 January;13(1):9-20]

In 2003 The Italian President of the Council of Ministers adopted a law which sets the following EMF exposure limits for general population [Ref.: "DECREE OF THE PRESIDENT OF THE COUNCIL OF MINISTERS 8 JULY 2003 - Establishment of exposure limits, attention values, and quality goals to protect the population against power frequency (50 Hz) electric and magnetic fields generated by power lines"]:

Art. 3 Exposure limits and attention values

1. In case of exposure to electric and magnetic fields generated by power lines, the following exposure limits must not be exceeded: 100 μ T (1000 mG) for the magnetic flux density and 5 kV/m for the electric field, both expressed as rms values.

2. *As a cautionary measure to protect against any possible long-term effects that might be related to power frequency (50 Hz) magnetic fields, an attention value of 10 μ T (100 mG) is adopted in children's playgrounds, residential dwellings, school premises, and in areas where people are staying for 4 hours or more per day. The attention value is the median of values recorded over 24 hours, under normal operational conditions.*

Art. 4 Quality goals

1. *In designing new power lines in the neighbourhood of children's playgrounds, residential dwellings, school premises, and in areas where people are staying for 4 hours or more per day, as well as in planning developments in the proximity of existing electric power lines and installations, including the categories mentioned above, a quality goal of 3 μ T (30 mG) is adopted for the purpose of the progressively minimising exposures to electric and magnetic fields generated by 50-Hz power lines. The quality goal is the median of values recorded over 24 hours, under normal operational conditions.*

In June 2005 a paper on one epidemiological study published in the British Medical Journal and entitled "*Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study*" (authors: Gerald Draper, Tim Vincent, Mary E Kroll, John Swanson) reported an elevated risk of leukaemia in children living in proximity to high voltage power lines. The main results of the study are: Compared with those who lived > 600 m from a line at birth, children who lived within 200 m had a relative risk of leukaemia of 1.69 (95% confidence interval 1.13 to 2.53); those born between 200 and 600 m had a relative risk of 1.23 (1.02 to 1.49). There was a significant ($P < 0.01$) trend in risk in relation to the reciprocal of distance from the line. No excess risk in relation to proximity to lines was found for other childhood cancers.

The results of another epidemiological study carried out in Japan and published in February 2006 in the International Journal of Cancer under the title "*Childhood leukemia and magnetic fields in Japan: A case-control study of childhood leukemia and residential power-frequency magnetic fields in Japan*", provided additional evidence that the exposure to the time-weighted average power frequency magnetic field above 0.4 μ T (4 mG) was associated with a higher risk of childhood leukemia. The study included children whose mothers were exposed to high magnetic fields in residential settings while being pregnant. The outcome of this study is in agreement with conclusion of an earlier study carried out in Canada and reported in scientific literature in 2003 (Infante-Rivard C, Deadman JE. "Maternal occupational exposure to extremely low frequency magnetic fields during pregnancy and childhood leukemia.", *Epidemiology* 2003; 14: 437–441). This study concluded that:

Occupational exposure of mothers to high levels of magnetic fields during pregnancy has been associated with childhood leukaemia.

In February 2006 an Independent Advisory Group on Non-Ionising Radiation produced a report for the National Radiation Protection Board of UK under the title of: "*Power Frequency Electromagnetic Fields, Melatonin and the Risk of Breast Cancer*". The following was stated in the summary section of the report:

Investigations using cells, animals and humans have not given consistent or convincing evidence that EMF exposure affects melatonin production or action. However, there are deficiencies in the existing research, which leave open the possibility of an effect.

There is stronger evidence that melatonin can inhibit the growth of cancer cells in laboratory culture and in animals. Data on the possible relation of melatonin levels to risk of subsequent breast cancer in humans are limited and inconclusive. Studies investigating the effect of light exposure (which affects melatonin) on breast cancer risk in humans have given some evidence for an association, but left it unclear whether, if there is an association, it is causal in nature.

There is no consistent evidence, from research using cells, animals and humans, that EMF exposure is a cause of breast cancer, nor has any mechanism for such an association been demonstrated.

In 2002 the Planning and Environment Court of Queensland has imposed a magnetic field exposure limit of 0.4 μ T (4 mG) on a new electricity substation development at Tanah Merah. This decision follows an appeal by the power company Energex Ltd, against an earlier decision of the court. The case was officially closed on the 18th March 2002. The judgement was based on the findings of the NRPB AGNIR Report of April 2001 that exposure to magnetic fields above 0.4 μ T is associated with a doubling of the risk of childhood leukaemia. The court accepted that while there was no absolute proof that exposure to magnetic fields caused an increased risk of childhood leukaemia, nevertheless the policy of "prudent avoidance" should apply.

Other possible adverse health effect of the EMF is that it may adversely affect medical devices such as metallic prosthesis, cardiac pacemakers and defibrillators, neurostimulators, cochlear implants and other bio-electronic devices and implants.

The magnetic field measurements conducted in the case where a person was fitted with a neurostimulator showed some effect at the EMF level above 0.05 μ T (5 mG) and that it becomes painful above 0.5 μ T (50 mG).

A common practice in the Australian construction industry is to limit the maximum EMF exposure to 10mG or less in all area that can be regularly occupied by people for a significant period of time. This practice was first emerged in late 1980s on the basis of our finding that such EMF is below the level of interference with 14" and 15" computer monitors fitted with Cathode Ray Tubes.

We've also been able to equate the previous practice of limiting the EMF to 10 mG in all commercial buildings to the new requirements of containing the EMF within the time-weighted average limit of 4 mG.

If a child in a childcare centre or an expecting mother at work is exposed to 10 mG during 8 hours a day, then their time weighted average exposure level (TWA) over the entire week is less than 4 mG. This is calculated on the basis that statistically the average EMF exposure level for the majority of urbane population is less than 2 mG.

$$EMF_{TWA} = \frac{(10mG \times 8hours + 2mG \times 16hours) \times 5days + 2mG \times 24hours \times 2days}{24hours \times 7days} = 3.9mG$$

4. EMF AND INTERFERENCE

4.1 Interference with Electronic Devices

Electromagnetic immunity levels for electronic devices used in residential, commercial and light industry are specified in the Australian Standard AS/NZS 4251.1 "Electromagnetic Compatibility-Generic Immunity Standard", Part 1: Residential, commercial and light industry. 1:1994. The standard is technically equivalent to the European standard EN 50082-1 published in August 1997.

The immunity limits specified in the standards for the low frequency EMF are summarised in the table below.

Device type	Residential / commercial environment
CRT displays	1.25 μ T (12.5 mG)
Other equipment	3.75 μ T (37.5 mG)

The cathode-ray-tube (CRT) based computer monitors which are commonly used in homes and offices are susceptible to EMF interference. The threshold level of sensitivity to the EMF for most 14" and 15" CRT based computer monitors is 10 mG. The monitors with 17" screens can be affected by the magnetic field less than 7 mG, while the monitors with 20"-21" screens can be affected by the magnetic fields less than 5mG.

The jittery screen of the EMF affected computer monitors could also be a source of adverse health effect through causing eye strain and headache for computer users.

4.2 Transmitted Voltages to Telecommunication Network

Voltages transmitted to a Telecommunications Network from external sources, either by induction or conduction, should not to exceed the limits for Telecommunications Network Voltages (TNV), as specified in AS/NZS 60950.1

4.3 Power Frequency Transients

Transient EMFs can be generated during a short circuit condition. Such EMFs can cause damage to sensitive electronic and bio-electronic devices, interfere with data communication lines and corrupt magnetic data storage media.

Currently there is no Australian standard that sets the electromagnetic field emission limits for interference with electronics and communication devices and equipment due to the transient voltage and current surges in the low voltage power supply and reticulation systems.

5. CONCLUSIONS AND RECOMMENDATIONS

As a result of our physical measurements of the power frequency electric and magnetic field and also our computer simulated modelling and calculations of the magnetic field emission from the air-core reactors of the two 200 MVAR capacitor banks near the western side of the 330kV/123kV substation the following conclusions can be made:

- a) While the both the capacitor banks are out of service (this is the most frequent condition of the substation normal operation) the power frequency electric field in all locations along the substation fence from point "A" to point "E" in Fig.1 is either equal or less than 0.02 kV/m. This is 250 times less than what is considered to be acceptable for the safe human exposure. Due to the equipment layout within this part of the substation ground it is not envisaged that during the service operation of either one of the two capacitor banks the electric field outside the western fence of the substation would increase by more than 5 times above the measured values. In any case the power frequency electric field is effectively shielded by all building materials and trees.
- b) While the both the capacitor banks are out of service (this is the most frequent condition of the substation normal operation) the power frequency magnetic field in all locations along the substation fence from point "A" to point "E" in Fig.1 is ranging between 1.1 mG and 6 mG. This is at least 330 times less than what is considered to be acceptable for the intermittent human exposure. The effect of the long-term exposure to the power frequency magnetic field is not clearly defined and as such the safe exposure limits are not specified. However, the measured magnetic fields in this part of the ground is not higher than that which can be measured in many residential suburban street of Sydney due to the present of the low voltage power distribution lines.

- c) If the 200KVAR Capacitor Bank closest to the north-western corner of the substation ground is in service, then the power frequency magnetic field within the distance of 5m away from the western perimeter fence of the substation would be equal or greater than 10 mG. However, due to very infrequent and short duration operation of the capacitor banks for now and in the foreseeable future the exposure to such elevated magnetic field for the future residents within the proposed subdivision is only intermittent.
- d) The major sources of the EMF affecting the area to the north-west of the substation ground are the two 330kV overhead power lines that supplying the primary electric power to the substation. However, as the closest eastern boundary of the proposed residential subdivision is at least 30m away, in the horizontal plane, from the nearest phase of the nearest 330kV line, the highest measured magnetic field there is less than 10mG.
- e) It should be noted that in future years, due to the increase in electricity demand and consumption within the greater Sydney area, the power frequency magnetic field emitted by the substation would be higher. However, as the magnetic field is directly proportional to the load current, it can be clearly stated here that even if the substation load is doubled in the foreseeable future the magnetic field emitted by it would also double, but it would still be much below the acceptable safe exposure limit.

On the basis of the above conclusions we recommend that the eastern boundary of the proposed residential subdivision is located not closer than 5m distance from the substation western perimeter fence and not closer to the 35m distance from the western-most phase conductors of the 330kV lines approaching the substation from the north.