energy networks association

ENERGY NETWORKS ASSOCIATION

Electricity Industry EMF Measurement Protocol for High Field Areas

Contents

1 Introduction

1.1 Background

This protocol was prepared by the esaa EMF Advisory Committee in June 2004. When the responsibility for the EMF issue was transferred to the Energy Networks Association (ENA) in 2006, this protocol was also transferred. The protocol is reviewed periodically to ensure relevance and is currently in use within the industry.

The protocol will assist businesses in the electricity supply industry to:

- identify possible areas of high electric and magnetic fields (EMF) associated with their business operations; and
- measure high electric and magnetic fields in these work areas or locations.

Measurements made can then be used to assess compliance with present, recommended EMF exposure limits and any future EMF standard that may be adopted. This will result in improved protection of the health and safety of employees and the public.

The current limits of EMF exposure applicable to Australia are those in the National Health and Medical Research Council (NHMRC) Radiation Health Series publication No. 30 "Interim guidelines on limits of exposure to 50/60Hz electric and magnetic Fields (1989)" which is available from the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) website (www.arpansa.gov.au). These limits of exposure are generally not regulated or enforceable but constitute good practice and are generally followed by the electricity supply industry. However, they are called up by regulations in some jurisdictions, e.g. Victoria, where compliance is required.

A more recent exposure standard by the International Commission on Non-Ionising Radiation Protection (ICNIRP) of 1998 has been adopted for use in some overseas countries, particularly those of the European Union. In 2002, the Institute of Electrical and Electronics Engineers (IEEE) of the USA produced their first EMF (0 to 3 kHz) standard C95.6. It uses a different approach to the ICNIRP standard in deriving exposure limits and it is available from the IEEE. It has not yet been adopted in any country as a national standard.

This protocol covers generation (thermal and hydro) and network (transmission and distribution) businesses' areas of possible high electric and magnetic fields and considers employee and public exposures.

For the protocol, magnetic flux density is described in units of milligauss (mG rms) and electric field strength is in units of kV/metre (rms). (Note that 1mG equals 0.1 microtesla in SI units.) It should be noted that magnetic flux density is dependent on the current flowing and varies continuously as the load varies on any piece of electrical apparatus. However the electric field, being voltage dependent, is relatively stable over time.

Note that EMF measurements in residences are described in the ENA "Protocol for Measurement of Residential Electric and Magnetic Fields" available on the ENA web site www.ena.asn.au/emf.

1.2 High Field Areas

For this document, high field areas are considered to be those that may be comparable to or exceed the NHMRC or ICNIRP recommended limits of exposure at power frequencies in Tables 1 and 2.

Table 1. NHMRC (1989) recommended EMF limits of exposure

	Electric Field Strength (kV/m)	Magnetic Flux Density (mG)
Occupational		
• Whole working day	10	5000
• Short term	30	50000
• For limbs	-	250000
General Public		
• Up to 24h/day	5	1000
• Few hours/day	10	10000

Table 2. ICNIRP (1998) recommended EMF limits of exposure

	Electric Field Strength (kV/m)	Magnetic Flux Density (mG)
Occupational		
• Whole working day	10	5000
General Public		
• Up to 24h/day	5	1000

Note: short-term or instantaneous values.

Table 3 shows the corresponding limits of exposure for the IEEE standard for comparison.

Table 3. IEEE (2002) recommended EMF limits of exposure

	Electric Field Strength (kV/m)	Magnetic Flux Density (mG)
Occupational • Whole working day • For limbs	 20 -	 27100 758000
General Public • Up to 24h/day • Extremities	 5* -	 9040 758000

* Except 10 in power line right of way (easement)

Occupational limits of exposure apply to employees and contractors of the business who, by their training or experience, would be aware of possible risks associated with EMF from various sources.
General public limits of exposure apply to all others, such as employees of the business, visitors, etc., who from their backgrounds would be unaware of possible risks associated with EMF from various sources.

The protocol provides guidance on
- high field areas of possible interest;
- suggested measurement procedures; and
- some samples of measurement approaches.

2 High Fields Areas - Generation Businesses

For generating businesses, high magnetic flux density areas are more common than high electric field strength areas. When considering areas to be assessed in an EMF survey, exposure areas related to employees and the public should be considered separately. Normally, the public would only have close access to plant items in association with business staff or tour guides.

2.1 Thermal generation

Magnetic flux density assessment

As magnetic flux density is related to the current flowing in conductors, areas and items of plant that have large current flows (above 250A) should be considered. As a guide, areas within 10 metres of the current flow should be considered. Previously identified areas and items of plant are:

a) Busbars between the generator, step up transformers and auxiliaries transformers
The output of large generators can be several thousand amperes and thus high magnetic fields are common. Many power stations use phase isolated busbars (PIB) to connect the generator to step up transformers (see Figure 1). Areas around the PIB should be assessed for high magnetic fields including walkways, between the individual busbars, access ladders over the PIB and PIB connections to the step up and auxiliary transformers.

It is noted that access is sometimes permitted to the top of step up and auxiliary transformers and thus magnetic field assessment should be considered for these locations.

The generator star point and, if applicable, the main generator circuit breaker should be also assessed.

Magnetic field measurements should be carried out when the generator is at maximum load and at full reactive capability to ensure that full load currents are flowing through the busbars. For generators of several thousand ampere output, magnetic fields over 5000mG may be expected.

Figure 1. Busbars between a generator, step up transformers and auxiliaries transformers

b) Cabling between large transformers and switchboards:
As the cabling between large transformers (secondary side) and switchboards can carry large currents, the route of the connecting cable should be assessed (see Figure 2). Areas include:

- secondary side terminal boxes of the transformers;
- cable tunnels/trays accessible by staff; and
- switchboard's incoming cable cubicles.

Magnetic field measurements should be carried out when the transformer/switchboard is fully loaded.

Figure 2. Secondary side of large transformer should be assessed

c) Cabling between switchboards and large motors or loads

As the cabling between switchboards and large motors or loads can carry large currents, the route of the connecting cable should be assessed. Areas include:

- area surrounding switchboard circuit breaker;
- cable tunnels/trays accessible by staff; and
- motor (or load's) terminal box (see Figure 3).

Magnetic field measurements should be carried out when the motor (or load) is at full current capacity.

d) Miscellaneous areas

Other areas to be considered are:

- around the generator's operating and mezzanine floor area;
- guided tour routes;
- cable pits, trenches and tunnels; and
- control room, workshops, office areas and often used access ways (e.g. tunnels) that may be in close proximity to large current flows.

Figure 3. Cabling between switchboard and large motor.

Electric Field Strength assessment:

As noted above, there are fewer areas of high electric field strength in the generating businesses.

As electric field strength is related to the operating voltage of the equipment and the separation between source and measuring point, areas and items of plant that have high voltages and close approach distances should be considered. Screening can effectively mitigate high electric fields and the vast majority of equipment in the generating facility is well screened. As a guide, areas with no screening, high voltages (3.3kV or above) and short approach distances (a few metres or less) should be considered. The only previously identified area of high electric field strength in generating businesses is in areas which have overhead lines such as the generator (step-up) transformer and switchyard areas (see Figure 4). These areas are covered in more detail in section 3.

2.2 Hydro-electric generation

The high field areas for a hydro-electric generation business will be similar to the comparable areas in a thermal generation business.

Special consideration should be given to *underground areas, such as cable pits, trenches and tunnels*, with high voltage cables installed. These may cause employees or the general public to be in close proximity to cables carrying heavy currents and thus may result in high magnetic or electric fields.

Figure 4. Overhead lines in a generator (step-up) transformer and switchyard area.

3 High Field Areas - Transmission Businesses

Magnetic field is the primary issue, but electric field should also be recorded particularly in areas where persons may come into relatively close proximity to high voltage facilities - such as busbars in the case of substations and low conductors (normally mid span) of transmission lines.

When considering areas to be included in the survey, exposures in two categories, occupational and the general public, need to be considered separately.

- Occupational exposure assessment includes areas visited by workers (employees and contractors) for maintenance, inspections, etc., and may require personal monitoring for those carrying out tasks in high field environments.
- General public exposure assessment includes areas accessible to the general public. This would not normally include substations, which are a controlled environment and are only accessible to authorised persons or visitors under supervision of staff. It may apply to exposure in areas associated with transmission lines.

The following is not an exhaustive list, but offers guidance and suggestions.

Occupational Exposure - Substations

Examples of areas to be surveyed (limited duration occupancy) are:

- busbars;
- HV cables;
- around switchgear including operating or inspection positions;
- transformer bays - around cables and switchgear, etc.;
- cable pits, trenches and tunnels;
- under and adjacent to HV landing span; and
- high current equipment, such as static var compensators (SVC).

Examples of areas to be tested (extended duration occupancy) are:

- switchboards;
- electrical switchgear rooms;
- control rooms;
- workshops; and
- offices and workstations.

Figure 5. Transformer bay in transmission substation

Note that when live substation maintenance techniques are in use, some workers will be in high field environments (see comments below for lines)

Occupational Exposure - Lines

Live-line work requires an assessment of work methods and procedures to identify the tasks and areas of closest proximity to the energised conductors.

General Public Exposure - Substations

Normally the public do not have access to transmission substations; access would be limited to areas immediately outside the security fence. Such areas close to major plants items or low lines may need to be assessed.

General Public Exposure - Lines

Magnetic field levels in the vicinity of overhead transmission lines are unlikely to be close to current guideline limits; a desktop review of selected spans may be useful to confirm this. Magnetic field levels in the vicinity of underground transmission lines should be reviewed to ensure that fields at ground level do not approach current guideline limits.

Electric fields may, however, be quite substantial (5kV/m or greater) in some areas where the pubic has access, particularly under spans of 330 and 500kV transmission lines. Line profiles, mapping and aerial photography may be used to identify these spans. Underground cables will not produce electric fields at the surface.

4 High Field Areas - Distribution Businesses

Magnetic fields are the primary issue, but electric fields should also be recorded, particularly in areas where persons may come into relatively close proximity to medium voltage facilities - such as busbars in the case of substations and low conductors (normally midspan) of distribution and/or sub transmission lines.

When considering areas to be included in the survey, exposures in two categories, occupational and the general public, need to be considered separately.

- <u>Occupational exposure</u> assessment includes areas visited by workers (employees and contractors) for maintenance, inspections, etc., and may require personal monitoring for those carrying out tasks in high field environments.
- <u>General public exposure</u> assessment includes areas accessible to the general public. This would not normally include substations, which are a controlled environment and are only accessible to authorised persons or visitors under supervision of staff. It may include areas immediately adjacent to distribution substations, especially areas near low voltage switchboards and/or cabling.

The following is not an exhaustive list, but offers guidance and suggestions

Occupational Exposure - Substations

<u>Examples of areas to be surveyed (limited duration occupancy) are:</u>

- busbars;
- HV cables;
- around switchgear including operating or inspection positions;
- cable pits, trenches and tunnels;
- transformer bays - around cables and switchgear, etc.; and
- under and adjacent to HV landing span.

<u>Examples of areas to be tested (extended duration occupancy) are:</u>

- switchboards;
- electrical switchgear rooms;
- control rooms;
- workshops; and
- offices and workstations.

Note that with the introduction of live substation maintenance techniques, some workers will be in high field environments (see comments below for lines).

Occupational Exposure - Lines

<u>Live-line work</u> requires an assessment of work methods and procedures to identify the tasks and areas of closest proximity to the energised conductors.

General Public Exposure - Substations

Normally the public does not have access to zone substations, and access would be limited to areas immediately outside the security fence or building. Such areas close to major plants items or low lines may need to be assessed.

For substations in CBD areas and high-rise buildings in particular, areas immediately adjacent to distribution substations, especially areas near low voltage switchboards and/or cabling may need to be assessed.

General Public Exposure - Lines

Magnetic field levels in the vicinity of distribution and sub-transmission lines, whether these are overhead or underground, are unlikely to be close to guideline limits.

Electric fields could be recorded, particularly in areas where persons may come into relatively close proximity to medium voltage facilities such as low conductors (normally midspan) of distribution and/or sub transmission lines.

5 Measurement Protocol

If measurements are to be taken of high field areas, it is recommended that
- a clear purpose and scope of the measurement program be prepared; and
- suitably trained and experienced personnel are used.

The measurements and their documentation should be undertaken in the following manner:

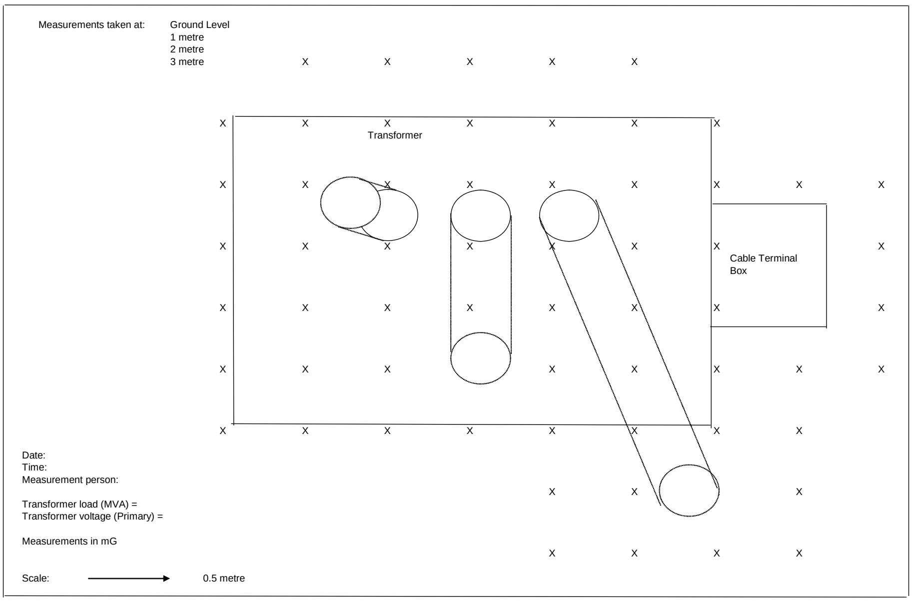
a) Use a suitable measurement standard (for example as the ANSI/IEEE standard 644-1987 "IEEE Standard procedures for measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines").
b) Use of suitable measurement equipment such as the EMDEX II RMS power frequency magnetic field exposure meter and an AC RMS Electric Field Meter (such as Monroe Electronics Inc). See examples in Appendix 2.
c) Set equipment at maximum current and normal voltage levels.
d) Take spot measurements to ascertain existence of high field areas.
e) Measurements should be representative of normal working conditions and thus should be taken at 0m, 1m and 2m heights for a standing person. If above ground access is possible then measurements should reflect possible access locations. The measurements do not represent whole body exposures.
f) For magnetic fields, measurements should be in a 1m grid around the equipment or in the area where a person may need to be located to operate or inspect a particular piece of apparatus.
g) The following information should be documented:
- measurement method used;
- instruments used including calibration detail;
- persons undertaking the measurement;
- heights that measurements were taken;
- diagram of measurement grid and equipment outline;
- units of measurement;
- date and time of measurement;
- current flowing in equipment;
- voltage level in equipment; and
- results and report conclusions.

Appendix 1: Example of Measurement Approach for Major Plant Items:

Example 1: Magnetic Field measurement around a generating business's major auxiliary transformers

The following picture shows a major auxiliary transformer (22kV/11kV 38MVA). The survey concentrates on the phase isolated bus connection on top of the transformer (which is accessible to maintenance staff via ladder) and the secondary side terminal box. It is noted that the magnetic fields inside the transformer are concentrated and contained in the transformer's core laminations and thus are generally not a source of high fields. The measurements would be taken at ground level, 1m, 2m and 3m off the ground to cover the area that could be accessed during normal operations and maintenance.

Figure A1. Cabling between large transformer and switchboards



Appendix 2: Details of Typical Meters

<u>ELECTRIC FIELD METER:</u>

<u>Manufacturer:</u>

Monroe Electronics Inc. Lyndonville Kentucky USA

Model: 238A – 1

<u>Technical Specifications:</u>

Analogue Scale readout – full scale options 5, 10, 25 kV / m – minimum reading is effectively 0.05 kV / m

Other details are not available

EMDEX II High Field Magnetic Field Meter

Manufacturer:

Enertech Consultants, 300 Orchard City Drive 17 Main Street Suite #132 P.O. Box 770 Campbell, CA 95008

Technical Specifications

Data Collection Actual Measurements

Range 0.004 - 120 G (0.4 µT - 12 mT)

Resolution 4 mG (0.4 µT)

Typical Accuracy ± 1%

Frequency Broadband: 40 - 3,000 Hz; Harmonic: 100 - 3,000 Hz

Max Sample Rate 1.5 Seconds

Internal Memory 156 Kb or 512 Kb

Display (mG or mT units) Alphanumeric 8-Character

Measurement Method True RMS

Typical Battery Life Alkaline: Up to 7 Days; Lithium: Up to 21 Days

Dimensions 6.6" x 2.6" x 1.5" (16.8 x 6.6 x 3.8 cm)

Weight 12 ounces (341 grams)

<u>HMI Systems EMF Survey Meter</u>

<u>Manufacturer:</u>

HMI Systems, 32 Grant Street, East Malvern, VICTORIA 3145

Technical Specifications

Meter Purpose	Digital Magnetic Field Survey Meter
Range	0.1 – 6 000 mG (0.01-600 µT)
Resolution	0.1 mG (0 – 99.9 mG), 1 mG (>100 mG),
Typical Accuracy	± 2%
Frequency Response	30 - 1,000 Hz
Sample Rate	1.0 seconds
Measurement Method	True RMS in three axes and resultant
Typical Battery Life	Alkaline: Over 48 Hours
Dimensions	120 x 60 x 25 mm
Weight	95 g (without battery)