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Upgrade of Concord 33kV/11kV Substation

Study of Electromagnetic Fields Produced by 11kV Cables and Switchboard

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Contents

1 Introduction

Ausgrid is planning to upgrade its existing substation located at 31 George Street, Concord West.

The upgrade is to replace the substation's aging switchgear and associated equipment. The replacement will ensure Ausgrid maintain a safe and reliable power supply to the area. Ausgrid proposes to construct a new switch room on Ausgrid's property, east of the existing substation adjacent to the Sydney Trains T9 Northern Railway Line. This is shown in the plan view of the site in Figure 1 below.

Figure 1 Proposed new works within Concord Substation

As part of the environmental assessment impact of this project it is necessary to determine the level of extremely low frequency electromagnetic field (EMF) produced by two sets of new 11kV transformer cables (shown in red on the drawing in Figure 1) and the new 11kV switchboard, which will be located inside the new switch room building (shown in green colour in Figure 1) into the areas across the substation. This report summarises the results of computer modelling of the magnitude of EMF produced by new electrical assets along southern boundary line and, if necessary, provides recommendations for implementation of appropriate measures to mitigate this field to the acceptable health exposure limit.

An electromagnetic field comprises of both, an electric field and a magnetic field. Since the project involves installation of underground 11kV cables and 11kV switchboard enclosed in metallic housing, only the magnetic field produced by these equipment will be analysed in this report. This is because the low frequency electric field is well shielded by physical materials, such as: the cable insulation, cable plastic conduits and soil that covers the trenches and by building materials and metallic enclosure that would cover the 11kV switchboard.

The cable route details of the two sets of the 11kV transformer cables are shown in red colour in Figure 2 below and the 11kV switchboard is in blue colour.

The cables will be installed in high density plastic conduits with outside diameter of 120mm that will be buried under the transformer roadway and encased in thermally stable backfill (TSB). The details of cable installation is shown in Figure 3 below.

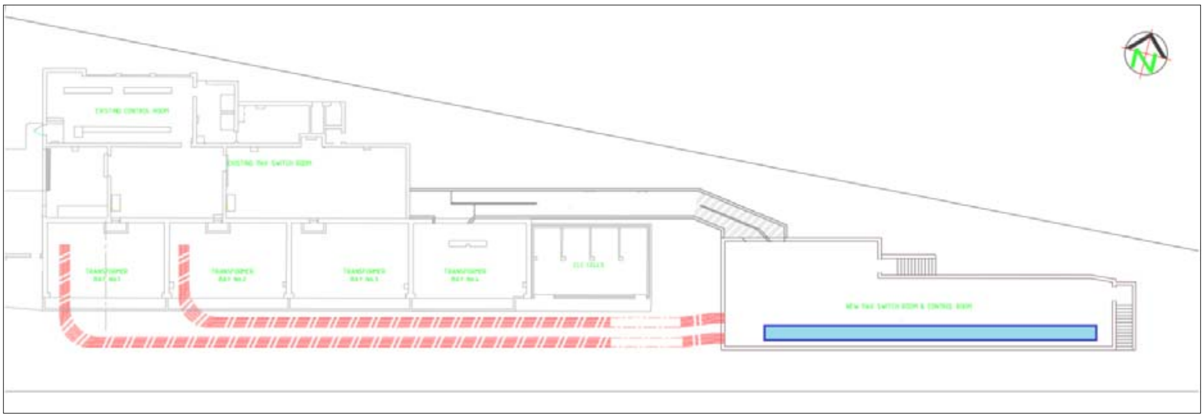


Figure 2 Plan view of Concord Substation with 2 sets of underground 11kV transformer cables connecting Transformer 1 and 2 to the new 11kV switchboard

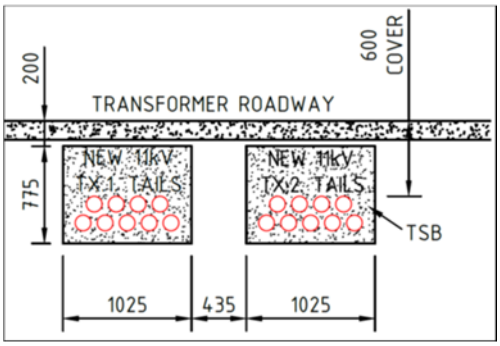


Figure 3 Plastic conduits for 11kV transformer cables

The electrical current while passing through a cable will produce electromagnetic fields (EMF) in the space surrounding the cable. The stronger the current the proportionally stronger the magnetic field produced by the cable is.

The 11kV transformer cables will be terminated to the 11kV Siemens switchboard entering the switchboard through the bottom apertures.

The plan view of the proposed new 11kV Siemens switchboard with designated compartments is shown in Figure 4 below, current will flow along copper busbars located inside the switchboard and will produce EMF. The Siemens switchboard is enclosed within metallic cladding and will be fully contained within the new switch room.

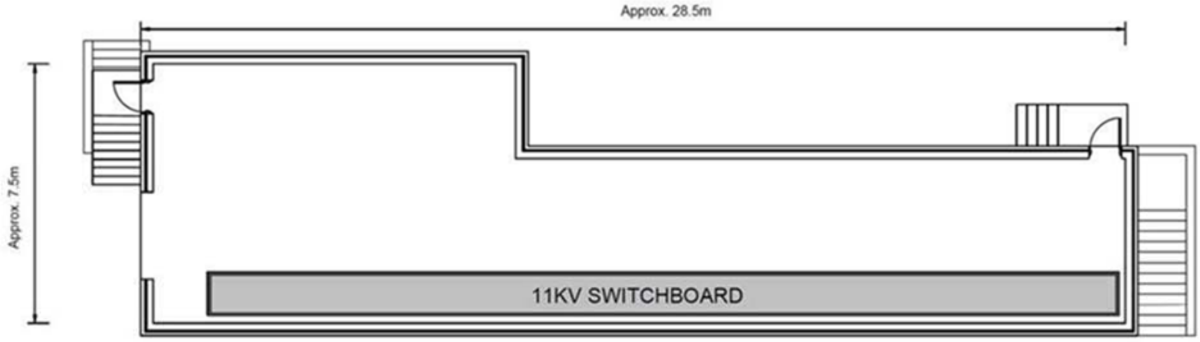


Figure 4 Proposed new 11kV switchboard

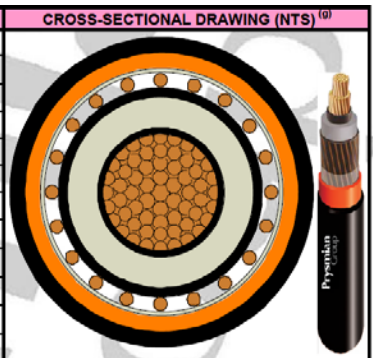
This report summarises the EMF modelling and calculations completed the southern substation property line.

2 Cable type and parameters

The Concord Substation comprises of four existing 33/11kV transformers, where the two eastern most transformers will be connected to the new 11kV switchboard by a set of three single-core 630 mm^2 Cu, XLPE insulated cables per phase or 9 cables per transformer. These cable will be installed in two separate ductlines along the existing transformer driveway, which is parallel with the substation southern boundary. The cable details as shown in Figure 5 below.

PHYSICAL CHARACTERISTICS			
Conductor Diameter	Nominal	(mm)	30.3
Conductor Stranding	Nominal	(No./mm)	59/3.80
Insulation Thickness	Nominal	(mm)	3.4
Diameter Over Insulation	Nominal	(mm)	39.0
5V-90 PVC Inner Sheath Thickness	Nominal	(mm)	1.2
HDPE Outer Sheath Thickness	Nominal	(mm)	1.2
Overall Cable Diameter	Nominal	(mm)	49.9
Cable Mass	(Approx)	(kg/km)	7.797
Minimum Bending Radius	During Installation	(mm)	1,245
	Installed	(mm)	750
Max. Pulling Tension	Stocking [f]	(kN)	6.0
	Conductor [f]	(kN)	25.0

CROSS-SECTIONAL DRAWING (NTS) [g]



ELECTRICAL CHARACTERISTICS [a]			
Max. DC Resistance	@ 20°C	(Ohm/km)	0.0283
	@ 90°C	(Ohm/km)	0.0361
Max. AC Resistance @ 50Hz	@ 20°C	(Ohm/km)	0.0343
	@ 90°C	(Ohm/km)	0.0412
Inductive Reactance @ 50Hz		(Ohm/km)	0.0961
Star Inductance		(mH/km)	0.307
Capacitance Per Core (Phase To Earth)		(µF/km)	0.725
Charging Current Per Phase		(A/km)	1.37
Maximum Design Stress		(kV/mm)	1.95
3 Phase Voltage Drop @ 50Hz & 90°C		(mV/A.m)	0.181
Zero Sequence Impedance @ 50Hz ($R_o + jX_o$) [c]	@ 20°C	(Ohm/km)	0.182 + j 0.0383
	@ 90°C	(Ohm/km)	0.231 + j 0.0383
Positive Sequence Impedance @ 50Hz ($R_1 + jX_1$)	@ 20°C	(Ohm/km)	0.0343 + j0.0961
	@ 90°C	(Ohm/km)	0.0410 + j0.0961

CONTINUOUS CURRENT RATING [b]		
Unenclosed Spaced In Air	(A)	908
Buried Direct (Trefoil)	(A)	690
Buried In Ducts (3 Cables In 1 Duct Trefoil)	(A)	608

SHORT CIRCUIT RATING		
Metallic Screen [d]	(kA/1 Sec.)	18
Phase Conductor [e]	(kA/1 Sec.)	90.1

Figure 5 11kV cables for connection between four transformers and switchboard

3 EMF profile across underground 11kV transformer cables

The cross-sectional view of the 11kV transformer cable installation is shown in Figure 3. However, the EMF emitted from the entire set of transformer cables is subject to the phasing of the cables installed in conduits. Depending on the phasing arrangement, the difference in the total EMF emission can be rather significant.

In the study several cable phasings were analysed several possible phase sequences and the arrangement which produced the lowest magnetic field was determined. This is presented in Figure 6 below.

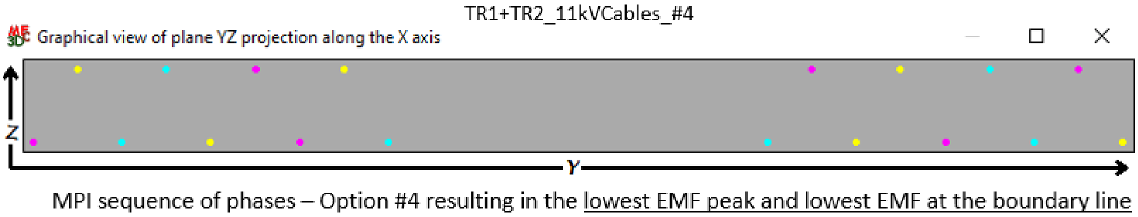


Figure 6 Phase arrangement which results in the lowest magnetic field.

The picture in Figure 7 below shows the representation of 18 x 1-core, in the Magshield (MPI) developed low EMF sequence of phases using 3D EMF modelling software.

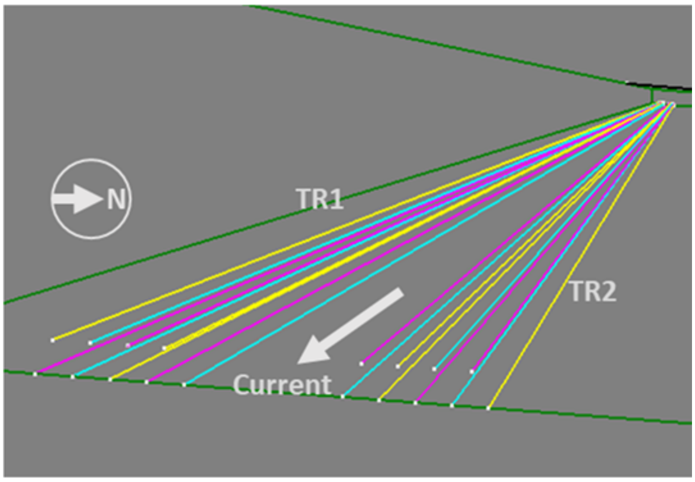


Figure 7 3D computer image of 11kV underground transformer cables

The EMF profile shown in Figure 8 below was calculated using the time-weighted average (TWA) load provided by Ausgrid. The TWA details are discussed in the next section of the report.

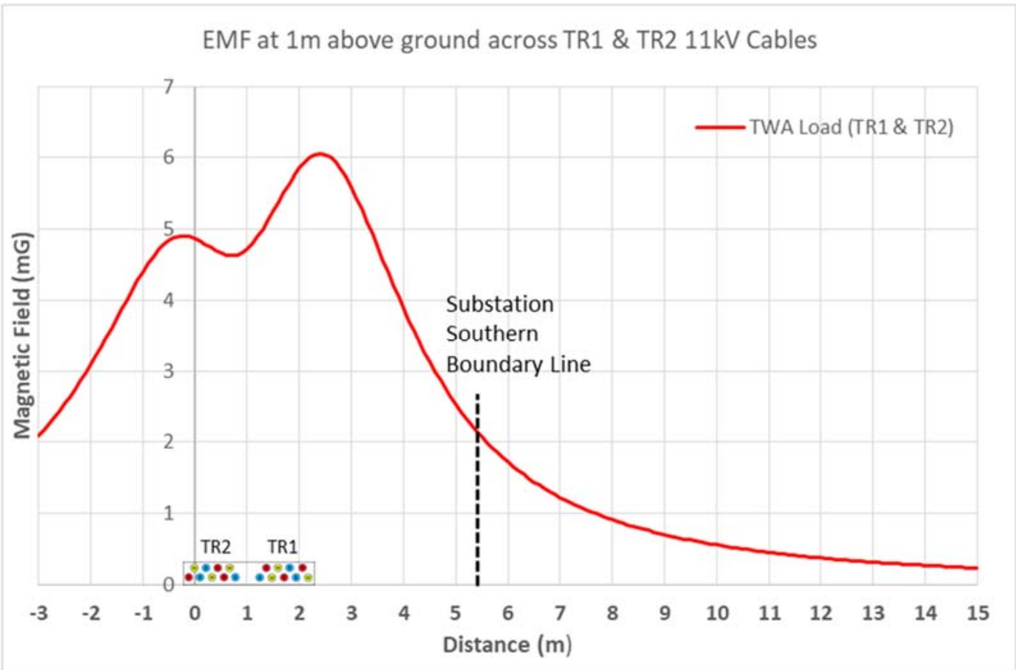


Figure 8 EMF profile calculated at 1m height across the 11kV cables of TR1 and TR2 transformers in the southerly direction.

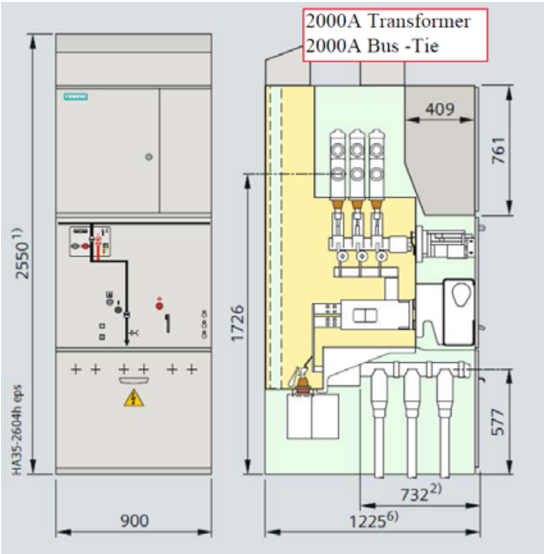
On the graph, the 5.4m mark is the distance from the northern most 11kV cable conduit to the southern boundary line of the substation ground.

As can be seen from the EMF profile across the two sets of 11kV transformer cables loaded with the TWA current (I_{TR1} = 315 A, I_{TR2} = 292 A), the highest EMF at the southern boundary line of substation is less than 4 mG and this field further reduces to less than 1mG at the front wall of the nearest residential building.

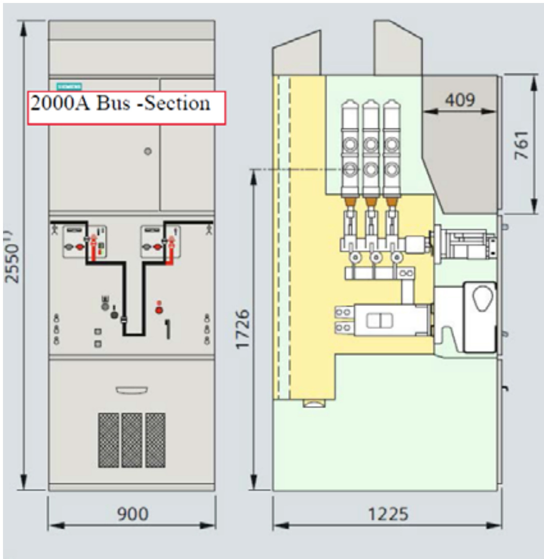
4 EMF from proposed new 11kV switchboard

The proposed new 11kV switchboard is of Siemens design and houses copper busbars located in the upper part of the common metallic housing of the switchboard.

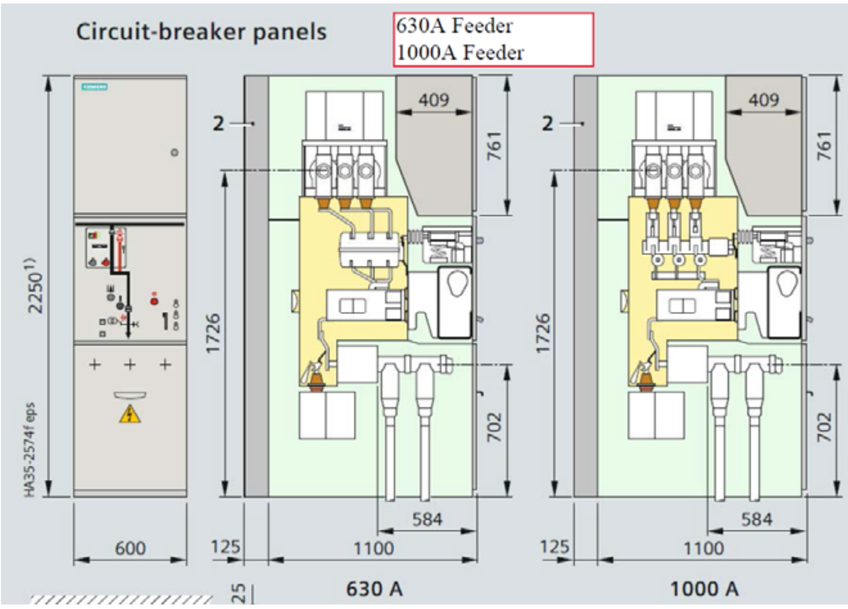
Front and side views of transformer and bus-tie compartments of the proposed switchboard are shown in Figure 9(a), and the Bus-Section of the switchboard is shown in Figure 9(b). The front and side views of the feeder section is shown in Figure 9(c).



(a)



(b)



(c)

Figure 9 Transformer / bus-tie compartments (a), Bus-Section (b) and Feeder compartment (c)

Ausgrid provided for this study the extrapolated for the year 2022-23 load duration curve (LDC) for this substation. This is presented in Figure 10.

The LDC shows what percentage of time per a given period the substation electrical load was of a certain magnitude in amperes on its 11kV busbars.

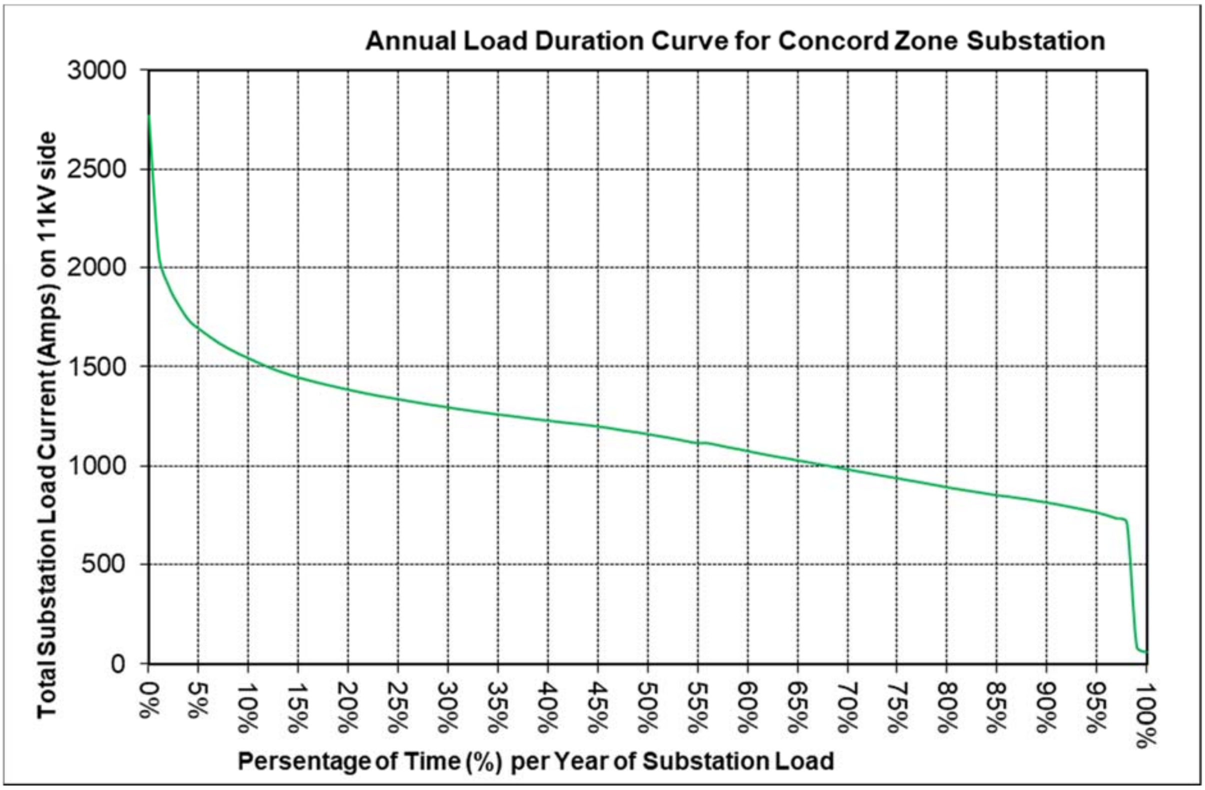


Figure 10 Extrapolated annual load duration curve for Concord Substation for 2022-23

Based on the LDC data it was possible to calculate the time-weighted average (TWA) level of the substation annual load on its 11kV bus. For the Concord Zone substation the calculated annual TWA is 1166 A.

The TWA of 1166 A and the percentage of the total TWA load current allocated by Ausgrid for each transformer was derived and is presented in Figure 11 below.

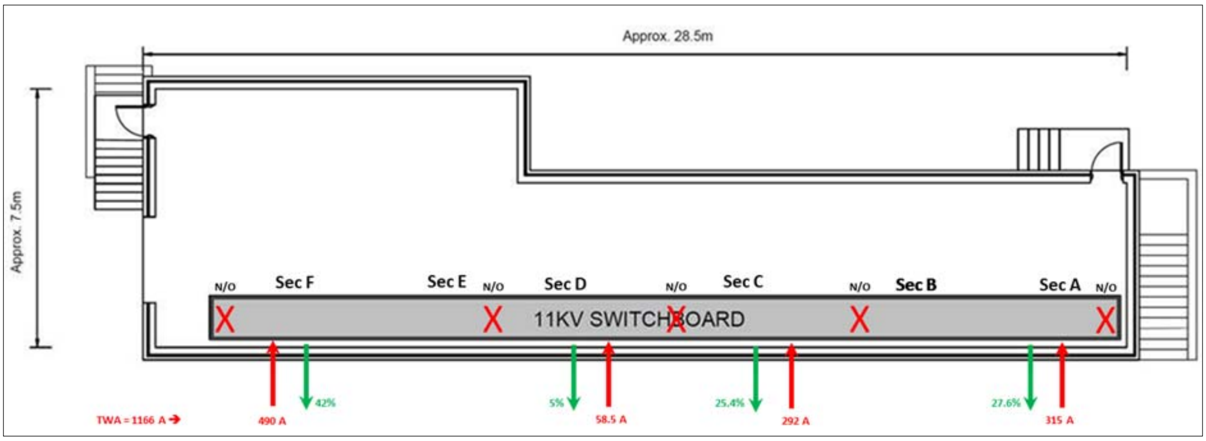
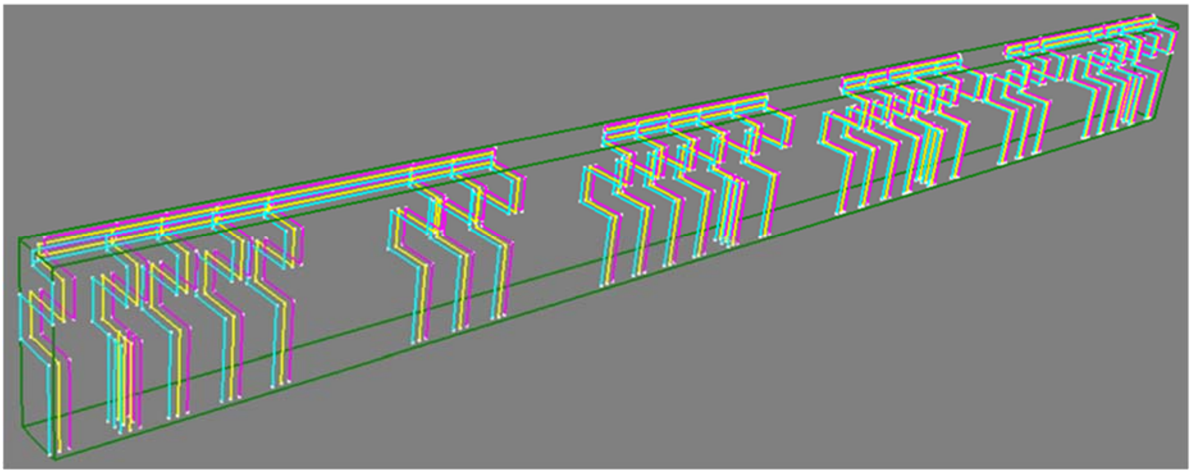


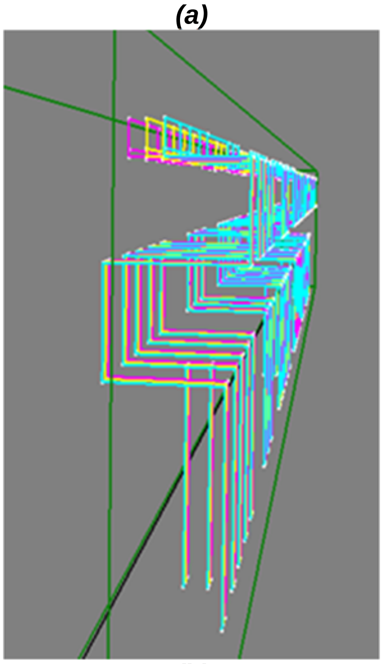
Figure 11 Loading scenarios for new 11kV switchboard that can be used for EMF calculations

In the drawing in Figure 11 the large red colour cross indicates a normally open bus-section circuit breaker (CB), the red colour arrow indicates the direction of incoming electrical power from each transformer towards the switchboard, the green colour arrow indicates the direction of the outgoing power from the section of the switchboard bus collectively into the all 11kV feeders connected to it. Each section of the switchboard is marked by a capital letter starting from A to F.

Using 3D modelling software the current carrying parts of the proposed new 11kV switchboard was accurately represented by numerous short straight lines set in different orientation in space and loaded with the allocated TWA load current. This model is visually presented in Figure 12 below.



(a)



(b)

Figure 12 3D computer modelling image of new 11kV switchboard

(a) Sections of switchboard from A at the far end to F at the near end

(b) 11kV switchboard in profile with dual busbars at the top

The EMF profile calculated at 3.4m distance behind the switchboard for TWA loading condition, is represented by red colour line in Figure 15.

The green colour profile line presented in Figure 13 was plotted with inclusion of shielding effectiveness (SE) of the switchboard's metallic enclosure. This is addressed in the next section of the report.

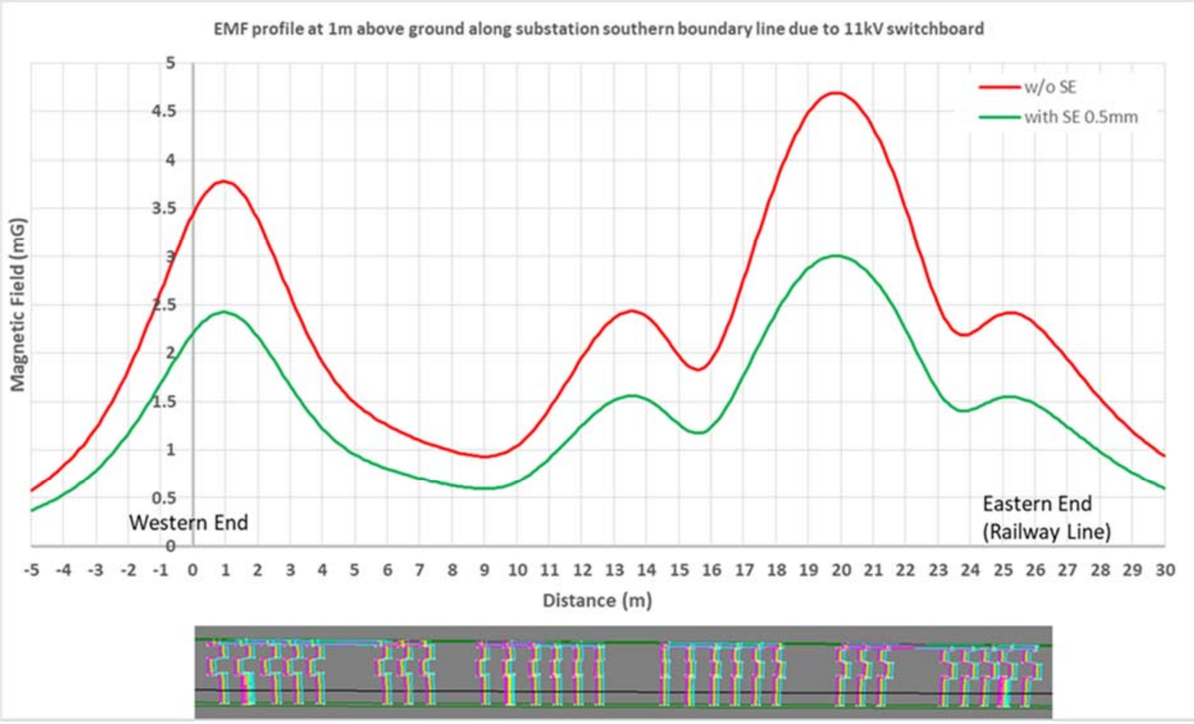


Figure 13 EMF profiles at 3.62m behind 11kV switchboard for different loading scenarios

Looking at two EMF profiles obtained from calculations it is obvious where the highest peak is along the length of the switchboard. Using this location the EMF profile was plotted along a cross-section perpendicular to the southern property line. This cross-section illustrates how the magnetic field decreases with distance from the new switchboard towards the adjacent property.

These profiles are presented in Figure 14.

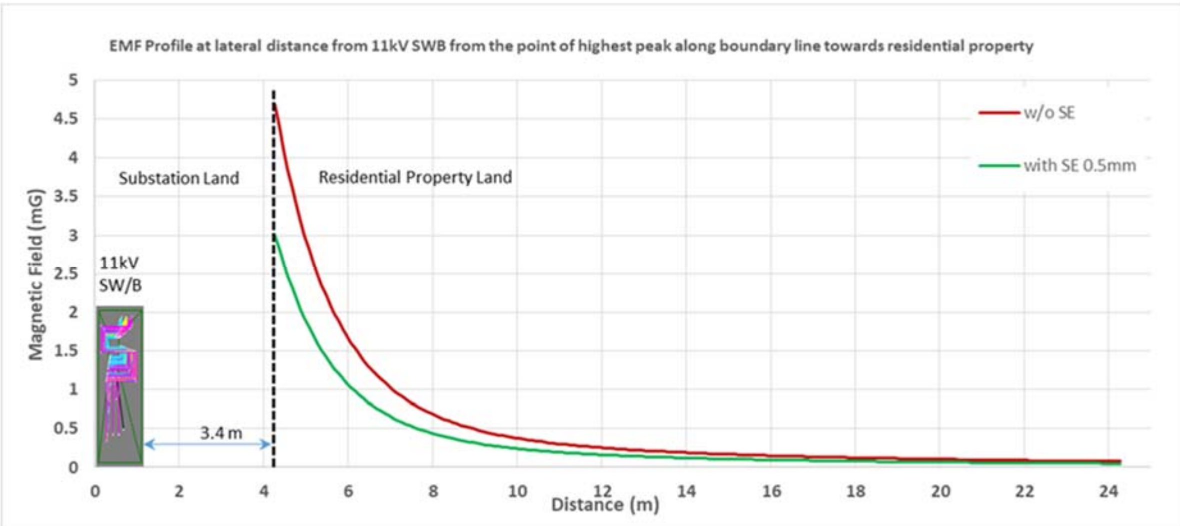


Figure 14 EMF profiles at lateral distance from 11kV switchboard from the point of the highest peak of profiles shown in Figure 16.

5 Shielding effectiveness of switchboard enclosure

A shield usually refers to a metallic enclosure that either partially or completely encloses electronic and electrical circuits or devices.

There are two purposes a shield can serve:

- to prevent the electrical and electronic circuits and devices from radiating electromagnetic noise outside their boundaries;

- to prevent radiated emission external to the product from causing interference in the product.

Therefore a shield is, conceptually, a barrier to the transmission of electromagnetic fields and is used to control the propagation of the field from one region to the other.

The metallic cladding of the Siemens switchboard acts as a shield. Additional EMF modelling was carried out which considered the influence of this shield and the results are graphed in green, in Figures 13 and 14.

6. Conclusions and Recommendations

This study was carried out exclusively to determine the impact of the proposed upgrading of the substation equipment on the EMF along the southern boundary line of the substation where the substation is adjacent to the existing residential properties.

The proposed new upgrades included three new EMF emitting sources, consisting of two sets of 11kV underground transformer cables and a new 11kV switchboard. All this equipment will be located in the southern area of the substation ground, and as such, might impact on the EMF level along the southern boundary line.

3D EMF modelling and calculations conducted for two sets of 11kV underground transformer cables and for the new 11kV switchboard resulted in the following outcome, which is summarised in Table 1 below

Table 1

Magnetic Field Calculated in mG				
TR1 & TR2 11kV cables	**peak value**	**at boundary line**	**at 5m from boundary line**	**at 10m from boundary line**
Case #4 for TWA current	6.0	2.2	0.8	0.3
11kV Switchboard ^	N/A	3.0	0.07	0.05

Note: ^ Magnetic field was calculated for the TWA load current with inclusion of SE for switchboard metallic enclosure

The following conclusions can be derived from the result of this study:

1. *Using the TWA load current the calculated EMF emitted from two sets of transformer cables and from the switchboard in the direction towards residential properties is quite small. Please note, the calculations were performed for the extrapolated electrical load for the year 2022-23 and not beyond it.*

2. *To effectively suppress the EMF from two sets of 11kV cables connecting the transformers, to the new 11kV switchboard, the cables should be installed in conduits using Magshield developed low EMF phase sequencing as shown in Figure 6.*

3. *The EMF emission from the proposed new 11kV switchboard in the direction of residential properties located south of the substation is sufficiently small not to warrant any remedial measures.*

4. *The results of 3D modelling and calculations show that there is no practical requirement to mitigate the EMF beyond the appropriate low EMF phase sequencing of the 11kV transformer cables. The predicted EMFs are sufficiently small and well below the acceptable health exposure limits as specified in the national and international standards and guidelines.*