EARTHING ASSESSMENT REPORT

Catherine McAuley College
Electrical Projects Australia

November 2017

safearth
consulting

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Rev	Date	By	Purpose of Revision
0	29 Nov 2017	B. Pawlik	Initial release

Executive Summary

Safearth has carried out an Earthing Assessment of Medowie ZS and the incoming 33kV Feeders for the impacts on the proposed Catherine McAuley Catholic College. The assessment has been performed based on information provided by Ausgrid and Electrical Projects Australia.

The findings of the Earthing Assessment indicate that the proposed Catherine McAuley College Development is expected to be compliant with ENA EG-0 for earth faults associated with Medowie ZS and the proximate 33kV feeders.

✓ Based on the Catherine McAuley Catholic College Site Plan Electrical Layout no remotely earthed metallic infrastructure is expected to be installed within the BY/TDB hazard contour around Medowie ZS as part of the Catherine McAuley College Development.

✓ Based on the Catherine McAuley Catholic College Site Plan Electrical Layout no buildings or significant metalwork interconnected with the MEN has been identified within the most onerous MEN/TDMEN hazard contour.

! If any remotely earthed metallic infrastructure is to be installed within the BY contour specified in section 3.3 as part of future development, further assessment of the voltage hazards associated with the new infrastructure due to earth faults at Medowie ZS is required.

! If any future buildings are to be installed within the MEN contour specified in section 3.3 Safearth recommend an earthing system design be included as part of the building design process.

! If a significant number of street lights are to be installed as part of future Car Parks within the MEN contour specified in section 3.3 Safearth recommend that either further assessment of the street light earthing system is performed; or that the street light LV circuit is double insulated to prevent the possibility of any soil voltage transfer into the MEN. Details for double insulating the Street light LV circuit are provided in Appendix C.

Contents

Appendices

1 Introduction

Safearth Consulting has been engaged by Electrical Projects Australia (EPA) to assess the impacts on a new school development near the existing 33/11kV Medowie Zone Substation (ZS) in the Ausgrid franchise area.

The Catherine McAuley College is proposed to be built on Medowie Rd with a new kiosk substation to supply power to the site. Both the College buildings and the kiosk are potentially impacted by the earthing system and associated voltage rise at the ZS.

This report assesses the potential impacts of the proximity of the proposed College to the earthing system of Medowie ZS and the 33kV poles that will be located in an easement in the College.

2 Inputs and Considerations

2.1 Supplied Documents

The following documents have been used in the assessment.

Table 2-1 Supplied Information

Document Title
17185 SKE1 A Catherine McAuley Catholic College Site Plan –Electrical Layout
Medowie Soil Potential Charts and Fault Levels – provided in email from Ausgrid on 4 October 2017
Raw test data for meadowy ZS EPR west - provided in email from Ausgrid on 23 October 2017
11kV Feeder fault notes - provided in email from Ausgrid on 23 October 2017
Soil Model Kingfisher Rd Medowie - provided in email from Ausgrid on 23 October 2017
33kV poles voltage contours Medowie - provided in email from Ausgrid on 23 October 2017
AusGrid Notification: 1900076266, Preliminary Service Advice _ Catherine McAuley Catholic College – 507 Medowie Road Medowie

2.2 System Configuration

In order to ensure the safety of an earthing system, it is imperative to assess the system under all possible fault scenarios. This includes determining the system response to all cases that will result in an earth potential rise.

Medowie ZS is an AusGrid substation supplied at 33V and feeding the local 11kV network. For this assessment AusGrid have supplied the worst case earth potential rise (EPR) for both the primary and secondary fault scenarios associated with the ZS.

The most onerous EPR of the 33kV poles in the easement have been established via computer modelling of the test data supplied by Ausgrid.

Ausgrid have also supplied the single line diagram (SLD) of the 11kV network supplied by Medowie ZS. Safearth has determined from the Medowie ZS SLD that there are less than 160 earthed assets supplied by the ZS.

It is Safearth's position that, as low impedance earth faults typically only occur at earthed infrastructure, the fault rate of the secondary system may be adjusted based on the number of earthed assets supplied by the ZS. Consequently the fault rate of the secondary system will be conservatively calculated based on 160 earthed assets supplied by Medowie ZS.

2.3 Soil Resistivity Data

Soil resistivity data for the site has been provided by AusGrid. Previous soil resistivity tests in the vicinity of the site conducted by Safearth have been considered in determining an appropriate soil resistivity for determining personal safety criteria and for modelling the performance of OHEWs.

Based on this information, to ensure appropriately conservative outcomes, the calculation of personal safety voltage limits is based on a surface layer consisting of 100Ωm soil. For the purpose of modelling the performance of the OHEW a homogenous 70Ωm soil resistivity will be used as it will conservatively minimise coupling into the OHEW.

Additional information regarding the soil resistivity in the area is presented in Appendix A.

! Due to the large variance in the soil models presented in Appendix A, Safearth recommend soil resistivity testing be conducted at the location of the proposed padmount site to be used in the design as part of stage two of this project.

2.4 Fault Data and Earthing System Parameters

The relevant information supplied by AusGrid applicable to the assessment of the impacts of the Medowie ZS and 33kV pole earthing systems on the proposed Catherine McAuley College development for primary and secondary faults at the substation are documented in Table 2-2 and Table 2-3 respectively.

Table 2-2 AusGrid Primary Earth Fault Parameters

Item	Supplied Data
33kV SLG Fault level	4.346 kA
33kV EPR	191 V
33kV System Impedance	0.044 Ω
33kV Clearing Time	0.7 s

Table 2-3 AusGrid Secondary Earth Fault Parameters

*Most onerous fault current identified by AusGrid

Item	Supplied Data
11kV Earth Return Current*	2.014 kA
11kV EPR	503 V
11kV System Impedance	0.25 Ω
11kV Clearing Time	0.2 s

While some data was provided by AusGrid with respect to the performance of the 33kV poles to be located in the college easement, there is not enough information to perform the assessment on that information alone. Instead computer modelling of the system has been performed to conservatively estimate the expected performance of the poles during all operating conditions.

The feeder earthing system parameters provided by AusGrid upon which computer modelling is based are documented following in Table 2-4. The EPR and pole current at the respective poles has been calculated from test data provided by AusGrid and scaled to the Medowie ZS 33kV earth fault level during the simulation of which they were tested.

Table 2-4 AusGrid 33kV Pole Parameters for a 33kV Fault at Medowie ZS

Item	Supplied Data
33kV UGOH Pole KR-90041 EPR	135 V
33kV Pole KR-90056 EPR	116 V
33kV Pole KR-90056 Pole Current	21 A
33kV Pole KR-90056 Footing Resistance	5.6 Ω

Based on the geographic orientation of the 33kV feeder through the college and the soil resistivity data presented in section 2.3 a cursive computer model of the 33kV feeder into Medowie ZS has been created and conservatively tuned to match the test data supplied by AusGrid for the simulated 33kV fault at Medowie ZS. This model has then been utilised to conservatively establish the worst case expected EPR for feeder faults affecting the 33kV poles.

The modelling confirmed that the 708V estimated EPR for 33kV pole KS-90032 provided by AusGrid is adequately conservative for the assessment of feeder faults affecting the 33kV poles that will be encroached upon by the college development.

2.5 Design Standards and Safety Targets

The safety criteria in the following sections will be used to determine the contours around earthed HV electrical infrastructure within which metallic infrastructure associated with the college will require further consideration. A summary of the applicable standards and their application is provided Appendix B.

2.5.1 Substation Safety Criteria

ENA EG-0 has been used to calculate the safety criteria applicable to hazards associated with earth faults at Medowie ZS. Safety criteria applicable to primary and secondary fault scenarios derived from ENA EG-0 (now consistent with AS2067:2016) are presented in Table 2-5.

Table 2-5 EG-0 Touch Voltage Limits for Personal Safety.

* Based on less than 160 earthed assets supplied by Medowie ZS (see section 2.2) and a fault rate of 0.1 per year at each of these assets.

Fault Case	Contact Scenario Negligible Risk Voltage Threshold (Soil Resistivity =100 Ωm, Footwear Type = Standard)		
	Urban Interface (UI) Contacts / Year = 135 Contact Duration = 4s	Back Yard (BY) Contacts / Year = 416 Contact Duration = 4s	MEN Contacts / Year = 2000 Contact Duration = 4s
33kV Earth Fault 0.1 faults per year 0.7s clearing time	3373	299	172
11kV Earth Fault 16 faults per year* 0.2s Clearing Time	380	243	83

The above Urban Interface criteria will be used to assess touch voltage hazards to any HV infrastructure occurring due to respective primary or secondary faults at the ZS.

Safearth contend that the Back Yard contact scenario is applicable to the assessment of metallic infrastructure affected by soil voltage rise local to the asset only. Consequently the above Back Yard criteria will be used to establish contours around HV earthed assets affected by the respective fault scenario within which metallic infrastructure not associated with the HV network should not be installed without further consideration.

The MEN contact scenario will be applied to metallic infrastructure affected by a voltage rise on the MEN or where the soil voltage rise affects a significant area of MEN infrastructure. Consequently the above MEN criteria will be used to establish contours around HV earthed assets affected by the respective fault scenario within which building or significant metallic infrastructure should not be installed without further consideration.

2.5.2 Feeder Fault Safety Criteria

AS7000 has been used to calculate the safety criteria applicable to hazards associated with earth faults on the 33kV poles that will be located in the proposed easement through the college.

The standard AS 7000:2010 specifies the general requirements applicable to encroachments on overhead lines to ensure that the acceptable levels of safety are maintained. The hazards presented to the public during an overhead line earth fault scenario is outlined in Section 10 of the standard and is based on an assessment under the risk based guidelines proposed in ENA EG-0.

AS7000 presents a series of curves for assessing acceptable prospective touch voltages associated with earth faults. The contact scenarios presented in the standard that define the voltage curves applicable to the college encroachment are presented following in Table 2-6.

Table 2-6 AS7000 Contact Scenarios Applicable to Assessment of Transmission Line Faults

Refer Table 10.2 AS7000

Associated Curve	Acronym	Contact Frequency	Contact Duration	Footwear
Distribution Urban Interface	DU	135 per year	4 s	Standard
Transmission Distribution Backyard	TDB	416 per year	4 s	Standard
Transmission Distribution MEN	TDMEN	2000 per year	4 s	Standard

The curves are then generated by assumptions about the fault rate of the line and the surface soil resistivity in the area. The standard specifies the following parameters:

- 0.1 faults/year (10 faults/100km/year for 1km distribution line section, 10 by 100m spans, with an overhead earth wire)
- Clearing time 1 second
- 50 Ωm soil resistivity

For the assessment of the college encroachment not all of the above parameters are applicable and as such it has been reassessed under Appendix U of AS/NZS 7000 in conjunction with ENA EG-0.

Safety criteria for the contact scenarios derived from ENA EG-0 using the ENA Argon Software tool [11] are equivalent to the voltage thresholds established in Table 2-5 for the 33kV earth fault scenario, where the UI voltage threshold is equivalent to the DU threshold, the BY threshold equivalent to TDB, and MEN equivalent to the TDMEN.

Hazard contours around HV earthed assets for earth faults on the 33kV poles will be established as per the safety thresholds in section 2.5.1 for faults at the ZS.

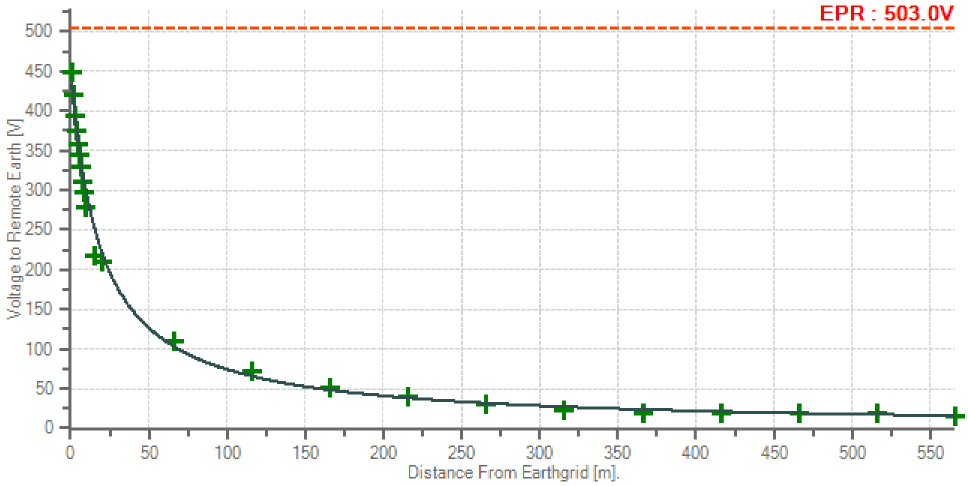
3 Earthing System Hazard Assessment

3.1 Earth Faults at Medowie ZS

Test data of the Medowie ZS earthing system fall of Potential (FOP) was provided by AusGrid to be utilised in this assessment. As the EPR of the 11kV earth fault is larger than that of the 33kV case, and the negligible risk voltage threshold for the 11kV fault scenario is lower, the 11kV earth fault scenario is clearly the most onerous earth fault scenario applicable to the ZS. Hence consideration the 11kV earth fault scenario only will be sufficient in establishing hazard contours around the earthed HV assets for faults at the ZS.

The Medowie ZS FOP test data supplied by AusGrid, corrected for remote earth and scaled to the EPR of the earth fault scenario provided by AusGrid, is shown following in Figure 3-1.

Figure 3-1 Medowie ZS FOP for 11kV Earth Fault at Medowie ZS



The FOP test data of UGOH pole KR-90041 and pole KR-90056 provided by Ausgrid, conservatively scaled to the 11kV fault scenario and corrected for remote earth, are shown following in Figure 3-2 and Figure 3-3 respectively. It is assumed that the earthing system performance of these poles is representative of all the poles of the equivalent type (i.e. 33kV UGOH pole or standard pole) in the easement.

Figure 3-2
UGOH pole KR-90041 FOP for 11kV Earth Fault at Medowie ZS

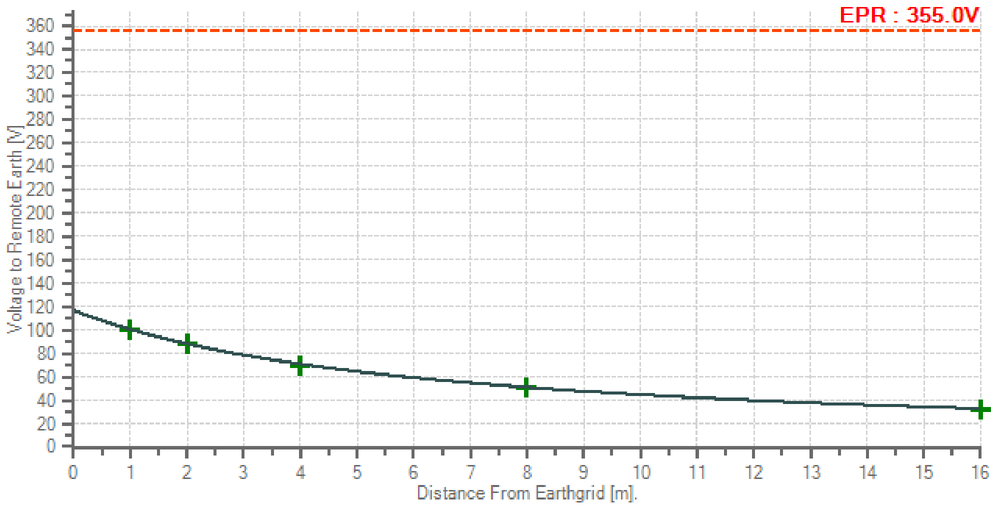
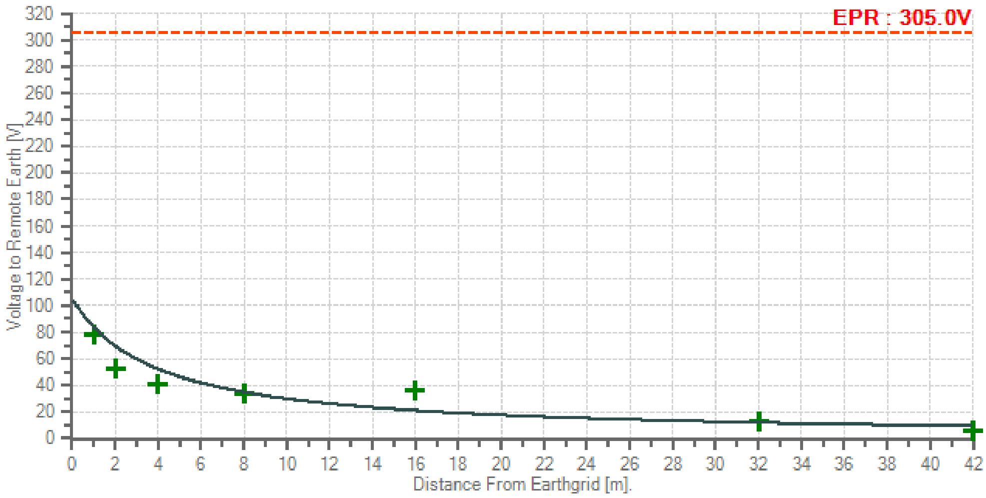


Figure 3-3
pole KR-90056 FOP for 11kV Earth Fault at Medowie ZS



As can be seen from Figure 3-1 the contours applicable to the UI, BY and MEN contact scenarios are as documented following in Table 3-1.

Table 3-1
Hazard Contours for 11kV Earth Fault at Meadowie ZS

*Soil voltage is less than the respective negligible risk voltage threshold.

Earthed HV Assets	Distance of Contour from Earthing System		
	UI	BY	MEN
Medowie ZS	4 m	20 m	85 m
33kV UGOH Pole	NA*	NA*	4 m
33kV standard Pole	NA*	NA*	2 m

Further, as the EPR of the poles due to transferred substation EPR are less than the UI contact scenario touch voltage hazards to all poles for faults at Medowie ZS are considered negligible risk and compliant to ENA EG-0.

3.2 Earth Faults on 33kV Poles

The FOP test data of UGOH pole KR-90041 and pole KR-90056 provided by Ausgrid scaled to the 708 V, established as the most onerous EPR associated with the AusGrid Poles for 33kV feeder faults in section 2.4, are shown following in Figure 3-4 and Figure 3-5 respectively.

Figure 3-4
UGOH pole KR-90041 FOP for 11kV Earth Fault at Medowie ZS

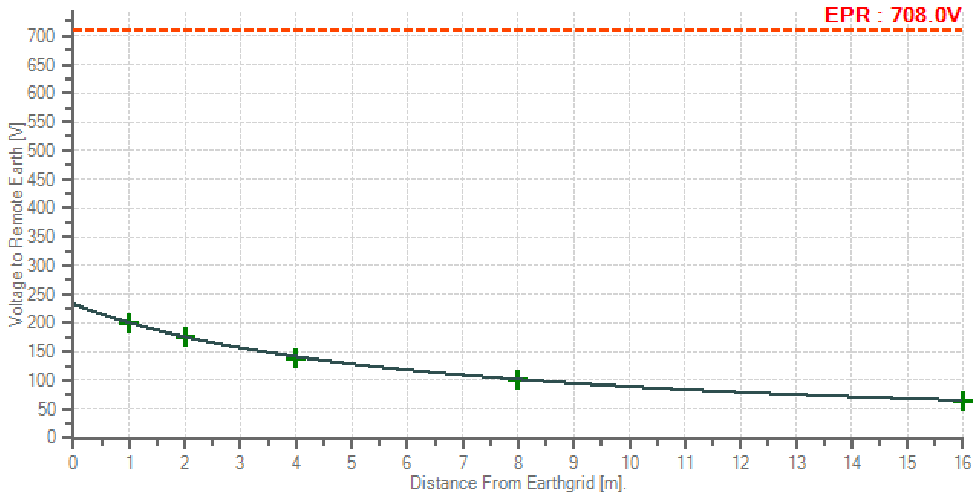
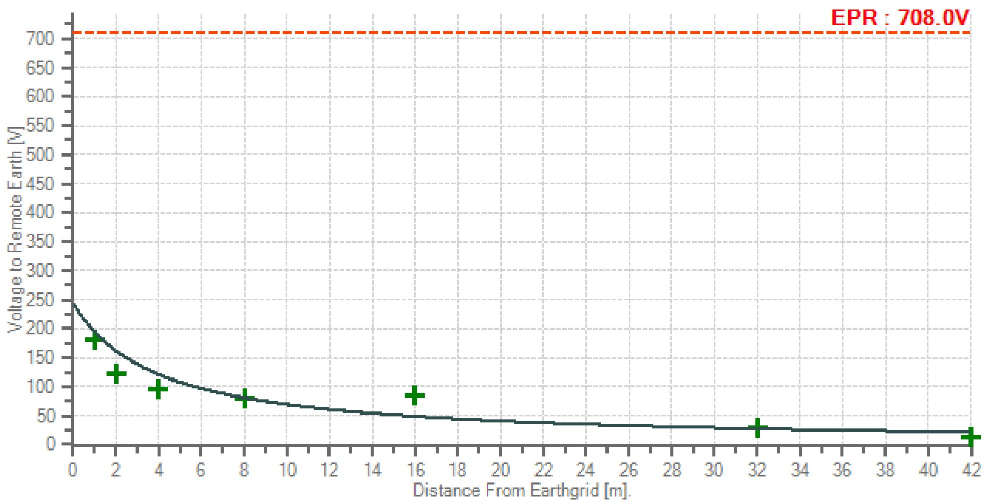


Figure 3-5
pole KR-90056 FOP for 11kV Earth Fault at Medowie ZS



As can be seen from Figure 3-1 the contours applicable to the DU, TDB and TDMEN contact scenarios are as documented following in Table 3-2.

Table 3-2
Hazard Contours for 33kV Feeder Faults

*Soil voltage is less than the respective negligible risk voltage threshold.

Earthed HV Assets	Distance of Contour from Earthing System		
	DU	TDB	TDMEN
33kV UGOH Pole	NA*	NA*	3 m
33kV standard Pole	NA*	NA*	2 m

Again, as the EPR of the poles is less than the DU contact scenario touch voltage hazards to all poles are considered negligible risk and compliant to both AS7000 and ENA EG-0.

3.3 Summary

Analysis of both earth faults at Medowie ZS and on the 33kV feeder within the college easement identified the most onerous contours around the earthed assets are as follows in Table 3-3.

Table 3-3 Most Onerous Hazard Contours

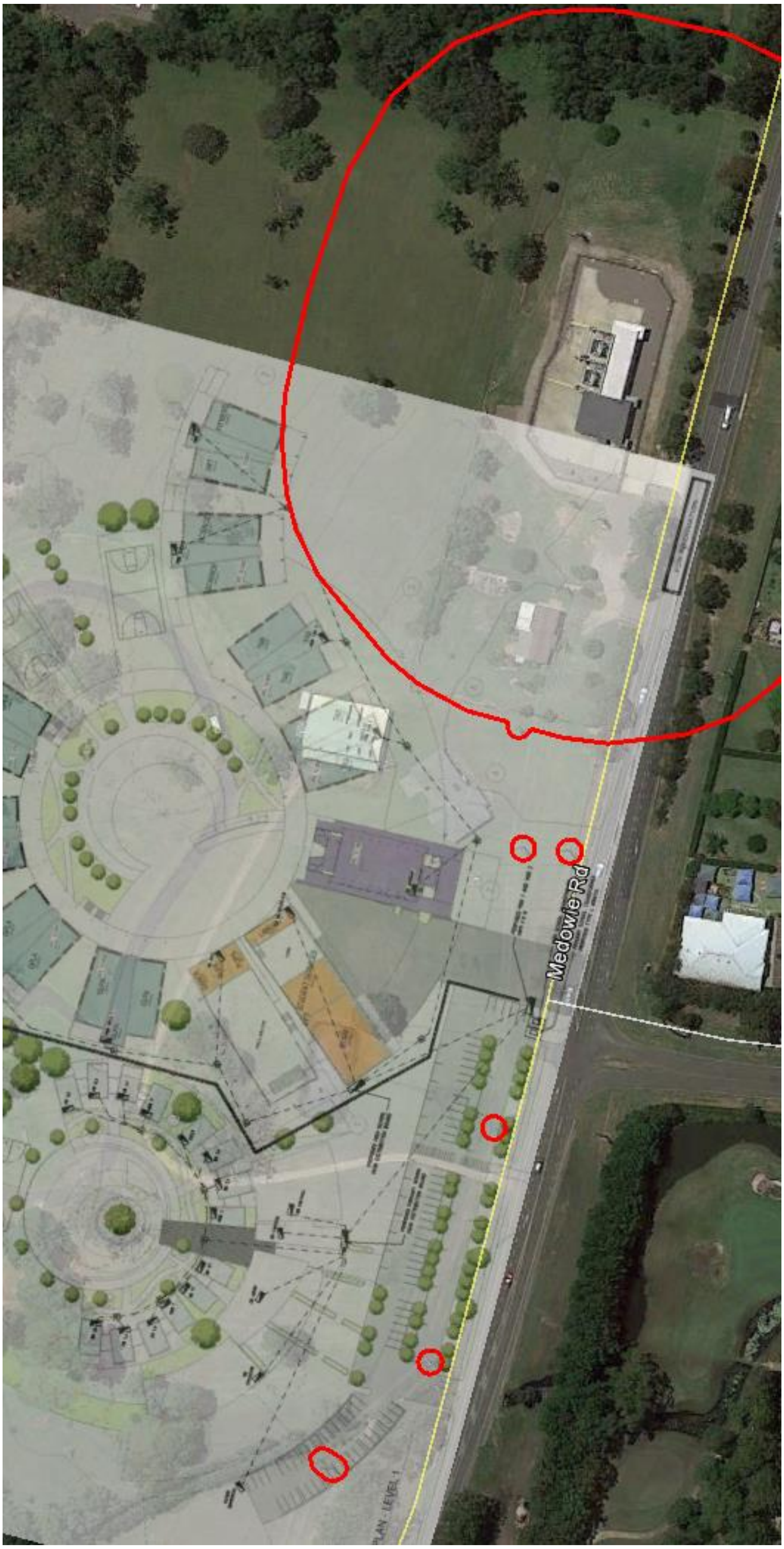
*Soil voltage is less than the respective negligible risk voltage threshold.

Earthed HV Assets	Distance of Most Onerous Contour from Earthing System		
	UI / DU	BY / TDB	MEN / TDMEN
Medowie ZS	4 m	20 m	85 m
33kV UGOH Pole	NA*	NA*	4 m
33kV standard Pole	NA*	NA*	2 m

The most onerous BY/TDB and MEN/TDMEN contours are shown geographically in Figure 3-6 and Figure 3-7 in red. The UI/DU contour is contained within the Medowie ZS property fence and requires no further consideration.

Figure 3-6 Most Onerous BY/TDB Hazard Contour around Medowie ZS

Figure 3-7
Most Onerous
MEN/TDMEN Hazard
Contours around
Earthed HV Assets



✓ Based on the Catherine McAuley Catholic College Site Plan Electrical Layout no remotely earthed metallic infrastructure is expected to be installed within the BY/TDB contour around Medowie ZS as part of the Catherine McAuley College Development.

✓ Based on the Catherine McAuley Catholic College Site Plan Electrical Layout no buildings or significant metalwork interconnected with the MEN has been identified within the most onerous MEN/TDMEN contour.

Consequently the proposed Catherine McAuley College Development is expected to be compliant with ENA EG-0 for earth faults associated with Medowie ZS and the proximate 33kV feeders.

! If any remotely earthed metallic infrastructure is to be installed within the BY contour shown in Figure 3-6 as part of future development, further assessment of the voltage hazards associated with the new infrastructure due to earth faults at Medowie ZS is required.

! If any future buildings are to be installed within the MEN contour shown in Figure 3-7 Safearth recommend an earthing system design be included as part of the building design process.

! If a significant number of street lights are to be installed as part of future Car Parks within the MEN contour shown in Figure 3-7 Safearth recommend that either further assessment of the street light earthing system is performed or that the street light LV circuit is double insulated to prevent the possibility of any soil voltage transfer into the MEN. Details for double insulating the Street light LV circuit are provided in Appendix C.

4 Bibliography

[1] ENA EG-0 'Power System Earthing Guide Part 1: Management Principles.' Energy Networks Association. August 2010.

[2] AS/NZS 7000:2010 'Overhead Line Design – Detailed Procedures'. Standards Australia.

[3] AS/NZS 3000:2007, 'Electrical Installations (known as the Australian/New Zealand Wiring Rules)'. Standards Australia.

[4] AS/NZS 3835.1:2006 'Earth Potential Rise - Protection of Telecommunications Network Users, Personnel and Plant - Code of practice'. Standards Australia.

[5] AS/NZS 4853:2012, 'Electrical Hazards on Metallic Pipelines'. Standards Australia.

[6] AS/NZS 1768:2007, 'Lightning Protection'. Standards Australia.

[7] AS 2067:2016 'Substations and high voltage installations exceeding 1 kV a.c.'. Standards Australia.

[8] AS/NZS 60479:2010 'Effects of current on human beings and livestock', Standards Australia.

[9] ANSI/IEEE Std 80-2000, 'IEEE Guide for Safety in AC Substation Grounding'. The Institute of Electrical and Electronic Engineers AS/NZS 1768:2007 'Lightning Protection'. Standards Australia.

[10] IEC61936-1:2010 'Power installations exceeding 1kV a.c. – Part 1: Common rules'. International Electrotechnical Commission.

[11] Energy Networks Association, *ARGON software*, http://www.ena.asn.au/?cat=568

[12] MDI 0045:Amd 0, 'Cable sheath bonding design', Endeavour Energy

[13] MDI 0047:Amd 0, 'Overhead transmission mains design', Endeavour Energy.

[14] Working Group 07, 'The Design of Specially Bonded Cable Systems', Cigrè, No 28, 1973.

[15] "Risk Targets – Where to Start, What to Calculate and Where to Stop", Bale, Palmer, Woodhouse and Tocher. RISK Conference 2014 Brisbane Australia.

[16] Work Health and Safety Act 2011, No.137, Australian Government.

Appendix A Soil Resistivity Considerations

Introduction

To correctly design and analyse earthing systems it is necessary to understand the electrical structure of the local soil. Soil resistivity testing is often used to determine electrical characteristics of the soil in which the earth grids are buried and upon which the structure stand. Test data should always be considered in conjunction with past test data from the region, published soil resistivity range data and other available geo-technical data. Possible sources of local error such as excavations, fences, buried pipelines and transmission system should also be considered.

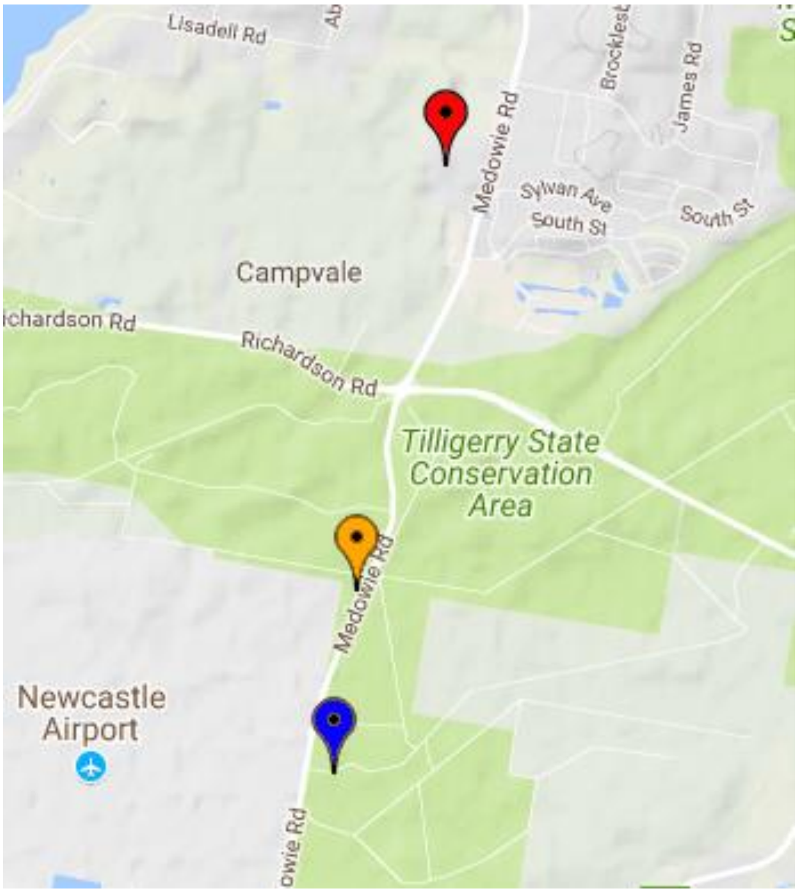
AusGrid provided soil resistivity results of two test locations. One location is indicated as Kingfisher Road, the approximate location is shown in red in the following figure. The location of the other test performed by AusGrid is unknown. The location of tests previously performed by Safearth are shown in orange and blue in the same figure.

The result of the resistivity tests are displayed in corresponding colours in the figure labelled Soil Resistivity Test Results. The soil model supplied by AusGrid for the unknown location is shown in grey.

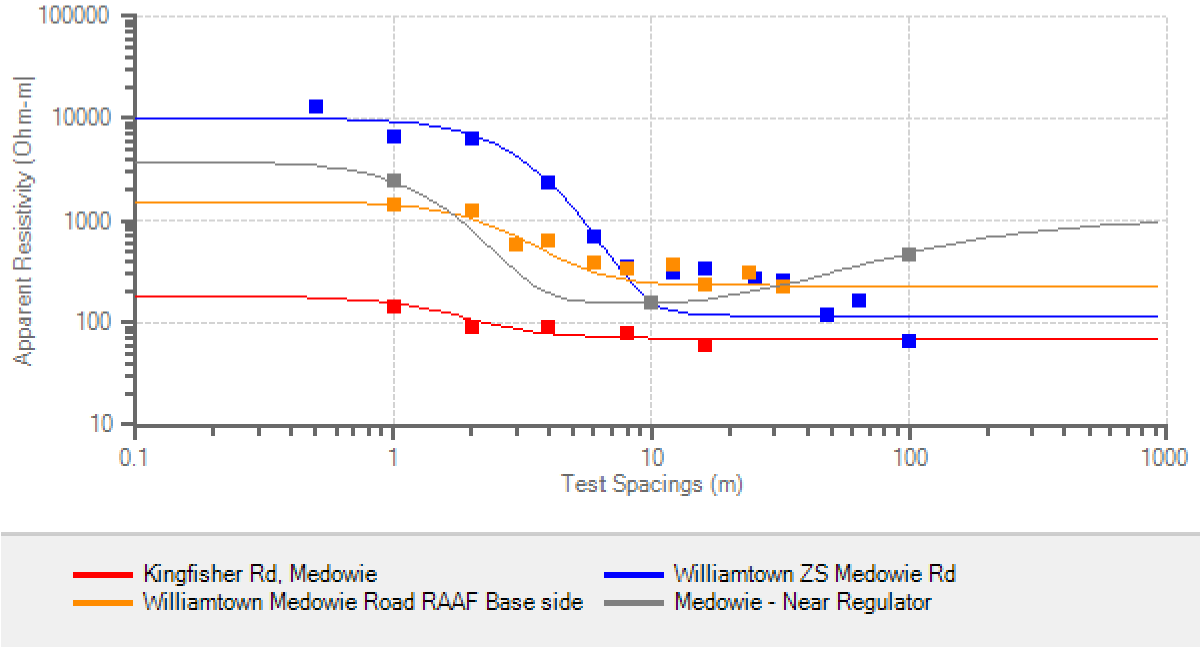
The figures show the soil resistivity across the site varies significantly. Recommendations with respect to the applicability of the soil resistivity models are provided in section 2.3.

Test Locations and Soil Models

Substation Site Soil Resistivity Test Locations



Soil Resistivity Test Results


100000
10000
1000
100
10
Apparent Resistivity [Ohm-m]
0.1
1
10
100
1000
Test Spacings (m)
Kingfisher Rd, Medowie
Williamtown ZS Medowie Rd
Williamtown Medowie Road RAAF Base side
Medowie - Near Regulator

Appendix B Electrical Safety Criteria

Introduction to Design Standards and Safety Criteria

Applicable Standards

In Australia there are a number of regulations pertaining to safety criteria for electrical installations. Some are clearly applicable in various situations and sometimes the applicable criteria are not easily determined. In any case the overriding responsibility is that of due care based on the recognised best practice and current research. The following is a list of the foremost and commonly referred to standards that define safety criteria for the relevant concerns:

ENA EG-0:2010	Earthing System Risk Assessments
AS 7000:2010	Transmission and Distribution Assets
AS 3000: 2007	Australian Wiring Rules
AS 3835:2006	Telecommunications Assets impacted by EPR
AS 4853:2012	Conductive Pipelines impacted by EPR & LFI
AS 1768:2007	Lightning Protection
AS 2067:2016	All high voltage substations >1kV a.c.

Other standards that may be of value depending on the application may include:

AS 60479:2010	Effects of current on humans
IEEE 80	Substation Grounding (American)
IEC 61936:2002,2010	Power installations exceeding 1kV a.c. (European)

In the following sections we shall discuss risk, consider generally earth fault safety criteria applicable to the public, criteria specifically applying to pipelines and criteria related to telecommunications installations.

Deterministic Voltage and Risk Quantification

Safearth is of the considered opinion that earthing system safety assessments should consider and compare the various available and contemporary sources of applicable safety criteria in order to demonstrate due diligence and a level of appropriate conservatism for the safety targets chosen for a given application.

That process has become complicated by the fact that there is a growing trend away from the traditional deterministic (pass/fail) safety criteria approaches to modern earthing risk quantification (risk quantification As Low As Reasonably Practicable - ALARP).

One complication is that the most widely used guide recommending safety criteria for substation earthing, ENA EG-1, recommends Dalziel's deterministic method for safety voltages as published in IEEE80. An alternative risk quantification method initially published in ENA EG-0 has now been adopted by a growing number of Australian Standards including AS2067 and AS7000.

The 2011 WHS Act requires those holding a duty to eliminate or otherwise minimise safety risks so far as is reasonably practicable to prevent harm to workers and the public. The use of risk in managing earthing safety generally began in Australia with the publishing of the ENA guide EG-0 which advises the ALARP approach. As low as reasonably practicable is a process that identifies foreseeable hazards, determines the risk associated with each hazard and then applies controls to the hazard until the remaining risk is as low as reasonably practicable. Safearth are widely published on the appropriateness of the ALARP risk based processes and support ALARP along with the broader risk society in its applicability to WHS legislation.

The ALARP process is familiar to engineering practitioners because the hierarchy of engineering controls is a valid mechanism used in identifying risk reduction measures, and, risk quantification tools (such as ENA EG-0) are therefore vital in being able to calculate and make this risk value judgement. It is important that risks be managed to levels that are demonstrably as low as reasonably practicable with any further risk reduction methods conceived being grossly disproportionate in cost compared to the reduction in risk achieved.

Public/Personnel Safety Criteria – Major Substations

The deterministic EG-1 safety criteria calculations, applicable to most major substations, do not stipulate differing contact scenarios, but does offer two contact categories: the 50kg category for public access and the 70kg category for secure areas without public access. Note however that neither category has allowed for the resistance afforded by shoes in the calculation but the resistivity of the soil can be included to account for feet to ground contact resistance. Note also that a single body impedance of 1000Ω irrespective of the current path through the body was assumed by Dalziel. This simplification does allow touch and step voltage measurements to be performed for either the prospective 'open circuit' case or the 'loaded' case to identify situations where dominant source and contact impedances may attenuate the actual voltage hazard by loading the voltage across the body with the current flowing through the entire circuit.

Calculations of the applicable ENA EG-1 safety criteria is typically performed with a conservative surface layer resistivity to account for seasonal and soil composition variations across sites. For Non-public access a crushed rock layer may be included in the calculation: typical thickness and resistivity is 100mm, 3000Ωm respectively.

Note step voltages may be calculated using Dalziel's method, however due to the gross inconsistency that presently exists between various safety criteria sources, in particular ENA EG-0 and Biegelmeier's heart current factor data presented in AS60479. If soil voltage measurements indicate step voltages may be a concern then a bespoke assessment can be performed.

Public/Personnel Safety Criteria – Transmission Systems and Distribution Substations

AS7000:2010 is the source Australian standard for safety criteria applicable to transmission circuits and distribution substations with low voltage secondary windings. It is also being adopted as a reasonable alternative for other utility infrastructure, such as zone substations, as a means of demonstrating reasonable due care. AS7000:2010 is a direct reinterpretation of the ENA guideline EG-0:2010 and therefore EG-0 will be used to calculate applicable negligible risk targets and to aid in quantifying earthing risk for the project and client as the duty holder.

The risk management process outlined by EG-0 is similar to other risk management procedures used across various industries where negligible risk scenarios identified as contributing insignificantly can be acknowledged and discounted from further analysis (refer section 5.4 ENA EG-0).

The method with which EG-0 will be applied is summarised in Table 5-1 of ENA EG-0. Where possible, compliance will be assessed via the first pass *probabilistic safety criteria case studies* published in appendix E of ENA EG-0. Where these standard constant probability of fatality curves appear overly conservative and result in unreasonable or unnecessary risk reduction measures then more detailed investigation will be conducted.

Hazards that may be incurred by the exposed reasonably based individual will then be analysed with a view to identifying worst case hazard magnitudes. The behaviour of the exposed individual cannot be accurately defined (number of contacts to various items throughout day to day life), therefore it is a reasonable approach, and one which is supported by ENA EG-0, to consider and identify worst case voltage hazards at items affected by a foreseeable earth fault scenario (ENA EG-0 Table 5-1 Step 4).

The contact scenarios suggested by ENA EG-0 and AS7000 are summarised following:

MEN contact (MEN) —Contact with LV MEN interconnected metalwork (for example, household taps) under the influence of either LV MEN voltage rise and/or soil potential rise (2000 contacts of less than 4 seconds duration).

Backyard (BY) —An area with a contactable metallic structure (for example, fence, gate) subject to fault induced voltage gradients. This metallic structure is not an HV asset but becomes live due to earth fault current flow through the soil (416 contacts of less than 4 seconds duration).

Urban Interface (UI)—Asset outside normal public thoroughfare with low frequency of direct contact by a given person (100 contacts of less than 4 seconds duration).

Remote— A location in a remote location where people are unlikely to visit without specific cause related to the structure (10 contacts per year of less than 4 seconds). For most cases, where fault rates and protection clearing times are within industry standards, the coincidence probability is less than 1e-6.

The fault rates suggested by ENA EG-0 and AS7000 are summarised following:

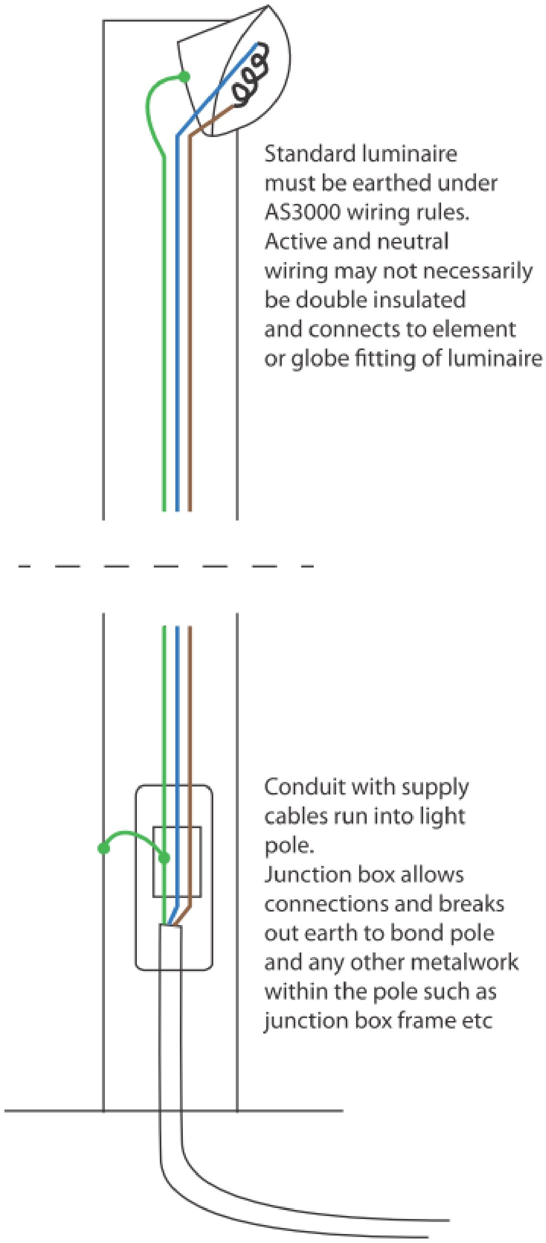
Transmission Assets – 2km long transmission section (for example, asset interconnected by 10 spans each up to 200m in length with and OHEW) contributing at a fault rate of 5 faults/100km/year yielding 1 fault per 10 years.

Distribution Assets – A fault rate of 1 fault per 10 years relates to a range of distribution assets including:

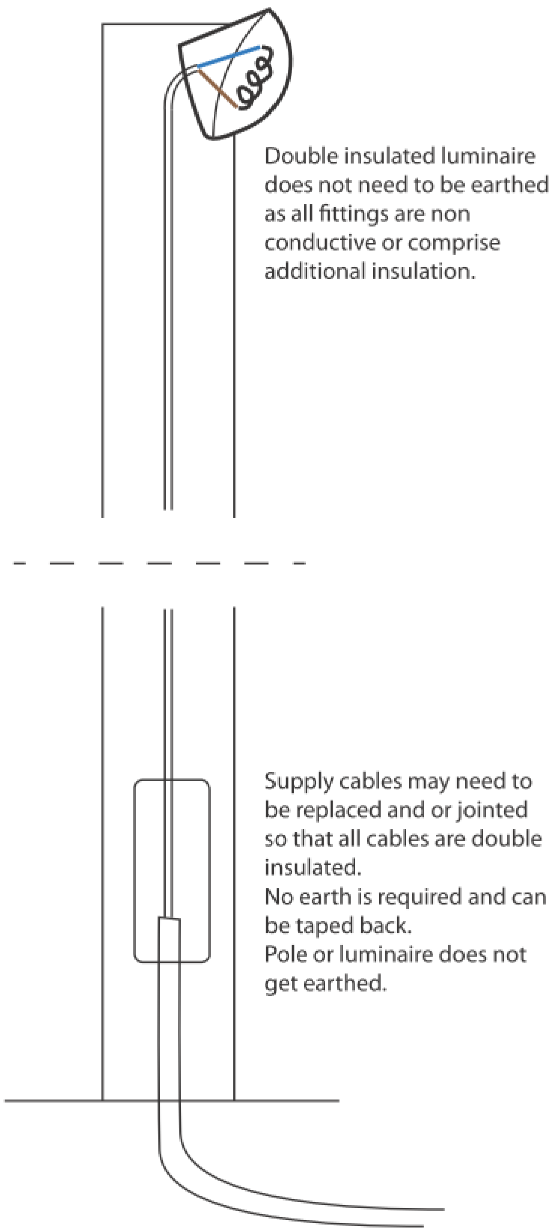
- 1km isolated underground cable at 10 faults/100km/year
- 2 by 500m of underground cable feeding a substation at 10 faults per 100km/year
- 1km line section with an earth wire shielding at 10 faults/100km/year
- 2 by 100m spans without an earth wire at 40 faults/100km/year
- 2 by 100m spans without an earth wire and pole mounted substation at 40 faults/100km/year

Appendix C Street Light Double Insulation Details

Standard light pole - Not double insulated (Left) and Light pole - With double insulation (Right)



Basic Insulation



Double Insulation

Appendix D Glossary

Glossary Entry	Definition
Clearing Time	Time taken for protective devices and circuit breaker to isolate the fault current
Coupling Factor	The magnitude of the current returned on a faulted circuits screens and sheath, or OHEW expressed as a percentage of the fault current magnitude.
ECC	Earth Continuity Conductor – Typically a PVC covered conductor run in parallel to transmission cables, especially where the feeder screens are single point bonded
Earth Grid	A connection to the greater mass of the earth, usually made by burying metallic conductors in the soil
EPR	Earth Potential Rise - The maximum voltage that a station earth grid will attain relative to a distant earthing point assumed to be at the potential of remote earth
Fault Current	The current flowing as the result of a line to ground fault on the power system.
Induced Voltage	The voltage on a metallic structure resulting from the electromagnetic or electrostatic effect of a nearby power line.
LFI	The induced voltage created by electromagnetic fields created by normal power system operating frequencies, typically 50 or 60 Hz.
MEN	Multiple Earth Neutral. In the context of earthing design this typically defines the interconnected earthed blob that is the low voltage network
Mesh Voltage	The V_{Mesh} is the touch voltage within a mesh, and the maximum value used for design purposes with a station grid.
MER	MER is an occurrence whereby voltage coupling between earth systems affects the apparent impedance of the combined systems. Soil resistivity structure, system sizes and separation, and current relationship contribute to MER's significance.
Proximity Effect	Phenomenon whereby diminishing returns are obtained by installing more and more in-ground earthing in proximity to an existing system. Soil resistivity structure, system sizes and proximity, and current relationship contribute to the significance of proximity effect.
Shielding Factor	One hundred percent minus the magnitude of the current returned on a faulted cable's screens and sheath expressed as a percentage of the fault current magnitude.
Step Voltage	Prospective: The open-circuit voltage difference between two points on the earth's surface separated by a distance equal to a man's normal step (approximately 1 metre). Loaded: The difference in surface potential experienced by a person's body bridging a distance of one metre with his feet without contacting any other grounded object.

Glossary Entry	Definition
Touch Voltage	Prospective: The open circuit voltage difference between a conductive structure (within 2.4 metres of the ground), and a point on the earth's surface separated by a distance equal to a man's normal horizontal reach (approximately 1 metre). Loaded: The voltage across a body, in a position described as for Prospective but allowing for the voltage drop through the touch voltage circuit caused by current flow in the body
Transfer Voltage	A special case of Touch Voltage where the conductive item touched is connected to a remote point or alternatively is connected to the station grid and is touched at a remote location.
Zero Sequence Current	The fault current flowing through phases and all earth return paths as the result of line(s) to ground faults on the power system ($I_{Fault} = 3I_0$)