Standard for Distribution Line Design Underground

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Approver	Ana Smith De Perez Group Manager Asset Standards	
If RPEQ sign off required insert details below.		
Ergon Energy		
Certified Person name and Position	Registration Number	
Carmelo Noel Manager Line Standards	8802	

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Standard for Distribution Line Design Underground

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Document approvals

Name	Position title	Signature	Date
Peter Price	Head of Corporate Strategy & Executive General Manager Asset Safety & Performance		
Ana Smith De Perez	General Manager Asset Standards		
Tim Hart	General Manager Asset Lifecycle Management		

Stakeholders / distribution list

Name	Title	Role
Russ Christ	Regional Manager Southern Networks	Endorse
Keegan Oliver	Regional Manager Northern Networks	Endorse
Adam Bletchly	UG & PL Standards Engineer	Endorse
Michael Derrick	Networks Manager South West Burnett	Comment
Steven Lowry	Networks Manager Capricornia West	Comment
Greg Canavan	Networks Manager Pioneer Tropical North	Comment
Darrin Hoffensetz	Networks Manager Herbert Flinders	Comment
Sean Mc Guinness	Manager Lines Design & Engineering	Endorse
Glen Boisen	Southern Distribution Design Manager	Comment
Tristan Turner	Northern Distribution Design Manager	Comment
Michael Pitton	Lines & Lighting Engineering Manager	Comment
Ray Boland	Lines Design Support Manager	Comment
Jeff Shears	Manager Lifecycle Engineering Lines	Endorse

Table of Contents

1 Overview 1
1.1 Purpose 1
1.2 Scope 1
2 References 2
2.1 Ergon Energy controlled documents 2
2.2 Other documents 2
3 Legislation, regulations, rules, and codes 3
4 Definitions, acronyms, and abbreviations....3
4.1 Definitions 3
4.2 Acronyms and abbreviations 4
5 High Voltage Network Design 5
5.1 Network Planning Arrangement 5
5.1.1 General 5
5.1.2 Residential Development....5
5.1.3 Commercial and Industrial Development 6
5.1.4 Rural Developments 8
5.1.5 Padmounted Substation Determination 8
5.1.6 Community Powerline Projects....8
5.2 Padmounted Substation HV Switchgear Selection 8
5.2.1 General 8
5.2.2 Interconnected Backbone Feeders 9
5.2.3 Radial Feeders 10
5.3 Padmounted Substation Site Selection 12
5.3.1 General 12
5.4 Pole Top Selection....13
5.5 Cable Selection....14
5.5.1 General 14
5.5.2 Standard Underground Cables 14
5.5.3 Cable Route Selection....15
6 LOW VOLTAGE NETWORK DESIGN 16
6.1 Network Planning and Design Arrangement....16
6.1.1 General 16
6.1.2 Residential Subdivisions....16
6.1.3 Commercial and Industrial Development 19
6.2 Pillar / Distribution Cabinets and Pits Site Selection 24
6.2.1 General 24
6.2.2 Community Title Scheme (CTS) 24
6.3 Cable Selection....24
6.3.1 General 24
6.4 Pole Top Selection....25
6.5 Installation Guidelines 26
7 ELECTRICAL DESIGN....27
7.1 Ferroresonance....27
7.1.1 Methods of controlling ferroresonance....28

7.2 Electromagnetic fields (EMF) 30
7.3 HV & LV Isolators (Links) Capacitive Charging Current Limitation....31
7.4 Metallic Pipelines in Close Proximity to High Voltage Installations 32
8 CABLES 34
8.1 HV Cable Data – Non insect Protected 34
8.2 HV Cable Data – Insect Protected....35
8.3 LV Cable Data – Non Insect Protected....36
8.4 LV Cable Data – Insect Protected 37
8.5 Cable Installation – Design Considerations....38
8.5.1 Route Selection....38
8.5.2 Cable Pulling 38
8.5.3 Conduits....42
8.6 Cable Ratings 43
8.6.1 General 43
8.6.2 Soil Thermal Resistivity (ρ) 43
8.6.3 Soil Temperatures....44
8.6.4 Depth of Cover 45
8.6.5 Mutual Heating Affects 45
8.6.6 Conduit....46
8.6.7 Cyclic Rating Factors....46
9 EARTHING....47
9.1 Earthing System....47
9.1.1 CMEN 47
9.1.2 Separate Earthing 47
9.2 CABLE SCREEN EARTHING....47
9.2.1 General 47
9.2.2 Zone Substations Exits....48
9.2.3 Earthing of Feeder and Radial Cables....49
9.3 LOW VOLTAGE EARTHING....50
9.3.1 General 50
9.3.2 Earthing at Pillars (Design Rules)....50
9.3.3 Earthing at OH LV Cable terminations....50
9.3.4 Earthing of Public Lighting Columns....50
9.3.5 Earthing of Bridge Lighting 51
9.4 PROXIMITY TO TELECOMMUNICATIONS 51
9.4.1 Telecommunications 51
9.5 Approach to Earthing Design for Developer Design and Construct Works and for other Ergon Energy Works....52
10 Easement....54
10.1 Community Title Developments 54
11 AGREEMENTS 55
11.1 QR DESIGN REQUIREMENTS 55
11.1.1 Prior Approval 55
11.1.2 General 55
12 APPENDIX A – CABLE PULLING TENSION CALCULATOR INSTRUCTION....57
13 Amendment Record....58

1 Overview

1.1 Purpose

This standard has been compiled in order to provide support for Designers and Asset Managers in the application of Ergon Energy Corporation's Construction Standards.

1.2 Scope

This standard contains design information and guidelines necessary to allow use of the Underground Construction Standards structures in a manner consistent with optimum economic, reliability and safety objectives.

It is proposed that the standard will be expanded in conjunction with future issues of the Underground Construction Manual.

The provisions of this standard are in accordance with relevant Australian Standards and / or recognised electricity design practice and have RPEQ sign off. Designs carried out in accordance with this standard can be considered to comply in this regard.

Support for this design standard is available from the Line Standards staff as follows:

Overhead	Fabio Zaini, Johnson Chung, Craig Avenell & Paul Relf
Underground & Public Lighting	Adam Bletchly, Boyd Brunsmann & Kim Slater
Materials	Subramanian (Jegan) Ramsaubramanian
Estimating & Compatible Units	Darren Sayers
Drafting	Leon Burton & Tim Borg

2 References

2.1 Ergon Energy controlled documents

Document number or location (if applicable)	Document name	Document type
EP48	Electric and Magnetic Field	Policy
ES000904F100.	Magnetic Field Calculator - User Notes (Reference)	Reference (Form)
ES000904R104	EMF Guideline for New Infrastructure	Reference
ES000904R105	EMF Assessment Protocol for Existing Electrical Infrastructure	Reference
ES000904W108.	Management of EMF Queries and Public Communications (Work Instruction)	Work Instruction
NA000404R100	Power Coordination Guidelines Agreement between Ergon Energy and Telstra (Distribution Only)	Guideline (Reference)
PW000803R104	Easement and Wayleave	Reference

2.2 Other documents

Document number or location (if applicable)	Document name	Document type
AS/NZS 2067	Substations and high voltage installations exceeding 1kV a.c.	Standard
ESAA C(b)2	Guide to the Installation Cables Underground	Guide
AS 5488	Classification of Subsurface Utility Information	Standard
IEEE Std 525	Guide for the Design and Installation of Cable Systems in Substations	Standard
ESAA HB100	Coordination of power and telecommunications - Manual for the establishment of safe work practices and the minimization of operational interference between power systems and paired cable telecommunications systems	Handbook
AS/NZ 3853.1	Earth potential rise – Protection	Standard

	of telecommunications network users, personal and plant Part 1: Code of practice	
AS/NZ 3853.2	Earth potential rise – Protection of telecommunications network users, personal and plant Part 2: Application guide	Standard

3 Legislation, regulations, rules, and codes

Legislation, regulations, rules, and codes
Electrical Safety Act 2002
Electrical Safety Regulation 2013
Work Health and Safety Act 2011
Work Health and Safety Regulation 2011
Electricity Act 1994
Electricity Regulation 2006
Building Code of Australia (BCA) – National Construction Code 2015

4 Definitions, acronyms, and abbreviations

4.1 Definitions

For the purposes of this standard, the following definitions apply:

Term	Definition
Electric Fields	Fields, produced by voltage, which increase in strength as the voltage increases. The electric field strength is measured in units of volts per meter (V/m) or kilovolts per meter (kV/m).
Electric and Magnetic fields (EMF)	A term used to refer to both electric and magnetic fields. This guideline applies to extremely low frequency (under 3kHz) electric and magnetic fields around power lines, electrical apparatus and electrical wiring.
Magnetic fields	Fields, resulting from the flow of current through wires or electrical devices, which increase in strength as the current increases. Magnetic fields are measured in units of gauss (G) or tesla (T). Gauss is the unit most commonly used in Australia. Tesla is the internationally accepted scientific term. Since most environmental EMF exposures involve magnetic fields that are only a fraction of a tesla or a gauss, these are commonly measured in units of microtesla (µT) or milligauss (mG). To convert a measurement from microtesla (µT) to milligauss (mG), multiply by 10. That is, 1 µT = 10 mG.
Sensitive Areas	Areas or potential areas where children congregate such as schools, child-care and kindergarten centres and playgrounds.
Time Weighted Average (TWA)	A weighted average of exposure measurements taken over a period of time that takes into account the time interval between measurements. When the measurements are taken with a monitor at a fixed sampling rate, the time-

	weighted average equals the arithmetic mean of the measurements.
Common Area	Refers to the common areas within Community Title developerments.
Community Title	Refers to residential development on land which has been divided into lots and common property and registered under the Building and Group Title Act 1980 and for which a separate Certificate of Title for each lot has been issued.
Easements	An easement is defined by survey and is not effective until it is registered on the title deed in the office of the Registrar of Title. Easements are acquired to ensure security for electric lines of various voltages. Registered easements remain in perpetuity or until such time as they are no longer required to accommodate electrical works, in which case they may ne surrendered by the guarantee (Ergon Energy).

4.2 Acronyms and abbreviations

The following abbreviations and acronyms appear in this standard.

Abbreviation or acronym	Definition
ABS	Air Break Switch
ADMD	After Diversity Maximum Demand
CARE	Cyclone Area Reliability Enhancement
CB	Circuit Breaker
CFS	Combined Fuse Switch
CMEN	Common Multiple Earth Neutral
CPP	Community Powerline Project
EMF	Electromagnetic Fields
HV	High Voltage
ICNIRP	The International Commission on Non-Ionising Radiation Protection EMF Exposure Reference Limits 2010 [4].
LV	Low Voltage
NPO	Network Planning Officer
POS	Point of Supply
RMU	Ring Main Unit (also previously known as GMS or ground mounted switchgear)
SDO	Senior Design Officer
STR	Soil Thermal Resistivity
UDC	Underground Distribution Construction
URD	Underground Distribution Development

5 High Voltage Network Design

5.1 Network Planning Arrangement

5.1.1 General

The design of any underground work must be integrated into an overall vision for development of the network. Planning provisions cater for the orderly and cost effective growth and development of the network and its safe and reliable operation through:

- prudent investment in network assets
- the avoidance of costly augmentation and
- replacement of assets to meet demand growth.

Easements for Ergon Energy underground infrastructure are required where these assets are located on private property. In general, non-volumetric easements are suitable for Urban Residential Developments (URD) and volumetric easements will generally be required for Commercial and Industrial areas or developments. Refer to PW000803R104. Easement and Wayleave (Reference) for further details.

5.1.2 Residential Development

Residential developments can range from small isolated developments through to the extensive developments covering large tracts of land.

The network should be designed to achieve the minimum number of padmounted substations necessary to meet the calculated design demand and voltage regulation requirements. For conventional subdivisions a 500 kVA transformer is the largest padmount capacity that can practically be distributed, but in most cases a 315 kVA transformer capacity will be sufficient (refer to Section 6 - LV Network Design).

As a **design rule** the transformer capacity should be chosen to achieve:

- 90% utilisation as a minimum, and
- 125% utilisation as a maximum

The above utilisation figures shall be based on the estimated demand at the time of commissioning given the limitations imposed by the range of transformer sizes available.

Radial feeders are allowed under the following circumstances:

- Where the final connected capacity will not exceed 1.2 MVA
- Provision of additional conduits to allow for loop-in / loop-out arrangement if the connected capacity is likely to exceed 1.2 MVA.
- Developers will be required to fund the loop-in / loop-out arrangement when the connected capacity exceeds 1.2 MVA – see Figure 5.1.2-1

Where the design capacity requirement of a development or the combined design capacity with adjoining developments exceeds 1.2 MVA, and the Developer is building successive stages, the Developer can exceed the 1.2 MVA if all of the following conditions are met:

- A detailed staged development master plan must be provided and agreed with Ergon Energy.
- The connected transformer capacity of the radial must not exceed 2 MVA.
- The developer is to provide a Bank Guarantee to Ergon Energy for the agreed sum that it would cost Ergon Energy to construct a connection to remedy the radial arrangement.
- The developer has 3 years to progress the development and complete the connection so that the radial connected capacity no longer exceeds 1.2 MVA.

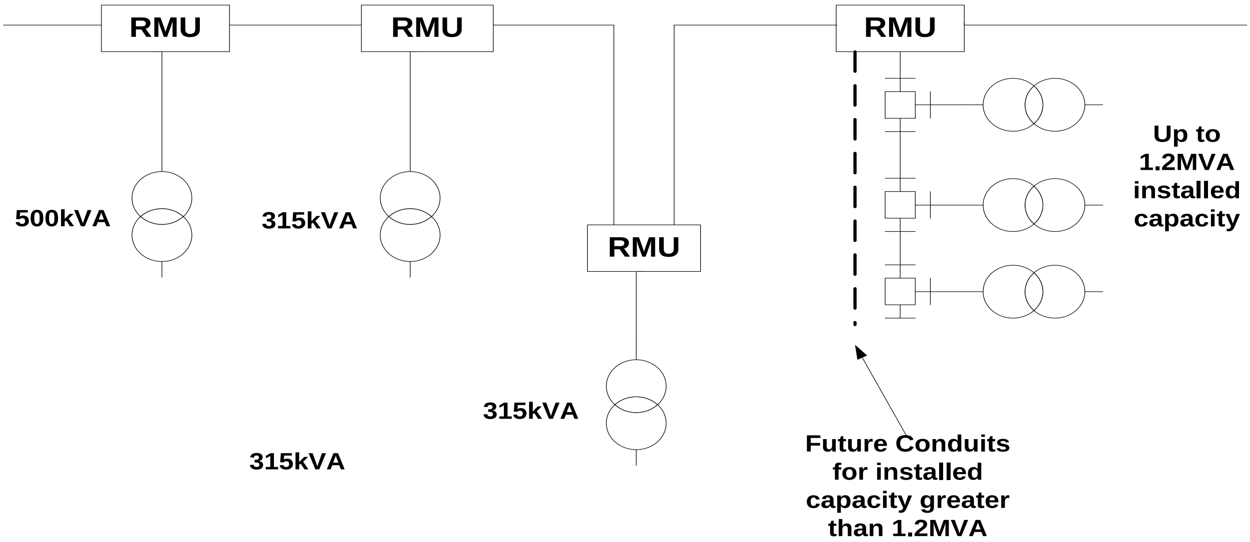


Figure 5.1.2-1 Radial connection

Information will often be sketchy and incomplete and the strategy plan may need to cater for a number of contingencies but nevertheless the plan will enable an orderly development of the network. Designers must also consult with the Regional Manager Northern Networks and Regional Manager Southern Networks and the SDO to establish whether the development they are designing is part of an established network development strategy plan.

Guidelines for the selection of switchgear and cable sizes for these network arrangements are provided in Sections 5.2 and 5.5.

5.1.3 Commercial and Industrial Development

5.1.3.1 Subdivisions

In general the same principles apply as Underground Residential Development (in addition to no tee-offs as shown in Figure 5.1.3-1) because the substation supplies distributed customers. However for this customer class the electrical requirements of allotments are generally unknown and less predictable.

Padmounted substation transformer capacities up to 1500 kVA for 11 kV and 1000 kVA for 22 kV are available for commercial and industrial applications. It is important however not to rely too heavily on large transformers and LV distribution for supply to distributed customers. There is a risk of over investment in LV distribution to cater for the volatile and unpredictable demands associated with this customer class. Consequently it is generally better to minimise the number of LV circuits by establishing another substation site or future site as this will provide greater flexibility for meeting demand variables.

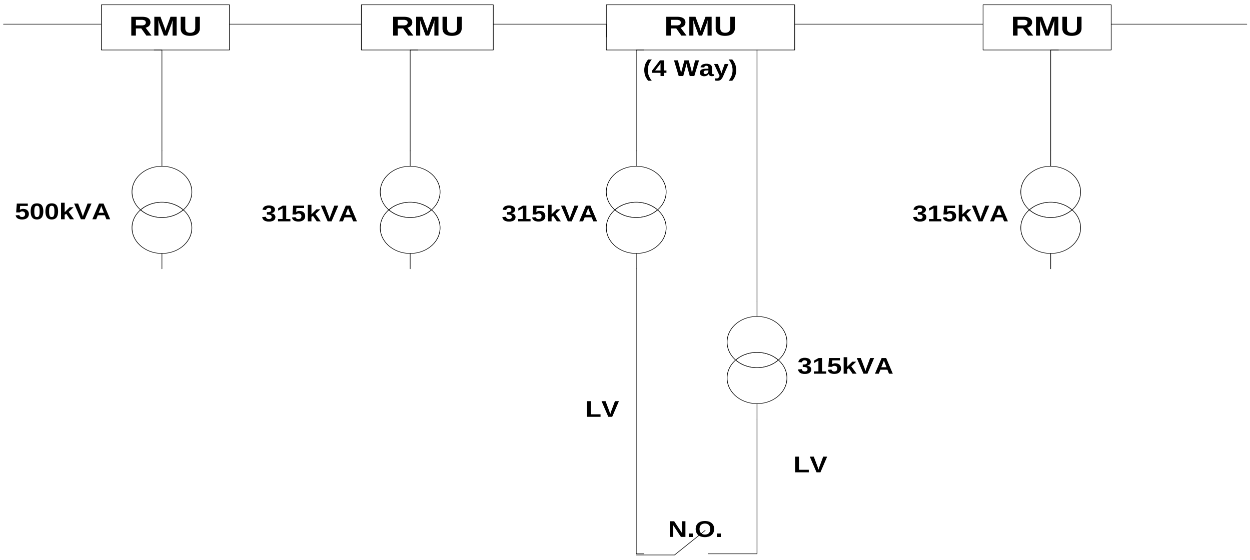


Figure 5.1.3-1 Commercial and Industrial applications

5.1.3.2 Larger Customers

Electrical requirements may be established from existing operations, or in the case of a new plant from knowledge of the equipment to be installed with a working diversity applied.

For larger customers the substation should be situated as close as practical to the customers load centre regardless of whether this makes the provision of an external low voltage interconnection impractical. This cannot however be hard and fast rule because of the different situations that will be encountered and good engineering practice will need to be applied.

Padmounts are preferred for supply requirements up to 1500 kVA for 11 kV and 1000 kVA for 22 kV, provided a site satisfactory to Ergon Energy and the customer can be established. Multiple padmounts may be used under certain conditions in consultation with Distribution Network Standards. Otherwise an indoor/chamber type substation will be required.

When assessing the customer's supply requirements future growth must be taken into account as it may be necessary to establish an indoor/chamber substation initially to cater for the longer term needs.

Some industrial customers may, because of the nature of their business, seek to have an alternative HV supply. In such cases commercial considerations will apply. As a **design rule** Ergon will not normally provide a second supply cable and the associated switchgear in these situations.

Designers must consult with the Networks Manager before a "ring feed" is considered for network purposes in these circumstances.

5.1.4 Rural Developments

For rural developments the likely demand will not generally warrant an interconnected HV network unless this is required for other reasons. The selection of the substation transformer size must be a practical balance between the cost of padmounts, HV cables, LV cables, and reliability considerations.

As the number of connected customers falls there will be less diversity of demand and a greater impact from unbalanced supply factors making the extensive use of LV networks unattractive. The best solution will depend on allotment size and it should be expected that transformer size and the extent of LV networks will decrease with an increase in allotment size.

An arrangement using overhead high voltage (HV) pole substations and overhead services is the preferred construction for large allotments.

5.1.5 Padmounted Substation Determination

Where the agreed maximum demand will exceed 100 kVA Ergon Energy has a Legislated right to require a padmount substation site on the property.

A connection with no padmount may be approved as long as allowance is made for a future padmount to be installed to cater for future load growth.

If there is to be a padmount substation established and the Regional Manager Northern Networks and Regional Manager Southern Networks approves the connection with no padmount substation then an easement may be required dependent upon the existing Network performance and possible future growth in load requirements by the customer concerned.

Regional Manager Northern Networks and Regional Manager Southern Networks will determine in consultation with the DPO what feeder connection is made to the substation where more than one feeder is available.

Proposed sites that are for redevelopment where Ergon Energy already has a substation must retain provision for at least equivalent substation capacity within the redeveloped site. Any proposal to relinquish the padmount site or reduce the substation capacity will require Regional Manager Northern Networks and Regional Manager Southern Networks approval.

5.1.6 Community Powerline Projects

The Community Powerline Projects (CPP) scheme is a long-term scheme initiated by Ergon Energy to reduce the impact of powerlines on streetscapes and the environment. Eligible projects will be considered for financial assistance towards relocation, undergrounding or replacement of existing powerlines, the emphasis being in areas of environmental, historic or scenic significance, or high pedestrian use. Projects must benefit the local, if not the wider, community and generally require local government support.

5.2 Padmounted Substation HV Switchgear Selection

5.2.1 General

The selection of switchgear for the electrical design of any project must be based on the planning and reliability considerations discussed earlier, any specific operational functionality required and physical conditions affecting the placement of the equipment.

Padmounts are purchased as modular units fitted out with either a:

For 11 kV –

- o LV board comprised of an isolating switch and 4 fuse switches (the capacity of the isolating switch is dependent on transformer size required). 1000 kVA are provided

with right angle adaptor brackets for the option of direct mounting of up to 3x300mm2 cables per phase to the busbar system.
- Circuit breakers are also available and are required for single loads of starting from 800A.

For 22kV –
- 315 and 500 kVA LV board comprising of an isolating switch and 5 fuse switches, plus provision for a spare;
- 1000 kVA LV board comprise of a transformer isolating switch and 2 fuse switches, plus provision for a spare, together with a circuit breaker.
- Circuit breakers are also available and are required for single loads of starting from 800A

The type of HV switchgear, if any, is purchased to fit the application. The Underground Construction Manual, PADMOUNTED SUBSTATIONS set out the available combinations.

5.2.2 Interconnected Backbone Feeders

Interconnected underground systems used by Ergon Energy are normally a "ring main" arrangement with incoming and outgoing feeder cables being connected to load break / fault make switching at padmounts. The transformer is connected to the bus linking the feeder switches by a switch fuse combination as generally shown in Figure 5.2.2-1.

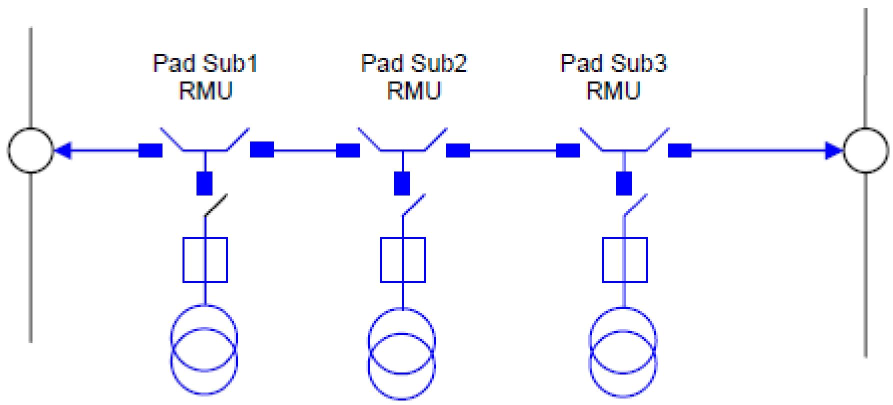


Figure 5.2.2-1 Interconnected backbone feeders

Pole top arrangements for the connection of the underground network to the overhead system are set out in Section 5.4.

As an underground network grows there will be a need to establish interfeeder ties along the backbone. As a **design rule,** a tie should be considered for every 2 MVA design demand along a feeder for 11 kV and 3-4 MVA for 22 kV. Switchgear is available for 22 kV padmounts with 3 feeder switches as shown in Figure 5.2.2-2 (refer Underground Construction, Manual PADMOUNTED SUBSTATIONS) to enable this.

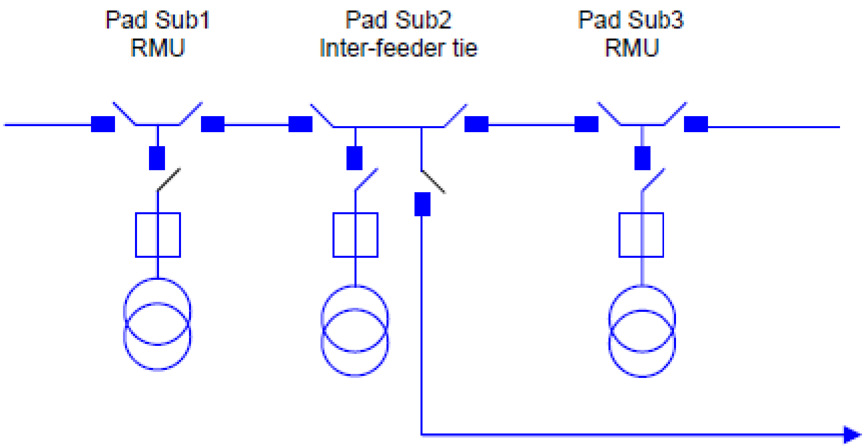


Figure 5.2.2-2 Interfeeder tie for 22kV or 11kV

5.2.3 Radial Feeders

5.2.3.1 General

Radial supplies will generally supply only one or two padmounts and with this arrangement there is no alternative high voltage supply in the event of damage to the cable or a failure. The time to fix a high voltage cable fault can run into days and therefore the choice of a radial connection must take account of the consequential affect this will have on the customer and the community (i.e. essential services).

In some circumstances it may be possible to provide a limited alternative supply from low voltage interconnections but this will generally be inadequate for the time required to repair a cable fault.

While every case must be assessed individually the general **design rule** is that demands less than 1.2 MVA are acceptable for a radial connection subject to the availability of portable generation.

Many commercial and industrial customers will desire an alternative high voltage supply. Where the design rule requirements for a radial supply apply and no other planning, operational or reliability requirements affect this then, commercial conditions may apply to the provision of the second cable.

Designers should seek further advice if in doubt from the Networks Manager.
A RMU shall be used for all loop-in / loop-out on radial feeders.

5.2.3.2 Connecting to an Underground Backbone

For 22 kV systems a ring main switch with an additional switch fuse unit is available. This enables a radial supply to be taken off an underground backbone to a padmount with a direct connection to the transformer (refer Underground Construction Manual, PADMOUNTED SUBSTATIONS drawing No's 5082/2 & /4). Because the cable is fused at the supply end 35 mm^2 cable with limited screen fault rating can be used.

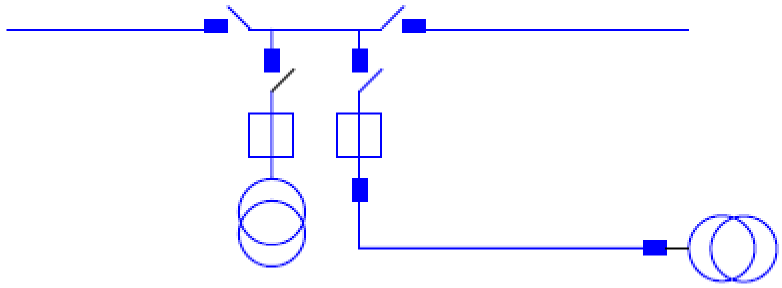


Figure 5.2.3-1 Backbone connection for 22kV only

For 11 kV systems this is not available, however radial feeds are possible by using the interfeeder unit (refer Underground Construction Manual PADMOUNTED SUBSTATIONS drawing No's 5096/3) and a feeder rated cable (refer Section 5.5). A switch fuse arrangement will be required at the radial padmount to protect the transformer (refer Underground Construction Manual PADMOUNTED SUBSTATIONS drawing No's 5096/1 & /2).

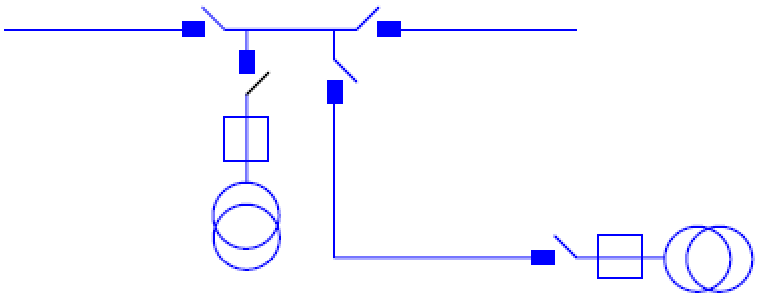


Figure 5.2.3-2 Backbone connection for 11kV / 22kV

This option should be used for 11 kV application or 22 kV application where a feeder rated cable for possible future use is a requirement.

5.2.3.3 Connecting to an Overhead Line

The choice of padmount/s for a radial connection to an overhead system should be the lowest cost arrangement available.

Generally, radial cables will need to be protected by a switch fuse combination at the pole top connection to protect the cable and transformer and avoid the risk of ferroresonance (see Section 7.1). For a single padmount arrangement Underground Construction Manual, PADMOUNTED SUBSTATIONS drawing No's 5094 for 11kV and 5104 for 22kV will apply.

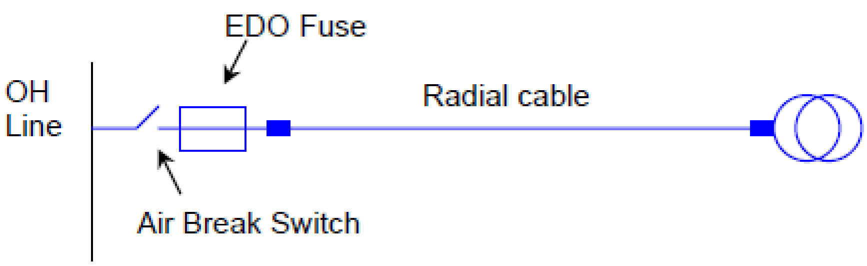


Figure 5.2.3-3 Radial connection to OH line

For 2 substations on a radial supply the first will need to incorporate a ring main unit (RMU).

Feeder cables may also be used for radial connections. This may be done to utilise accumulated short cable lengths from other projects or to allow future conversion to a feeder cable.

In situations where there is a significant possibility of the LV load being disconnected for extended periods padmount selection may require a switch fuse arrangement for transformer protection. This is to prevent ferroresonance overvoltages occurring following a single phase fuse operation at the cable source end. Feeder rated cable should be used for these applications.

For 11kV systems a single switch fuse unit is available for a single padmount arrangement and may be used in conjunction with ring main units for a multiple padmount arrangement (refer Underground Construction Manual, PADMOUNTED SUBSTATIONS drawing No's 5096/1 & /2).

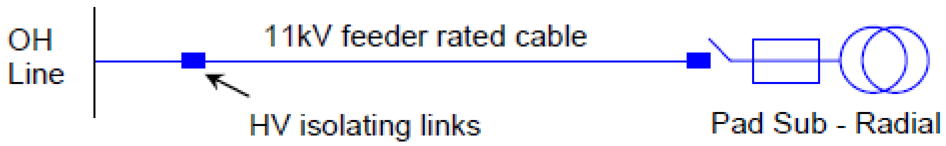


Figure 5.2.3-4 Alternative feeder cable connection to OH line

Pole top arrangements for the connection of the underground network to the overhead system are set out in Section 5.4.

5.3 Padmounted Substation Site Selection

5.3.1 General

The selection of the site for a padmounted substation should be as close as practical to the optimum position for electricity supply distribution. The site must also:

- be sensitive to the local environment
- be secure from third party and environmental damage
- be relatively flat and structurally sound
- not be subject to tidal inundation, storm surge, or flooding (1:100 year risk)
- provide secure and safe access for operational purposes
- consideration for road safety and
- not be an obstruction or public nuisance.

It may not be possible to fully meet all these criteria and the local government authority may have preferences for these sites, which need to be taken into account.

Site selection must also take into account the following:

- Effect of Electro Magnetic Fields (EMF) (see Section 7.2), in particular, on surrounding dwellings. The effective means of reducing EMF levels at surrounding buildings is to limit the transformer kVA rating and also provide reasonable separation between its LV bushing and the buildings.

- For the padmount locations as detailed in the Underground Construction Manual PADMOUNTED SUBSTATIONS drawings to apply, the LV cabinet must face the street.

- Other clearances are covered in the Underground Construction Manual EARTHING folder, drawing 5250 for clearances to earthing systems, communication plant and fire hydrants.

- General compliance with the requirements in AS2067 Substations and high voltage installations exceeding 1kV a.c.

- The site shall border a property boundary, which provides access from the road reserve. Proposal to locate a padmounted substation in other locations within a lot shall require approval from the Regional Manager Northern Networks and Regional Manager Southern Networks

5.3.3.1 Common Earth Sites

For 11kV –

- Refer Underground Construction Manual PADMOUNTED SUBSTATIONS drawing No's 5000/1 to /4, 5010, 5174 and accompanying drawings.

For 22kV –

- Refer Underground Construction Manual PADMOUNTED SUBSTATIONS drawing No's 5114/1 to /4, 5116/1 to /2, 5176 and accompanying drawings.

5.3.3.2 Separate Earth Sites

For URD installations a CMEN system is generally required. A separate earth arrangement is considered not practical due to the necessity of a considerably larger site needed to provide clearance between the padmount site (HV) earth system and nearby conductive structures. Note also the required separation of the padmount site (HV) earth system from communications assets and fire hydrants.

Site requirement needs to be identified in the initial stages of design & negotiation with the Developer as an increase in size is almost certainly not practical at the time of construction. An exception to the foregoing may be where a padmount is located in parkland and the separation, site size, and other requirements are met.

For 11kV –

- Refer Underground Construction Manual PADMOUNTED SUBSTATIONS drawing No 5000/1 to /4 & 5175.

For 22kV –

- Refer Underground Construction Manual PADMOUNTED SUBSTATIONS drawing No 5114/1 to /4 & 5177.

5.4 Pole Top Selection

The Underground Construction Manual HV CONSTRUCTION drawing No's 5101, 5076 & 5248 detail the standard arrangements for 11kV, 22kV and 33kV pole top assemblies respectively for cable connections to the overhead network.

Pole top construction options provided and their applications are as follows:

Manual Gas Switch, Air Break Switch (ABS) and Expulsion Drop Out fuses (EDOs)

- Basic arrangement used for Single padmounts with no HV switchgear.
- The cable would generally be 35mm^2 but could be feeder rated cable used to use up odd lengths.

Links only

- used for single padmounts with HV switch fuse or RMU (in situations where LV load may be disconnected for significant periods and which would present a ferroresonance risk following failure of a pole mounted EDO fuse)
- used for supply to a section with multiple padmounts with an RMU at the first transformer
- used for transitions from OH to UG cable. **Feeder rated cable would always be used with this option.** These links are provided primarily as an isolation point to assist with fault location.

The SGNW0006 Switching Equipment Application Strategy document provides further clarification to the application of switches. Any deviation from the standard pole top arrangement must be in consultation with Distribution Network Standards.

5.5 Cable Selection

5.5.1 General

Cables used in the network can be generally categorised as one of the following:

Substation Exit –

1. Cable from the feeder CB to the first operating device in the distribution network and is protected by the feeder CB.
2. Designed to carry the full feeder load and half the adjacent feeder load under contingency (4 / 6 MVA at 11kV and 8 / 12 MVA at 22kV) when laid in the proximity of up to 6 other stations exit cables.

Note – For rural zone substations and other low demand applications, feeder rated cables may be used as station exits. Network Development should be consulted.

Feeder Cable –

1. Forms part of the interconnected network, backbone supply and is protected by the feeder CB.
2. Designed to carry full feeder load and half the load of an adjacent feeder under contingency (4 / 6 MVA at 11kV and 8 /12 MVA at 22kV) without any de-rating from the mutual heating of adjacent cables.

Fuse Protected Radial –

1. Must be fuse protected to ensure that the cable insulation is not raised to temperatures that will cause permanent damage under short circuit conditions.
2. Designed to carry the load nominated from the mutual heating affects of any adjacent cables.

Non-Fuse Protected Radial –

- Protected only by the feeder CB and requires the same short circuit performance characteristics as a feeder cable.

5.5.2 Standard Underground Cables

The standard Ergon range of cables is set out in Section 8 Cables, together with their electrical characteristics and ratings. Other cables should not be used in the Ergon Energy network without the agreement of Distribution Network Standards.

Note: Ergon Energy has adopted a rationalised range of 11kV, 22kV and 33kV cables and in some instances insect protected cables are the only option for use in areas where insect protection is not required. Refer to the table 5.5.3.

5.5.3 Cable Route Selection

Cable routes are required to be in the road reserve. If any distribution asset including spare conduits needs to cut through any property to supply another part of the subdivision or a connection to the distribution network, a 3m width pathway surveyed and registered as road reserve is required.

Any departures to this requirement must first be discussed with the Regional Manager Northern Networks and Regional Manager Southern Networks.

11kV **Not Insect Protected**	
Application	**Cable**
Station Exit Cable	#Triplex 400mm^2 Al XLPE Triplex 185mm^2 Al XLPE
Feeder Cable / Non Fuse protected Radial	Triplex 185mm^2 Al XLPE
Fuse protected Radial	Triplex 35mm^2 Al XLPE
# Note: Insect Protected cable to be used. **Insect Protected**	
Application	**Cable**
Station Exit Cable	Triplex 400mm^2 Al XLPE Triplex 185mm^2 Al XLPE
Feeder Cable / Non Fuse protected Radial	Triplex 185mm^2 Al XLPE
Fuse protected Radial	Triplex 35mm^2 Al XLPE
Special Applications (Including Feeder Exits where significant grouping factors apply)	1C 400mm^2 Cu XLPE

Table 5.5-1 Standard cable types for 11kV

22kV **Not Insect Protected**	
Application	**Cable**
Station Exit Cable	1C 630mm^2 Al XLPE
Feeder Cable / Non Fuse protected Radial	Triplex 185mm^2 Al XLPE
Insect Protected	
Application	**Cable**
Fuse protected Radial	Triplex 35mm^2 Al XLPE

Table 5.5-2 Standard cable types for 22kV

33kV **Insect Protected**	
Application	**Cable**
Feeder Cable / Non Fuse and Fuse protected Radial / Station Exit Cable	1C 300mm^2 Al XLPE
Feeder Cable / Non Fuse and Fuse protected Radial	1C 50mm^2 Al XLPE

Table 5.5-3 Standard cable types for 33kV

6 LOW VOLTAGE NETWORK DESIGN

6.1 Network Planning and Design Arrangement

6.1.1 General

The LV network is the end delivery vehicle of electricity supply to customers and the way it is designed determines the make-up of the remainder of the network that supplies it.

The LV network design is constrained by:

- Regulated voltage limits that must be maintained at the customers terminals.
- Ergon Energy's range of standard conductor sizes.

Substations must be situated (refer Section 5.3) to enable the distribution of the LV supply to customers by the standard cable sizes within statutory voltage limits.

Great care must be taken in design as the cost to augment underground networks is much greater than that of an overhead network and any future works will be disruptive to our customers. Accordingly, due consideration must be given to future network expansion and provision for demand growth.

Where there is uncertainty regarding future expansion and/or volatility in demand then reliance on extensive LV networks should be avoided and provision made to grow the HV network to cover expansion and demand growth risks.

Most voltage calculations will be associated with distributed customers and this requires consideration of demand, diversity, and unbalance. These vary with customer class and are dealt with separately below by the category of customer.

6.1.2 Residential Subdivisions

6.1.2.1 Network Arrangement

The LV network is a loop pillar arrangement as generally shown in the Figure 6.1.2-1 below.

A single size mains cable (3φ – 240 mm^2 Al) is looped from supply pillar to supply pillar to form a circuit. Tee connections to other roadways are also made in the distribution pillars.

The pillars (supply and cross-road) are situated at every other adjacent property boundary on both roadsides with a 3φ 16 mm^2 Cu cable connecting the supply pillars on the main's cable roadside to the cross road pillars on the remote roadside.

The customer's main is connected through a fuse in the pillars on both roadsides.

Street lighting columns are supplied from the nearest pillar via a fuse protected cable.

Circuits of adjacent substations are connected in linking pillars that incorporate a "combined fuse switch unit" (CFS).

Details of pillar construction and connections are shown in the Underground Construction Manual, LV CONSTRUCTION drawings.

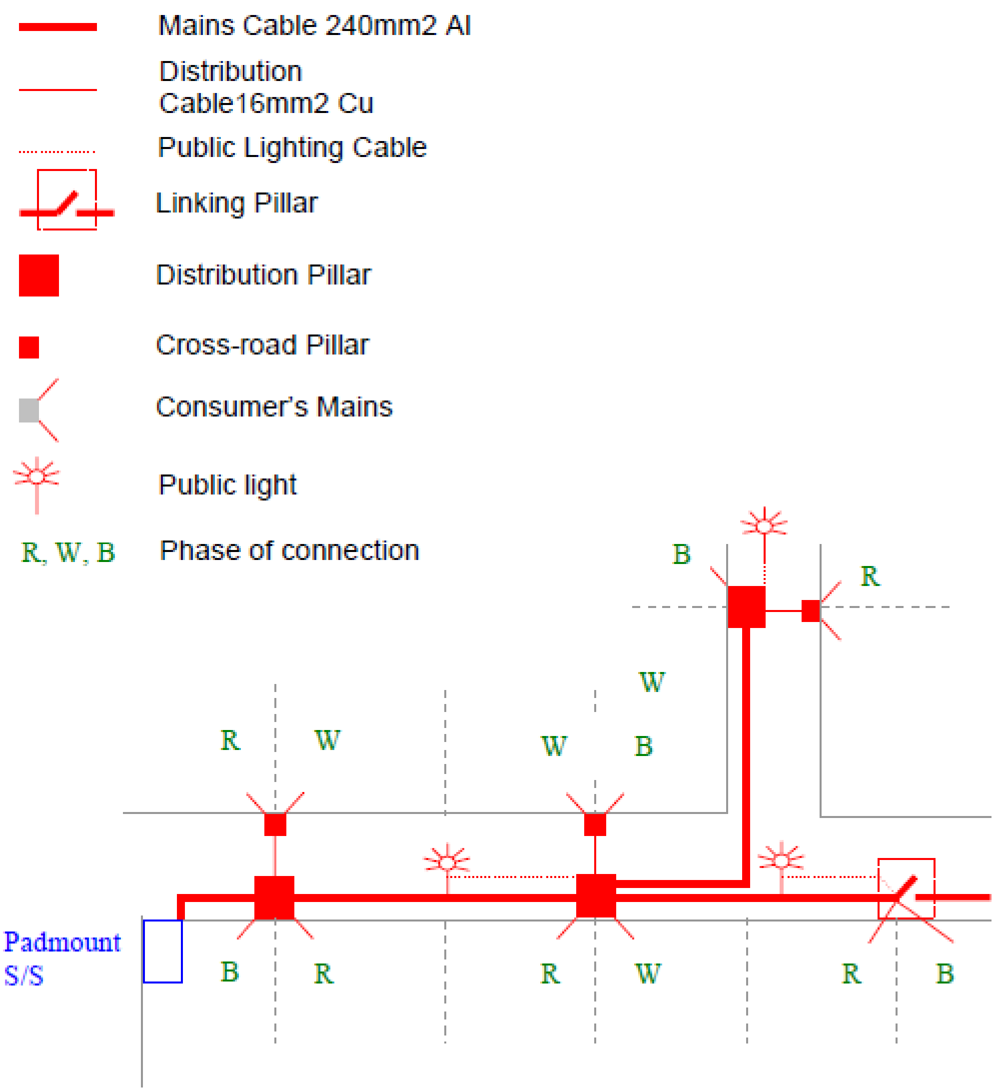


Figure 6.1.2-1 Typical LV circuit from padmount

Detail of the cables are shown in the Underground Construction Manual MATERIAL DATA drawing No's 5108 and 5110.

It must be noted that the use of linking pillars does not mean that transfer capacity is provided. This facility is only for low capacity alternative supply in periods of light load for maintenance activities.

The following **design rules** apply:

- The maximum number of customers must be connected to a circuit that voltage limits will allow
- Circuits must be radial
- One link via a switch per circuit should be provided to a circuit emanating from another transformer (where interconnection is only possible to a circuit of the same transformer, then this is acceptable)
- All services in a linking pillar must be connected to the same supply side of the pillar
- Lighting columns connected to linking pillars must be connected to the supply side on which the column is physically located
- Service connections must be balanced over the three phases and continuously along a circuit.

- Use of the 4th LV Combined Fuse Switch is allowed where a padmount substation is designed with an ultimate utilisation greater than 90%.
- Leap frogging from pillar to pillar is not acceptable.

The use of parallel LV express feeder is allowed with the following condition:

1. Paralleling of LV cables is only permitted on the first segment from the padmounted substation between the LV CFS and the first connection point on that circuit. Both cables must terminate on the same CFS in the padmounted substation and in the first connection point.
2. The first connection point of any parallel feeder shall be a CFS. This CFS can either be in the form of a distribution cabinet or a link pillar.
    a. Where a parallel feeder terminates into a Distribution cabinet it shall terminate on the LV isolator
    b. Where a parallel feeder terminates in a Link Pillar the CFS unit shall be fitted with a maximum fuse size of 160A.
3. One (1) parallel LV express feeder per padmounted substation is acceptable. Where additional parallel LV express feeder is proposed, this must be referred to Regional Manager Northern Networks and Regional Manager Southern Networks for consideration.
4. Provision of LV schematics in laminated A3 sheets shall be placed on all padmounted substation whether a parallel LV express feeder exists or not.
5. Cable runs greater than 250m must be referred to Regional Manager Northern Networks and Regional Manager Southern Networks for consideration and cable pulling calculations shall be provided with the design.
6. LV cable joints are not acceptable on parallel LV express feeder cable runs.
7. Conduits for the parallel LV express feeder shall be installed together (side by side) along their full length.
8. Leap frogging from pillar to pillar is not acceptable.

Information Notes

Historically tapered main’s sizes have been used but the cost associated with bringing 2 cable drums to site and the inventory expense of an additional cable and accessories, outweigh the marginal cost benefit achieved in purchasing the smaller conductor size.

The loop pillar arrangement is favoured by most utilities in Australia. It maximises flexibility during construction and minimises delays in locating and isolating faults. It is, however, subject to pillar damage particularly during the building development stage. Some States employ a buried tee arrangement that has advantages where the works are undertaken by the land developer and it is less prone to damage in the development phase. However, it causes considerable coordination difficulties with the developer where the utility undertakes the cable laying and jointing. This arrangement will also require the consent of the Electricity Safety Regulator in Queensland as it does not currently conform with regulations if used in the same manner as other states.

6.1.2.2 ADMD

To design a low voltage circuit supplying distributed customers it is necessary to know the demand load of the customers to be supplied. This is required to determine padmount substation requirements and carry out voltage drop calculations.

An After Diversity Maximum Demand (ADMD) can be determined and applied to all customers on a circuit. The figure is derived from an accumulated knowledge of circuit demands and the number of customers connected. The confidence in this approach increases with the number of customers connected to a circuit.

The ADMD adopted will not be the same throughout all of Ergon Energy because of climate differences, the availability of alternative energies, and socio-economic factors.

The following **design rules** are provided for conventional housing development in regional centres where reticulated gas is available. They have been determined from historical data, plus a provision for future demand growth.

- South West, Wide Bay and Capricornia (SW, WB & CA) **–** ADMD = 4 kVA per Lot

- North, Far North and Mackay (NQ, FN & MK) **–** ADMD = 5 kVA per Lot

Local knowledge will need to be applied where the base assumptions listed above are not met and variations to the nominated figures would be expected to be upward.

6.1.2.3 Voltage Drop Calculations

The permissible voltage range at the customer's terminal (located at Ergon Energy pillars on adjacent property boundaries) is:

- 400/230 Volts +10%, -6%, or;

- 253 to 216 Volts φ-N

The nominal voltage level will be changed at some future date to conform with Australian standards. For this reason voltage drops are considered for calculation purposes as a % change from nominal and ADMD's have been selected to accommodate associated demand changes.

Design rules:

- The volt drop on the mains cable must not exceed 5% (to the last distribution pillar)

- The volt drop on the distribution cable (from the distribution pillar to the customer's terminals in the cross-road pillar) is to be taken as 1%.

Voltage Drop calculations should be performed using the software program "LV Drop". The following inputs are **design rules** that will apply.

- Transformer Type – Low Impedance
- Unbalance Factor 1.8
- Cable Confidence Factor 2.0
- Volt Drop Confidence Factor 2.0
- TXF Confidence Factor 1.65
- Standard Deviation = ADMD

6.1.3 Commercial and Industrial Development

6.1.3.1 Network Arrangement

The range of circumstances encountered in new developments and renewal sites will be much more diverse than in residential areas. Demand and future growth will be unpredictable and other constraints will be imposed in the placement of substations. As a consequence designers must be flexible in seeking solutions and aware of the limitations of LV networks to cope with the unpredictable nature of this type of development.

New Developments

The basic network arrangement used in new Commercial / Industrial developments are the same Loop Pillar system as those for URD/UDC except that supply pillars are used on both roadsides. The maximum 3φ supply to a customer from a supply pillar is 80 amps, this being limited by the fuse capacity in the pillar.

The cross road cable rating must be matched to the anticipated demand (see below Section 6.2 Cable Selection).

For most applications the 80 amp limitation has been found to be sufficient remembering that only 4 customers can be connected to a circuit at that rate of supply and subject to voltage drop requirements being meet (see Figure 6.1.3-1 below).

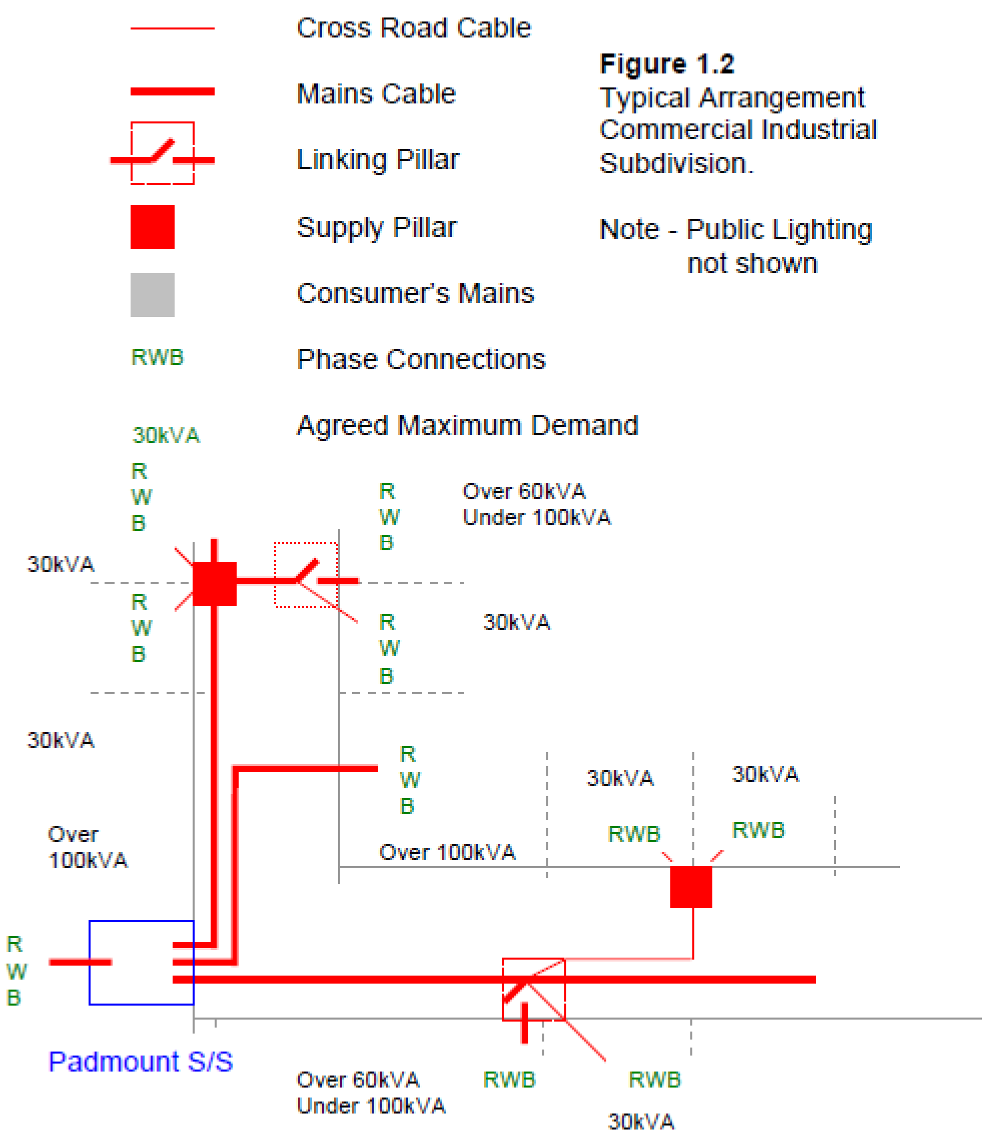


Figure 6.1.3-1 Typical arrangement Commercial / Industrial Subdivision

The cross road cable rating must be matched to the anticipated demand (see below Section 6.2 Cable Selection).

Where the anticipated maximum demand of a commercial and industrial customer will exceed the fuse rating of a supply pillar a pillar type “A” should be used. The customers main is connected to the load side of the CFS and where the mains cable is looped in the pillar these are connected back to back up on the supply side terminal.

The CFS unit has a capacity of 160A but as a **design rule -** if the customers anticipated maximum exceeds 100kVA (140 amps) they will be supplied by either:

- a substation situated on the customers property, or,
- dedicated circuits to the customers terminals from the substation (see below *Supply to Individual Customers*).

The forgoing is based on the presumption of knowledge of the prospective customer's maximum demand. Reality is that this will generally be unknown (see below Section 6.1.3.2 ADMD Commercial and Industrial). It is possible that pillars and cross road cables will need to be augmented. Where the agreed maximum demand will exceed 100 kVA, Ergon Energy has a Legislated right to require a padmount substation site on the property and this right should be exercised wherever provision of that supply weakens Ergon Energy's ability to meet future demand growth of other customers.

In general, the right to install a padmount may be exercised, however, in the range of 100A to 200A the decision pillar or padmount would be based on the likely future demand on the site and near proximity.

Spare conduits will be laid (**design rule**) to cover future contingencies for HV and LV network augmentation and including cross road conduits. Refer to Regional Manager Northern Networks and Regional Manager Southern Networks and SDO for conduit numbers and sizing

Renewal Projects
The redevelopment of existing commercial areas generally results in changes in purpose and/or amenity and consequently electrical demand. This can pose a number of challenges as it is generally difficult to site substations at desired locations or to establish new sites. This requires optimal utilisation of available sites.

Distribution Cabinets (see figure below) enable distribution points to be established at locations remote from the substation sites (see Figure 6.1.3-2 below). The cabinets can facilitate up to 5 – 630 amp fuse strips for distribution circuits with isolators controlling the incoming main (refer Underground Construction Manual LV CONSTRUCTION drawing No 5136).

The mains cable feeding the distribution cabinet will need to be sized to meet demand and voltage requirements. Standard arrangements would be either a 1 x 240mm^2 or 2 x 240mm^2 mains. Any other arrangements would require the agreement of the SDO and the Networks Manager.

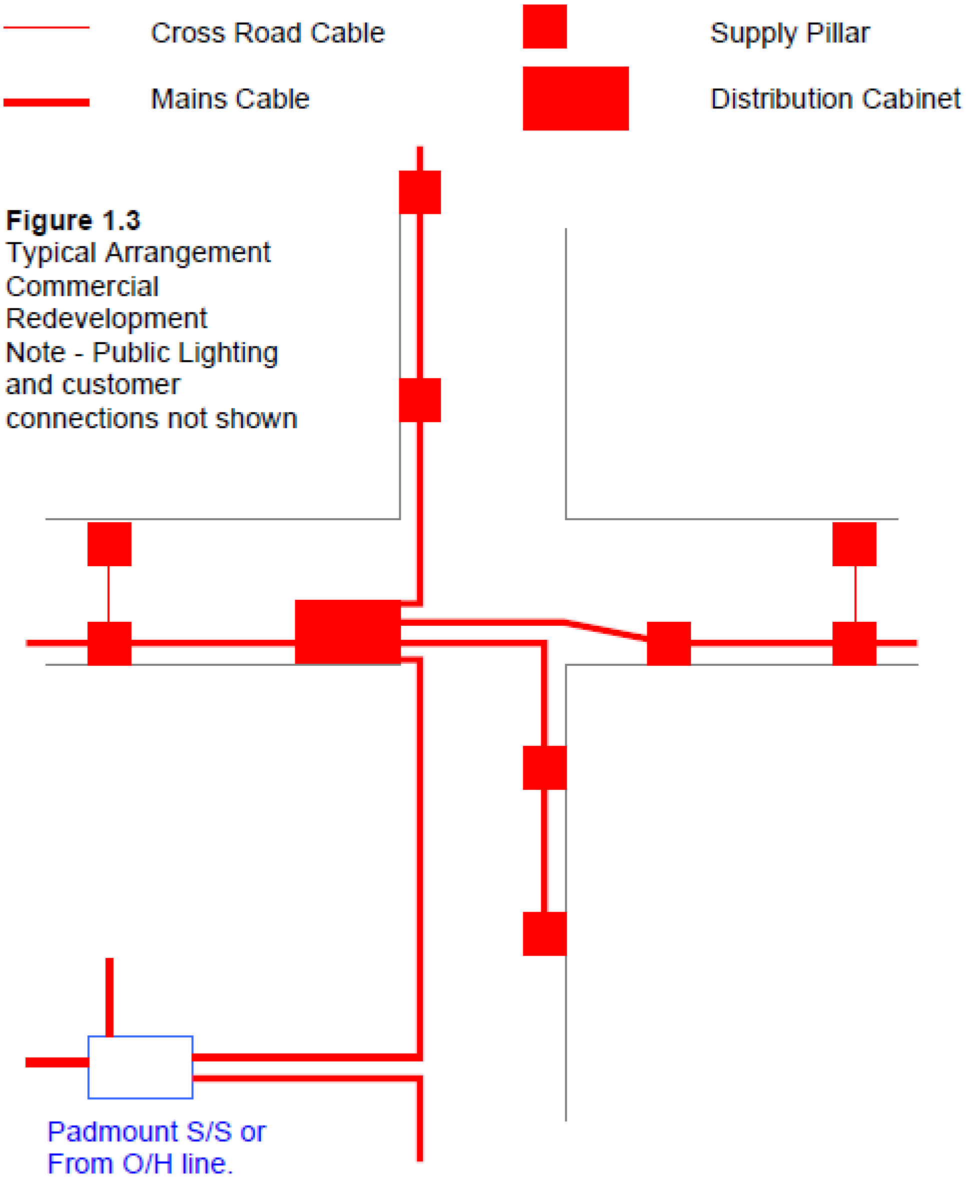


Figure 6.1.3-2 Typical arrangement Commercial Redevelopment. Public lighting and customer connections not shown

Supply to Individual Customers.

The low impedance of underground cables makes them ideal for providing relatively large parcels of supply from existing assets either overhead or underground. This can enable the use of unutilised substation capacity via a dedicated circuit.

In these circumstances the supply cable should be taken directly to the customers terminals. The customer must provide the facility (switchboard / cabinet / pillar or the like) to accommodate this which must be located within **5 metres** of the property boundary (**Design Rule**). Supply can be extended up to 10m onto the property as good engineering practice (e.g. the main switchboard is in close proximity) and with the agreement of an SDO.

It is not Ergon Energy's responsibility to extend the supply to the customers load centre in these circumstances. This should correctly be part of the customer's installation and be subject to the requirements of the wiring rules.

6.1.3.2 ADMD (Commercial / Industrial)

30kVA/0SD per lot has been determined for LV Drop calculations for Commercial & Industrial subdivision designs.

A figure of 100 VA per m² may be applied to known office space for lighting and air-conditioning load, but otherwise, the estimated demands will generally need to be based on the knowledge of similar developments.

A demand allocation can be assigned by allotment size and a substation/s sited to meet the resulting demand. Subsequent supply requests exceeding allocations may require the establishment of another substation and the assigned allocations will need to be incorporated into supply agreements for the subdivision.

Of note however is that demand in these developments is more unpredictable than for residential developments. Local knowledge should provide a guide for likely demand based on similar developments if the above requirement is not suitable. For design purposes a demand may be allocated to each property. This may be on the basis of allotment size where this has been demonstrated as an appropriate measure from previous developments. Designers use the agreed demands as provided by the Regional Manager Northern Networks and Regional Manager Southern Networks and these must be included into supply agreements as “agreed rates of supply”.

6.1.3.3 Voltage Drop Calculations

The permissible voltage range at the customer’s terminal (located at Ergon Energy pillars on adjacent property boundaries) is:

- 400/230 Volts +10%, -6%, or;

The following **design rules** apply:

- The volts at the transformer terminals are to be taken as 230 volts.
- The volt drop on the mains cable must not exceed 5%
- The volt drop on the service cable (from the main to the customers terminals) is to be taken as 1%

Voltage Drop calculations should be performed using the software program “LV Drop”. The following inputs are provided as a guide to these factors.

- Unbalance Factor 1.8
- Cable Confidence Factor 2.0
- Volt Drop Confidence Factor 2.0
- TXF Confidence Factor 2.0
- Standard Deviation = 0

Due to the uncertainties associated with this customer class some fine-tuning may be required to account for local knowledge. Designers should seek the advice of a SDO in this regard, who in turn should escalate the matter through established protocols where further advice is required.

6.2 Pillar / Distribution Cabinets and Pits Site Selection

6.2.1 General

The selection of the site for a Pillar / Distribution Cabinet and Pit should be on road reserve or an easement. The site must also:

- be sensitive to the local environment
- be greater than 1000 mm from the kerb or edge of trafficable areas
- be secure from third party and environmental damage
- be relatively flat and structurally sound
- provide secure and safe access for operational purposes (gradient across site shall be less than 1:4)
- Not be located in or within 1 metre of areas that are designed to permanently capture and store water, floodways or other locations where likely to sustain significant and repetitive damage due to water inundation[1].
- not be subject to tidal inundation, storm surge, or flooding events exceeding an 10% AEP (Annual Exceedance Probability)
- not be an obstruction or public nuisance.

Pillars **shall not** be located in non-urban area, due to the risk of vehicle (e.g. slashers) impacts and fire damage. Proposals to locate pillars in non-urban locations need the approval of Line Standards and the Networks Manager for the area.

It may not be possible to fully meet all these criteria and the local government authority may have preferences for these sites, which need to be considered.

6.2.2 Community Title Scheme (CTS)

Where Pillars / Distribution cabinets and Pits are required inside a Community Title Scheme (CTS) the requirements of Clause 6.2.1 shall apply, expect where varied below.

Pillars / Distribution Cabinets and Pits within Community Title Schemes (CTS) shall be located on common property only. A separate easement is not required for Pillar / Distribution Cabinet or Pit, however they may by located within the cable easement where practical.

6.3 Cable Selection

6.3.1 General

6.2.1.1 Introduction

Cables used in the LV Underground network can be categorised as:

- Mains cable
- Cross-road cable
- Service cable

[1] This does not include intermittent run-off during weather events, e.g. run-off across a footpath.

6.2.1.2 Mains Cable

Mains cables form the backbone of the LV circuits looping between supply pillars, distribution cabinets and substations. A single mains cable size is used (**design rule**) - 240mm² Al, 4/C stranded sector cable, XLPE insulated PVC or NJ-PVC* sheathed.

The demand requirement from distribution Pillars may require 2 x 240mm² Al, 4/C stranded sector cable, XLPE insulated PVC or NJ-PVC* sheathed (see CABLES section 2, Cable Ratings).

*Termite areas

6.2.1.3 Cross-road Cable

Cross-road cable connects between the mains cable in the supply pillar to the cross road pillar on the remote road side. The size of the cross road cable will depend on the application, as follows (**design rules**):

URD - 16mm² Cu, 4/C stranded circular cable, XLPE insulated, PVC / NJ-PVC* sheathed

Commercial / Industrial

> ***Supply up to 75kVA*** - 50mm² Cu, 4/C stranded circular cable, XLPE insulated, PVC / NJ-PVC* sheathed.
>
> ***Supply over 75kVA*** - 240mm² Al, 4/C stranded sector cable, XLPE insulated, PVC or NJ-PVC* sheathed.
>
> *Termite areas

6.2.1.4 Service Cables

Underground service cables connect the distribution network assets to the customer's terminals (generally at the POS). This could be from overhead or underground network assets.

In the loop pillar system this generally occurs in the pillars and there is no service cable.

The rating of the service cable must be matched to the customer's maximum demand (see CABLES section 8.6, Cable Rating).

6.4 Pole Top Selection

In some situations underground LV cables will need to connect to the overhead network as a source of supply or for linking purposes. Connections may also be made for earthing purposes (See EARTHING Section 9.1).

The Underground Construction Manual LV CONSTRUCTION drawing No 5056 details the standard arrangements for LV pole top assemblies including cable connections to the overhead network.

Any deviation from the standard pole top arrangement must be in consultation with Distribution Network Standards.

6.5 Installation Guidelines

LV underground cables are generally installed in lengths between pillars and cabinets and consequently lengths are relatively short. Nevertheless the same principles apply as those set out for HV cables in Section 8.5 Cable Installation – Design Considerations.

The Underground Construction Manual, MATERIAL DATA drawing No's 5108 & 5110 detail the physical properties and installation limitations of the standard LV cable range.

Historically various trenching arrangements and alignments have been agreed to by Ergon Energy's predecessors with local government authorities and other utilities. While a long term goal is to standardise arrangements current policy is to continue with the standing regional practices.

The Underground Construction Manual, TRENCHING folder, sets out each of the regional trench arrangements including: cross road arrangements, alignments, and pillar base installation.

The Underground Construction Manual, TRENCHING folder, also covers the entry arrangements for padmounted substations, distribution cabinets and pole termination (trench and conduit) arrangements.

LV cables are normally protected by fuses which are located at:

- The LV board of padmount substations (for isolation of faults on the mains cable)
- The LV board in Distribution Cabinets (for isolation of faults on the mains cable)
- Pole terminations (for isolation of faults on the mains or service cables)
- Pillars (protecting the upstream LV network from faults on the customers installation)
- Pillars protecting public lighting cables

Cross-road cables are not normally fused.

The table below sets out the recommended fuse size for the cable applications.

Application	Fuse Rating
URD	
Substation Circuit	250A
Pillar	63 A(Note 2)
Commercial / Industrial	
Substation Circuit	315
Customer Circuit	(Note 1)
Distribution Cabinet Circuit	160A
Pillar (Supply)	80A
Pillar (C&I) CFS Unit	160A
Pillar (C&I)	80A
Service Cable	(Note 1)

Table 6.4-1 Cable fuse sizing

[#] Where the circuit supplies a Distribution Cabinet and the demand requires 2x240mm^2 Al cables for current rating the fuse size is 400A.

Note 1: Fuse size is the best match to the customers agreed Maximum Demand.

Note 2: Fuse size may be increase to 80 A where customer demand indicates the 63 A is not suitable.

7 ELECTRICAL DESIGN

7.1 Ferroresonance

The phenomenon of ferroresonance is the occurrence of high voltages which may occur when a modest size capacitance is either in series or in parallel with nonlinear inductance, such as an iron cored transformer.

In power systems, the most common place to find ferroresonance is with a three phase distribution transformer energised through an underground cable of moderate length. Under no load, or very light load conditions, the capacitance of the cable is sufficient to precipitate ferroresonant behaviour under single phase switching conditions (eg. the operation of an HV fuse or asynchronous operation of singlephase 11kV switches such as a drop-out fuse unit.)

The trend towards undergrounding of distribution assets and the increasing installation of URD has resulted in a higher incidence of situations where single phase switching of the cable connecting the transformer could result in dangerous overvoltage due to ferroresonance.

The simplest form of occurrence of a ferroresonance circuit in a URD distribution system is when the single-phase operating switchgear or switch fuses are located some distance away from the transformer itself, with a length of cable joining the switchgear and transformer. A circuit of this sort could occur, for example, where a substation is supplied from a set of EDO's on a cable termination pole.

In the case where single phase switching is performed directly at the transformer terminals, there is no capacitance in circuit and as a result no abnormal circuit. Since the equivalent circuit of a cable under no load conditions is essentially a capacitive circuit, the presence of the cable introduces a capacitance into the circuit and forms a series LC circuit consisting of the transformer winding, which under no load can be represented by an iron cored inductance, in series with the core-sheath capacitance of the cable. [Note that this circuit applies to 3-core screened and single core cables, ie. There is no core to core capacitance.] The three-phase equivalent circuit is shown in Figure 6.2.1-1.

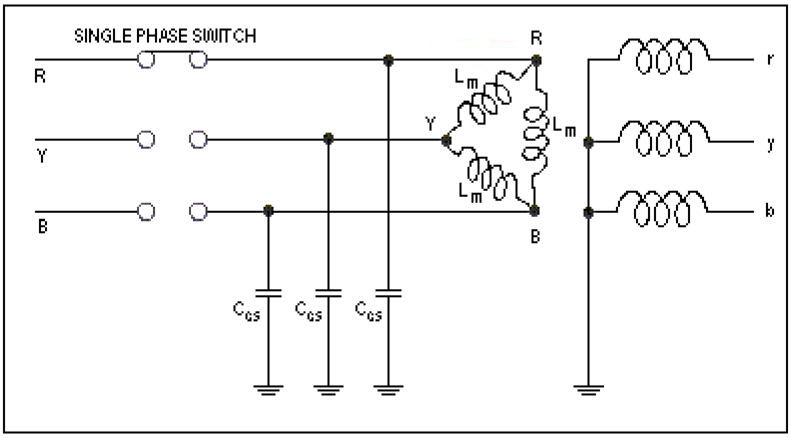


Figure 6.2.1-1 Ferroresonance circuit

With one phase energised (R phase for example as shown in Figure 6.2.1-1) a series circuit is formed consisting of the magnetised inductance Lm between R and Y phases and the Y phase core-to-sheath cable capacitance. In parallel with this circuit is a second identical series circuit consisting of the magnetised inductance Lm between R and B phases and the B phase core-to-sheath capacitance. Since each branch of this parallel circuit is identical, the potential between the points Y and B is zero and therefore the magnetising inductance Lm between Y and B phases does not enter into the circuit. Combining the circuit components results in an equivalent series circuit consisting of a capacitance in series with a nonlinear inductance which is therefore the ferroresonant circuit as shown in Figure 6.2.1-2.

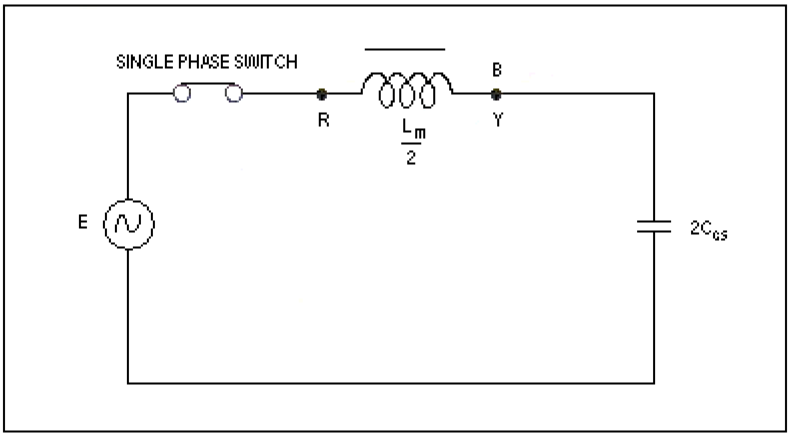


Figure 6.2.1-2 Equivalent ferroresonance circuit.

It is the interaction of this non-linear inductance in series with the capacitance of the cable that can cause severe overexcitation of the transformer and impose large overvoltages on the HV and LV systems.

7.1.1 Methods of controlling ferroresonance

The four most effective methods of controlling ferroresonance are:

1. three-phase switching;
2. single-phase switching at transformers;
3. resistive load on the transformer; and
4. limiting cable length.

Methods (1) and (4) require action on the part of the system designer. Methods (2) and (3) require special operating procedures to ensure that there is effectively no length of cable being energised or de-energised at the same time as the transformer or the presence of some load.

Three-phase Switching
The use of ganged three-phase switching is one of the most effective and commonly used methods of avoiding ferroresonance.

Single Phase Switching at Transformers
The practice of switching at the transformer terminals themselves is a particularly effective means of controlling ferroresonance. By doing this the cable length between the transformer and the switch is essentially zero and the only possible capacitance in the network is that of the internal capacitance of the transformer.

This is a particularly suitable method and can be applied in distribution systems using single-phase switchgear. Where a cable transformer combination is to be energised the cable only should be energised and then the transformer. Conversely on de-energising the transformer only should be de-energised first and then the cable. Both sets of switchgear can then be single phase operating.

Since the critical cable length, which is actually proportional to the critical cable capacitance, is inversely a function of the square of the voltage the critical capacitance for higher system voltages is quite small and the transformer capacitance can become significant.

Resistive Load on the Transformer
A resistive loading of 2 to 3% is generally sufficient to control ferroresonance. However in a distribution network alternative supply is often provided by paralleling the low voltage network to

adjoining substations. Should the LV network not be disconnected before HV switching back energisation of the transformer would occur. Therefore this option is generally unavailable. Similarly on commissioning a transformer there is usually no load available for this option to be used.

Limiting Cable Length

The derivation of the formula for the critical cable length assumes that the critical length is that which will result in a ferroresonant over-voltage of 2.73 times rated phase-to-ground system voltage. For an 11kV system this is 17.4kV phase-to-ground. This is also equal to the maximum acceptable power frequency voltage on the system. The expression for critical cable length is given by:

$$l_{crit} = \frac{0.6 I_{mag} \% kV.A_r 1000}{\left(1.58 + \frac{C_{cc}}{C_{cs}}\right) 62.8 (kV_r)^2 C_{cs}} \quad (metres)$$

Where:

$I_{mag}\%$	=	transformer magnetising current (typically 0.8% of rated current)
$kV.A_r$	=	3-phase transformer rating (kV.A)
C_{cc}	=	core-core capacitance (μF/km)
C_{cs}	=	core-sheath capacitance (μF/km)
kV_r	=	system nominal voltage (kV)

Inspection of the formula shows that the critical length is:

i) directly proportional to transformer capacity and therefore the cable length for small transformers can be quite small;

ii) directly proportional to transformer exciting current. (Old transformers which were manufactured before cold rolled grain oriented steel was used and had magnetising currents of typically up to 5% allowed for considerably longer cables than for modern transformers);

iii) inversely proportional to the square of the rated system voltage. (22kV and 33kV systems therefore can have maximum cable lengths of only one quarter and one ninth respectively of the 11kV cable length); and

iv) inversely proportional to the cable core-to-sheath capacitance (since cable capacitance is a logarithmic function of the cable size this is the least sensitive term in the expression).

Distribution Transformer Size (kVA)		100	200	315	500	750	1000	1500
Cable	mm²							
TRIPLEX	35 Al	12	24	38	60	90	119	179
TRIPLEX	185 Al	7	13	21	51	51	67	101

Table 7.1-1 Critical cable lengths for 11kV XLPE insulated cables in metres

Distribution Transformer Size (kVA)		200	315	500	750	1000	1500
Cable	mm²						
TRIPLEX	35 Al	7	11	18	26	35	53
TRIPLEX	185 Al	4	6	10	15	21	31

Table 7.1-2 Critical cable lengths for 22kV XLPE insulated cables in metres

The cable lengths given in the above tables are less than the values calculated using the equation. The cables lengths have been adjusted to suit the over voltage withstand capability of the surge arresters.
Other standard cables with cross-sectional area of 400 or greater are not included as the critical lengths are very small. This limitation also extends to 33kV cables.

7.2 Electromagnetic fields (EMF)

Magnetic Fields are fields resulting from the flow of current through wires or electrical devices, and increase in strength as the current increases. Magnetic fields emitted by underground cables are directly proportional to the distance between cables. The smaller the distance between the cables the smaller the magnetic field emitted at a given point.

Magnetic fields are measured in units of Gauss (G) or Tesla (T). Gauss is the unit most commonly used in Australia. Tesla is the internationally accepted scientific term. Since most environmental EMF exposures involve magnetic fields that are only a fraction of a Tesla or a Gauss, these are commonly measured in units of microtesla (μT) or milligauss (mG), multiply by 10. That is 1μT = 10mG.

Table 7.2-1 lists the distances from Electricity infrastructure at which point it can be expected that magnetic field strength levels will fall below the recommended level for continuous exposure. This applies to electrical infrastructure in the Ergon Energy network and relates to extremely low frequency (under 3 kHz), electric and magnetic fields. These figures define the desirable minimum design clearances from buildings, for which human occupation can be expected for significant periods of time. Other regulatory clearance requirements or design practices will override these values in many cases. The figures are based on maximum generally accepted plant rating practice and in most cases the magnetic field strength levels will be less, however these recommendations will allow for future load growth. Situations which differ from the standard cases listed below, or have higher than usual loads will require an engineering review and should be submitted for approval to the Ergon Energy contact person, in the case of designs carried out externally, or Ergon Energy Asset Management staff for designs carried out internally. Installations such as multiple cable installations in a common trench, and Indoor Substations with LV Distribution Boards may come into this category.

For multiple circuits Ergon Energy Line Designers can use ES000904F100 Magnetic Field Calculator.

Construction Type	Clearance from Centre Line/Radius (m)
RESIDENTIAL	
11kV Underground	*No Limit
22kV Underground	*No Limit
33kV Underground	*No Limit
315kVA Padmount Sub	3
500kVA Padmount Sub	4.5
240mm Underground LV Cable	*No Limit
COMMERCIAL	
11kV Underground	*No Limit
22kV Underground	*No Limit
33kV Underground	*No Limit
315kVA Padmount Sub	4
500kVA Padmount Sub	5
750kVA Padmount Sub	6
1000kVA Padmount Sub	7
240mm Underground LV Cable	*No Limit
SCHOOL	
315 Padmount – School	4.5
500 Padmount – School	5.5
750kVA Padmount Sub	7
1000 Padmount - School	8

Table 7.2-1 Layout clearances for magnetic fields

Notes:

- *For Padmount transformers, the distances are a radius from the front corner of the enclosure adjacent to the LV switchgear*
- *The EMF clearance levels are at a height of 1m above ground level*
- **No Limit means the maximum magnetic field strength level for a construction does not exceed the limit*

7.3 HV & LV Isolators (Links) Capacitive Charging Current Limitation

HV isolators or links are only capable of opening and closing a circuit with 'negligible current' when no significant change occurs in the voltage across the terminals. The definition given in the Australian Standard AS 62271.102 High voltage switchgear and controlgear - Alternating current disconnectors and earthing switches for **'negligible current'** implies currents such as the capacitive currents of very short lengths of cable for rated voltages 420kV and below is **0.5A**. HV isolators or links are also capable of carrying currents under normal circuit conditions and carrying for a specified time currents under abnormal conditions such as those of short circuit.

Capacitive current on UG cable is dependent on cable size and cable length. The size relates to the distance between cable core and copper wire screens. Therefore the bigger the cable size (the larger the distance between cable core and screens) and/or the longer the cable route length, the quicker the 0.5A limit is reached. For Ergon Energy standard UG cables the maximum allowable cable length connected to HV or LV isolators are given in the Table 7.3-1 and Table 7.3-2 below.

		NON INSECT PROTECTED						
		LV CABLE		6.35/11 (12) kV CABLE			12.7/22 (24) kV CABLE	
		16mm² Cu	240mm² Al	35mm² Al	185mm² Al	400mm² Al	630mm² Al	185mm² Al
Capacitance per phase in microfarads per 1000 metres at 20°C	µf/km	0.2869	0.7231	0.208	0.377	0.523	0.444	0.261
Charging current	A/km/phase	0.05	0.14	0.414	0.752	1.043	1.771	1.041
Maximum allowable cable length (m)	m	**10000**	**3500**	**1200**	**650**	**475**	**275**	**475**

Table 7.3-1 Maximum cable lengths for HV and LV links – non-insect protected cables

		INSECT PROTECTED									
		LV CABLE			6.35/11 (12) kV CABLE				12.7/22 (24) kV CABLE	19.1/33 (36) kV CABLE	
		16mm² Cu	50mm² Cu	240mm² Al	35mm² Al	185mm² Al	400mm² Al	400mm² Cu	35mm² Al	50mm² Al	300mm² Al
Capacitance per phase in microfarads per 1000 metres at 20°C	µf/km	0.2869	0.4293	0.7231	0.208	0.377	0.523	0.534	0.151	0.129	0.236
Charging current	A/km/ phase	0.05	0.08	0.14	0.414	0.752	1.043	1.065	0.602	0.514	0.941
Maximum allowable cable length (m)	m	**10000**	**6250**	**3500**	**1200**	**650**	**475**	**450**	**825**	**950**	**525**

Table 7.3-2 Maximum cable lengths for HV and LV links – insect protected cables

7.4 Metallic Pipelines in Close Proximity to High Voltage Installations

Electrical hazards may exist when a metallic pipeline runs in parallel or in close proximity to HV installations. The magnitude of the electrical hazards are dependent on a number of factors such as: the distance of the metallic pipeline in relation to the overhead conductor; underground cables or earthing system; the load of the conductor and/or cable; the coating of the metallic pipeline (if any); soil resistivity; fault current magnitude and clearing time; and network configuration (single circuit, double circuit, OHEW, etcetera).

These hazards are often classified into the following categories:

- Low frequency induction (LFI)
- Earth potential rise (EPR)
- Capacitive coupling

Its occurrence is not limited to single-phase or three-phase systems. It is also present in the SWER network. The consequence of such hazards could lead to electric shock, injury or death. It is therefore necessary to design such HV installations to mitigate exposure to an acceptable level.

AS/NZS 4853 Electrical hazards on metallic pipelines provides guidelines to calculate the magnitude of the electrical hazards, and to assess the effectiveness of methods used to mitigate the hazard. It is important to note that the application of the standard is appropriate to any conductive structures that run in parallel or in close proximity to HV installations. Typical examples include: conductive fences made of star pickets connected with a plain or barbed wire, steel post supporting a chainwire meshed fencing, and aluminium pool fencing. The standard approach is based on risk management methodology that requires application of physical and procedural controls that will reduce the risk to an acceptable level. Designers should seek assistance from the Lines Design Engineering Group.

8 CABLES

8.1 HV Cable Data – Non insect Protected

PARTICULARS		6.35/11 (12) kV CABLE			12.7/22 (24) kV CABLE	
		35mm² Al TRIPLEX TR-XLPE PVC/HDPE	185mm² Al TRIPLEX TR-XLPE PVC/HDPE	400mm² Al TRIPLEX TR-XLPE Anti Termite MDPE	630mm² Al 1 Core TR-XLPE LAT/PVC/HDPE	185mm² Al TRIPLEX TR-XLPE LAT/PVC/HDPE
I.I. No		2429942	2429959	2433811	2429926	2429934
Nominal area of core conductors	mm²	35	185	400	630	185
Maximum continuous current carrying capacity of 3 single cores in ground (1 circuit) in trefoil formation with 3 cables in 1 enclosure (PVC duct)	A	130 (103)	320 (254)	472 (428)	595 (421)	320 (255)
Emergency two hour current rating factor - cable at 70% load prior to emergency In trefoil formation with 3 cables in 1 enclosure	A	159 (116)	541 (404)	940 (734)	1074 (710)	553 (415)
Design maximum conductor operating temperature						
(a) Normal	°C	90	90	90	90	90
(b) Emergency (2 hour)	°C	105	105	105	105	105
(c) Short Circuit	°C	250	250	250	250	250
Positive and negative sequence impedance at 50Hz of completed cable (resistive and reactive components) at max. operating temperature	Ω/km	1.11 + j0.143	0.211 + j0.110	0.102 + j0.0987	0.063 +j0.097	2.11 + j0.117
Zero sequence impedance at 50Hz of completed cable at 20°C (resistive and reactive components)	Ω/km	2.10 + j0.0770	0.537 + j0.0501	0.278 + j0.0442	0.296 + j0.0428	0.538 + j0.0586
Voltage drop - 3 phase @ pf =0.9	mV/A/m	1.95	0.418	0.1754	0.203	0.42
Three-phase symmetrical fault rating for 1 second	kA	3.3	17.5	38.2	59.6	17.5
Capacitance per phase in microfarads per 1000 metres at 20°C	µf/km	0.208	0.377	0.5230	0.47	0.261
Fault rating of cable screen	kA 1s	3.3	10.2	13.5	14.2	10.2
Conductor insulation values (nominal)	MΩ/km	11000	6000	4300	5300	8900
Sheath insulation values (nominal)	MΩ/km	1000	1000	1000	1000	1000

NOTES:

1. The maximum continuous current rating of the cables is based on the following assumptions:
   - soil ambient temperature 30°C;
   - soil thermal resistivity 1.2° K m/W;
   - cable screens are bonded at both ends;
   - depth of burial 800mm.
   - In brackets () depth burial of 1100mm.
2. Additional cable data can be located in the “Underground Construction Manual” in the “MATERIAL DATA” folder.

8.2 HV Cable Data – Insect Protected

PARTICULARS		6.35/11 (12) kV CABLE				12.7/22 (24) kV CABLE	19/33 kV CABLE	
		35mm² Al TRIPLEX TR-XLPE PVC/NJ/HDPE	185mm² Al TRIPLEX TR-XLPE PVC/NJ/HDPE	400mm² Al TRIPLEX TR-XLPE PVC/NJ/MDPE	400mm² Cu 1 Core TR-XLPE PVC/NJ/HDPE/PE	35mm² Al TRIPLEX TR-XLPE PVC/NJ/HDPE	50mm² Al 1 Core TR-XLPE NJ/HDPE	300mm² Al 1 Core TR-XLPE NJ/HDPE
I.I. No.		2429967	2429975	2433829	2429918	2429991	2423655	2424984
Nominal area of core conductors	mm²	35	185	400	400	35	50	300
Insect protection details								
(a) Material		Nylon	Nylon	Nylon	Nylon	Nylon	Nylon	Nylon
(b) Material thickness	mm	0.8	0.8	0.8	0.8	0.8	0.8	0.8
(c) Construction		Extruded	Extruded	Extruded	Extruded	Extruded	Extruded	Extruded
Maximum continuous current carrying capacity of 3 single cores in ground (1 circuit) in trefoil formation with 3 cables in 1 enclosure (PVC duct)	A	130 (103)	320 (254)	472 (428)	570 (484)	130 (103)	140 (129)	371 (337)
Emergency two hour current rating factor - cable at 70% load prior to emergency In trefoil formation with 3 cables in 1 enclosure	A	202 (147)	540 (403)	526 (457)	1020 (783)	227 (167)	231 (192)	612 (502)
Design maximum conductor operating temperature								
(a) Normal	°C	90	90	90	90	90	90	90
(b) Emergency (2 hour)	°C	105	105	105	105	105	105	105
(c) Short Circuit	°C	250	250	250	250	250	250	250
Positive and negative sequence impedance at 50Hz of completed cable (resistive and reactive components) at max. operating temperature	Ω/km	1.11 + j0.143	0.211 + j0.110	0.102 + j0.0987	0.0629 + j0.0984	1.11 + j0.156	0.822 + j0.156	0.129 + j0.121
Zero sequence impedance at 50Hz of completed cable at 20°C (resistive and reactive components)	Ω/km	2.10 + j0.0770	0.537 + j0.0501	0.278 + j0.0442	0.308 +j0.0410	2.10 + j0.0896	1.50 + j0.0971	0.369 + j0.060
Voltage drop - 3 phase @ pf = 0.9	mV/A/m	1.95	0.418	0.1754	0.213	1.95	1.46	0.311
Three-phase symmetrical fault rating for 1 second	kA	3.3	17.5	38.2	57.2	3.3	4.9	28.4
Capacitance per phase in microfarads per 1000 metres at 20°C	μf/km	0.208	0.377	0.523	0.534	0.151	0.129	0.236
Fault rating of cable screen	kA 1s	3.3	10.2	13.5	13.5	3.3	4.9	13.8
Conductor insulation values (nominal)	MΩ/km	11000	6000	4300	4300	15000	18000	9800
Sheath insulation values (nominal)	MΩ/km	1000	1000	1000	1000	1000	1000	1000

NOTES:

1. The maximum continuous current rating of the cables is based on the following assumptions:
   - soil ambient temperature 30°C; - soil thermal resistivity 1.2°K m/W; - cable screen bonded at both ends; - depth of burial 800mm;
   - in brackets ( ) depth of burial 1100mm.
2. Additional cable data can be located in the "Underground Construction Manual" in the "MATERIAL DATA" folder.

8.3 LV Cable Data – Non Insect Protected

PARTICULARS		240mm² Al 4 Core Sector XLPE PVC	16mm² Cu 4 Core XLPE PVC
I.I. No.		1634155	1632489
Nominal area of core conductors	mm²	240	16
Maximum continuous current rating in ducts	A	320	88
Emergency two hour current rating factor - cable at 70% load prior to emergency in ducts	A	370	95
Design maximum conductor operating temperature			
(a) Normal	°C	90	90
(b) Emergency (2 hour)	°C	105	105
(c) Short Circuit	°C	250	250
Maximum AC resistance of conductor of completed cable at 50Hz and 90°C	Ω/km	0.162	1.47
Positive and negative sequence impedance at 50Hz of completed cable (resistive and reactive components)			
(a) At 20°C	Ω/km	0.126+j0.062	1.15+j0.089
(b) At max. operating temperature	Ω/km	0.162+j0.062	1.47+j0.089
Zero sequence impedance at 50Hz of completed cable at 20°C (resistive and reactive components)	Ω/km	0.500+j0.062	4.6+j0.089
Voltage drop - 3 phase	mV/A/m	0.300	2.55
Three-phase symmetrical fault rating for 1 second	kA	22.7	2.3
Capacitance per phase in microfarads per 1000 metres at 20°C	µf/km	0.045	0.035
Insulation megger readings 100 metre section tested with 2.5kV megger - Phase/Phase			
(a) Expected Value	GΩ	1.0	1.0
(b) Minimum accepted value	GΩ	0.1	0.1
Insulation megger readings 100 metre section tested with 2.5kV megger - Phase/Earth			
(a) Expected Value	GΩ	1.0	1.0
(b) Minimum accepted value	GΩ	0.1	0.1

NOTES:

1. The maximum continuous current rating of the cables is based on the following assumptions:
   - soil ambient temperature 30°C;
   - soil thermal resistivity 1.2°K m/W;
   - depth of burial 600mm.
   - In brackets ( ) depth of burial 900mm.
2. Additional cable data can be located in the “Underground Construction Manual” in the “MATERIAL DATA” folder.

8.4 LV Cable Data – Insect Protected

PARTICULARS		240mm² Al 4 Core Sector XLPE PVC - NYL/PVC	50mm² Cu 4 Core XLPE PVC - NYL/PVC	16mm² Cu 4 Core XLPE PVC - NYL/PVC	16mm² Cu 2 Cond. NS PVC - NYL/PVC	4mm² Cu 2 Cond. NS PVC - NYL/PVC
I.I. No.		2400272	2410371	2400273	2406943	2400260
Nominal area of core conductors	mm²	240	50	16	16	4
Insect protection details						
(a) Material		Nylon	Nylon	Nylon	Nylon	Nylon
(b) Material thickness	mm	0.8	0.8	0.8	0.4	0.4
(c) Construction		Extruded	Extruded	Extruded	Extruded	Extruded
Maximum continuous current rating in ducts	A	320	171	88	97	44
Emergency two hour current rating factor - cable at 70% load prior to emergency in ducts	A	370	190	95	105	45
Design maximum conductor operating temperature						
(a) Normal	°C	90	90	90	90	90
(b) Emergency (2 hour)	°C	105	105	105	105	105
(c) Short Circuit	°C	250	250	250	250	250
Maximum AC resistance of conductor of completes cable at 50Hz and 90°C	Ω/km	0.162	0.494	1.47	1.4	5.61
Positive and negative sequence impedance at 50Hz of completed cable (resistive and reactive components)						
(a) At 20°C	Ω/km	0.126+j0.062	0.388 + j0.082	1.15+j0.089	1.15 + j0.140	4.61 + j0.174
(b) At max. operating temperature	Ω/km	0.162+j0.062	0.494 + j0.082	1.47+j0.089	1.40 + j0.140	5.61 + j0.174
Zero sequence impedance at 50Hz of completed cable at 20°C (resistive and reactive components)	Ω/km	0.500+j0.062	1.55 + j0.082	4.6+j0.089	2.20 + j0.0555	7.84 + j0.0719
Voltage drop - 3 phase	mV/A/m	0.300	0.868	2.55	2.970	11.7
Three-phase symmetrical fault rating for 1 second	kA	22.7	7.2	2.3	1.6	0.4
Capacitance per phase in microfarads per 1000 metres at 20°C	µf/km	0.045	0.038	0.035	0.772	0.56
Insulation megger readings 100 metre section tested with 2.5kV megger - Phase/Phase						
(a) Expected Value	GΩ	1.0	1.0	1.0	0.5	0.5
(b) Minimum accepted value	GΩ	0.1	0.1	0.1	0.05	0.05
Insulation megger readings 100 metre section tested with 2.5kV megger - Phase/Earth						
(a) Expected Value	GΩ	1.0	1.0	1.0	0.5	0.5
(b) Minimum accepted value	GΩ	0.1	0.1	0.1	0.05	0.05

NOTES:

1. The maximum continuous current rating of the cables is based on the following assumptions:
   - soil ambient temperature 30°C;
   - soil thermal resistivity 1.2°K m/W;
   - depth of burial 600mm.
   - In brackets ( ) depth of burial 900mm.

2. Additional cable data can be located in the “Underground Construction Manual” in the “MATERIAL DATA”.

8.5 Cable Installation – Design Considerations

8.5.1 Route Selection

Route selection is more than determining the shortest distance. The route of the cable must also be chosen to:

- facilitate the future development of the network
- avoid natural and man-made obstructions that will add to the cost of installation
- avoid environmentally sensitive and polluted areas
- provide safe access for installation and repair
- account for the physical limitations of affecting the pulling of cables (see Section 1.2)

In most regions cable is procured cut to length and, to enable this service, forecasting is required. Designers should also be aware of drum lengths of uncut cable for when cut lengths are not possible or available as this may need to be taken into account in determining the route.

Joint locations should be avoided where future access will be difficult (under paved areas / public activity areas) and close to conduit ends that enter inaccessible areas. This must be balanced with the need to keep the number of joints to the minimum practical.

It is inevitable that, over time, short lengths of cable will be left more than required for other applications. The cost of high voltage cable makes it desirable to use these short lengths, however, this needs to be balanced with the cost of the joints and the potential increase in risk to reliability associated with joints.

Joints are designed to match the performance of the cable but are subject to more risk because of the environmental conditions during installation and workmanship variables.

As a **design rule** the number of joints in a piece of cable, that would otherwise be available in a single piece, should be limited to one and the cost benefit of the short lengths should be 20% > salvage value of the cable + cost of joints.

8.5.2 Cable Pulling

Designers must be conscious of the factors affecting the pulling of cables. A poor design can result in making the cable pull impossible without damage to the cable.

The Underground Construction Manual, MATERIAL DATA drawings set out the minimum bending radii and maximum pulling tensions and the following demonstrates, in a practical example, how designers need to confirm the practicality of their designs.

Calculation of Pulling Tensions

The approximate pulling tension required to install cables can be calculated by the following formula. A more comprehensive guide can be found in C(b)2 – 1989 Guide to the Installation of Cables Underground.

$T = T_0 + \mu WL$ **(straight sections) and**

$T = T_0 e^{\mu\theta}$ **(for bends)**

Symbols used:

T_0	**=**	**Tension at the commencement of a section (N)**
T	**=**	**Tension at the end of a section (N)**
M	**=**	**Mass of cable per unit length (kg/m)**
W	**=**	**Equivalent cable force per unit length = 9.81xM (N/m)**
μ	**=**	**Coefficient of friction in a given section**
L	**=**	**Length of cable in metres (m)**
R	**=**	**Radius of a horizontal bend (m)**
θ	**=**	**Angle of subtended arc in a bend or angle of an incline to the horizontal (rad)**
F	**=**	**Side wall force (N/m)**

Calculations on reasonably flat ground will only need to consider the horizontal plane but if there is significant inclines the following should be applied:

$T = T_0 \pm WL(\sin\theta \pm \mu\cos\theta)$ [-ve for declines or +ve for inclines]

For upward and downward, concave and convex bends the same approximate formula for bends shown above applies.

The following is given as an example for an installation on level ground of an 11kV, 185mm² Al TRIPLEX cable in conduit without lubricant. Mass of the cable is 5.4 kg/m.

For new clean conduits μ can be assumed as 0.3.

From the formula it can be seen that the affect of bends is a multiplier of the tension in the cable entering the bend and the magnitude of the multiplier increases with the magnitude of the angle of the bend. Consequently the direction in which the cable is pulled should be chosen so that bends are in the section closest to the feed end rather than the pulling end and angles of deviation should be kept as small as possible. This is demonstrated in the worked example below.

Angle of Bend in Degrees	**Value of $e^{\mu\theta}$**				
	μ = 0.7	μ = 0.6	μ = 0.5	μ = 0.4	μ = 0.3
15	1.2	1.17	1.14	1.11	1.08
30	1.44	1.37	1.30	1.23	1.17
45	1.73	1.60	1.48	1.37	1.27
60	2.08	1.83	1.68	1.52	1.37
75	2.50	2.11	1.92	1.69	1.48
90	3.0	2.57	2.19	1.87	1.60

Table 8.5-1

Pulling from A to F

Tension at B	$T_1 = T_0 + \mu WL$
	$T_1 = 0 + 0.3 \times (5.4 \times 9.81) \times 20$
	$T_1 = 318$ Newtons
Tension at C	$T_2 = T_1 e^{\mu\theta}$
	$T_2 = 318 \times 1.27$
	$T_2 = 404$ Newtons
Tension at D	$T_3 = 404 + 0.3 \times (5.4 \times 9.81) \times 30$
	$T_3 = 881$ Newtons
Tension at E	$T_4 = 881 \times 1.17$
	$T_4 = 1031$ Newtons
Tension at F	$T_5 = 1031 + 0.3 \times (5.4 \times 9.81) \times 100$
	$T_5 = 2620$ Newtons

Pulling from F to A

Tension at E	$T_1 = T + \mu WL$
	$T_1 = 0 + 0.3 \times (5.4 \times 9.81) \times 100$
	$T_1 = 1589$ Newtons
Tension at D	$T_2 = T_1 e^{\mu\theta}$
	$T_2 = 1589 \times 1.17$
	$T_2 = 1859$ Newtons
Tension at C	$T_3 = 1859 + 0.3 \times (5.4 \times 9.81) \times 30$
	$T_3 = 2336$ Newtons
Tension at B	$T_4 = 2336 \times 1.27$
	$T_4 = 2967$ Newtons
Tension at A	$T_5 = 2967 + 0.3 \times (5.4 \times 9.81) \times 20$
	$T_5 = 3285$ Newtons

Pulling from F to A requires 25% more effort than pulling from A to F.

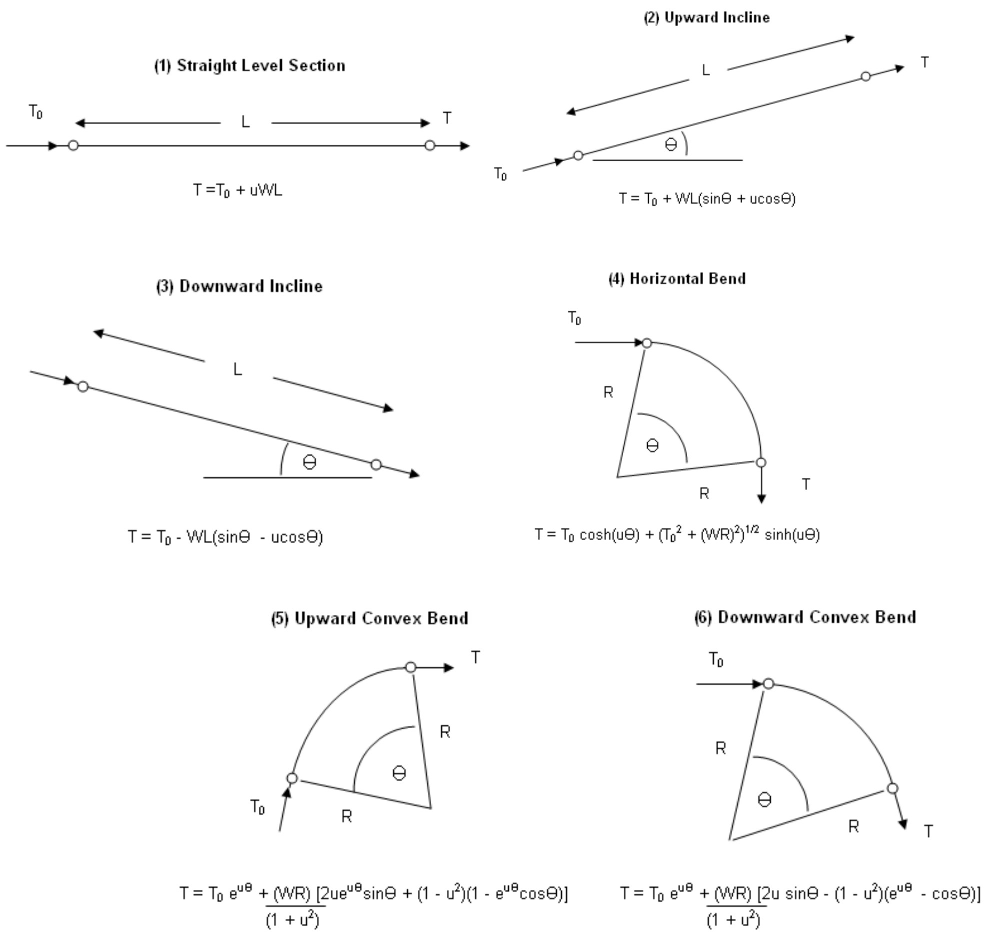
The side wall force is also an important factor to be considered. It shall be limited to 1450kg/m for PVC or HDPE sheathed cables and is calculated using the following formula:

$$F = \frac{T}{R}$$

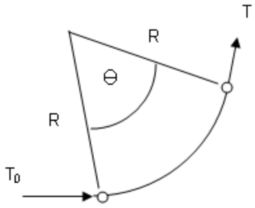
8.5.2.1 Cable Pulling Tension Calculator

The program is designed to allow the calculation of the winching tension required to pull a cable through a trench or duct in a predetermined path. The calculator also calculates the tension should the cable be pulled in the reverse direction. Additionally, the side-wall force is also calculated for those cables that pass through bends in the path. The calculator has been specifically designed to cover the Ergon Energy Standard range of LV, 11kV, 22kV and 33kV cables.

Complex route geometries must first be subdivided into simple subsections, each identifiable with one of the basic shapes shown below. The formula accompanying each illustrated shape gives a determination of the tension (T) imposed upon the leading end of a cable as it exits from the section when the tension (T_0) at the commencement of that section is known.

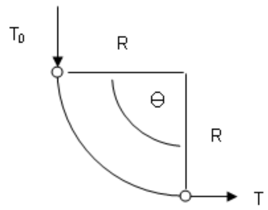


(7) Upward Concave Bend



$$T = T_0 e^{u\Theta} - \frac{(WR)}{(1 + u^2)} [2u \sin\Theta - (1 - u^2)(e^{u\Theta} - \cos\Theta)]$$

(8) Downward Concave Bend



$$T = T_0 e^{u\Theta} - \frac{(WR)}{(1 + u^2)} [2ue^{u\Theta}\sin\Theta + (1 - u^2)(1 - e^{u\Theta}\cos\Theta)]$$

8.5.3 Conduits

Ergon Energy's practice is to use conduit for all cable installations. This has been found to be the most practical way to coordinate the works with the available resource.

Installing new underground Hv and LV cables within conduit minimises the need for re-excavation at a later time during the replacement and modification of the network.

The Designer should allow extra conduits for additional circuits that have a reasonable possibility of being required in the next decade or two. The provision of a spare conduit can save considerable future cost and community disruption. **But** the provision of a spare conduit that will never be used is a sunk investment for which the business will never derive a return. Underground Construction Manual TRENCHING drawings set out trenching arrangements used regionally.

RAMS will decide whether to include spare conduit/s to cater for future development of the network.

The provision of a spare conduit can save considerable future cost and community disruption. **But** the provision of a spare conduit that will never be used is a sunk investment for which the business will never derive a return. Consequently prudent judgement is required, that is made with the best available information and knowledge of the cost to the business.

The following **design rules** apply:

Spare conduits should be installed in the following circumstances to meet future HV network needs:

- Where the Regional Manager Northern Networks and Regional Manager Southern Networks identifies a future network requirement
- Where the SDO / Networks Manager identifies a future supply requirement
- In CBD precincts, the number is to be determined in consultation with the Networks Manager and the SDO
- In locations where future access to the cable will be impossible or extremely difficult
- Along designated routes where future communications will be required
- In other situations, with the endorsement of the Networks Manager or the SDO
- When installing spare conduit attach an Electronic marker ball to the end of each conduit run to aid in locating the conduit/s for future use.

Designers must consult the Networks Manager and/or SDO as appropriate.

8.5.3.1 Maximum Continuous HV Cable Runs

Cable is installed between plant and equipment in the network creating points at which the cable can be isolated and accessed. Generally the distances involved cause no network operational management issues but where cable runs become long consideration must be given to the time and difficulty involved in identifying and isolating faults and the limitations of test equipment.

Most fault location equipment has the capability of locating faults on long cable runs (10-20km using wave reflectometry and even further with bridge networks). However the accuracy diminishes and the interpretation of results becomes more difficult with distance making the pin point location of any faults much slower. The cable route may also need to be traced before fault location is identified causing greater delays.

HV Cable testing equipment (VLF proof tests) has a maximum reach of 5km.

Cables runs can be broken up using cabinets, cable terminations and connecting bus work. Switchgear should not be used in the cabinets as the incidence of faults will be rare and the location will have no operational purpose in the network.

The installation of “Fault Indicators” will enable the faulted section of cable to be identified.

The use of cabinets will impact on the cost of projects (diminishing with distance) and their use can only be justified where the limitations discussed previously apply. As a **design rule** cabinets should be employed where the continuous length of cable would otherwise be 4 km or greater, having regard for the network arrangement and the customers affected.

Designers must consult the Networks Manager and the SDO before proposing the use of cabinets.

8.6 Cable Ratings

8.6.1 General

The continuous ratings of the standard range of cables are given in Sections 8.1 to 8.4. It should be noted that the ratings are based on assumptions regarding the environment and installation conditions listed.

Cumulatively these will generally be conservative in order to cover the range of conditions that will apply throughout the State. Conversely in extreme environmental and installation situations the assumptions may not be sufficient for local conditions and it is prudent to review these against local conditions on all projects. The use of CYMECAP software is recommended to determine cable ratings in this instance.

All zone substation exit and critical feeder cables shall be fully designed and must take into account the factors listed in the following sub-sections.

8.6.2 Soil Thermal Resistivity (ρ)

Soil Thermal Resistivity (STR) is the measure of the cable backfill bedding materials’ ability to transfer heat, generated by cable losses, away to the general environment (usually to the atmosphere). It is a product of soil composition, texture, moisture content and compaction.

The figure used for the ratings in the above drawings is ρ = 1.2 °K m/W. This is conservatively representative of most clay based soils in Queensland (CSRIO figures for around Townsville are about 1.0 °K m/W.). Coarse dry sand scoria, punis and similarly structured materials should be avoided (ρ up to 6.0 °K m/W in extreme cases) as backfill material and replaced with a fine particle material such as loams with some clay content or fatty sands. Refer to Table 8.6-1 for a general guide to the thermal resistivity of different materials. These are general guides only and actual thermal resistivity of the soil can be identified by testing.

Substation exit cables are at greatest risk of exceeding their rating as they must carry the full feeder load and sometimes exposed to overloads. Controlled backfill material (flowable thermal backfill) should be used in this situation and where a maximum rating of the cable needs to be assured the use of manufactured material is appropriate.

Material	**Thermal Resistivity ρ K.m/W**
Air	4 (Large duct)
Air (still)	6 (Normal duct)
Aluminium	0.0045
Asphalt	1.2
Backfill - FTB	1.0
Backfill - stabilised	1.2
Bentonite	1.2
Concrete (dry)	0.8
Copper	0.0026
Lead	0.0286
PVC duct	6.0
Rock	0.4
Soil	1.2
Stainless steel	0.0617
Steel - mild for armouring	0.02
Water (fresh)	1.8
Water (sea)	
XLPE - semiconductive	3.5
XLPE & HDPE	

Table 8.6-1 Material thermal resistivity

In recent years, the Advance Analysis Ratings Group has progressed drastically in this area with the group acquiring a test laboratory based in Townsville. As a result, regionally based sources of thermal backfill bedding materials have been investigated and approved on a project by project basis.

8.6.3 Soil Temperatures

The temperature gradient through the soil to the atmosphere is the driving force that transfers the heat generated by cable losses away to the atmosphere.

The ratings in the Sections 8.1 to 8.4 are based on soil temperatures of 30 °C and a summer peak demand. It will be conservative for most southern and inland applications but has been adopted for standardisation. If additional rating is required for particular applications refer to Advance Analysis Ratings Group in determining a rating based on the local conditions.

Location	Summer (Dec-Mar) maximum temperature	Winter (Jun-Aug) maximum temperature
Brigalow	31	23
Brisbane	29	20
Cairns	31	26
Charleville	34	23
Mt Isa	34	27
Rockhampton	32	26
Townsville	35	28
Warwick	26	18
Weipa	33	30

Table 8.6 - 2 Ground temperatures at 1,000mm depth

8.6.4 Depth of Cover

The rating of cables decreases with an increasing depth of cover over the cable. This is because the heat generated by cable losses needs to escape to the atmosphere. Putting the cable deeper increases the length and hence the thermal resistance of the escape path.

The ratings in Section 8.1 and 8.2 are based on depths of 800mm and 1100mm and the ratings in Section 8.3 and 8.4 are based on depths of 600 and 900mm. It is often necessary to go deeper under other services or other obstructions. As a **design rule** this can be ignored for rating purposes provided that the length of extra depth does not extend any further than 6 metres. It can be assumed that sufficient heat will be conducted along the conductor core for short distances to maintain core temperatures within manageable tolerances. Particular care must be taken at substation exits where rating is more critical.

Where a cable needs to be laid at a greater depth than normal, designers should seek assistance from the Lines Design Engineering Group.

8.6.5 Mutual Heating Affects

Where a number of cables are laid in proximity there is a combined heating affect that raises the temperature of the cores in order to disperse the additional heat. This means that the cables must be derated to avoid core temperatures that will damage the cable dielectric. The separation of cables and the number of cables in proximity will determine the amount of de-rating necessary (group rating factor).

The ratings in the above drawings are based on a single circuit. For multiple circuits in a flat configuration a group de-rating factor should be applied.

Group rating factors that account for the mutual heating of adjacent cables are provided in the table below. Designers should seek the assistance from the Lines Design Engineering Group for different configuration.

8.6.6 Conduit

Placing cable in conduit de-rates the cable as the air space in the conduit has a higher thermal resistance than the surrounding soil. There are, however, other good reasons for using conduit and this is currently Ergon Energy practice.

If there is a need to improve the rating of a cable in conduit the conduit can be filled with "Bentonite" or a similar product. The effect of the conduit can then be ignored for rating purposes.

8.6.7 Cyclic Rating Factors

Cables laid in the ground have a thermal inertia and consequently there is a thermal time constant associated with heating and cooling cycles.

The ratings given in Section 8 are a continuous rating for simple application, however, this will be conservative for some customer classes e.g. domestic residential.

For particular applications where rating is critical a cyclic rating factor can be determined based on knowledge of the daily load curve.

As a general guideline Table 8.6-2 shows the de-rating factors applied on cables in single way ducts laid on the same horizontal plane.

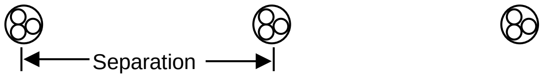
Number of ducts in group	Group rating factors for triplex cables in single way duct, horizontal formation - Refer cable Data sheets 			
	Minimum separation	0.30 m	0.45m	0.6m
2	0.88	0.91	0.93	0.94
3	0.8	0.84	0.87	0.89
4	0.75	0.81	0.84	0.87
5	0.71	0.77	0.82	0.85
6	0.69	0.75	0.8	0.84

Table 8.6-2 De-rating factors for single way ducts on the same horizontal plane

Designers should seek the assistance from the Lines Design Engineering Group where application of a cyclic loading factor is required.

9 EARTHING

9.1 Earthing System

9.1.1 CMEN

The following deals with the treatment of high voltage earthing systems with respect to the low voltage earthing systems.

The Electrical Safety Code of Practice 2010 issued in conjunction with the Queensland Electrical Safety Act 2002 and Electrical Safety Regulation 2013 sets out earthing practices for distribution networks. Ergon Energy considers the Common Multiple Earth system (CMEN, i.e. the bonding of the two systems) as the preferred system. Studies undertaken, assessing the associated risks, support this view so where it is possible to meet the criteria for CMEN connection this should be done.

The arguments supporting CMEN and the criteria for connection of CMEN Earthing systems are set out in NA000403R481 Guideline for the Adoption CMEN Earthing System document.

It will not always be possible for physical reasons and reasons of cost to meet the criteria for CMEN. Designers must be diligent in doing their assessment for CMEN connection as the common earthing resistance value required for the padmounted substation is not normally sufficient alone to hold the voltage rise of the earthing system at a safe level across the range of prospective fault levels possible. Most situations will require the interconnection of the LV with adjacent substations for the arrangement to operate safely.

For URD installations a CMEN system is generally required. In isolated developments consideration should be given to using an interconnecting LV cable or extending the HV earth along the cable trench to enable it to be bonded to an existing LV network if such exists. Refer Section 5.3 for site requirements.

For isolated supplies such as Commercial or Industrial padmounted substations consideration should be given to using an interconnecting LV cable or extending the HV earth along the cable trench to enable it to be bonded to the existing LV network.

The Underground Construction Manual, EARTHING drawing No’s 5013 and 5123 sets out the earthing arrangements and requirements for 11kV and 22kV padmounted substations respectively.

9.1.2 Separate Earthing

Where the criteria set out in NA000403R481 Guideline for the Adoption CMEN Earthing System for CMEN connections cannot be met the HV and LV earth will be separated.

The Underground Construction Manual, PADMOUNTED SUBSTATIONS drawings define site size and requirements for 11kV and 22kV padmounted substations.

The Underground Construction Manual, EARTHING drawings set out the earthing arrangements and requirements for 11kV and 22kV padmounted substations.

9.2 CABLE SCREEN EARTHING

9.2.1 General

The metallic screens of cables are designed to provide an effective earth return path for fault current resulting from failed equipment and cables. This enables the speedy detection and isolation of the faulted equipment from the network by protective devices and switchgear. There will, of course, generally be discontinuity in the path because of connections to the overhead lines and plant and equipment. At these locations the screen must be effectively earthed and the following provides guidance on how this should be done.

9.2.2 Zone Substations Exits

9.2.2.1 Earthing Options

Option 1 - Earth Both Cable Ends

Connection of the cable screen at the substation to the substation earth provides the most secure and reliable fault return path. It does, however, transfer potential rises appearing on the substation earth out into the distribution network. This includes, not only rises associated with disturbances on that feeder, but also with that on other feeders, the subtransmission network and those internal to the substation, but the substation earth is designed to manage these at safe levels. The magnitude of the fault current on distribution feeders is a maximum for a fault at the zone substation because of the low fault impedance. The cable, if connected to the substation earth, must have sufficient capacity to pass the prospective fault current without damage to the cable. The damage being a result of heating (I^2t) affects and governed by the upstream fault impedance and the performance of protection and circuit breakers in clearing the fault.

Maximum fault levels at Zone Substations for line-to-ground faults (June 2015 Normal) are normally considered to be:

- 11kV – 20.0 kA for 1 sec
- 22kV – 13.1 kA for 1.25 secs

For a cable screen to experience these currents the following coincident contingencies would be required:

- A single phase-to-ground bolted fault at the remote end of an exit cable.
- A primary plant or protection failure.
- All fault current returns in the cable screen.
- The process being adiabatic (no heat loss or transfer)
- All station transformers installed and connected.
- All the above occurring at a station with slow back-up clearing times.

Ergon Energy uses both single core and triplex cables for zone substation exits. Single core cables laid in a touching trefoil arrangement can be considered as a triplex cable. As the screens of the cable cores are insulated from one another an electrical potential will be induced on the cable screens by mutual electromagnetic induction. The magnitude of the voltage is a function of the current being carried, the length of the cable and the spacing of the cores. Earthing both ends of the cable will eliminate this voltage, but causes a current to flow through the screen resulting in heat and de-rating the cable. The symmetry of a touching trefoil arrangement minimises the losses (<5%) through cancellation of most of the voltage induced but care must be taken with single core cables as losses rise quickly with loss of symmetry and separation of the cores.

Option 2 - Earth the remote End Only of the Exit Cable

Earthing the remote cable end would appear to eliminate all the issues associated with option 1.

- The size of the cable screen is not material as no current from faults can pass directly through it to the station.
- No circulating currents can flow in single core and triplex cables screens.
- Does not extend the station earth into the distribution network

There are however other issues:

- The passage of fault current from both an exit cable fault or through fault must be returned via the ground and one practice is to install an additional earthing conductor with the substation exit cable to minimise any transfer (step and touch) potential.
- For single core and triplex cables a voltage will exist on the open cable screen end. This can be insulated but it would be prudent to limit its level which will place constraints on the maximum length of a cable exit. For single core cables this voltage will be a minimum for a touching trefoil arrangement but increases with core separation.
- For single core and triplex cables sheath voltage limiters may be required at the open screen to manage transient voltages induced by fault currents, lightning surges and switching surges that could potentially puncture the sheath or cause a “flash over” at the screen termination.

CYMECAP can be used to determine the standing voltage on the sheath during transient conditions.

Signage will be required to identify the use of single point bonding to mitigate the standing voltage hazard.

9.2.2.2 Earthing Policy at Zone Substation Exits

Design Rule - Screens of all exit cables are earthed at both ends of the cable unless otherwise approved by Line Design Engineering and Substation Standards groups.

The ratings given in for 3 x 1C cables and triplex cables in Section 8.1 and 8.2 are for a touching trefoil arrangement with both cable ends bonded and earthed.

Where a touching trefoil arrangement cannot be maintained designers should seek engineering advice on de-rating factors or alternative arrangements such as single point bonding, centre point bonding, and cross-bonding arrangements.

In some situations, such as close to Generators, fault levels can exceed the above. Engineering advice should be sought in these circumstances.

Feeder rated cables may be used for rural zone stations exits and other special applications. The screen size in this case will not be sufficient for a maximum fault under N –1 contingencies, however, as the risk of achieving a maximum fault in these circumstances is low (refer Section 9.2.2.1) the standard screen capacity of a feeder cable is acceptable.

9.2.3 Earthing of Feeder and Radial Cables

The same general principles apply in the earthing of feeder and radial cables as for substation exit cables.

Design Rule - **Screens of all feeder and radial cables are earthed at both ends of the cable** unless otherwise approved by Distribution Network Standards and Line Design Engineering groups.

The screen capacity for a feeder cable has been set as 10kA for 1 second which is consistent with industry practice and represents a low risk balance of the range of fault levels experienced along a feeder.

The screen capacity of a radial cable has been set as 10kA for 0.1 of a second which is consistent with industry standards and protection practice.

Long cable runs require earthing at (disconnect) cabinets (refer Section 8.5.3.1). Where the required current rating approaches the maximum allowable for the cable cross bonding of cable screens may be required. Engineering advice should be sought if this is the case.

9.3 LOW VOLTAGE EARTHING

9.3.1 General

The different earthing systems used by Ergon Energy (CMEN, Separate Earthing) are discussed in detail in Section 9.1. In this section it is not intended to go over earthing philosophy again but to set out where the LV underground cable network, beyond the substation, should be earthed. This will apply regardless of the earthing system employed.

9.3.2 Earthing at Pillars (Design Rules)

An earth must be fitted at the end Supply Pillar of each radial feed of the main's cable (240mm^2 Al). Cross road pillars are not normally earthed.

An earth must be fitted at every 4th Supply Pillar on a circuit, but must be no further than 180m from the furthermost consumer's switchboard.

An earth must be fitted at every:

- Linking Pillar
- Commercial and Industrial Pillar
- Distribution cabinet.

Earths must be fitted in accordance with the underground Construction Manual, EARTHING Drawing No 5085.

Notwithstanding the above rules the location of earthing should provide reasonable equality in distribution along a circuit.

9.3.3 Earthing at OH LV Cable terminations

An earth will be fitted at every LV OH cable termination. Due to the various combinations of pole mounted equipment associated with a cable termination pole, including earthing requirement, earthing of these poles is included in Overhead Construction Manual, EARTHING folder.

A MEN connection is required at LV pole terminations.

Metal cable guards must be earthed in accordance with the applicable drawing in Overhead Construction Manual EARTHING.

9.3.4 Earthing of Public Lighting Columns

Conductive public lighting columns are considered as being earthed by their ground mounting. The body of the column must be bonded to the low voltage MEN neutral by a 6mm^2 Cu earth connection at the terminal panel of the column.

The neutral at the pillar end of the public lighting cable must be connected to the neutral bar of the fuse panel in the pillar.

9.3.5 Earthing of Bridge Lighting

Where the pole foundations cannot provide an "effective earth" (e.g. bridges), then a separate earth conductor must be installed clear of the structure to ensure adequate earthing.

Where Ergon Energy Owned & Operated or Gifted and Ergon Energy Operated public lighting is installed on a pedestrian and/or vehicular bridge a separate earthing system is required.

This earth conductor will be installed with the supply cabling and shall have a cross section area according to the requirements of the Wiring Rules. The conductor shall have a cross sectional area of not less than $6mm^2$ (Cu).

The earth wire is to be connected to an "effective earth point" at the first appropriate pole or pillar (where there is a MEN point / earth rod). At each pole on the bridge, the earth cable is to be bonded to the pole and the neutral conductor.

The provision of this clause will also apply to public lighting installed on other structures that do not provide an effective earth.

9.4 PROXIMITY TO TELECOMMUNICATIONS

9.4.1 Telecommunications

Electricity and telecommunications infrastructure must co-exist in the same environment as they provide services to the same customers. This proximity can give rise to LFI and EPR (as discussed in Section 7.4) affecting telecommunication systems under high voltage fault conditions on the electricity network. These voltages are short duration but can reach dangerous levels.

The symmetry of cables minimises the affects of LFI and the exposure of underground networks to telecommunications / EPR difficulties are primarily limited to locations where high voltage cables are earthed at substations, pole terminations, and switchgear.

The voltage rise that will appear at the earth under fault conditions is dependent on fault levels and soil resistivity and will reduce with distance from the earth.

Required separation from telecommunications assets normally located on footpaths is defined in Underground Construction Manual, EARTHING folder. Further reference can be sited on NA000404R100 Power Coordination Guidelines Agreement between Ergon Energy and Telstra (Distribution Only) for information on separation at Telephone Exchange Sites (including Radio Sites, Above Ground Equipment and Housings).

Designers must ensure that relevant telecommunications companies are advised, with reasonable notice, of details of the route of any proposed underground cables and the location of substations, pole terminations, and other equipment that will be earthed along the route.

The Telecommunications Companies have the responsibility of advising Ergon Energy of any situations they believe to be at risk from EPR or LFI. The resolution of this matter is then a joint responsibility of both parties.

Designers can seek engineering advice if assistance is required and further information can be obtained from the publications; ESAA HB100 and the Joint ESAA / ATC EPR Code.

9.5 Approach to Earthing Design for Developer Design and Construct Works and for other Ergon Energy Works

Approach to earthing design requirements in Developer Design and Construct works and other Ergon Energy works is outlined in Table 9.5-1 below. It identifies the action required by the Developer or Developer's Consultant and Ergon Energy based on the works required (new or extension).

For non-developer design and construction works, Ergon Energy is the "Developer" for the purposes of the table below.

Condition	Action
Extension to existing residential and commercial subdivision development where **CMEN** is already established [i] and continuing with **CMEN**	Developer 10 ohms LV disconnected earth resistance required per padmount or RMU Ergon Energy 1. Retrieve fault level 2. Retrieve protection operating time 3. Determine earthing resistance required • >1 ohm – no action required • 1< ohm – i. Retrieve earthing information of padmounts and MEN – measured or assumed ii. Use NA000403R482 spreadsheet to determine new padmount/s earthed resistance iii. Ergon Energy to identify and arrange rectification if required [ii]
Extension to existing residential and commercial subdivision development where **Separate Earth** is already established and continuing with Separate Earth New residential and commercial subdivision development where **Separate Earth** is going to be established.	Developer As per Ergon Energy Construction Manual Ergon Energy No action required

Condition	Action
Extension to existing residential and commercial subdivision development where **Separate Earth** is already established but converting to CMEN New residential and commercial subdivision development where **CMEN** is going to be established, separate to any existing CMEN system.	Developer Retrieve from Ergon Energy padmount/s earthing resistance Ergon Energy 1. Retrieve fault level 2. Retrieve protection operating time 3. Determine earthing resistance required (this may not be required) • >1 ohm – no action required • 1< ohm – i. Retrieve earthing information of padmounts and MEN ii. Use NA000403R482 spreadsheet to determine new padmount/s earthed resistance iii. Ergon Energy to identify and arrange rectification if required iv. Provide to Developer

Table 9.5-1

[i] CMEN is taken to be “established” if **ALL** the following conditions are meet:
- Existing CMEN connected equipment (Padmounted Substation / RMU) within 500 m; and
- Connected to same feeder / protective zone (i.e. similar protection clearing time); and
- Connection to adjacent CMEN equipment via interconnected continuous LV network or HV cable screen

[ii] A design review to confirm CMEN compliance prior to offer is not required. A design review post offer is required to confirm CMEN compliance. Where major works are required to achieve a complaint CMEN network, new equipment can still be connected and a follow up NICW project created.

10 Easement

10.1 Community Title Developments

As community title developments are all on private land and there are no road reserves, easements will be required for all Ergon Energy assets. The following easements are required:

- Padmounted Substations, site size shall be as per drawings 5000 and 5114. The easement will be exclusive to Ergon Energy, i.e. no other services can cross the easement
- Cable trenches, easement width shall be equal to the required trench size. The easement for cable trenches will not restrict other services from crossing the easement provided the minimum separations are maintained.
- Pillars will not require an easement.

In all cases Ergon Energy assets are to be located on common land within the community title and not within individual lots.

Easements for padmounted substations and cable trenches are to be granted at no cost to Ergon Energy and are required to be registered prior to energisation of the connection assets.

11 AGREEMENTS

11.1 QR DESIGN REQUIREMENTS

11.1.1 Prior Approval

Where electric lines cross railways a written application must be lodged (together with a fee) to Queensland Rail in accordance with the “Agreement for Overhead and Underground Electric Lines Crossing Railways in Queensland”. Queensland Rail has 2 weeks in which to reply and may impose terms and conditions on the work. Before any such work commences written notice must be given to Queensland Rail at least 2 weeks prior to when the proposed work is intended to begin.

11.1.2 General

Underground electric lines shall be installed in accordance with the following requirements:

Orientation and Location of Underground Electric Lines

1. Underground electric lines should be orientated so as to pass through QR property in a straight line and within approximately 5° of 90° to the track centreline. This restriction may be relaxed in exceptional circumstances at the discretion of the Rail Manager if the depth of the service is greater than 4m below formation level or if geotechnical investigation shows that the bore will be self-supporting under railway loads.
2. No underground electric lines are to be located under track turnouts or crossovers.
3. No manholes, chambers, pits or anchor blocks are to be installed in QR property.
4. Where QR uses or jointly owns an underground electric line, and where that line runs along the corridor, the alignment will be:
    a. within approximately 1m of the boundary fence;
    b. more than 6m from the toe of a bank or top of a cutting, and;
    c. more than 10m from the nearest rail.

Depth of Underground Electric Lines

1. Where passing under railway tracks, the top of any underground electric line shall be laid at a depth of not less than two (2) metres below rail level and maintained at the depth for not less than three (3) metres beyond the outer rails measured at right angles to the track.
2. Elsewhere within the boundary of the railway, underground electric lines shall be laid at least one (1) metre below ground surface and drain inverts.

Separation

1. Underground electric lines shall be separated by a clear spacing of at least 2m in the horizontal plane from existing pipelines and power and communication cables, unless agreed to otherwise, in writing, by the parties.
2. No underground electric lines will be allowed vertically above / below and parallel to another service or an existing service.
3. Where new underground electric lines are to pass above / below an existing service at 90°, a vertical clearance greater than 450mm should be achieved.
4. No underground electric lines should pass within 5m horizontally of any infrastructure foundation within the boundary of the railway.

Geotechnical Advice

A geotechnical assessment of the ground conditions (soil types and depth of water table) over the length of the bore is required prior to any excavation work commencing on the site for bore holes / tunnels greater than 150mm diameter. For smaller diameter holes this advice can be sought at Ergon Energy’s’ discretion. This information is to be used to determine the most suitable method for the work and the detailed equipment requirements to successfully complete the bore without causing any disruption to the track and ground surface.

Installation
These requirements apply to low and high voltage cables. There are three acceptable methods of installation.

1. **Trench**
This method is suitable for HDPE conduits where the top of a protection slab (above the conduits) is between 2m and 3m depth below both formation level and ground level. An enveloping pipe is not required in this case. Protection from future excavation will be achieved with the use of a protection slab similar to that described in AS4799. The slab is to be minimum 150mm thick reinforced concrete designed to resist excavator impact. It is to be 600mm greater in width than the group of conduits and is to be placed centrally over the conduits. Electrical warning tapes are also to be used. The minimum depth of the top of the conduits below the underside of the slab is to be 300mm. Groups of conduits below the slab are to be protected by backfilling the trench with flowable grout (approximately 2MPa) up to a minimum of 300mm above the uppermost conduit.
2. **Directional Drilling**
HDPE conduits (without an enveloping pipe) may be used where the depth of the top of the bore is greater than 3m below both formation level and ground level. The conduits are to be installed within a single bore with a maximum diameter of 350mm. If a larger bore is necessary, a different installation method must be used.
3. **Micro-tunnelling**
This method can be used in conjunction with an enveloping pipe of HDPE where the top of the bore is between 2m and 3m below formation level and ground level.

Cable Markers
1. Cable markers shall be installed adjacent or above the route of the underground electric line as follows:
    a. where the underground electric line enters and leaves the boundary of the railway;
    b. at changes in direction of the route of the underground electric line;
    c. at distances between consecutive markers of the lesser of 200m or line of sight;
    d. at all drains or other points of potential hazard;
    e. at the ends of the under track crossing (the end of the under track crossing is taken as the point three (3) meters beyond the outer rail or toe of the embankment).
2. Cable markers shall be maintained by Ergon Energy PROVIDED THAT Queensland Rail shall repair, reinstate, or replace as applicable any cable markers which have been damaged or removed by Queensland Rail or any of its servants, agents or workmen.
3. Cable markers shall comply with the following requirements:
    a. Stand at least 800mm out of the ground, to the bottom of the marker plate
    b. Be of non-combustible material for the marker plates and of at least fire-resistant material for the pole.
    c. Wording on markers be legible, permanent, and formed in a non-combustible medium, or otherwise approved by QR.
4. Descriptive wording and instructions that are shown on cable markers shall face the railway tracks.
5. Wording on cable markers shall include the following:
    a. The owner's name.
    b. A warning of the presence of a buried service.
    c. The nature of the buried service.
    d. Contact advice in the event of an emergency.

Upon Completion
Upon completion of work Queensland Rail must again be notified promptly in writing and a copy of the "as constructed drawings" of the infrastructure, the subject or the result of the work is to be provided. These drawings shall be prepared in accordance with construction and design methods approved by a professional engineer or certified by a professional engineer if required by law.

12 APPENDIX A – CABLE PULLING TENSION CALCULATOR INSTRUCTION

To use the program

- Select the **Calculator** sheet.
- Enter a description of the current design in the text area **Your Reference**. This description will be displayed on any electronically stored or hard copy design produced.
- Use the **Cable** drop down box to select the cable for this pull from the list of all Ergon Energy Standard cables. The technical data on the chosen cable and the values used as the coefficient of friction in the calculations are shown to the left of the screen, below the **Cable** drop down box.

  - Each cable pull can be divided into a number of pull sections. There are eight section types and they are listed under **Cable Section Types**. Click on the section name to view an example of the particular section type. Each section type has been assigned a number from 1 to 8.
  - In the row **Section Number 1**, select the **Cable Section Type** (number from 1 to 8) from the drop down list.
  - If **Cable Section Type 1** is selected, enter the **Section Length** in the respective column.
  - If **Cable Section Type 2** or **3** is selected, enter the **Section Length** and the **Angle of Incline** in the respective columns.
    The **Slope Calculator** sheet can be used to determine the angle of incline. Enter the **Rise** and the **Run** in the respective text area, and the program will calculate the angle.
  - If **Cable Section Type 4** is selected, enter the **Angle of Subtended Arc in Bend** and the **Section Radius** (which will be 1.83) in the respective columns.
  - If **Cable Section Type 5**, **6**, **7** or **8** is selected, enter the **Angle of Subtended Arc in Bend** and the **Section Radius** (which will be 1.2) in the respective columns.
  - In the row **Section Number 2**, select the **Cable Section Type** from the drop down list and enter the required information as stated previously. Continue this process for all of the cable sections in the cable pull.
  - To complete the calculation click the **Click to Calculate Values** button.
  - The results of the calculation are shown in the table adjacent to the **Click to Calculate Values** button. The **Pull Tension Value**, **Pull Tension Limit**, **Side-Wall Tension Value** and **Side-Wall Tension Limit** are all displayed for the specified cable pull and for a pull in the reverse direction. Intermediate pull tension and side-wall force values are also shown for each cable section in the table below.
  - Read the **Messages** box to determine if there are any problems associated with the values calculated for this pull.
- The spreadsheet can be printed and saved as per a normal Excel spreadsheet.

13 Amendment Record

14/06/2019
Version 2

Section	Sub-Section	Brief Description of Amendments
1	1.1	Deleted second paragraph referencing the STNW 3369 (this document) replaces Blue Book
	1.2	Line Standards staff list updated.
2	2.2	Update Ergon Energy Controlled Document reference list.
5	5.1.1	Paragraph added regarding easement requirements for electrical assets on private property.
	5.1.3.1	Paragraph regarding load allowance moved to Section 6.1.3.2.
	5.1.4	Update to remove the option of pillars in rural subdivisions.
6	6.1.2.3	Nominal voltage reference updated to 400/230.
	6.1.3.2	Paragraph from section 5.1.3.1 added.
	6.1.3.3	Nominal voltage reference updated to 400/230.
	6.2	New Section added. Section covers the site selection criteria for pillars / distribution cabinets and pits.
9	9.5	Heading updated to include reference to Ergon Energy Works. Note added to clarify conditions for established CMEN network. Note added to clarify when CMEN study is to be completed as part of works.

08/04/2016
Version 1
Initial issue of Standard for Distribution Line Design Underground