Distribution Design Rules

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STAKEHOLDERS *The following positions shall be consulted if an update or review is required:*	
Asset Managers	Strategic Asset Management Consultant
Manager Health and Safety	Field Practices Coordinator
Senior Asset Frameworks Engineer	Supply Chain Manager

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1 GENERAL

1.1 Purpose

This document sets out rules for standard distribution design for Horizon Power networks. Designs that do not follow the rules contained herein are considered non-standard, and warrant greater scrutiny when reviewed.

Standardisation of network components also provides benefits to Horizon Power in risk assessment, work practices, and supply chain management.

1.2 Scope

1) This chapter 1 defines the scope of the Distribution Design Rules both as to its content and application
2) The objectives of these Distribution Design Rules are that they:
   a) apply to the Distribution System (as described in Appendix D)
   b) are consistent with good electricity industry practice
   c) are consistent with Horizon Power standards and relevant Australian Standards, and
   d) are relevant to written laws and statutory instruments.

1.3 Application

The Distribution Design Rules apply to the design of the distribution system and shall be read in conjunction with construction standards and policies.

“Preplanning” and “Safety in Design” activities must be undertaken for distribution system design and construction works.

Where distribution networks are not designed in accordance with these rules, the associated risk with the design must be reviewed by Horizon Power or their authorised representative.

1.3.1 Formal Safety Assessments (FSA)

A formal safety assessment is required for every design. FSA seeks to achieve a consensus on the risk level to the HP network from the design.

FSA is a guided process that identifies, evaluates and mitigates risk and documents all assumptions and decisions relevant to the design that impacts on a built asset during its life cycle. (Refer to FSA Procedure CS10# 4921337)

1.4 Design Process and Inputs

The steps involved in the design of a network will depend on the individual project and the context in which the design is performed.

It is an iterative process, with the designer making some initial assumptions, e.g. conductor/cable type and rating, which may later be adjusted as the design is checked and gradually refined. The final outcome is an optimum arrangement that meets all constraints. Horizon Power uses Electric Office software to aid the design process.

1.4.1 Network Requirements

Design must take into account both present and future network requirements. This information is typically covered in the relevant planning report, design specification and equipment specifications.

1.4.2 Planning

For new distribution networks or extension to existing distribution networks, planning is carried out during concept development stage. Details covered in the planning reports that need to be considered include:

1) Load size;
2) Load distribution centres;
3) Load cycle;
4) Nature of load;
5) Required transfer capacity;
6) Potential interconnection point; and
7) Automation requirements.

1.4.3 Equipment

Design specification and equipment specifications play a role in capturing requirements that need to be addressed during design. This includes:

1) Equipment and cable rating for normal load, emergency load and for fault conditions
2) Equipment or cable operating conditions (e.g. Broome versus Esperance)
3) Network tolerance limits (e.g. statutory voltage tolerance limits);
4) Standard installation requirements and
5) Protection grading requirement.

In special cases, there may also additional requirements such as:

6) Customer request for a higher security supply; and
7) Coordination with road lighting design

2 OVERVIEW OF DISTRIBUTION SYSTEM

An overview of Horizon Power's distribution system is provided in Appendix D.

3 DISTRIBUTION SYSTEM DESIGN AND CONSTRUCTION

3.1 MV Distribution System Planning

The Horizon Power's Technical Rules (HPC-9DJ-01-0001-2012) set out the criteria for planning the distribution MV network, including:

- Loading and utilisation of MV feeders,
- Voltage control,
- Voltage drop on network components, and
- MV and LV voltage limits.

It is intended that future versions of the technical rules will also contain the requirements for inverter-connected energy sources, such as photo-voltaic panels and battery storage.

3.1.1 Voltage Control

Impedance in each of the following components of the distribution system leads to voltage drop:

1) Medium Voltage Feeder
2) Distribution Transformer
3) Low Voltage Network
4) Customer Service Leads/Cables (from LV mains to point of attachment)

After a distribution system has been constructed, there are only two locations where voltage levels can be adjusted:

5) at the zone substation (bus-bar voltage set-point and the use of Line Drop Compensators), and
6) at the distribution transformers (off load tap changers).

Non-adjustable parts of the system must be designed to fully utilise the voltage control equipment at these locations to keep the customers' voltages within the statutory voltage tolerance limits. Voltage drop limits that are allowed in distribution system components are provided in Table 1:

Table 1 – Voltage Drop Limits with respect to nominal voltage

Non-Adjustable System Component	Maximum Voltage Drop
Medium Voltage Feeder	5.0%
Distribution Transformer	4.0%
Low Voltage Network	5.0%
Customer Service Cable	2.0%

3.2 Loading of MV Distribution Feeders

There are two types of distribution feeders:

- Overhead line, and
- Underground cable

3.2.1 Interconnection of MV Feeders

Normally-open interconnection points must be provided between adjacent distribution feeders, where it is technically and economically feasible, as specified by the regional asset manager, on a case-by-case basis. Distribution feeders supplying critical loads, such as town centres and hospitals, must have a normally-open interconnection point with spare capacity, as per clause 3.2.3.

3.2.1.1 Switching between Distribution Feeders and Feeder Spurs

With the exception of switching operations, MV feeders in microgrids must not be operated in parallel unless approved by Capacity Management Services.

Switching devices must be located to allow sections of the lines to be either isolated or energised (i.e. radial tee-offs from the backbone of network feeders) during fault finding exercises.

Switching of distribution feeders and distribution feeder spurs in microgrids shall be limited to the maximum switching loads given in Appendix J, due to constraints in generator step load response.

3.2.2 Loading Capacity of MV Feeders

Distribution feeder loads must be limited to the values given in the subsections below. The utilisation criteria in Section 3.2.3 must also be considered based on the feeder arrangement. Feeders dedicated to individual customers can be loaded up to these limits.

Larger loads in the Pilbara Grid need to be connected to the transmission network.

Loads that can be connected to microgrids are limited by the capacity of the individual system.

3.2.2.1 6.6 kV Feeders

The following rules apply to 6.6 kV feeders installed within the Horizon Power network.

1) The load attached to 6.6 kV feeders must not exceed 3 MVA (260 A). Refer to Figure 1.

Individual customer loads:

2) Must not exceed 2.4 MVA (80%) per connection point
3) Greater than 2 MVA but less than 4 MVA requiring a higher reliability of supply must be provided with an alternate redundant supply at an additional cost to the customer

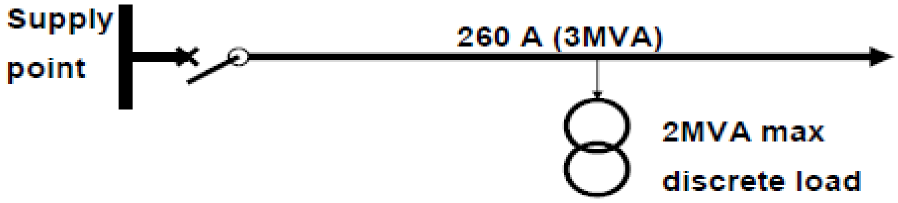


Figure 1 – 6.6 kV network arrangement

3.2.2.2 11 kV Feeders

The following rules apply to 11 kV feeders installed within the Horizon Power network.

1) The load attached to 11 kV feeders must not exceed 5 MVA (260 A). Refer to Figure 2.

Individual customer loads:

2) Must not exceed 4 MVA (80%) per connection point
3) Greater than 4 MVA but less than 8 MVA requiring a higher reliability of supply must be provided with an alternate redundant supply at an additional cost to the customer

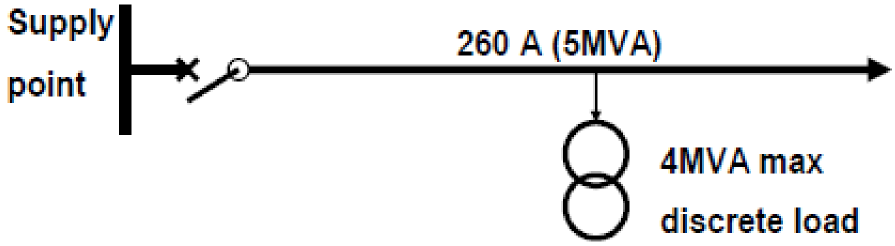


Figure 2 – 11 kV network arrangement

3.2.2.3 22 kV Feeders

The following rules apply to 22 kV feeders installed within the Horizon Power network.

1) The load attached to 22 kV shared feeders must not exceed 10 MVA (260 A). A feeder may be split two ways with 5 MVA (130 A) on each split leg. Refer to Figure 3.

Individual customer loads:

2) Must not exceed 4 MVA (80%) per connection point. Two connection points may be connected to separate legs of a split feeder.
3) Greater than 2 MVA but less than 4 MVA requiring a higher reliability of supply must be provided with an alternate redundant supply at an additional cost to the customer.

4) Greater than 8 MVA but less than 15 MVA must be provided with a dedicated feeder. Customers requiring a higher reliability of supply must be supplied with a dedicated feeder and reserved capacity on an alternate feeder, at an additional cost to the customer.

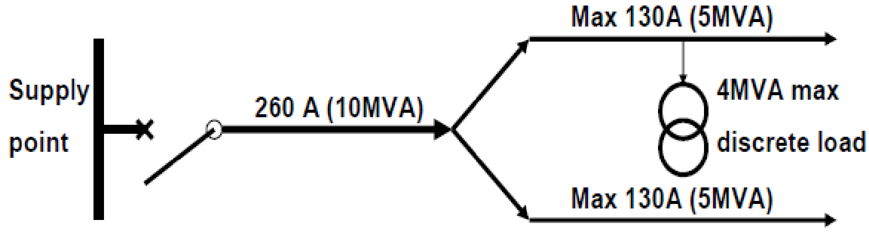


Figure 3 – Shared feeders using a 'Y' arrangement (22 kV)

3.2.2.4 33 kV Feeders

The following rules apply to 33 kV feeders installed within the Horizon Power network.

1) The load attached to 33 kV shared feeders must not exceed 15 MVA (260 A). A feeder may be split two ways with 7.5 MVA (130 A) on each split leg.

Individual customer loads:

2) Must not exceed 6 MVA (80%) per connection point. Two connection points may be connected to separate legs of a split feeder.
3) Greater than 2 MVA but less than 4 MVA requiring a higher reliability of supply must be provided with an alternate redundant supply at an additional cost to the customer.
4) Greater than 8 MVA but less than 15 MVA must be provided with a dedicated feeder. Customers requiring a higher reliability of supply must be supplied with a dedicated feeder and reserved capacity on an alternate feeder, at an additional cost to the customer.

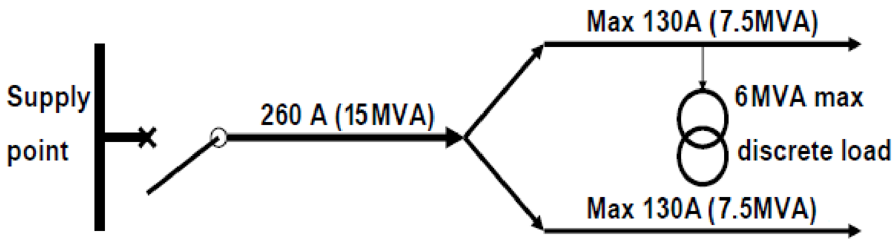


Figure 4 – Shared feeders using a 'Y' arrangement (33 kV)

3.2.2.5 Summary values

Table 2 summarises the loading capacity for each voltage level, where 'L' is the discrete load in MVA.

Table 2 – Loading of Feeders

Discrete load in MVA			Method of Supply
6.6 kV	**11 kV**	**22 or 33 kV**	
L ≤ 2	L ≤ 4	L ≤ 4	Shared feeder
2 < L ≤ 4	4 < L ≤ 8	4 < L ≤ 8	Load to be split evenly across feeder segments, each of which are supplied from a different feeder
-	-	8 < L ≤ 15	Load to be supplied from a dedicated feeder
L > 4	L > 8	L > 15	Load must be assessed on an individual basis

3.2.2.6 Single Phase MV Lines

All new single phase lines must be supplied via an isolation transformer for operation as a single phase line.

An exception to this is allowed when supplying a single customer, with load not exceeding 10 A (125 kVA at 12.7 kV and 200 kVA at 19.1 kV). Single-phase lines to such customers do not require an isolation transformer.

3.2.3 Utilisation Criteria for Loading MV Feeders

The following rules apply to the utilisations of MV feeders within the Horizon Power network. The loading of feeders in Section 3.2.2 must also be considered.

1) For radial feeders, without interconnection, 85% utilisation is allowed. However, Horizon Power must be alerted at the design phase so a contingency plan can be considered to minimise the outage duration to less than 12 hours.
2) If a distribution feeder is able to be interconnected to one other adjacent feeder, the feeder utilisation limit shall be 60%. If each feeder is loaded to 50% capacity (assuming the feeders have equivalent capacity) then the total load can be carried by one feeder in the event of the loss of a feeder, i.e. ½ L + ½ L = $\frac{2}{2}$ L.
3) If a distribution feeder is able to be interconnected to two other adjacent feeders, the utilisation limit shall be 75%. If each feeder is loaded to two thirds capacity or 66% then the total load can be carried by two feeders in the event of the loss of a feeder, i.e. $\frac{2}{3}$ L + $\frac{2}{3}$ L + $\frac{2}{3}$ L = $\frac{3}{3}$ L + $\frac{3}{3}$ L
4) If a distribution feeder is able to be interconnected with three other adjacent feeders, the utilisation limit shall be 85%. If each feeder is loaded to 75% capacity then the total load can be carried by three feeders in the event of the loss of a feeder, i.e. ¾ L + ¾ L + ¾ L + ¾ L = $\frac{4}{4}$ L + $\frac{4}{4}$ L + $\frac{4}{4}$ L

3.3 Low Voltage System

Low voltage mains distribute power at low voltage. Normally open interconnection points must be provided between adjacent LV mains, where it is technically and economically feasible, as specified by the regional asset manager, on a case-by-case basis. Interconnection of LV mains must allow for the transfer of loads during the failure of a transformer or LV mains.

All new low voltage service connections and upgrades to existing overhead service mains must be underground. Where service connections are required to overhead mains, the service must be underground, using a pole-to-pillar configuration.

3.4 Distribution System Demand Assessment

The size of the load must be determined before commencing the design process. Examples for estimating loads are available in Appendix C of AS/NZS 3000.

Design After Diversity Maximum Demand (DADMD) is a special estimate of the electrical load of every customer connection (at low voltage). When the DADMD of every connection is summed, and multiplied by a diversity factor, the result is the load as seen by the supply transformer. The loads of all distribution transformers connected to a medium voltage feeder contribute to the total load on that feeder.

DADMD values and diversity factors must be used when estimating load for Horizon Power's distribution systems. These are provided in Appendix E.

3.5 Overhead Line Design

Overhead lines must be designed to perform at suitable levels of reliability and security for the weather expected in the region it is installed, for the entirety of its intended life. The design methodology must comply with comply with AS/NZS 7000 – Overhead Line Design (Detailed Procedures).

The design of an overhead line must consider the loading of the MV distribution system (clause 3.1) and of MV feeders (clause 3.2). Selection of a suitable conductor must consider:

- Conductor type to carry load current at designed utilisation
- Insulation requirements
- Structures
- Clearances to ground and structures
- Easement for overhead lines

Refer to Appendix F for more details.

3.5.1 Line Security Levels and Wind Return Periods

Horizon Power's overhead distribution lines shall be designed to Level 1 security, except for:

- Lines over waterways, railway crossings and lines supplying defined high security installations which shall be designed to Level 2- security as per Table 6.1 of AS/NZS 7000.

The minimum design wind return period shall be:

- 50 years for Level 1 security, and
- 100 years for Level 2 security.

3.6 Underground Cable Design

The design of an underground cable network as a distribution feeder shall consider the utilisation criteria as defined above. Selecting the appropriate cables must at least consider:

1) Cable type to carry load current at designed utilisation
2) Insulation requirements
3) Cable installation inside and outside road alignments
4) Cable installation in proximity to other services
5) Easements for underground cables

Design of networks for subdivisions shall be in accordance with Underground Distribution Schemes Manual (HPC-5DA–07–0012-2012). Cable installation shall be in accordance with Utility Providers Code of Practice for Western Australia and Horizon Power's Cable Installation Manual.

Refer to Appendix G for more design related information. Cable must be installed in ducts for any road or rail crossing and where dictated by the project requirements.

3.7 Substation Design

Distribution substations must be designed in accordance with the WADCM. The substation arrangement must follow one of those provided in the Distribution Substation Manual Substation Arrangements (HPC-5DA-07-0003-2012). In addition to this, the designer must consider:

- Minimum land requirements (refer also to Appendix H)
- Installation requirements
- Earthing and minimum separation for earth potential rise hazards (refer also to Appendix H)
- Fire safety requirements and fire separation (refer also to Appendix H)
- Proximity limits to other services

3.8 Street Light Design

Street light designs shall comply with the luminance requirements as specified in AS/NZS 1158.3.1 and AS/NZS 1158.1.1. Refer to Appendix I.

LED luminaires must be used for new street lights and replacement of existing street light luminaires. Horizon Power's standard luminaires are double insulated to make them safer to touch from any probable touch voltages.

3.9 Earthing

Earthing of the distribution network must be designed in accordance with the principles in Horizon Power's Distribution Line Earthing Standard (HPC-9DC-08-0001-2012). Earthing system designs must be based on the ALARP (As Low as Reasonably Practical) principle within Horizon Power's risk management framework. Refer to Appendix C.

3.10 Safety Requirements

Safety procedures in accordance with the *Distribution Construction Standards Manual*, *Field Instruction Manual* and Horizon Power's *Health and Safety Management System (The Zone)* shall be complied with in the design, construction, operation and maintenance of the distribution system.

3.11 Land, Environment, Native Title and Heritage Requirements

An Environmental Clearance Request Form (available at http://powerlink/operational/land/Pages/Clearance-Request-Form.aspx) is required to be completed prior to any field and project works (including overhead works and inspections) to ensure that legislative and regulatory requirements are fulfilled.

3.12 Location of Distribution Components

Refer to Appendix H for guidance on the location of distribution components.

4 OVERHEAD SYSTEM CORE COMPONENTS

This section describes the core components of the overhead system. Detailed design principles are provided in Appendix F.

4.1 Supports

Historically, Horizon Power has used poles of only four lengths, as shown in Table 3. The required depths and pole lengths for cohesive soils are also shown.

Table 3 – Poles lengths and embedment for cohesive soil

Required height above ground (m)	Use	Embedment depth (m)	Standardised pole length (m)
7.95	Intermediate	1.55	9.50
9.30	Intermediate	1.70	11.00
10.65	Intermediate	1.85	12.50
12.00	Intermediate	2.00	14.00

The height above ground should be maintained regardless of the foundation required.

Table 4 lists the standard steel poles.

Table 4 – Steel Poles – Rating

Pole Length (m)	Pole Rating (kN)	Maximum pole tip load, maximum wind condition (kN)	Maximum pole tip load, serviceability condition (kN)
9.50	20	20	12
11.00	20	20	12
11.00	30	30	18
12.50	40	40	24
14.00	35	35	21

4.2 Stays

Ground stays with 19/2.00 or 19/2.75 SC/GZ (galvanised steel) conductor and GY3 insulator shall be used.

4.3 Cross-arms

4.3.1 MV Cross-arms

Galvanised steel cross-arms shall be used on MV overhead lines to support MV conductors on insulators:

- 2.4 m steel cross-arm (with nominal cross-sectional dimensions of 100 x 100 mm)
- 3.3 m steel anti-swan cross-arm (with nominal cross-sectional dimensions of 125 x 75 mm)

4.3.2 LV Cross-arms

LVABC is the standard method of LV construction.

Wood or composite cross-arms must be used only when

1) Installing new LV conductor on existing MV line (long spans where LVABC cannot be strung) poles and
2) Replacing current LV cross-arms on low voltage bare conductor networks.

The following LV cross-arms have limited use:

- 2.1 x 0.1 x 0.1 treated hard wood cross-arm (as intermediate)
- 2.1 x 0.12 x 0.12 untreated hard wood cross-arm (as strain or termination)
- 2.1 x 0.1 x 0.1 composite cross-arm (as either strain, termination or intermediate)

4.4 Insulators

1) Polymeric post and strain insulators must be used at MV. Post type must be used for intermediate poles, and strain type must be used for angle, strain and termination poles
2) LV insulators must be used on wood or composite cross-arms only for limited applications (refer to clause 4.3.2). Pin type must be used for intermediate poles, and shackle type must be used for angle, strain and termination poles
3) Shackle type LV insulators shall be used for running earth conductors on MV feeders

4.5 Conductors

The following conductors are standard in the overhead network:

Table 5 – Standard Conductors with Electrical Ratings

Name	Number of strands / strand diameter (mm)	Material	Current rating – Region A (Amperes)	Current rating – Regions C, D (Amperes)	Fault rating (kA for 1 s)
Krypton	19/3.25	AAAC	422	395	11.5
Iodine	7/4.75	AAAC	366	340	9.0
Chlorine	7/2.50	AAAC	171	159	2.5
	3/2.75	SC/AC	70	62	1.5
150 mm² LVABC		Al (XLPE insulated)	282	256	14.6
95 mm² LVABC		Al (XLPE insulated)	216	196	9.3

Table 6 – Standard Conductor Horizontal Tension

Conductor material	Ruling span (m)	Tension at 15°C, everyday load (% of CBL)	Maximum stringing tension (% of CBL)
AAAC	Less than 60	7%	24%
	60 or more	18% (armour rods must be used)	
SC/AC	Any length	17.5% (vibration dampers not required)	31%
		25% (vibration dampers must be used)	
LVABC	Any length	5%	28%

4.5.1 Conductor Applications

1) MV overhead radial feeders from a zone substation (Pilbara Grid) or power generating station (Microgrids) shall be iodine 7/4.75 AAAC conductor.

This conductor has sufficient current-carrying capacity for allowable feeder load; however, feeder length may be limited by voltage drop limits.

Krypton 19/3.25 AAAC conductor must be used as the first segment of feeder from a zone substation (Pilbara Grid) or power generating station (Microgrids) where the faults level exceeds the capacity of iodine 7/4.75 AAAC conductor (9 kA for 1 s).

2) Where the running earth is under-slung, the running earth conductor must be the same as the phase conductors
3) Where the running earth is above the phase conductors (providing lightning protection), 3/2.75 SC/AC conductor must be used
4) Chlorine 7/2.50 AAAC conductor may be used for MV three-phase spur lines supplying loads up to 1 MVA, provided the fault rating does not exceed 2.5 kA for 1 s
5) 3/2.75 SC/AC conductor must be used for single phase MV lines
6) 150 mm² LVABC must be used as LV mains conductors
7) LV mains distributed from 315 kVA transformers must be separated as two separate circuits to distribute the load
8) 95 mm² LVABC may be used as LV spurs and as LV mains with transformer ratings up to 63 kVA, provided the fault rating does not exceed 9.3 kA for 1 s
9) No new bare LV conductor must be installed. Iodine 7/4.75 AAAC conductor must be used for LV only when LVABC cannot be used (such as when existing poles are spaced for long MV spans)
10) 95 mm² LVABC (with each phase physically separated), must be used as droppers or taps on MV conductors for pole-top transformers and pole top equipment connected to 3/2.75 SC/AC conductors
11) 150 mm² LVABC (with each phase physically separated), must be used as droppers or taps on MV conductors (excluding 3/2.75 SC/AC) to equipment other than pole top transformers

4.5.2 Conductor Attachments

4.5.2.1 Conductor Ties to Insulators

1) Aluminium ties suitable for top and side securing must be used to attach AAAC conductors to insulators at MV and LV
2) Aluminium clad steel pre formed ties suitable for top and side securing must be used to attach SC/AC conductors to insulators at MV

4.5.2.2 Conductor Terminations

1) At termination poles, aluminium dead end helical terminations must be used to terminate AAAC and SC/AC conductors
2) At angle poles, aluminium alloy angle suspension clamps must be used terminate AAAC conductors
3) At angle poles, galvanised steel angle assembly must be used terminate SC/AC conductors
4) To terminate LV overhead services, strain clamps (wedge clamps) must be used. This is only for replacement of existing services of same capacity
5) For LVABC at intermediate and angle poles, suspension clamps must be used
6) For LVABC at termination and in-line strain poles, strain clamps must be used

7) Where LVABC is connected to LVABC (as a tee-off) at intermediate and angle poles, strain clamps and suspension clamps must be used
8) Where LVABC is connected to bare LV mains (as a tee off), strain clamps must be used. Krone fuses must be used, unless LV bare conductors are fused at the transformer
9) Façade mounting of LV ABC is permitted so far as window openings are avoided and non-tensioned construction is used.

4.5.2.3 Conductor Joints under Tension

Table 7 – Tension Joints

Conductor material	Joint required
AAAC	Full-tension crimp joint
SC/AC	Full-tension helical joint
LVABC	Full-tension crimp sleeves

4.5.2.4 Conductor Joints not under Tension

1) Parallel groove (PG) clamps must be used to join bare conductors that are not under tension.
    a) Two PG clamps must be used for all connections to LV neutral conductors
    b) The PG clamp must suit the conductor material. Clamps are available for aluminium to aluminium, aluminium to copper (bi-metal), copper to copper, and SC/GZ to SC/AC.
    c) PG clamps must not be used to join 7/16 SC/GZ conductors
2) Bi-metallic lugs must be used to terminate LVABC droppers on to equipment
3) Insulation piercing clamps must be used to connect (tee off) to LV services and street light services via fuses from LVABC conductors
4) Pre-crimped aluminium splices (stalk lugs) must be used to connect LVABC conductors to bare aluminium conductors with PG clamps
5) Live line clamps must be used to connect transformers on the SWER system to the single phase line conductor. The connection must not be made directly onto the line conductor, but instead via a stirrup made up of two PG clamps joined by a stainless steel conductor

4.5.2.5 Running Earth Attachments

Running earth conductors AAAC and SC/AC must be attached to poles using helical pre formed terminations and:

1) Angle assembly at angle poles
2) LV shackle insulators (clause 4.4 3) at intermediate poles
3) Clevis thimble at termination poles

5 OVERHEAD EQUIPMENT

5.1 Pole-Mounted Distribution Transformers

Pole-mounted transformers are used only when upgrading existing transformers. Smaller rural supplies may be provided from 25 kVA and 10 kVA transformers. Pole mounted transformers capacities are in Table 8.

Table 8 – Pole Mounted Transformers

MV Voltage	MV Phases	Capacity (kVA)
6.6/11 kV	3	25, 63, 100, 200, 315
	2	10 (2 Bushing-250/500V)
22 kV	3	25, 63, 100, 200, 315
	2	10, 25 (2 Bushing-250/500V)
33 kV	3	25, 63, 100, 200, 315
	2	25 (2 Bushing-250/500V)
12.7 kV	1	10, 25
19.1 kV	1	10, 25

5.1.1 Transformer Installation Constraints

Maximum size of transformers on the Microgrids is given in Appendix J.

5.1.2 SWEWR Isolating Transformers

Refer to clause 3.2.2.6.

5.2 Reclosers

5.2.1 Purpose

1) Reclosers must be used to:
   a) Segment MV feeders to minimise customer exposure to faults
   b) Prevent prolonged outages to a critical load (e.g. large town) due to faults downstream of its location.
   c) Prevent temporary (transient) faults (e.g. tree branches short circuiting conductors momentarily) from causing prolonged outages
2) Reclosers must be used to automatically interrupt and close MV feeders during faults according to a predetermined sequence of opening and reclosing operations. The usual sequence is two instantaneous trips followed by two delayed trips.

5.2.2 Application

1) Reclosers must be located to ensure planned fault coverage on overhead MV feeders, and located to meet back-up protection requirements
2) Feeder sectionalisation, load breaking and fault breaking requirements must be considered when locating Reclosers on MV feeders
3) Reclosers on MV feeders must be three phase (ganged) and be rated to match the estimated maximum load with allowance for future load increase
4) Single-phase reclosers must be used to protect distribution transformers instead of HV drop-out fuses where MV feeder reliability can be impacted by transient faults on the LV side
5) Reclosers by themselves must not be used as points of isolation
6) Reclosers must not be used to protect underground MV cables
7) Switching capability of reclosers is provided in Appendix K.
8) Each switching point (where possible) shall be capable of remote operation regardless of the availability of communications, to allow future remote operation when communications are made available
9) The effect of the switched load on the upstream power station or substation must also be considered. The load between two switches must not exceed 1000 kVA in the Pilbara Grid, and the values provided in Appendix J for networks in the Microgrids.

5.3 Load Break Switches

5.3.1 Purpose

Load Break Switches must be used to:

1) Segment MV feeders by planned switching on-load
2) Switching feeders on-load and under fault conditions (when restoring faults)
3) Facilitate remote operation when connected to SCADA

5.3.1.1 Application

Load Break Switches:

1) must be located to segment MV feeders and facilitate switching between feeders or feeder segments to reduce planned and unplanned switching times (refer to clause 3.2.1)
2) must be three phase (ganged) and be rated to match the estimated maximum load with allowance for future load increase
3) must be used in place of pole-top switches where:
   a) remote operation is required and/or
   b) maintenance of PTS is costly and inefficient (i.e. location of PTS is more than 100 km from depot, or within 1 km from coast)
4) may be used as points of isolation, with appropriate work procedures

5) may be used to switch underground MV feeders at points of connection with overhead MV feeders
6) Switching capability of reclosers is provided in Appendix K
7) Each switching point (where possible) shall be capable of remote operation regardless of the availability of communications, to allow future remote operation when communications are made available
8) The effect of the switched load on the upstream power station or substation must also be considered. The load between two switches must not exceed 1000 kVA in the Pilbara Grid, and the values provided in Appendix J for networks in the Microgrids.

5.4 Pole-Top Switches

Pole-top switches shall be used to:

1) Segment MV feeders by planned switching (note they have no capability to switch load)
2) Feeder switching when restoring faults (they cannot switch load current)

5.4.1 Application

Pole-top switches:

1) must be located to segment MV feeders and facilitate switching (refer to clause 3.2.1) on no load (or load not exceeding 10 A)
2) must be three phase (ganged) and be rated to match the estimated maximum load with allowance for future load increase
3) may be used as points of isolation, with appropriate work procedures
4) may be used to switch (on no-load or load less than 10 A) underground MV feeders at points of connection with overhead MV feeders
5) Must be used to switch on no-load or load less than 10 A (including at points of intersection with underground MV cables)

5.5 Drop-Out Fuses

Drop-out fuses shall be used to electrically protect:

1) A single transformer
2) Single-phase feeder spurs with load capacity 1 MVA or less
3) Three-phase MV cables of limited length

5.5.1 Application

Drop-out fuses:

1) must be located on the same pole as the transformer it protects or on the pole before
2) when used to protect single-phase spurs, must be located on the first pole of the spur

3) must not be installed in series with another drop-out fuse
4) may be used as points of isolation, with appropriate work procedures
5) may be used to protect underground MV cables supplying ground mounted transformers at points of connection with overhead MV feeders, provided the cable length does not exceed values in Table 9 must not be exceeded.

Table 9 – Ferro Resonance – Critical Cable Length

Transformer Rating (kVA)	Critical Cable Length (m)	
	35 mm² /22 kV Cable	50 mm² /33 kV Cable
160	8	4
315	38	17
630	143	77
1000	367	191

Fuses for pole-mounted distribution transformer protection are given in Table 10 and for isolation transformer protection, in Table 11.

Table 10 – Pole Mounted Distribution Transformer MV Fuses

Transformer kVA	MV Fuse (A)			
	6.6.kV	11 kV	12.7/22 kV	19.1/33 kV
10	3.15	3.15	3.15	3.15
25	5	3.15	3.15	3.15
63	10	5	3.15	3.15
100	16	10	5	5
200	31.5	25	10	8
315	40	25	16	10

Table 11 – Pole Mounted Isolation Transformer MV Fuses

Transformer kVA	MV Fuse (A)			
	Source Side Voltage (kV)	**Load Side Voltage (kV)**	**Source Side Fuse (A)**	**Load Side Fuse (A)**
63	33	19.1	5	5
63	22	12.7	5	10
200	33	19.1	16	16
200	33	12.7	16	25
200	22	12.7	16	25

5.6 MV Disconnectors

MV Disconnectors must be used to isolate reclosers that are to be used as isolation points. They must not be used as switching devices and must not be operated only under load.

5.7 Lightning Arresters

Lightning arresters must be installed to protect equipment from lightning damage.

In the Kimberley, where the frequency of lightning is very high, line arresters should not be installed. This is because they fail to a short-circuit, and there is no visible indication of failure. Line arresters may be used in other areas, -however it should be remembered that they provide protection only for the insulators on the same pole as the arrester.

5.7.1 Application

Lightning Arresters must be installed on:

1) Transformers (MV side), reclosers, load break switches, capacitors and reactors installed on poles
2) MV cable terminations on poles

5.8 Voltage Regulators

Voltage Regulators must be considered for controlling voltage on MV lines automatically depending on load.

5.9 Capacitors

Capacitors must be considered for increasing voltage on MV lines particularly when there are large loads at the end of lines that consume reactive power.

5.10 Reactors

Reactors must be considered for decreasing voltage on MV lines automatically particularly on very long lightly loaded lines.

5.11 Fault Indicators

Fault indicators must be installed at locations that facilitate the speedy restoration of normal network conditions following a fault. It enables fault crews to identify a faulty feeder segment beyond a fault indicator.

5.11.1 Application

Fault indicators are generally applied at the following locations:

1) At the beginning of spur lines not having a recloser or sectionaliser
2) On MV feeders at key switch positions
3) On the incoming cable of a ring main unit

5.12 Earthing

The following equipment must be earthed in accordance with Appendix C:

1) Pole
2) Transformer
3) Recloser
4) Load-break switch
5) Pole-top switch
6) MV Cable termination
7) Lightning Arrester
8) Voltage Regulator
9) Capacitor
10) Reactor

5.13 Overhead LV Disconnectors

Overhead LV Disconnectors must be used as open points for interconnecting overhead LV mains from different transformers.

5.14 LV Mains Protection

5.14.1 Overhead Lines

1) Bare and LVABC overhead lines must be protected with fuses at the transformer as per Table 12.
2) Existing unfused bare overhead lines must be fused when lines are extended or when augmentation work is done
3) With 315 kVA transformers, LV Mains must be segregated to two separate mains, with load attached to each mains not exceeding 250 A. Each main must be separately fused.

Table 12 - Pole Mounted Transformer LV Fuses

Transformer kVA	LV Fuse (A)	Type of Fuse
10	30	Flowline HRC
25	100	Flowline HRC
63	100	Flowline HRC
100	200	Krone HRC
200	315	Krone HRC
315	315 (see clause 3)	Krone HRC

5.15 Service Mains Fuses

1) Service mains tapped off the overhead LV network are protected by Flowline HRC fuses (rated 10 A, 60 A and 100 A) or Krone HRC fuses (rated 200 A and 315 A) depending on the supply capacity. Fuse rating must be equal or lower than cable rating
2) Single phase and three phase circuit breakers mounted in a box are also used to protect service mains.

5.16 Street Lights

LED luminaires must be used for new street lights. Horizon Power has four standard sizes, shown below in Table 13.

Compared with gas discharge lamps, LED lamps are more energy efficient. They have a more even dispersion pattern, but have a sharp drop-off (i.e. less spill). Table 13 below provides approximate equivalent LED luminaires, compared to gas discharge luminaires.

Table 13 – LED Luminaires

Gas Discharge Luminaire (type and power)	Equivalent LED Luminaire power
Compact fluorescent 42 W	Size L2: 25 to 35 W
Metal halide 70 W	
Mercury vapour 80 W	
Mercury vapour 125 W	Size L3: 55 to 65 W
High-pressure sodium 150 W	Size L4: 100 to 130 W
High-pressure sodium 250 W	Size L6: 170 to 220 W

5.16.1 Street Light Fuses

Street light luminaires supported on power poles and supplied by the LV overhead network must be protected by a HRC fuses rated at 10 A.

Street lights supplied from a pillar via 16 mm^2 cable must be protected at the pillar by Red Dot fuses rated at 20 A.

The cables supplying the luminaire from the connection box within the street light standard must be protected by HRC fuses rated at 10 A.

6 UNDERGROUND SYSTEM CORE COMPONENTS

6.1 Standard Cables

The standard cable used for MV circuits within Horizon Power's network is single core laid a trefoil formation.

For LV cables circuit a 3 core neutral screened is used, except for 630 mm², where single core cables are laid in trefoil.

6.1.1 6.6 kV, 11 kV and 22 kV networks

The following cable components will be used for 22 kV networks. For 22 kV feeder cables, 185 mm² and 400 mm² aluminium, XLPE insulated, Copper screen, PVC/HDPE sheath. For 22 kV transformer cables, 35 mm² aluminium, XLPE insulated , Copper screen, PVC/HDPE sheath.

6.1.2 33 kV networks

The following cable components will be used for 33 kV networks. For feeder cables, 185 mm² aluminium, XLPE insulated, Copper screen, PVC/HDPE sheath. For transformer cables, 50 mm² aluminium, XLPE insulated, Copper screen, PVC/HDPE sheath.

6.1.3 Low Voltage Mains Cables

Low voltage main cables must be either three-core 240 mm² aluminium conductor with copper neutral screen, or single-core 630 mm² aluminium. All shall be XLPE insulated, with PVC or HDPE sheath.

6.1.4 Service cables, minor branch and road crossing cables

Service and minor branch cables must be 25 mm² copper cable, neutral screened, XLPE insulated.

Service and minor branch cables must be installed in ducts.

Road crossing service cables must be installed in ducts.

6.1.5 Street light cable

Street light cables must be 16 mm² copper cable, neutral screened, XLPE insulated.

6.2 Cable Applications

6.2.1 MV Cable networks

Feeder cables from a zone substation (Pilbara Grid) or power generating station (Microgrids) must be as per clauses 6.1.1 and 6.1.2 depending on the voltage level. Feeder lengths will be limited by voltage drop exceeding the permitted limits.

The following rules apply to MV cable networks.

1) Where current capacity limits are exceeded or voltage limits cannot be achieved and feeder load management is required, this must be done via a RMU

2) Where required, interconnection of feeders must be done via RMUs. This enable the transfer loads in case of emergency
3) Connections to MV loads must be via RMU's
    a) with fuse switch for loads ≤ 1 MVA and
    b) with MV circuit breaker for loads > 1 MVA (customer owned substations)
4) MV cables located on a customer's property must have additional mechanical protection (as per the Western Australia Distribution Connections Manual) and kept as short as possible, with MV equipment located at the property boundary.

District and Sole Use substations installed within customer's property must be within 30 meters of the property boundary.

6.2.2 LV Cable Networks

The following rules apply to LV cable networks.

1) LV mains cable from a distribution substation shall be 240 mm² or 630 mm² aluminium, XLPE insulated cable
2) Extension of LV mains when required, must be via a universal pillar and not by making joints
3) Where interconnection between mains cables from different transformers (open points) is required, this must be via a universal pillar
4) 630 mm² aluminium, XLPE insulated cables must be used to connect transformer LV terminals to LV Distribution Frames in non-MPS substations.

- One per phase for 160 kVA
- Two per phase for 315 kVA and 630 kVA,
- Three per phase for 1000 kVA

5) Neutrals must be at least 50% of the size of phase conductors in clause 4) for district substations or as specified by the customer for sole use substations
6) LV mains cables must be protected by fuses at LV Distribution Frame (refer to clause 7.3.5)

6.2.3 LV cables to supply customer loads

The following rules apply to LV cable supplying customer loads.

1) Customer loads supplied by teeing off LV mains cable must be via a universal pillar
2) Customer connections for loads up to 100 A with 25 mm² copper cable, neutral screened, XLPE insulated via mini pillar. In some cases, via Universal Pillars.

6.3 Cable Joints and Terminations

All cable joints must be installed in accordance with details outlined in the Underground Cable Installations Manual (HPC-5DJ-03-0001-2012), and the manufacturer's instructions supplied with joint kits. Where not published in specific detail clarification will be sought from the supplier.

6.3.1 Medium Voltage Cable Joints and Terminations

All MV joints, including transition types, shall use heat shrink materials, except where otherwise approved.

6.3.1.1 Straight through joints

Straight through joints are joints used for joining cable of the same insulation type. Straight through cable joints and bolted cable connectors must be used to join XLPE cables. They can be used to extend cable length with the same size or smaller size cable.

1) Single core 22 kV cable joints are available in the following sizes for jointing XLPE cables.
   a) 25 mm² to 95 mm²
   b) 95 mm² to 240 mm²
   c) 240 mm² to 400 mm²
2) Single core 33 kV cable joints are available in the following sizes for jointing XLPE cables.
   a) 35 mm² to 95 mm²
   b) 150 mm² to 300 mm²

6.3.1.2 Transition joints

Transition joints are joints use for joining cables of different insulation. Transition cable joints and bolted cable connectors must be used to join XLPE to PILSWA cables. They can be used to extend existing PILSWA cables with XLPE cables of similar current carrying capacity.

Joints are available in the following sizes for use at 22 kV to join 3 x 1 XLPE cables to 3-core PILSWA cables.

- 50 mm² PILSWA to 35 mm² XLPE
- 185/240 mm² PILSWA to 185/400 mm² XLPE

6.3.2 Medium Voltage Cable Terminations

1) Medium voltage terminations suitable to terminate 35 mm², 50 mm², 185 mm² and 400 mm² cables must be used to terminate medium voltage cables on pole tops and on ground mounted transformers supplied from Drop Out Fuses.
2) Separable insulated connectors (non-load-break type and rated at 200 A) must be used to terminate cables on MPS and non-MPS substation transformers and on ring-main switchgear.
3) Dead end plugs must be used to protect separable connectors when they are not connected to transformer bushings. Dead end receptacles must be used to protect transformer bushings when separable connectors are not connected.

6.3.3 Low Voltage Cable Joints and Terminations

6.3.3.1 Straight through, breech and tee joints

The following types of joints must be used to connect low voltage mains and service cables.

1) Straight joints:

- 10 mm² to 16 mm²
- 25 mm² to 25 mm²
- 185 mm² to 185 mm²
- 185 mm² to 240 mm²
- 240 mm² to 240 mm²

2) Breeches joints:

- 120 mm² to 240 mm²

3) Tee joints:

- 16 mm² to 16 mm²
- 25 mm² to 25 mm²
- 120 mm or 185 mm² to 2 x 25 mm²
- 240 mm² to 2 x 25 mm²

6.3.4 Low Voltage Cable Terminations

LV cable terminations must be used to terminate low voltage cables on to the following equipment:

1) Mini pillars (terminate service cables and street light cables)
2) Uni-pillars (terminate mains cables and large customer service cables)
3) LV distribution frames (terminate mains cables and sole use customer cables)
4) LV bare overhead mains (terminate 185 mm² and 240 mm² cables via Krone switch fuse and pre-crimped Aluminium splices)
5) LV bare or LVABC overhead mains (terminate service cables and street light cables)
6) Like for like terminations must be used for aluminium to aluminium, aluminium to copper (bi-metal) and copper to copper

7 UNDERGROUND EQUIPMENT

7.1 MV Equipment

7.1.1 Ring Main Units (RMU)

22 kV and 33 kV RMU's must be used for switching of the underground medium voltage network. RMU combinations suitable for use are:

1) Two switches plus one fuse switch (2+1)
2) Three switches plus two fuse switches (3+2)
3) Three switches plus one fuse switches (3+1)
4) Three switches plus zero fuse switches (3+0)
5) Four switches plus zero fuse switches (4+0)
6) One switch plus zero fuse switches (1+0) extensible switch disconnector
7) Zero switch plus one fuse switch (0+1) extensible fuse switch

Extensible switch disconnectors (6) and extensible fuse switches (7) shall be used when disconnectors / fuse ways are required to be added for switching.

7.1.1.1 Outdoor Applications

For outdoor applications, RMUs must be incorporated into either 3, 4 or 5 way kiosks. Kiosks are a freestanding aluminium body mounted on a steel frame. The steel frame is buried in the ground to provide a firm foundation and allows easy access to the cables and terminations below the switchgear.

7.1.1.2 Indoor Applications

Indoor compounds comprising brick enclosures with roof must be used to house RMUs and transformers. They are used to cater for larger loads (> 630 kVA). Extensible and non-extensible RMUs must also be installed within buildings owned by customers, if required by customers, but accessible to Horizon Power at all times.

7.1.2 Earth Switches

Earth switches must be used at all RMU cable termination points.

7.1.3 MV Circuit Breakers

MV circuit breakers must be used:

1) for connecting (switching) MV feeders from Zone Substations (Pilbara Grid) or Power Generating Stations (Microgrids) to the network
2) to protect customer owned substations containing transformers greater than 1000 kVA

7.1.4 MV Fuses

Transformers must be protected on the MV side with fuses.

A fused switch must be used to connect a RMU to a transformer less than 1000 kVA.

Full range fuses for ground mounted transformer protection are given in Table 14.

Table 14 – Ground Mounted Transformer MV Fuses

Transformer kVA	MV Fuse (A)			
	6.6.kV	11 kV	22 kV	33 kV
160	31.5	25	10	6.3
315	50	31.5	16	16
630	100	50	31.5	20
1000	160	80	40	40

7.1.5 Switching Capability of MV Ground Mounted type Switching Devices

The switching capability of ground mounted type MV switching devices is available in Appendix K.

Each switching point (where possible) shall be capable of remote operation regardless of the availability of communications, to allow future remote operation when communications are made available.

7.1.6 MV Switchboards

1) Dual fire-segregated switchboards are required for loads in excess of 4 MVA
2) In customer owned substations where Horizon Power has a bus section switch between two switchboards, operated with the bus section open (i.e. two feeders/feeder legs operating radially), mechanical interlocking or Horizon Power operational locking is required. This is to prevent closed ring operation via the customer's switchboards while Horizon Power's bus section switch is open
3) Where a customer is supplied from a dedicated feeder/s, consideration shall be given to Horizon Power's requirement to carry out periodic maintenance of the circuit breaker and busbar at the zone substation, to provide alternative supply to the customer

7.2 Ground Mounted Transformers

Ground mounted transformers suitable for use in distribution substations are:

1) MPS – 63 kVA, 160 kVA, 315 kVA and 630 kVA
2) Non MPS District – 160 kVA, 315 kVA, 630 kVA and 1000 kVA
3) Non MPS Sole use – 160 kVA, 315 kVA, 630 kVA and 1000 kVA

7.2.1 Transformer Installation Constraints

The following rules apply to transformer installations

1) Maximum size of transformers that must be installed on the Microgrids are given in Appendix J.
2) Where transformers are housed within buildings, a maximum of two transformers can be housed in a single two hour fire rated enclosure. Transformer pairs must be separated by a two hour fire rated wall.
3) Piggy backing of transformers is prohibited.

7.3 Low Voltage Switchgear

7.3.1 LV Distribution Frames (LVDF)

LV distribution frames are connected via cable to the LV bushings of transformers. The incoming connection of the LVDF busbar is controlled via an underground LV disconnector. The busbars supply a number of feeder ways and are rated up to 2000 A depending on the size of the transformer used. The feeder ways are fitted with LV fused disconnectors.

Kiosk type LVDFs are available in three different configurations suitable for outdoor or indoor installation and can accommodate up to five fuse ways and two disconnectors.

7.3.2 Underground LV Disconnectors

Underground LV disconnectors rated at 1600 A must be used to isolate at the LV distribution frame in non-MPS district substations for:

- The cable between transformer and LV distribution frame, and
- The cable to the customer's main switchboard and LV distribution frame. This must be contiguous with Horizon Power's substation.

7.3.3 LV Pillars

LV pillars are used as a point of connection between:

1) distribution mains cables and
2) other distribution mains cables and consumer mains cables.

There are two types of pillars:

- universal pillars and
- mini pillars.

The universal pillar is a ground mounted structure with a detachable lid. The pillar will accommodate up to three cables. Three mains cables for interconnections or two mains cables and one consumer mains cable (300 mm^2 or 2 x 185 mm^2). It provides options for a fused network connection point via a set of fuses, or can be configured to supply a single customer with a load >100 A. The universal pillar can also accommodate a double link arrangement.

The mini pillar is a smaller ground mounted structure with a detachable lid. This pillar is designed to provide a connection point between the service cable and the consumer mains cable. The mini pillar is used to supply customer's loads of <100 A and has two terminals for incoming cables (on the street side) and three terminals for outgoing cables (on the property side). One service mains cable

(25 mm²) and if required, a road crossing cable (25 mm²) is on the incoming side, with two consumer mains cables (25 mm²) and if required, one street light cable (16 mm²) on the outgoing side.

Refer to Appendix C for earthing requirements for LV pillars.

7.3.4 LV Fuse Switches

Underground cables must be protected by:

1) LV fuses when current in cable is 400 A or less (refer to Table 15)
2) LV circuit breakers when current in cable exceeds 400 A. (refer to clause 7.3.5)

LV fused switches must be used on LV distribution frames to switch and protect outgoing LV mains cables from LV distribution frame. They must be suitable for three phase switching (ganged).

Table 15 – LV Fuse Ratings and Maximum Demand on LV Feeder

Transformer (kVA)	LV Fuse (A)	Max demand on feeder (A)
160	200	200
315	315	315
630	400	400
1000	400	400

7.3.5 LV Circuit Breaker Board (LVCBB)

In district and sole use substations the customer's switchboard (and customer circuit breaker) must be contiguous with the Horizon Power's substation, so that the unprotected cable length is short. When the customer's main switch board cannot be contiguous with the substation and the customer's load exceeds 400 A, switching of incoming cables from transformer to consumer service mains cables must be via a LVCBB.

Withdrawable LV air circuit breakers rated for use at 1200 A or 1600 A, must be fixed onto a LVCBB.

7.4 Consumer Mains Fuses

Consumer mains supplied via Uni Pillars or LV Wall Mounted Boxes must be protected by HRC fuses (rated 63 A, 200 A and 315 A) depending on the cable used.

7.5 Street light Fuses

Refer to Section 5.16.1.

8 MV METERING UNITS

When connecting to customer owned substations, metering units are available for use at 11 kV, 22 kV and 33 kV for underground supplies and at 22 kV and 33 kV for overhead supplies.

MV metering units must be installed between two MV switches, one on the customer's side and the other Horizon Power's side. The customer's side MV switch must only be operated by Horizon Power. This principle also applies in any common busbar arrangement when connecting to customer owned substations.

MV metering units must be installed contiguous to a RMU when installed on the ground as standalone units.

APPENDIX A REVISION INFORMATION (INFORMATIVE)

Horizon Power has endeavoured to provide standards of the highest quality and would appreciate notification of errors or queries.

Each Standard makes use of its own comment sheet which is maintained throughout the life of the standard, which lists all comments made by stakeholders regarding the standard.

A comment sheet found in CS10# 3754221, can be used to record any errors or queries found in or pertaining to this standard. This comment sheet will be referred to each time the standard is updated.

Date	Rev No.	Notes
24/04/2017	0	Intial Document Creation

APPENDIX B GLOSSARY

AAC	All Aluminium Conductor
AAAC	All Aluminium Alloy Conductor
CBL	Calculated Breaking Load (of an overhead conductor)
Conductive	Shall include metallic and any reinforced or prestressed concrete parts of an installation.
Consumer mains	Those conductors between the Point of Supply and the Customer ‘s main switchboard
Contiguous	Applicable to Customer’s main switchboard location with respect to a Substation. Contiguous means adjoining or very close to the Substation enclosure to ensure that cable/s connecting the substation equipment to the main switchboard has zero probability of being damaged with consequent risk to safety and reliability. In the case of Sole Use Substations, contiguous means also visible means of isolation
Customer (consumer)	Person or entity to which electricity is sold for the purpose of consumption
Customer Owned Substation	A substation where the Customer is on a Medium Voltage tariff and owns and is responsible for all electrical equipment other than Horizon Power’s metering equipment and any medium voltage switches connecting the substation to the Horizon Power network. For loads greater than 4 MVA, Horizon Power’s and customer MV switchgear are installed in an enclosed room provided by the customer. For loads less than or equal to 4 MVA, Horizon Power’s and customer MV switchgear can be installed outdoors
Distribution Feeder	A medium voltage radial circuit forming part of the distribution system that is supplied from a zone substation
Distribution System	Any apparatus, equipment, plant or buildings used, or to be used for, or in connection with, the transportation of electricity at a nominal voltage of less than 35 kV

District Substation	A substation that has LV connections to the street mains. Horizon Power owns and is responsible for all electrical equipment within the substation. Modular Packaged Substations (MPS) complete with single transformer and LV switchgear, housed in a self- contained metal enclosure for maximum load of 630 kVA. For larger loads Non MPS arrangement comprising one or more transformers plus LV switchgear and MV switchgear as required
Fire Rated	A minimum fire rating Level of 120/120/120
Fire Resistant Surface	A surface having a fire rating Level of 120/120/120
High Voltage	Steady state voltages greater than 35 kV
Low Voltage (LV)	Low Voltage is defined as steady state voltages less than 1 kV
LVABC	Low Voltage Aerial Bundled Conductor
Low Voltage Mains	Low voltage conductors emanating from a distribution substation
Low Voltage Services (also called Service Mains)	Low voltage conductors that connect Low Voltage Mains to a Point of Supply
Main Switchboard	A switchboard from which the supply to the whole electrical installation can be controlled (refer to clause 1.4.92 of AS3000)
Medium Voltage (MV)	Steady state voltages equal to or greater than 1 kV and less than or equal to 35 kV
MEN	Multiple Earthed Neutral Installation
Modular Packaged Substation (MPS)	A District or Sole Use substation where the transformer and/or medium voltage switchgear and/or low voltage switchgear is housed in a self-contained metal enclosure/s connected as a single package

Microgrids	The isolated networks in East Kimberley (Kalumburu, Wyndham, Kununurra, Lake Argyle, Warmun and Halls Creek), West Kimberley (Derby, Camballin/ Looma, Fitzroy Crossing, Yungngora, Bidyadanga, Broome, Beagle Bay, Djarindjin/Lombadina and Ardyaloon), East Pilbara (Marble Bar and Nullagine), West Pilbara (Onslow) Gascoyne/Midwest (Exmouth, Coral bay, Carnarvon, Denham, Gascoyne Junction, Meekatharra, Cue, Mt Magnet, Yalgoo, Wiluna and Sandstone) and Esperance (Esperance, Norseman, Hopetoun, Laverton, Leonora and Menzies)
Pilbara Grid	The interconnected network located in the Pilbara region.
PILSWA	Paper Insulated Lead Sheath Wire Armoured
Point of Supply	The junction of the Consumer Mains with conductors of an electrical Distribution System
Policy	A brief, straightforward statement indicating intention and direction, and enabling the decision-making process
Preplanning	Means thinking, preparing and deciding about how to get something done before starting on it
Procedure	Prescribed means of accomplishing policy through a series of steps or processes
Regions	Horizon Power's Regional Business Units in Broome, Karratha, Carnarvon and Esperance
Safety in Design	is a process defined as the integration of hazard identification and risk assessment methods early in the design process to eliminate or minimise the risks of injury throughout the life of a structure or system being designed
SC/AC	Aluminium-clad steel conductor
SC/GZ	Steel (galvanised) conductor
Site	All parts of the works that are the subject of the offer and acceptance between Horizon Power and the Customer for the provision of electrical services
Sole Use Substation	A substation established for a single customer and which has no LV interconnection with the street mains. Horizon Power owns and is responsible for all electrical equipment within the substation. Non MPS arrangement comprising one or more transformers plus LV switchgear and MV switchgear as required

Structural Engineer	A qualified person who is engaged by the Customer to design and prepare structural documentation for the substation enclosure to resist loads and forces as outlined in AS 1170 where relevant
Substation (Distribution Substation)	A collection of switchgear and/or a transformer/s on a single site (which may or may not be screened or enclosed) connected to the Distribution System.
SWEWR	Single Wire (with) Earth Wire Return. A single-phase overhead supply. Similar to the 'SWER' (single-wire earth return) used in other utilities, except an under-slung earth wire is used.
Terminal Substation	A bulk transmission point connecting transmission lines at the same voltage level (220 kV) and also step down and distribute power to Zone Substations e.g., Karratha Terminal and Hedland Terminal
Transmission System	Any apparatus, equipment, plant or buildings used, or to be used, for, or in connection with, the transportation of electricity at nominal voltages of 66 kV or higher, and which forms part of the Pilbara Grid
WADCM	Western Australian Distribution Connections Manual
WAER	Western Australian Electrical Requirements
Zone Substation	A substation that transforms electricity from a transmission system voltage to a distribution system voltage. E.g., Murdoch Drive and Pegs Creek

APPENDIX C EARTHING REQUIREMENTS

C.1 Earthing Design Objectives

The design of an earthing system must ensure that:

1) All conductive parts consisting of metalwork and equipment within the reach of a person standing on the ground are effectively earthed. This is to ensure hazardous touch, step and transfer voltages that can occur during fault conditions are mitigated to satisfactory risk levels;
2) A low impedance earth is available to effectively carry power frequency earth fault currents to earth. This facilitates the operation of protective equipment, to isolate faults and also to carry transient currents caused by lightning and switching surges;
3) Future increase in network earth fault levels are considered. It is suggested the fault current at the time of design is increased by 20%, capped at the primary plant ratings stated in the *Technical Rules HPC-9DJ-01-0001-2012*; and
4) Testing and future modifications, particularly those below ground, can be carried out with minimal interruption to installation operation.

Earth conductors, electrodes and connections (joints) must be designed and constructed to ensure that:

5) Fault currents are carried to earth without damage to these components;
6) Possibility of inadvertent mechanical damage and interference is minimised; and
7) Corrosion is minimised.

C.2 Essential Requirements

In order to achieve the objectives in clause C.1, a suitable earth resistance value must be attained to ensure that the probability of fatality from hazardous touch, step and transfer voltages is as low as reasonably practical (ALARP). For boundary calculations a risk level of 1×10^{-6} must be used in the design process.

The risk must be assessed in accordance with Horizon Power's Distribution Line Earthing Standard: HPC-9DC-08-0001-2012 and Distribution Power Lines in the Vicinity of Conductive Installations Standard: HPC-9DC-15-0001-2012 and must be acceptable to Horizon Power.

C.3 Combined Earthing System

For distribution substations, a combined earthing system must be used, where the MV and LV earthing systems are interconnected at 'an earth terminal bar' (DSM-6-11 and DSM-6-12) or a 'grading ring'. Details of earthing connections are provided in DSM-6. The combined earthing system must have a resistance sufficiently low (generally ≤ 1 Ohm may be sufficient but the risk level must be estimated) to ensure that the design objectives of Clause C.1 are fulfilled. In certain cases, an earth resistance > 1 Ohm may provide an acceptably low risk level at low cost.

C.3.1 Ground Mounted Equipment

A grading ring must be installed around ground mounted equipment installations to mitigate hazardous touch voltages. The grading ring is installed around equipment that is earthed and subject to hazardous voltage rise during fault conditions. It is installed around the equipment at a distance of 750 mm (with doors open) and buried at a depth of 500 mm. The grading ring is connected to two earth electrodes which are installed diagonally at opposite ends, which makes up the earthing system.

Two electrodes must be used to ensure that there is adequate redundancy in the event that one electrode is disconnected from the grading ring for some reason including testing. A maximum resistance of 10 Ohms per electrode is permitted to allow upstream protection to operate correctly. The grading ring is to provide an equipotential area for a person touching the equipment only, and protects only against the touch voltage hazard of touching that particular piece of equipment.

C.3.1 Difficulty in getting the required Combined Earth Resistance

The number of customer installation electrodes associated with the LV MEN system connected to the substation will influence the combined resistance value. Where there are an insufficient number of customers connected, it may be difficult to obtain a combined resistance value low enough to attain a low risk level.

Low resistance earths can be installed at pillars located away from the substation, where the soil resistivity may be conducive to obtaining a low resistance earth, and may also be beyond the zone of influence of the substation earth. These may be ‘deep earths’ (typically 30 m) which extend to a depth where there is a lower resistivity layer.

C.4 Separate MV and LV Earthing Systems

Where a combined earthing configuration does not provide for safe touch, step and transfer voltages, segregation of MV and LV earthing systems must be considered, but this is not the preferred option. The separation required can be determined as per *Distribution Power Lines in the Vicinity of Conductive Installations Standard: HPC-9DC-15-0001-2012*.

By separating the MV and LV electrodes, the transfer of EPR from the MV system to the LV system can be controlled. However, the integrity of the separated MV and LV earthing systems must be maintained during the life of the installation. Therefore, they must be captured in Horizon Power’s Geospatial Information system (GIS). This will minimise the possibility of other earthed structures being installed within the physical separation distance.

C.4.1 Issues with Separated MV and LV Earthing Systems

Separated MV and LV earthing systems may not be effective in controlling hazardous step and touch voltages in the event of a MV line to LV line contact at the distribution transformer, or on a conjoint MV/LV line section. The following options may be considered for protecting against MV to LV contacts:

- Ensuring the configuration of LV lines at the distribution transformer poles is such that MV to LV contact is unlikely; and

- Replacing bare LV conductors over conjoint MV/LV spans with LV buried cable and LVABC cable.

When the LV earthing system is segregated from the MV earthing system at a distribution substation, the total earth impedance of the LV earthing system (including associated MEN earths) must be sufficiently low to ensure that the MV feeder protection will operate in the event of a MV winding to LV winding fault.

LV insulation breakdown which can cause the transformer tank to be live will not be cleared by protection and persist until it becomes a hazard. To mitigate this hazard, a low voltage gapless surge arrester must be fitted between the low voltage neutral and transformer tank.

C.5 Size of Earthing Conductors

The size of earth conductors must be as per AS 2067-2008.

C.6 Conductive Structures in the Vicinity of Substations

An earthing design must take into consideration the close proximity of continuous metallic objects that can give rise to transferred voltages. Transferred voltage is the voltage rise of an earthing system during a fault, transferred by means of a connected conductor (for example, a metallic cable sheath, metallic pipelines, metallic fences or rail) into areas with low or no voltage rise relative to earth. This results in voltage difference occurring between the connected conductor and its surroundings.

When the voltage rise on the earthing system is transferred by metallic pipes (water or gas), or a fence earthed at regular intervals along its length, such conductive parts will rise to a voltage somewhere between the maximum and minimum voltage rise affecting it. When such metallic structures are insulated from the ground, the maximum voltage transferred to the structure will be maintained along the structure.

Such conductive structures must be separated from the substation earth grading ring by at least two metres. Metal bollards installed outside substations must be located at least two metres away from the earth grading ring. If located within two metres, the bollard must be bonded to the grading ring and included within the grading ring.

Telecommunications plant, gas pipelines and metallic fences can be subject to transfer voltages from substation installations. Refer to the *Standard – Power Lines and Cables in the Vicinity of Conductive Installations: HPC-9DC-07-0001-2012*, which provides guidance on calculating the EPR and LFI (Low Frequency Induction) on such conductive structures.

APPENDIX D DISTRIBUTION SYSTEM OVERVIEW

D.1 System Configuration

Steps in supplying energy to customers are explained in the clauses below.

D.1.1 Power Generating Stations

Horizon Power manages 38 systems: the Pilbara Grid in the Pilbara and the connected network between Kununurra, Wyndham and Lake Argyle in the Kimberley, and 34 stand-alone systems in regional towns and remote communities.

D.1.2 Transmission System

Horizon Power has two transmission systems, the one in Pilbara Grid, and the other between Kununurra, Wyndham and Lake Argyle in the Kimberley. The Pilbara Grid consists approximately 464 km of overhead transmission lines and 10 substations transporting energy from Power Generating Stations to major load centres via transmission line networks that operate at voltages of 66 kV, 132 kV and 220 kV. At major load centres supply may be given directly to a major customer at transmission voltage (e.g. 66 kV) or transformed at zone substations to medium voltages for distribution purposes.

D.1.3 Distribution System

Energy is taken from zone substations (in the Pilbara Grid) or directly from Power Generating Stations (in the Microgrids) at a voltage of 33 kV, 22 kV or 11 kV and supplied to customers by a combination of medium voltage feeders, distribution substations and low voltage mains. Major customers may elect to take supply at medium voltage.

Figure 5 shows the Functional Components of a distribution system and their position and role in the overall system.

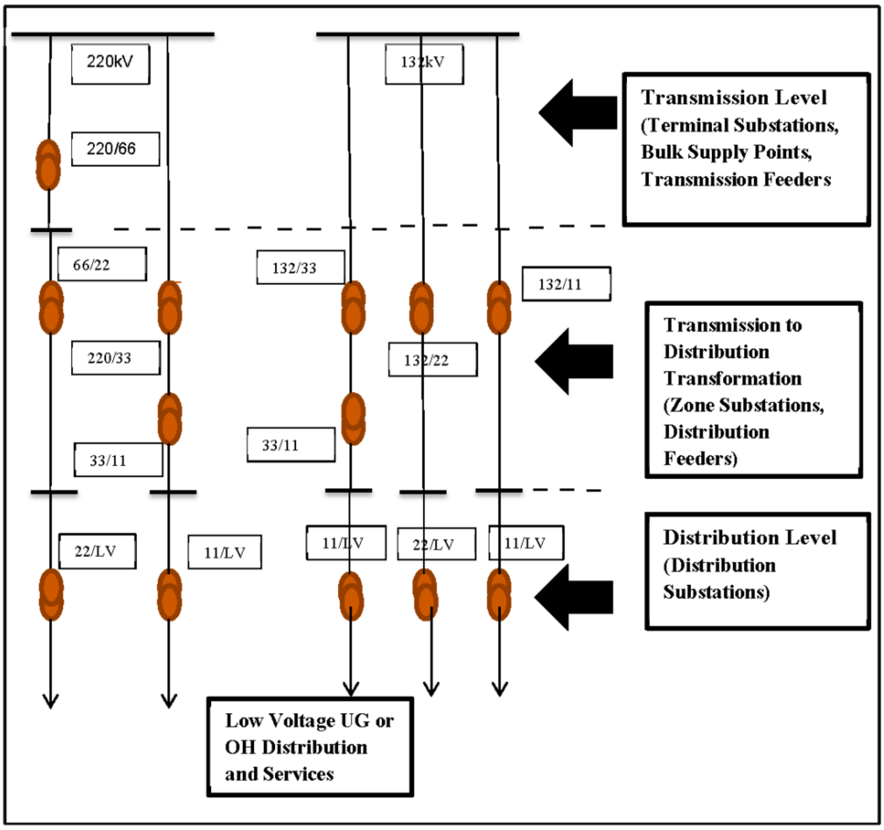


Figure 5 – Functional Components of a Distribution System

D.2 System Components

D.2.1 Terminal Substations

Terminal substations are interconnection points for the high voltage networks. Karratha Terminal (132 kV) and Hedland Terminal (220 kV) are examples of two terminal substations in the Pilbara Grid.

D.2.2 Zone Substations

Zone substations receive electrical energy at high voltage and transform to medium voltage for distribution via medium voltage feeders.

D.2.3 Distribution Feeders

The distribution feeder is a significant component of the distribution network. In the Pilbara Grid, it is the link between a zone substation and the customer. In the Microgrids, it is the link between the power generating station and the customer. A customer may be supplied directly from a distribution feeder, or via a distribution substation and the LV network. There are two types of distribution feeder:

- Overhead line
- Underground cable

D.2.4 Distribution Substations

Distribution substations transform medium voltage to low voltage (415/240 V). There are a number of different types of substations in the distribution network.

1) Pole mounted substations (limited to 315 kVA capacity)
2) Ground mounted substations

Ground mounted substations are of three different types:

3) District Substations (with LV street feeds)
4) Sole use Substations (with no LV street feeds)
5) Customer owned substations (customer is supplied at medium voltage)

D.2.5 Low Voltage Mains

Low voltage mains distribute power at low voltage.

D.2.6 Low Voltage Services

All new low voltage service connections and upgrades to existing overhead service mains are underground, even if the service mains are to be connected to overhead low voltage mains.

APPENDIX E DADMD FOR TOWNS AND DIVERSITY FACTORS

Table 16 – List of Towns with DADMD Values

Town	**Residential DADMD (kVA)**	**Town**	**Residential DADMD (kVA)**
East Kimberley			
Halls Creek	6	Lake Argyle	6
Kalumburu	6	Warmun	4
Kununurra	6	Wyndham	6
West Kimberley			
Ardyaloon	4	Derby	6
Beagle Bay	4	Djarindjin/Lombadina	4
Bidyadanga	4	Fitzroy Crossing	6
Broome	6	Yungngora	4
Camballin/Looma	4		
East Pilbara			
Marble Bar Nullagine	4 4	Port Hedland (Note 1) South Hedland (Note 1)	10 10
West Pilbara			
Karratha – Single lot	10	Onslow	10
- Duplex	7.5	Point Samson	10
- Triplex	5.5	Roebourne	6
- Quadr'ex	3.5		
Gascoyne/Midwest			
Carnarvon	6	Leonora	6

Town	Residential DADMD (kVA)	Town	Residential DADMD (kVA)
Coral bay	6	Meekatharra	6
Cue	6	Menzies	6
Denham	4	Mt Magnet	6
Exmouth	6	Sandstone	4
Gascoyne Junction	4	Wiluna	4
Laverton	6	Yalgoo	4
Esperance			
Esperance	3	Norseman	3
Hopetoun	3		

Note 1: Where multiple occupancy lots are developed in towns with DADMD of 10 kVA, the corresponding DADMD values shown for Karratha apply.

The design DADMD values are based on measured DADMD values with an allowance for potential growth over the life of the cable asset. This allowance reflects the range of climatic zones, socio-economic and expansion potential factors applicable in each town.

The DADMD values (Table 16) and Diversity Factors (Table 17) are applied as follows:

1) A diversity factor is applied where there are less than 60 customers connected to a transformer. In such case the transformer load is estimated as equal to: <DADMD Value> x <diversity factor> x <number of customers>.
2) When there are 60 customers or more connected to a transformer, the load is estimated as equal to: <DADMD Value> x <number of customers>.
3) For low voltage mains emanating from a transformer, the total load on any mains cable is estimated as per clauses 1) and 2) above, taking the number of customers connected to the low voltage mains, the relevant DADMD value and the diversity factor.

Table 17 – Diversity Factors

No of customers	Diversity factor
1	3.0
2	2.57
3	2.2
4	2.0
5	1.89
6	1.8
7	1.74
8	1.71
9	1.69

No of customers	Diversity factor
10	1.64
11	1.61
12 -14	1.57
15-17	1.50
18-20	1.46
21-23	1.42
24-26	1.4
27-29	1.38
30-59	1.37
≥60	1.0

APPENDIX F OVERHEAD LINE DESIGN PRINCIPLES

F.1 Design Principles

The main technical aspects in the design of overhead lines must ensure that:

1) mechanical load forces do not exceed the strength of structures or other components, and
2) clearances are adequate – between the conductors and the ground or from other objects in the vicinity of the line, as well as between the conductors and circuits themselves so that conductor clashing does not occur.

The line must comply with these requirements over the full design range of weather and other load conditions that could reasonably be encountered – when the line is cold and taut, when at its maximum design temperature and consequently when conductor sag is at a maximum, and under maximum wind conditions. The load conditions to be considered for Horizon Power lines are set out in the following clauses, where applicable wind pressures, temperatures and load factors are provided.

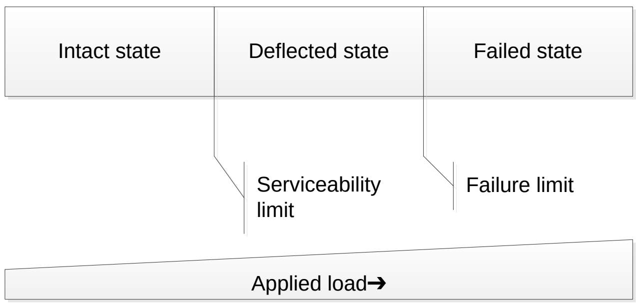
F.2 Design Basis

The limit state design approach as per AS/NZS 7000 must be used with a reliability based (risk of failure) approach. This approach matches component strengths (modified by a factor to reflect strength variability) to loads, calculated on the basis of an acceptably low probability of occurrence.

F.2.1 Limit State Design

Limit state design approach takes into account statistical variations in loads, and also variation in material properties of structures such as poles. This variation is matched against a desired level of reliability.

Limit state loads are compared with the limit state strength (which includes a deflection limit state). The limit state strength needs to be greater than the limit state loads for each load combination. Also, the design deflection limits need to be greater than the load effect on deflection.



Limit state principles apply to components of an overhead power line, including poles, conductors and insulators, and also to electrical clearances. All electrical components have properties which vary with manufacturing and weather conditions.

F.2.1.1 Limit State Design Loads

Limit state loads must include variable factors (load multipliers) which account for the uncertainty in the magnitude of the load from various effects such as wind, component weight, etc..

F.2.1.2 Limit State Design Strength

Limit state design strength considers modification factors for durability, processing effects, fatigue, load sharing, temperature effects, duration of load creep etc., as appropriate, as well as the more general component strength factor.

F.2.2 Design Wind Speed

A complete coverage of wind loading is given in Appendix B of AS/NZS 7000.

The design site wind speed is taken as –

$V_z = V_{50} M_d M_{z,cat} M_s M_t$

where:

$M_{z,cat}$ is the gust winds speed multiplier for terrain category, based on AS/NZS 1170.2

- M_d is the wind direction multiplier (taken as equal to 1, for wind in any direction)
- M_s is the shielding multiplier is taken as equal to 1 ignoring the effects of shielding provided by buildings and other structures.
- M_t is the topographic multiplier for gust wind speed normally taken as 1.
- V_{50} is the basic regional wind velocity for the region corresponding to the 50 year return period. (39, 52 and 60 m/s for regions A, C and D respectively). Please note that for V_{100} , the corresponding values are 41, 56 and 66 m/s. (Refer to Table 21 for wind regions)
- Note: As per Appendix B3 of AS/NZS 7000, cyclonic wind amplification factors are not applicable to Regions C and D.

The design pressure q_z is be calculated as follows:

$$q_z = 0.6V_z^2 \times 10^{-3}\text{kPa}$$

A few towns such as Marble Bar and Ivanhoe fall into Region B, however considering the small number of assets in these areas, they will be assumed to be located in Region C, for ease in performing calculations.

F.2.3 Wind Loads

Wind loads must be applied to all elements of an overhead line.

The design wind pressure q_z for different types of surfaces can be calculated by multiplying with the drag force coefficient for that particular surface (Cd)

$$q_z = 0.6V_z^2 \times C_d \times 10^{-3}\text{kPa}$$ (Refer to clause F.2.4)

The drag force coefficients (C_d), for various equipment, are given in Table 18.

Table 18 – Drag Coefficients for Components

Equipment	Suggested C_d Factor
Round Poles Smooth	1.0
Round Poles Rough (including 12-sided poles)	1.3
Octagonal pole	1.4
Transformers	1.5
Regulators	1.2
Conductors (assumed SRF =1)	1.0
Cross–arms (end/wide face)	1.2/1.6
Insulators (post/pin/strain)	1.2

Table 19 – Terrain Height Multiplier

Terrain Height Multiplier ($M_{z,cat}$)				
Height (m)	**Category 1 Region C, D**	**Category 2 Region C, D**	**Category 3 Region C, D**	**Category 4 Region C, D**
8	0.98	0.98	0.854	0.854
10	1.0	1.0	0.89	0.89
12	1.028	1.028	0.926	0.914
14	1.056	1.056	0.938	0.938
16	1.084	1.084	0.962	0.962

Note: Terrain Multiplier for Region A is taken as 1 for structures up to 60 m height. (Figure B.3 of AS/NZS 7000). Terrain Categories are defined in Table 20)

Table 20 – Terrain Categories Definition

Terrain Category	Description
1	Exposed open terrain
2	Open terrain, water surfaces, grassland with few well scattered obstructions having heights generally from 1.5 m to 10.0 m.
3	Terrain with numerous closely spaced obstructions 3 m to 5 m high such as areas of suburban housing.
4	Terrain with numerous large, 10 m to 30 m high and closely spaced obstructions such as large city centres and well developed industrial complexes.

F.2.4 Regional Wind Speeds and Wind Pressures

Regional wind speeds and wind pressures that are used to calculate loads on structural components are given in Table 21. These use 1.0 for all multipliers ($M_{z,cat}$, M_d, M_s, and M_t).

Table 21 – Regional Wind Speeds and Wind Pressures

Region	Description	Wind Pressure					
		V_{50} 50 year return period			V_{100} 100 year return period		
		(Pa)	(km/h)	(m/s)	(Pa)	(km/h)	(m/s)
A	Esperance and any other area beyond 200 km from the coast	900	140	39	1000	148	41
C	Broome, Wyndham, Kununurra	1600	187	52	1900	202	56
D	Port Hedland, Karratha, Onslow, Carnarvon	2150	216	60	2600	238	66

F.2.5 Span Reduction Factor (SRF)

The span reduction factor takes into account the spatial characteristics of wind gusts and inertia of conductors. When determining wind pressure on conductor, for conductor tension calculations, SRF for the related tension section must be used for:

1) Region A, where spans are 200 m or less, SRF = 1

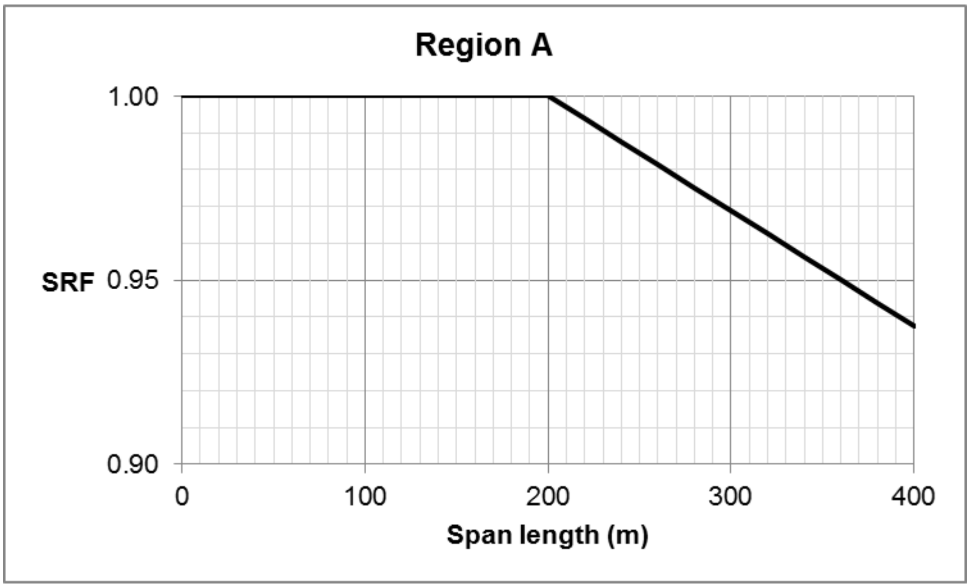
2) Region A, where spans exceed 200 m, calculate SRF using the formula:

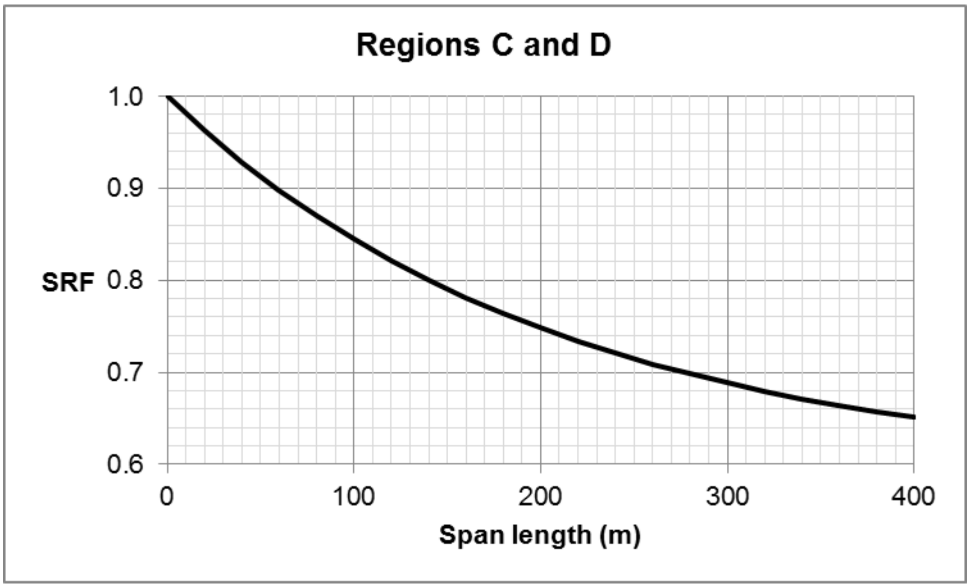
SRF = 1.0 – {(span length – 200)/1000} x 0.3125

3) Regions C and D, calculate SRF using the formula:

SRF = 0.59 + 0.41 e $^{(\text{- span length/210})}$

The calculated result should be checked against the following graphs:





F.2.6 Temperature

Ambient temperature for Region A is 40°C (summer) and 15°C (winter), and for Regions C and D 45°C (summer) and 35°C (winter).

Maximum conductor temperature must not exceed 75°C, to ensure that electrical clearances are maintained.

F.2.7 Strength and Serviceability Limit States

F.2.7.1 Ultimate Strength Limit State

Ultimate limit state is the maximum load carrying resistance of a structure or structural element. It is associated with collapse or other forms of structural failure due to excessive deformation, loss of stability, overturning, rupture or buckling.

F.2.7.2 Serviceability Limit State

Serviceability limit state is the state beyond which specified service criteria for a structure or a structural element is no longer met. In this state, a structure and all its components mechanically function whilst maintaining prescribed electrical clearances.

F.2.7.3 Strength Reduction Factors

The strength reduction factor (ϕ) takes into account variability of material and workmanship for structural components used in overhead lines as well as some modification factors. Table 22 gives strength reduction factors applicable to different components of an overhead line.

Table 22 – Strength Reduction Factors (as per Table 6.2 of AS/NZS 7000)

Component of Overhead Line	Limit State	Strength Reduction Factor (ϕ)
Steel Poles and Cross arms	Strength	0.9
Bolts, Nuts and Washers	Strength	0.9
Untreated wood poles and cross-arms	Strength	0.5
Untreated wood poles and cross-arms	Serviceability	0.3
Fully treated wood poles and cross-arms	Strength	0.5 to 0.8
Fully treated wood poles and cross-arms	Serviceability	0.4
Fittings and pins, forged or fabricated/cast	Strength	0.95
Fittings, cast	Strength	0.9
Porcelain or glass cap and pin string insulator units	Strength	0.95
Porcelain or glass insulators (other than cap and pin string insulator units)	Strength	0.8
Synthetic composite suspension or strain insulators	Strength	0.5
Synthetic composite line post insulators	Strength	0.9 (max design cantilever load)
Conductors	Serviceability	0.5 of CBL
Stays	Strength	0.8

F.2.8 Load Combinations

F.2.8.1 General

In the design of an overhead line, a range of loading conditions must be considered. This provides due consideration for all possible service conditions that the line and individual supports may be subjected to, throughout its service life. Load factors are used to reflect the uncertainty in the derivation of the particular load. The value of each load component must be calculated separately for each loading condition.

These must include the potential effects of differential wire tensions across the structure due to the effects of unequal spans and wind pressures that may exist at the structure.

Ultimate and serviceability limit state loads are to be considered in determining structure deflections and strength ratings.

For loadings less than the serviceability limit, the deflections must be limited to a value that ensures that electrical clearances are not infringed.

F.2.8.2 Permanent Loads

Self-weight of structures, insulators, other fixed equipment and conductors resulting from adjacent spans act as permanent loads.

Vertical loads on poles foundations, cross-arms, insulators and fittings is the vertical force due to their own mass plus the mass of all ancillaries and attachments (G_s).

Vertical loads of conductors/cables and attachments such as marker balls, spacers and dampers form the design weight span (G_c).

F.2.8.3 Load Conditions and Load Factors

The following load conditions and factors must be used to determine the loading on structures:

- W_n is the wind load based on a selected wind period
- F_t is the load on structure due to intact horizontal component of conductor tension in the direction of the line for the appropriate wind load. This tension must be calculated using the appropriate temperature for the load condition.
- G_c is the vertical load due to conductors
- G_s is the vertical load due to cross-arms, insulators and fittings

F.2.8.4 Maximum Wind and Maximum Weight

Determined by the equation: $W_n + 1.25\ F_t + 1.1\ G_s + 1.25\ G_c$ (Table 7.3 of AS/NZS 7000)

The conductor tension must use a temperature of 15°C, as per the short duration load of Table 24.

F.2.8.5 Maximum Wind and Uplift

Determined by the equation: $W_n + 1.25\ F_t + 0.9\ G_s + 1.25\ G_c$ (Table 7.3 of AS/NZS 7000)

The conductor tension must use a temperature of 5°C as per the sustained load condition of Table 24.

F.2.8.6 Everyday Condition (sustained load)

Determined by the equation: $1.1\ F_t + 1.1\ G_s + 1.25\ G_c$ (Table 7.3 of AS/NZS 7000)

The conductor tension must use a temperature of 5°C as per the sustained load condition of Table 24.

F.2.8.7 Serviceability (deflection/damage limit)

Determined by the equation: $1.0 F_t + 1.1 G_s + 1.1 G_c$ (Table 7.3 of AS/NZS 7000)

The conductor tension must use a temperature of 5°C as per the sustained load condition of Table 24.

F.2.8.8 Failure Containment Load

These loads are as a result of the failure of an adjacent structure. For the failure containment condition, supports must be designed for the equivalent longitudinal loads resulting from conductors on the structure being broken with a minimum coincident wind pressure of 0.25 times the ultimate design wind pressure (W_n). The unbalance tension (F_b) resulting from these broken conductors is the residual static load (RSL) in the aerial phase conductors after severance of a conductor, or the collapse of a conductor support system. For aerial conductors supported by suspension insulator strings, an RSL factor of 0.7 must be used, otherwise 0.8 is used.

The unbroken conductors will be subject to the “Intact Conductor Tensions (F_t)”.

F_b and F_t tensions for conductors are based on the temperature corresponding to the everyday load condition with a minimum nominal wind pressure of 0.25 times the ultimate design wind pressure.

The conductor tension must use a temperature of 15°C as per Table 24. Accordingly, total load on a structure is:

$0.25W_n + 1.25 F_t + 1.1 G_s + 1.25 G_c + 1.25 F_b$

F.2.9 Pole Foundations

Embedment depths have not been calculated with the Brinch Hansen method stated in AS/NZS 7000. They have been calculated using a Winkler spring model (COM624P developed by the US Federal Highway Administration). The Brinch Hansen method in many cases is excessively conservative, and in some cases un-conservative. A strength reduction factor of 0.7 has been used for foundations.

Embedment depth may need to be increased if

1) sloping ground is present, or
2) trenches and open excavations are present close to the pole.

The soil parameters defined as ‘cohesive’ are provided in Table 23. These have been used to calculate the required pole embedment.

Table 23 – Assumed Soil Properties

Soil category	Cohesive
Density (kN/m³)	20
Internal friction angle (°)	0
Cohesion (kPa)	53
SPT blow count	9

The standard foundation will be adequate if the soil is equal or better than the above descriptions, as confirmed by an experienced geotechnical or structural engineer. If the soil condition is worse than the cohesive case, different solutions are required.

Where a geotechnical engineer is engaged to investigate soil properties, they should be given specific requirements to fulfil, corresponding to the parameters above. Failure to give specific requirements may be costly, as the engineer may investigate far more than what is required. The required parameters are:

- Soil description (i.e. medium density sand, stiff clay, etc.),
- SPT blow count at each layer within the expected foundation depth,
- Depth of water table (expected high level)
- If the line is particularly important the following additional measurements are recommended
- Soil internal friction angle (dry & saturated)
- Soil density (dry & saturated)
- Cohesion (dry & saturated)

Backfill should be mechanically compacted in 300 mm layers. If compaction is by hand, it should be done in 150 mm layers. Where concrete backfill is used, it should be mechanically vibrated, and have a minimum strength of 25 Mpa. Concrete cures over several days, and poles set in concrete should not be loaded during this period. Where it is required to load poles immediately, an approved polyurethane foam backfill may be used. Foam must have a minimum compressive strength of 750 kPa, and be self-extinguishing.

F.2.10 Conductors

F.2.10.1 Conductor Sag and Tension

Conductor tension will be increased due to wind and reduced due to the following factors causing increase in sag:

1) Increase in temperature
2) Creep due to ageing
3) Pole movement due to foundation collapse or stay relaxation

F.2.10.2 Conductor Tension Limits

Tension limits for conductors must not exceed the following under the temperature and wind conditions specified in Table 24

AAAC – 50%

SC/AC – 50%

LVABC – 28%

Table 24 – Temperature and Wind Conditions for Limit State Loads

Conductor load conditions	Temp	Wind
Sustained load condition	5°C	0 kPa (no wind)
Short duration load condition	15°C	Maximum Wind for Region
Intact conductor tension under average wind	15°C	0.5 kPa
Failure containment loads	15°C	0.25 times Maximum Wind for Region

F.2.10.3 Conductor Stress and Fatigue

Fatigue failure of overhead line conductors occur almost exclusively at points where the conductor is secured to fittings. The cause of such failures is dynamic stresses induced by vibration combined with high static stresses. It is therefore necessary to limit both the static and dynamic stresses if the conductor is to have acceptable fatigue endurance and thereby provide required life cycle performance.

In order to prolong the life of conductors, design tensions must be limited to below 50% of CBL. By using appropriate clamping of conductors to insulators static stresses can be controlled and dampers are used to control dynamic (vibration) stresses. Table 25 indicates recommended maximum horizontal tension as a percentage of CBL considering both static and dynamic stresses. The following must be considered in the application of Table 25:

1) The horizontal tensions are applied at 15°C

2) The table is a guide only, and need not apply to situations where proven line performance indicates a lower or higher tension as appropriate.

3) Smaller diameter conductors will vibrate at higher frequencies and reach their fatigue in a shorter time, however, such conductors are easier to damp effectively.

4) Increased span length requires increased vibration protection.

5) Vibration dampers are a purpose built device to reduce conductor vibration and armour rods are used to reduce damage to conductor caused by vibration.

6) For new conductors that are pre stressed, the tension limits in table may be applied to the after creep (final) tension.

7) For new conductors that are over tensioned, the tension limits in table may be applied to the initial stringing tension, especially if the sagging is carried out over the colder months.

Table 25 – Conductor Everyday Load Horizontal Tension (based on table Y1 in AS/NZS 7000)

Conductor Type	Base Case tension (% of CBL)	Recommended incremental Increase in horizontal tension (% CBL)							Recommended maximum horizontal tension (% of CBL)
		Static Stress Considerations			Dynamic Stress Considerations				
		Clamp Category*			Damping/Terrain Category				
					No Dampers			Fully damped all categories	
		Clamp Category			Terrain Category				
		A	B	C	1	2	3,4		
AAC	18	0	1.5	2.5	0	2	4	6.5	27
AAAC	15	0	1.5	2.5	0	2	4	6.5	24
ACSR	17	0	1.5	2.5	0	2	4	7.5	27
SC/GZ SC/AC	10	0	2.5	5.0	0	5	10	16	31
Clamp Category	Type A	Short trunnion clamp, post or pin insulator with ties (without armour rods)							
	Type B	Post or pin insulator (clamped or tied) with armour rods or shaped trunnion clamps with armour rods							
	Type C	Helically formed armour grip with elastomer insert or helically formed ties with armour rods							
Terrain Category	As per Table 20								

F.2.10.4 Conductor Span Ratios

Large differences in span lengths of adjacent spans can result in significant tension differences across intermediate structures, which may not be able to be equalised by the movement of the pole top and may cause ties or pins to fail.

1) In urban situations adjacent spans must be limited to a ratio of 2:1. For example, on a typical 50 m span length, adjacent spans must not be shorter than 25 m

2) In rural situations adjacent spans must be limited to a ratio of 5:4. For example, on a typical 110 m span length, adjacent spans must not be shorter than 80 m for AAAC conductors. For SC/AC conductors, span ratio must be limited to 2:1.

F.2.10.5 Conductor Strain Sections

Strain sections must not exceed 1.5 to 2.0 km for AAAC and 3.0 km for SC/AC conductors to prevent tensioning errors during construction.

Designs must specify the ruling span for each strain section and the distance between each pole on the design.

F.2.10.6 Conductor Clearances

Clearances to structures such as buildings and spacing between conductors of the same circuit or different circuits must be as per AS/NZS 7000. Clearances to earthed structures or to ground are extracted form AS/NZS 7000 and specified below.

F.2.10.6.1 Clearance to Earthed Structures

Minimum clearance to earthed structures must be as follows:

11 kV – 160 mm

22 kV – 280 mm

33 kV – 380 mm

Clearance must be increased in locations where bridging of insulators by birds/animals is probable.

F.2.10.6.2 Clearance to Ground

At a phase conductor temperature of 75°C, and a running earth conductor temperature of 50°C, the clearance of a conductor from ground must comply with Table 26.

Table 26 – Conductor Clearance from Ground

Voltage	Over roads	Over other than roads	Over location not traversable by vehicles ≤ 3 m high
Not exceeding 1000 V	5.5 m	5.5 m	4.5 m
Exceeding 1000 V but not exceeding 33 kV	6.7 m	5.5 m	4.5 m

Notes:

1) The distances specified are final conditions for conductors which have aged. When conductors are first erected, an allowance must be made for ‘settling in’ and ‘conductor creep’. (refer to clause F.2.10.3)
2) The distances specified are designed to protect damage to conductors, impact loads on conductor supports and protecting vehicles from contact with conductors.
3) When calculating ground clearance a construction tolerance of 300 mm should be included for long bay lengths and 100 mm for short bay lengths.

4) For the purpose of this clause, the term ‘ground’ includes any unroofed elevated area accessible to plant or vehicles and the term ‘over’ means ‘across and along’.
5) The above values are based on vehicles with a maximum height of 4.6 m.

F.2.10.6.3 Mid-span Conductor Separation

A mid-span separation constant (k) of 0.6 should be used. Where a constant less than 0.6 is used, the following information must be provided and documented for Horizon Power approval:

1) Projected worst case fault level (single-phase and three-phase)
2) Bushfire risk rating for the area
3) Wind condition
4) Indication if running disc angle to normal intermediate/strain transition is used as part of the construction

The use of k = 0.6 is non-negotiable if:

5) Projected worst case fault level exceeds 6 kA
6) The design is within close proximity to high or extreme bushfire risk area
7) The design is in a cyclonic region
8) Running disc angle to normal intermediate/strain transition forms part of a long bay construction.

F.2.11 Ratings for Overhead Line Conductors

Table 5 provides nominal continuous current rating and fault rating for overhead line conductors. Mechanical data for conductors is given in Table 27. The continuous current ratings are based on the following operating conditions:

1) Maximum conductor temperature 75°C
2) Maximum ambient air temperature 45°C (Regions C and D), 40°C (Region A)
3) Wind speed 1 m/s
4) Emissivity coefficient 0.9
5) Solar radiation 1000 W/m²

The fault current ratings are based on maximum conductor temperature of 160°C for AAAC, 400°C for SC/AC and 80°C for LVABC conductor.

(Refer to *Horizon Power Environmental Conditions Standard: HPC-9EJ-01-0001-2013*, for temperature conditions in various parts of the network)

Table 27 – Conductor Mechanical Data

Size	Type	Cross Sec. Area (mm²)	Nominal Diameter (mm)	Min. Breaking Load (kN)	Approx. Mass (kg/km)	Modulus of Elasticity (GPa)	Coef. Of Linear Expansion (10^{-6}/°C)
7/2.50	AAAC/1120	34.36	7.50	8.18	94.3	59	23
7/4.75	AAAC/1120	124.00	14.30	27.10	339.0	59	23
19/3.25	AAAC/1120	157.60	16.30	37.40	433.0	56	23
3/2.75	SC/AC	17.82	5.93	22.70	118.0	162	12.9
4 x 150 mm²	LVABC	150.00	45.60	84.00	2020.0	56	23
4 x 95 mm²	LVABC	95.00	38.40	53.20	1350.0	56	23

F.2.12 Mechanical Strength Ratings for Cross Arms

Mechanical strength ratings for cross-arms are in Table 28.

Table 28 – Mechanical Strength Ratings for Steel Cross-arms

Cross-arm cross-sectional dimensions, length (mm)	Bending capacity about X Axis (kN.m)	Bending capacity about Y Axis (kN.m)	Section compression capacity (kN)	Member compression capacity (kN)	Tension capacity (kN)	Shear capacity about X Axis (kN)	Shear capacity about Y Axis (kN)
75x75x3, 1900 (unitised)*	6.9	5.9	230.8	171.7	241.1	78.2	78.2
100x100x4, 2400	16.4	14.4	420.8	355.68	355.6	139.1	139.1
125x75x5, 3300 mm	19.5	15.9	513.4	199.2	536.2	217.4	122.9

*This cross-arm will no longer be standard in future revisions of these Rules.

Table 29 – Mechanical Strength Ratings for Composite Cross-arms

Cross-arm cross-sectional dimensions, length (mm)	Bending capacity ultimate (kN.m)	Bending capacity short term (vertical) (kN.m)	Bending capacity long term (vertical) (kN.m)	Bending capacity short term (longitudinal) (kN.m)	Bending capacity long term (longitudinal) (kN.m)	Tension capacity (Mpa)	Shear capacity (Mpa)
100x100x5, 2100	17.7	7.7	3.0	0.75	0.30	600	84

Table 30 – Mechanical Strength Ratings for Wooden Cross-arms

Cross-arm cross-sectional dimensions, length (mm)	Characteristic bending stress (Mpa)	Section modulus (mm³)	Compression capacity parallel to grain (Mpa)	Tension capacity parallel to grain (Mpa)	Shear capacity (kN)
100x100, 2100	40	161,000	30	25	3.7
125x125, 2100	65	318,000	50	40	5.0

F.2.13 Mechanical Strength Ratings for MV Insulators

Mechanical strength ratings for insulators are in Table 31.

Table 31 – Mechanical Strength Ratings for Insulators

Type	Voltage (kV)	Specified Cantilever Load (SCL) (kN)	Specified Tensile Load (STL) (kN)	Specified Mechanical Load (SML) (kN)
Line Post Tie Top Insulator	33	12.5	25	N/A
Line Post Clamp Type Insulator	33	12.5	25	N/A
Suspension Strain Insulator	46	N/A	N/A	66.7

F.2.14 Mechanical Strength Ratings for LVABC Clamps

Mechanical strength ratings for LVABC clamps are in Table 32.

Table 32 – Mechanical Strength Ratings for LVABC Clamps

Type	Safe Working Load (SWL) kN
Termination Clamp	15
Suspension Clamp	22
Angle Yoke Insulator	12

APPENDIX G UNDERGROUND CABLE DESIGN INFORMATION

G.1 Continuous Current Ratings for Underground Cables

The continuous current rating of a cable must be used in cable designs, unless cyclic loading studies have been performed.

The ‘cyclic rating’ of cables considers the load connected to the cable and is generally 10% - 40% lower than the ‘continuous current rating’ of the cable.

Table 33 provides nominal continuous current ratings for medium voltage cables:

- Buried direct in ground at a depth of laying of 0.8 m to the top of cable or group of cables
- In a duct with depth of laying of 0.8 m to the top of the duct

The continuous current ratings are based on the following operating conditions:

1) Maximum conductor temperature 90°C (XLPE insulated cables)
2) Ambient air temperature 40°C
3) Ambient soil temperature 25°C
4) Soil thermal resistivity 1.2°C.m/W

Table 33 – Continuous Current Ratings of Medium Voltage Cables

Cable Size	Conductor Material	Voltage (kV)	Current Rating (A) in Ground (Trefoil formation)	
			Direct Buried	In Duct
30 mm²	Al	22	135	110
185 mm²	Al	22	335	280
400 mm²	Al	22	470	410
50 mm²	Al	33	155	135
185 mm²	Al	33	325	275

Table 34 – Continuous Current Ratings of Low Voltage Cables

Cable Size	Conductor Material	Current Rating (A) in Ground	
		Direct Buried	In Duct
25 mm²	Al	115	85
120 mm²	Al	265	215
185 mm²	Al	340	280
240 mm²	Al	395	330

Cable Size	Conductor Material	Current Rating (A) in Ground	
		Direct Buried	In Duct
630 mm²	Al	685	590

The cable ratings in Table 33 and Table 34 shall be used only when the cable manufacturer's catalogues are not available.

Refer to Horizon Power Environmental Conditions Standard (HPC-9EJ-01-0001-2013) for temperature conditions in various parts of the network

G.2 Derating Factors for Underground Cables

Cables installed in environments which differ from the conditions outlined in clause G.1, must be modified using the formula below:

Continuous current rating = Current rating in relevant Table x factor for depth burial x factor for thermal resistivity x factor for ground temperature x other factors as per tables as appropriate

The rating modification tables in this clause must be used when the cable manufacturer's catalogues are not available.

Table 35 – Rating Factors for Depth of Laying Direct in the Ground

Depth of Burial (m) (to top of cable)	Low Voltage Cables		High Voltage Cables	
	≤ 300 mm²	> 300 mm²	≤ 300 mm²	> 300 mm²
0.6	1.0	1.0		
0.8	0.98	0.97	1.0	1.0
0.9	0.97	0.96	0.99	0.98
1.0	0.96	0.95	0.98	0.97
1.25	0.95	0.93	0.96	0.95
1.5	0.93	0.92	0.95	0.93
1.75	0.92	0.91	0.94	0.91
2.0	0.91	0.90	0.92	0.89

Table 36 – Rating Factors for Depth of Laying Direct in a Duct

Depth of Burial (m) (to top of duct)	Low Voltage Cables		High Voltage Cables	
	Single Core	Three Core	Single Core	Three Core
0.6	1.0	1.0		
0.8	0.97	0.98	1.0	1.0
0.9	0.96	0.97	0.99	0.99
1.0	0.95	0.97	0.98	0.99
1.25	0.92	0.96	0.95	0.97
1.5	0.91	0.95	0.94	0.96
1.75	0.92	0.95	0.92	0.96
2.0	0.89	0.94	0.91	0.95

Table 37 – Rating Factors for Variation in Thermal Resistivity (3-core MV cables laid directly in the ground)

Conductor size (mm^2)	Thermal Resistivity (°C.m/W)				
	1.0	**1.2**	**1.5**	**2.0**	**2.5**
35 to 150	1.07	1.0	0.93	0.84	0.76
185 to 400	1.07	1.0	0.92	0.82	0.74

Table 38 – Rating Factors for Variation in Thermal Resistivity (single-core MV cables laid directly in the ground)

Conductor size (mm^2)	Thermal Resistivity (°C.m/W)				
	1.0	**1.2**	**1.5**	**2.0**	**2.5**
Up to 150	1.07	1.0	0.91	0.81	0.73
185 to 400	1.07	1.0	0.90	0.80	0.72

Table 39 – Rating Factors for Variation in Thermal Resistivity (3-core cables laid in duct buried in the ground)

Conductor size (mm²)	Thermal Resistivity (°C.m/W)				
	1.0	**1.2**	**1.5**	**2.0**	**2.5**
35 to 150	1.03	1.0	0.96	0.90	0.85
185 to 400	1.04	1.0	0.95	0.87	0.82

Table 40 – Rating Factors for Variation in Thermal Resistivity (single-core cables laid in duct buried in the ground)

Conductor size (mm²)	Thermal Resistivity (°C.m/W)				
	1.0	**1.2**	**1.5**	**2.0**	**2.5**
Up to 150	1.05	1.0	0.94	0.87	0.81
185 to 400	1.06	1.0	0.93	0.84	0.77

Table 41 – Rating Factors for Variation in Ambient Temperature

Air Temperature (°C)	25	35	40	45	50	55
Rating Factor	1.14	1.05	1.0	0.95	0.89	0.84

Table 42 – Rating Factors for Variation in Ground Temperature

Ground Temperature (°C)	15	20	25	30	35	40
Rating Factor	1.07	1.04	1.0	0.96	0.92	0.88

Table 43 – Group Rating Factors for Circuits (3 single-core MV in trefoil laid directly in the ground)

Voltage	No of Cables in Group	Separation				
		Touching	**150 mm**	**300 mm**	**450 mm**	**600 mm**
Up to 33 kV	2	0.78	0.81	0.85	0.88	0.90
	3	0.66	0.71	0.76	0.80	0.83
	4	0.60	0.65	0.72	0.76	0.80

Table 44 – Group Rating Factors for Circuits (3-core MV cables laid directly in the ground)

Voltage	No of Cables in Group	Separation				
		Touching	150 mm	300 mm	450 mm	600 mm
22 kV	2	0.80	0.85	0.89	0.90	0.92
	3	0.69	0.75	0.80	0.84	0.86
	4	0.63	0.70	0.77	0.80	0.84
33 kV	2	0.80	0.83	0.87	0.89	0.91
	3	0.70	0.73	0.78	0.82	0.85
	4	0.64	0.68	0.74	0.78	0.82

G.2.1 Cables Buried Partly in Conduit

The current capacity of direct buried cables must be reduced when part of the cable is laid in conduit. Other derating factors shall apply as specified in clause G.2.

When the length of cable in conduit is greater than 20 times the cable diameter, the cable must be considered as if laid in conduit. Accordingly, MV direct buried cables greater than 3 m in length and LV direct buried mains cables greater than 2 m in length installed in conduit must be considered as laid in conduit.

If a material such as bentonite that has a thermal resistivity similar to that of ambient soil is used to fill the conduit, the derating factor can be considered to be 1.

G.3 Emergency Rating of Underground Cables

XLPE cables can be operated under emergency conditions up to a conductor temperature of 105°C for periods up to 36 hours, no more than 3 times per year. This is after leaving an allowance for high volume of expansion of XLPE above 100°C and compatibility of terminations. However, where metal tape screens are used, the overload temperature must be limited to 100°C. Refer to AS/NZS 1429.

G.3 Short Circuit Rating of Underground Cables

Short circuit current values allow conductor temperature to rise from 90°C to a maximum temperature of 250°C, assuming adiabatic conditions (i.e. neglecting heat loss). Where high fault currents are anticipated in single core cables, consideration must be given to electromechanical forces which will cause the cables to move apart if adequate restraint is not provided.

Cable screens must be rated to withstand 10 kA for 1 second (AS/NZS 4026).

APPENDIX H LOCATION OF DISTRIBUTION COMPONENTS

H.1 General Requirements

H.1.1 Safety

Safety of persons and livestock must be considered when locating distribution equipment. Particular attention must be given to:

1) Bushfire initiation
2) Electric arc limitation including explosive atmospheres (hazardous areas)
3) Touch, step and transfer voltages
4) Low frequency induction
5) Fire risk to infrastructure in vicinity
6) Safe clearances
7) Electromagnetic fields
8) Hazard to road users
9) Hampering accessibility to persons including emergency services
10) Restricting accessibility
11) Appropriate signage

H.1.2 Environmental

Impact to the environment from distribution equipment and vice versa must consider the following:

1) Bird flight paths – striking conductors
2) Bird and animal habitats – flashover initiation
3) Oil leakage – pollution particularly to waterways
4) SF6 and other gas leakages
5) Noise impact
6) Proneness to graffiti vandalism
7) Visual impact
8) Pollution from cement plants, quarries, mine sites, sea and salt lakes

H.1.3 Land Use

In locating distribution equipment consideration must be given to the following:

1) Public Utilities Code of Practice regarding alignments and sharing land with other services
2) Protected wetlands
3) Cultural heritage and native title
4) Declared rare flora and threatened ecological communities
5) Soils, dust, erosion, land entry permits, vegetation clearance permits

6) Clearing and removal of native vegetation
7) Restrictive covenants where required to maintain safety

H.1.4 Future requirements

When choosing and locating distribution equipment future requirements must be considered in terms of forecasts for:

1) Load growth
2) Economic growth
3) Land use

H.1.5 Installation and Maintenance

Installation and maintenance issues must be considered when locating distribution equipment including but not limited to the following:

1) Access to equipment and vehicles
2) Traffic management
3) Costs

H.2 Requirements for Overhead Lines

H.2.1 Clearance to Structures and Buildings

Clearance from conductors to any non-electrical infrastructure such as structures and buildings must be as per clause 3.11.2.1 of AS/NZS 7000.

H.2.3 Easement Requirements

When considering the width of an easement to provide clearance from structures refer to clause 3.11.2.2 of AS/NZS 7000.

H.2.4 Location of Poles

Distribution poles must be located within the designated 2.4 to 3.0 metre alignment, as laid out in the Utility Providers Code of Practice for Western Australia. Pole positions must comply with the designated alignment at all times, unless alternative offsets have been arranged with relevant local authority and service providers.

Guidance to setbacks and barriers is also provided in:

1) AS/NZS 1158.1.2 – Lighting for Roads and Public Spaces
2) AustRoads publications and guidelines for rural and urban road design
3) AS/NZS 3845 – Road Safety Barrier Systems and Devices

Pole locations and foundations may be affected by the slope in ground, trenches and excavations. Refer to clause F.2.9 for more information.

Poles should not be located:

4) within 1 m of a driveway crossover

5) at road intersections where visibility may be reduced for road users
6) in positions that inhibit access to underground services
7) within the projection of other utility easements

H.2.4.1 Railway Crossings

Overhead power lines must not cross railways unless it is unavoidable. If crossing railway lines, overhead lines crossing must be designed to:

1) the requirements of the railway authority
2) Level 2 security (refer to clause 3.5.1)
3) be strained at both ends
4) be unable to fall on the railway tracks under any circumstances

H.2.4.2 Water Crossings

Overhead power lines must not cross waterways unless it is unavoidable. If crossing waterways, overhead lines crossing must be designed as per the guidelines AS 6947 Crossing of Waterways by Electricity Infrastructure and HB 331 Overhead Line Design.

H.3 Requirements for Underground Cables

H.3.1 Agreed Road Alignments

1) Underground cables must be laid in the 0 – 500 mm alignment in accordance with the Utility Providers Code of Practice for Western Australia
2) Cables may be laid in the 2.4 m to 3 m alignment, centred on 2.7 m (which is reserved for pole lines) as a first preference when 0 – 500 mm alignment is not available
3) Cables installed outside the 0 – 500 mm alignment must be mechanically protected. When directional drilling is used to install cables, heavy duty conduits must be used as mechanical protection

H.3.2 Outside Alignments

1) In exceptional circumstances, cables may be laid outside the standard alignment (clause H.3.1.(1) and H.3.1.(2)) in:
   a) other utilities' alignment, with their permission
   b) road reserves, public open spaces, public access ways
   c) private property
2) Cables installed as per clause H.3.2.1 must be mechanically protected by polymeric cable cover with cable marker tapes installed a maximum of 300 mm below final ground level.
3) Cables installed as per clause H.3.2.1 by directional drilling must be encased in heavy duty conduit and additional cable protection covers and marker tape are not required.
4) Where cables cannot be installed at the required depth due to obstacles such as hard rock, they may be installed at a reduced depth not less than 300 mm

in concrete and inside conduits after performing a suitable risk assessment. The concrete must be a minimum thickness of 75 mm and be the upper surface of the ground. Compacted backfill may be used between the surface concrete and the conduit.

H.3.3 Proximity Limits to other Services

All cables must have a minimum clearance of 150 mm to other services.

H.3.4 Railway Crossings

Cables installed within railway boundaries must be designed in accordance with AS 4799 Installation of Underground Utility Services and Pipelines within Railway Boundaries

H.3.5 Water Crossings

Cables installed within waterways must be designed in accordance with AS 6947 Crossing of Waterways by Electricity Infrastructure.

H.3.6 Easements

1) Horizon Power cables installed within road reserves, public open spaces, public access ways (clause H.3.2.b) must be protected by an easement under the *Land Administration Act 1997*
2) Horizon Power cables installed within private property (clause H.3.2.c) must be protected by an easement under Section 167 of the *Planning and Development Act 2005.*
3) The minimum width of an easement must be 1 m.

H.4 Requirements for Substations

H.4.1 Site Requirements

Substation sites are to be located on public owned land (e.g. road reserve extension or public open space). Where available, parks are preferred over road reserve. Substation sites must also be located in the 'kink' of road reserve and as close as possible to the road boundary line extension along normal gazetted public road reserve. (refer also to clause H.5). When choosing a location to site substations in public open space (POS), the following shall be considered:

1) Suitable location of sites within public open space.
2) Size, shape, contour and dimensions of public open space.
3) Community standards of health, safety and amenity.

H.4.1.1 Minimum Land Requirements

Minimum land requirements for distribution substations are given in Distribution Substations Manual DSM – 5: (HPC-5DA-07-0003-2012). A summary of the requirements are given in Table 45 and Table 46.

Table 45 – Land Requirements for District Substations

Capacity up to	Switchgear	22 kV Area (mm x mm)	33 kV (mm x mm)
630 kVA MPS	No	4500 x 3800	4500 x 3900
	Yes	4500 x 6600	4500 x 6700
1000kVA	No	5100 x 4500	5400 x 4700
	Yes	6350 x 6000	6650 x 6000
2000 kVA	No	5300 x 8100	5600 x 8250
	Yes	6550 x 8100	6850 x 8250

Table 46 – Land Requirements for Sole Use Substations

Capacity up to	Switchgear	22 kV (mm x mm)	33 kV (mm x mm)
1000 kVA	No	4500 x 3800	4700 x 4100
	Yes	4500 x 6600	4500 x 6700
2000 kVA	No	3800 x 8100	3800 x 8250
	Yes	6550 x 8100	6850 x 8250

H.4.1.2 Additional Clear Zone

Considering the fire hazard risk (clause H.4.2) and the EPR, (earth potential rise risk, clause H.4.3) a minimum 2 m clearance zone around all substation footprints (Table 45 and Table 46) is required.

H.4.2 Fire Separation

Where transformers are housed outdoors, minimum separation requirements are given in Table 47.

Table 47 – Minimum Separation Distance – Transformers Installed Outdoors

Transformer Capacity	Horizontal clearance to other similar capacity transformers or non - combustible Surfaces	Horizontal clearance to combustible surfaces of buildings	Horizontal clearance to 2 Hr fire rated surfaces of buildings	Vertical clearance to 2 Hr fire rated surfaces of buildings
Up to 630 kVA (< 1000 L oil)	1 m	6 m	1 m	4.5 m
630 kVA or 1 MVA (up to 2000 L oil)	3 m	7.5 m	1.5 m	7.5m

Transformers in enclosures not fully enclosed, with open roof, must maintain clearance to non-fire rated building surfaces in accordance with Table 47 (details are available in DCS).

H.4.3 Separation for Earth Potential Rise

Medium voltage substations must have a below ground earth grading ring to minimise touch voltage hazards. In certain cases, the grading ring is at the limit of the substation footprint area. Conductive structures must be 2 m clear of the grading ring as per clause C.6.

To avoid future (after substation has been built) issues related to encroachment within the hazard zone, a clear zone of 2 m around the substation earth ring footprint is required.

H.4.4 Restricted Usage and Covenants

Suitable easements must be obtained to attain the requirements in clause H.4.1.2.

H.4.5 Proximity Limits to other Services and Hazardous Areas

1) Services including telecommunications, water and gas must not be installed either on or under or in close proximity to a substation site.

Refer to WADCM Section 14 for clearance to other services.

2) Horizon Power assets in the vicinity of hazardous areas (explosive atmospheres, such as those near fuel stations, fuel farms, and gas compression stations) should be placed only after checking the hazardous area dossier for that facility. The dossier should show the hazardous area zones in accordance with AS/NZS 60079.10.1 or AS/NZS 60079.10.2, and Horizon Power assets should be placed outside zones 0, 1 and 2, and where economical and practical, a further distance from these zone boundaries

H.4.6 Environmental Protection

H.4.6.1 Oil Containment

Oil containment of Distribution Transformers is covered in DSM-09 and Standard for Oil Containment of Distribution Transformers: HPC-9DJ-07-0001-2013.

H.4.6.2 Flood Proofing

Prevention of flooding of Distribution Substations is covered in DSM-09.

H.4.6.3 Noise Regulations

Noise limits are set by the Department of Environment and Conservation (DEC) in Western Australia through Environmental Protection (Noise) Regulations 1997.

The Noise Regulations define Noise Sensitive Premises as:

1) Premises occupied solely or mainly for residential or accommodation purposes;
2) Rural premises
3) Caravan parks and camping grounds;
4) Hospitals with less than 150 beds;
5) Rehabilitation centres, care institutions and the like;
6) Educational institutions;
7) Premises used for public worship;
8) Hotels which provide accommodation to the public;
9) Premises used for aged care or child care;
10) Prisons and detention centres; and
11) Any other promises not defined as industrial, utility or commercial premises as per the Noise Regulations.

The noise level limits for Noise Sensitive Premises are given in Table 48.

Table 48 – Noise Level Limits for Noise Sensitive Premises

Location of Substation	Assigned level (dBA)
Within 15 m from Noise Sensitive Premises	45 +Road Noise Level
Beyond 15 m from Noise Sensitive Premises	60 +Road Noise Level
Beyond 450 m from Noise Sensitive Premises	0

Road Noise Level is determined as follows:

1) Major Road (more than 15,000 vehicles per day) within 100 m of Noise Sensitive Premises = 6 dBA

2) Major Road (more than 15,000 vehicles per day) beyond 100 m of Noise Sensitive Premises = 2 dBA
3) Secondary Road (6,000 - 15,000 vehicles per day) within 100 m of Noise Sensitive Premises = 2 dBA
4) Secondary Road (6,000 - 15,000 vehicles per day) beyond 100 m of Noise Sensitive Premises = 1 dBA
5) Any other Road or any Road beyond 450 m from noise Sensitive Premises = 0 dBA

Horizon Power Transformers are designed to emit sound levels in accordance with AS 2374.6 and the maximum levels are given in Table 49.

Table 49 – Maximum Transformer Sound Levels

Transformer Capacity (kVA)	Sound level (dBA)
1000	65.0
630	63.0
315	58.5
≤ 200	56.0

H.4.6.4 Compliance with WA Noise Regulations

To comply with the WA Noise Regulations, the Noise Level Limits for Noise Sensitive Premises should not be exceeded. Where compliance is not achieved by transformer location with respect to the concerned Noise Sensitive Premises, the following options may be considered:

1) Using sound attenuating enclosures or barriers; and
2) Providing sufficient clearance to noise sensitive premises.

In the design of substations the following must be considered:

3) Impact on the local environment (Regulations/Guidelines);
4) Impact on the working environment (Occupational Health & Safety Regulations in WA); and
5) Equipment Noise (from Horizon Power's Transformer Specification and in accordance with AS 2374.6 for transformers).

Refer to DSM-6-09 for setback requirements from sensitive premises.

H.5 General Considerations in Locating Ground Mounted Equipment (GME)

When locating ground mounted equipment, consideration must be given to the probability of vehicles colliding with equipment. Collisions which can cause injury to vehicle occupants, danger to the public, exposure of electrical apparatus, loss of power and environmental damage must all be considered

H.5.1 GME Inside Road Reserves

GME must be installed:

1) Outside the clear zone relevant for the vehicle speed, traffic volume and road conditions
2) At road truncations provided it is of low enough profile to not impede driver visibility at the intersection, it is not in the clear zone and the relevant council or Main Roads WA has given written approval for the equipment installation
3) In a clear zone only with a high integrity crash barrier designed and installed to provide adequate protection
4) In a car park so that vehicle movement cannot impact it, preferably set back from a curb that shall prevent vehicle overhang of at least 3 m. Otherwise, bollards shall be installed
5) With bollards to protect all MV ground mounted equipment, as required

GME must not be installed:

6) In the middle of roundabouts and median strips. Pillars are permitted in roundabouts or median strips when they are 2 metres from a pole.
7) So as not to interfere with normal pedestrian movement

H.6 General Considerations in Locating Switching Devices

1) It is recommended that the location and type of switching devices should be made in consultation with the local operating personnel who have general knowledge of the area, the operational requirements of the network and customers
2) Switching devices (especially manual types) located on lines near to roads or before entering restrictive areas (i.e. fenced-off, hilly or swampy land), allow operators to easily isolate the associated line

APPENDIX I STREET LIGHTS

I.1 Objectives

The objectives of street lighting are to provide safety, security and amenity to road users. In certain areas where there are turtle hatching grounds, the impact of street lighting must be limited (refer to *Street Lighting for Turtle Nesting Standard: HPC-9DJ-14-0001-2015*).The street light asset family consists of:

- Luminaires; and
- Support Structures

I.2 Street Light Luminaires

1) Street light luminaire types currently installed are High Pressure Sodium (HPS), Mercury Vapour (MV), Metal Halide (MH), Compact Fluorescent (CFL) and Light Emitting Diode (LED).
2) New street light installations must be LED luminaires
3) Existing street lights must be replaced with LED luminaires when replacement is required

I.3 Street Light Supports

Street light luminaires are supported on:

1) Steel streetlight poles, including outreaches (single and double) specifically made for supporting luminaires
2) Power poles (steel, wood and concrete)

Steel streetlight poles are of four types:

3) Frangible poles
4) Cyclone rated poles
5) Slip base poles
6) Pivot poles

Standard lengths for these poles are 6.5, 10.5 and 12.5 m. The standard embedment depth of these poles is 1.5, 2.0 and 2.2 m respectively.

I.3.1 Frangible Poles

Frangible street light poles:

1) Must be installed only in Region A (refer to clause F.2.4)
2) Look similar to normal street light poles except that they remain attached to the base structure and absorb any impact energy by progressively deforming and entrapping the impacting vehicle.
3) The deformation of the pole is controlled by a 'designed' weakening of the pole stem over the lower length.
4) The thickness of steel is not more than 3 mm and weakening of steel is visible in the lower part.

I.3.2 Cyclone Rated Poles

Cyclone rated poles are:

1) Not frangible and must be installed in Regions C and D (refer to clause F.2.4)
2) Not recommended for installation in Zone 2 areas as per AS/NZS 1158.1.2:2010. However, they may be installed in Zone 2 when the width of Zone 2 is large and the required luminance levels on the road cannot otherwise be achieved.
3) Suitable for installation in Zone 3 areas as applicable under AS/NZS 1158.1.2:2010

Where road lighting designs are done for cyclonic areas, and it is desired to put poles in Zone 2, the use of guard rails (or other equivalent means) is recommended.

I.3.4 Slip Base Poles

Slip Base poles are not frangible but are considered suitable for installation in Zone 2 areas as per AS/NZS 1158.1.2:2010 on roads controlled by Main Roads WA.

I.3.5 Street Light Pole Foundations

Street light outreach foundations must be built to the requirements of the Distribution Construction Standard (drawing in S9-2) with a concrete collar. Poles installed in cyclonic areas require concrete encasement to a depth of 800 mm, with a diameter of 600 (for sandy soils) or 900 mm (for clay). The concrete strength must be N20.

I.4 Design of Street Lighting

Street light designs must comply with the luminance requirements as specified in AS/NZS 1158.3.1 and AS/NZS 1158.1.1. The lighting scheme must be nominated by the client, usually the shire council. The above standards do not apply where luminaires may be installed at irregular intervals on an otherwise unlit road or when additional luminaires may be installed for increased security.

I.5 Replacing Existing Street Lights

When replacing existing luminaires with LEDs on the assumption that the luminaires being replaced have been designed to the requirements of clause I.4, replacement LED luminaires must be selected in accordance with Table 13 (in section 5.16).

I.6 Street Light Wiring and Electrical Protection

1) LED luminaires and associated wiring must be double insulated.
2) Notwithstanding clause I.6.1), for steel street light outreaches, connection between the neutral and earth terminals of the street light cut out must be maintained, with an earth loop conductor connecting the earth terminal with the steel street light support frame.(street light supports must be considered as earthed structures)
3) Notwithstanding clause I.6.1), when wood power poles with luminaires are replaced with steel power poles, or luminaires are installed on steel power poles, and there is conductivity between the luminaire and the steel pole, a

connection must be established between the luminaire neutral connection and the steel power pole frame.

4) Electrical protection of street lights must be as per clause 5.16.1.

APPENDIX J MAXIMUM SIZE OF TRANSFORMERS AND MAXIMUM SWITCHING LOADS FOR MICROGRIDS

Table 50 – Maximum Size of Transformers and Maximum Switching loads for Microgrids

District	Town	Feeder	Max TX Size	Maximum Switching Load
Kimberley	Ardyaloon	All	100 kVA	250 kVA
	Beagle Bay	All	100 kVA	250 kVA
	Bidyadanga	All	100 kVA	250 kVA
	Broome	Substation Feeders	1 MVA	3000 kVA
		Broome Rd	200 kVA past the Voltage Regulator	
	Derby	All	1 MVA	3000 kVA
	Fitzroy Crossing	All	500 kVA	1000 kVA
	Halls Creek	All	500 kVA	1000 kVA
	Kununurra	6.6 kV Feeders	500 kVA	3000 kVA
		22 kV Feeders	500 kVA when the upstream protective device is the Feeder Circuit Breaker	3000 kVA
		Rural	200 kVA when the upstream protective device is a Recloser	1500 kVA (feeders 6 & 7)
	Lake Argyle	All	200 kVA	
	Looma	All	200 kVA	380 kVA
	Warmun	All	100 kVA	200 kVA
	Wyndham	All	315 kVA	500 kVA
Gascoyne	Carnarvon	All	1 MVA – Only for large single customer installations	3000 kVA

District	Town	Feeder	Max TX Size	Maximum Switching Load
		Lake McLeod	315 kVA on the 33 kV side of the Step Up Transformer	
	Coral Bay	All	315 kVA	500 kVA
	Denham	All	315 kVA	500 kVA
	Exmouth	11 kV	1 MVA	1500 kVA
		33 kV	1 MVA	1500 kVA
	Gascoyne Junction	All	100 kVA	125 kVA
Midwest	Cue	All	100 kVA	250 kVA
	Meekatharra	All	315 kVA	1000 kVA
	Mount Magnet	All	315 kVA	500 kVA
	Sandstone	All	100 kVA	125 kVA
	Wiluna	Thompson Nth Thompson Sth	200 kVA	250 kVA
		Wells St	100 kVA	
	Yalgoo	All	100 kVA	125 kVA
Esperance	Esperance	11 kV Feeder	1 MVA	4000 kVA
		33 kV Feeder (CB)	500 kVA	2750 kVA
		33 kV Feeder (R1)	315 kVA	2750 kVA
		33 kV Feeder (R2)	200 kVA	2750 kVA
		33 kV Feeder (R3)	100 kVA (if installed)	2750 kVA

District	Town	Feeder	Max TX Size	Maximum Switching Load
	Hopetoun	Rural feeders	200 kVA	750 kVA
		Town feeders	315 kVA	500 kVA
	Norseman	All	315 kVA	750 kVA
	Laverton	All	200 kVA	300 kVA
	Leonora	All	315 kVA	1000 kVA
	Menzies	All	100 kVA	100 kVA
Pilbara	Marble Bar	All	100 kVA	250 kVA
	Nullagine	All	63 kVA	100 kVA
	Onslow	All	200 kVA	1000 kVA

APPENDIX K SWITCHING CAPABILITY OF OVERHEAD AND GROUND MOUNTED TYPE SWITCHING DEVICES

Determining the loads that can be managed on distribution networks shall take into account the loading capacity of the line equipment. Larger loads warrant individual switching devices. These can be considered for load management, depending upon ease of access.

Load breaking and making capacity of switching devices is provided in Table 51 and Table 52.

Table 51 – Overhead Type Switching Devices

Item	Switchgear Type	Capacity		
		Load	Breaking	Making
1.	**Disconnects (should not be used as switching devices)**			
1.1	MVDO	Fuse Rating	Fault	Fuse Rating
1.2	S & C Fault Tamer	Fuse Rating	Fault	Fuse Rating
1.3	Stanger – In Line Links	250 A	50 A	50 A
2.	**Pole-Top Switch (Air-Break Switch) (should not be used as switching devices)**			
2.1	ALM	400 A	10 A	10 A
2.2	Falcon	400 A	10 A	10 A
2.3	Falcon Ezybreak	400 A	20 A	20 A
3.	**Load Break Switch**			
3.1	Nulec RL	630 A	630 A	12.5 kA
4.	**Sectionaliser (should not be used as switching devices)**			
4.1	Haycolec	Load Rating	Fault	Load Rating
5.	**Reclosers**			
5.1	McGraw Edison RV ACR	400 A	Fault	Fault
5.2	Nulec N24 & U27	630 A	12.5 kA	12.5 kA
5.3	Reyrolle OYT **	150 A	Fault	Fault

** - equipment is questionable and should be considered for urgent replacement

Table 52 – Underground Type Switching Devices

Item	Switchgear Type	Capacity		
		Load	Breaking	Making
1.	**Disconnects**			
1.1	Alstom FBA5	630 A	630 A	16 kA
1.2	Alstom FBX	630 A	630 A	16 kA
1.3	Alstom Fluokit M	630 A	630 A	31 kA
1.4	Felten & Guilleaume GA2K	630 A	630 A	16 kA
1.5	GEC DDFA **	400 A	Fault	Fault
1.6	Hazemeyer Magnefix MD **	250 A	250 A/Fuse	250 A/Fuse
1.7	Holec SVS	630 A	630 A	40 kA
1.8	Long & Crawford ** ETV3/2	200 A	200 A	Fault
1.9	Long & Crawford T4GF3	630 A	630 A	Fault
1.10	Long & Crawford GF3 J4 J R3	200 A 630 A 400 A 630 A	200 A 630 A 400 A 630 A	Fault
1.11	Merlin Gerin M6 Vercors	400 A/Fuse	400 A/Fuse	Fault
1.12	Nebb Brown Boveri RGB12	400 A/Fuse	400 A/Fuse	Fault
1.13	Schneider D14	100 A/Fuse	100 A/Fuse	Fault
1.14	Schneider RM6	400/630 A	400/630 A	40 kA
1.15	Siemens 8CK2	400 A/Fuse	400 A/Fuse	Fault
2.	**Breakers**			
2.1	Alstom HWX	2500 A	40 kA	40 kA
2.2	Email J18	800 A	26 kA	26 kA

Item	Switchgear Type	Capacity		
		Load	Breaking	Making
2.3	English Electric OLX **	800 A	13.1 kA	13.1 kA
2.4	GEC Alstom SBV 24	1250 A	16 kA	16 kA
2.5	GEC D4XD	400 A	Fault	Fault
2.6	Nilsen JB422/OMI	1600 A	Fault	Fault
2.7	Nilsen GEC OLX	800 A	Fault	Fault
2.8	Reyrolle 2A9T	800 A	Fault	Fault
2.9	Reyrolle LMVP	2500 A	Fault	Fault
2.10	Schneider AD4 MC	2000 A	Fault	Fault
2.11	Schneider RM6	400/630 A	16 kA	40 kA
2.12	Westinghouse J18	800 A	26 kA	26 kA
2.13	Yorkshire YSF6	630 A	Fault	Fault

** - equipment is questionable and should be considered for urgent replacement

APPENDIX L EXTERNAL REFERENCE DOCUMENTS

L.1 Legislation

1) Electricity Act 1945
2) Electricity System Safety Regulations 2015
3) Electricity (Licensing) Regulations 1991
4) Occupational Safety and Health Act 1984
5) Occupational Safety and Health Regulations 1996
6) WA Electrical Requirements

L.2 Australian Standards and Guidelines

1) AS 2067: Substations and High Voltage Installations exceeding 1 kV a.c.
2) AS 4799: Installation of Underground Utility Services and Pipelines within Railway Boundaries
3) AS 6947: Crossing of Waterways by Electricity Infrastructure
4) AS/NZS 7000: Overhead Line Design – Detailed Procedures
5) HB 331: Overhead Line Design Handbook
6) AS/NZS 3000: Electrical Installations (Wiring Rules)
7) ENA EG-0: Power System Earthing Guide –Part 1 – Management Principles: May 2010