	ELECTRICITY NETWORKS Asset Strategy and Performance Functional Scope	

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1.0	04.04.2016	Original	E. Green
1.1	19.04.2016	Updated ACRs	E. Green
1.2	06.01.2017	Updated based on GSB and WND installations	E. Green

1 Project overview

This project scope covers the migration of the Castlemaine zone substation (**CMN**) system to a resonant earthed network. Migration to a resonant network requires the installation and operation of a ground fault neutraliser (**GFN**). This changes the electrical operating characteristics of a zone substation and its distribution network as follows:

- full voltage displacement occurs on the system for operation of the GFN;
- this significantly stresses equipment on the system and may lead to failure;
- this equipment has been identified and included in this scope for replacement as part of the GFN installation; and
- other limitations will dictate part of the operational protocols that will be developed by Electricity Networks.

The GFN provides potential benefits to single-phase-to-ground faults on the 22kV three phase system. It provides no benefit on the following:

- the 12.7kV Single Wire Return System (**SWER**);
- the 66kV sub-transmission system; and
- the low voltage (**LV**) system.

1.1 Background

The Victorian Government has introduced changes to the Bushfire Mitigation Regulations that require distribution businesses with high voltage (**HV**) overhead assets in high bushfire consequence areas to meet new performance standards for detection and limiting of arc fault energy. These standards can only be achieved using rapid earth fault current limiters (**REFCLs**).

A REFCL is a network protection device, normally installed in zone substations that significantly reduce the arc fault energy generated during a phase to ground fault. The reduction in arc fault energy can be so effective that earth fault fire ignition on 22kV three phase networks is almost eliminated.

The Bushfire Mitigation Regulations mandate that REFCLs must provide the required capacity—required capacity means, in the event of a phase-to-ground fault on a polyphase electric line, the ability:

- to reduce the voltage on the faulted conductor in relation to the station earth when measured at the corresponding zone substation for high impedance faults to 250 volts within 2 seconds; and
- to reduce the voltage on the faulted conductor in relation to the station earth when measured at the corresponding zone substation for low impedance faults to:
  - 1900 volts within 85 milliseconds; and
  - 750 volts within 500 milliseconds; and
  - 250 volts within 2 seconds; and
- during diagnostic tests for high impedance faults, to limit:
  - fault current to 0.5 amps or less; and
  - the thermal energy on the electric line to a maximum I^2t value of 0.10;

  where:

- high impedance faults means a resistance value in ohms that is equal to twice the nominal phase-to-ground network voltage in volts;
- I^2t means a measure of the thermal energy associated with the current flow, where I is the current flow in amps and t is the duration of current flow in seconds;

- low impedance faults means a resistance value in ohms that is equal to the nominal phase-to-ground network voltage in volts divided by 31.75; and
- polyphase electric line means an electric line comprised of more than one phase of electricity with a nominal voltage between 1 kV and 22 kV.

1.2 Castlemaine zone substation

CMN zone substation is located on the corner of Elizabeth Street and Johnstone Street, Castlemaine. The substation has two 25/33MVA transformers in a fully switched configuration, meaning that the installation includes 22kV transformer and bus tie circuit breakers.

Table 1 CMN: existing characteristics (zone substation)

Zone substation	Volume
Feeders	5
Zone substation transformers	2
22kV buses	2
Capacitor banks	1
Station service transformers	1
22kV circuit breakers (switching configuration)	8 (fully switched)

Table 2 CMN: existing characteristics (network)

Network	Volume
Total route length (km)	906
Underground cable length (km)	19
Overhead line length (km)	888
Underground network (%)	2.1
Overhead single phase (km)	460
Estimated network capacitance (A)	111
Distribution transformers	1,922
HV regulator sites	3
Fuses	2,086

Network	Volume
ACRs	5
Surge arrestor sites	2,054
HV customers	5

2 ZSS requirements

This functional scope sets out the CMN zone substation requirements, including the following:

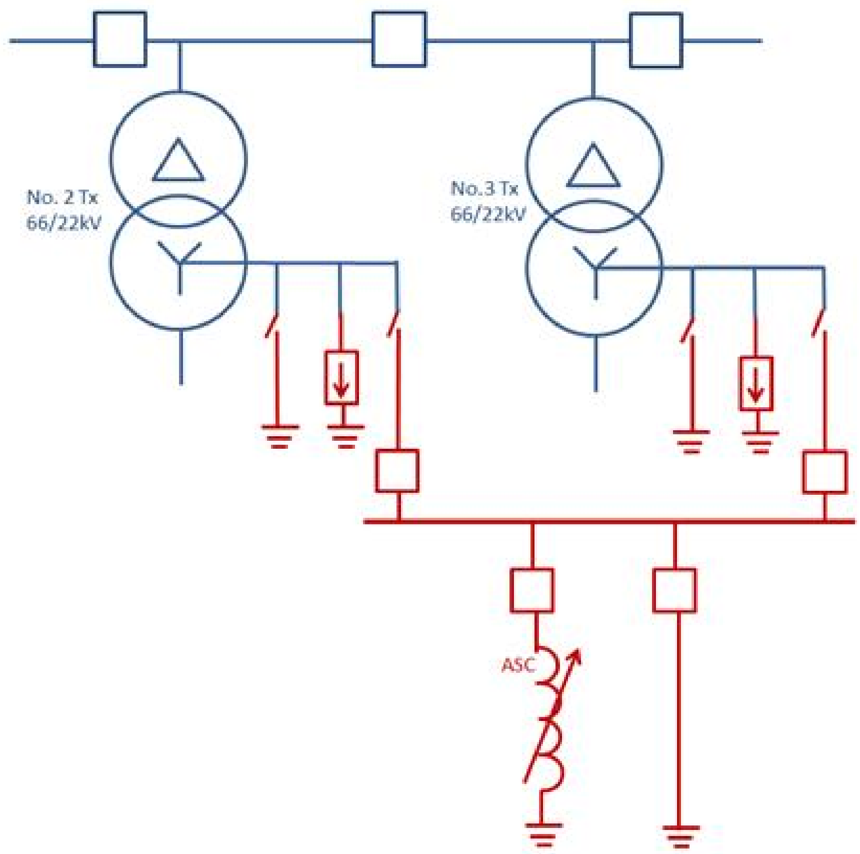
- Establish ASC bunds
- Install single Swedish Neutral GFN Arc Suppression Coil
- Modification of the 22/66kV transformer earthing arrangement
  - Installation of Neutral Bus System
    - Four (4) Bus CBs
    - ASC Terminations
    - Neutral VT installation
  - Installation of neutral ground bypass isolators
  - Installation of 19kV surge arresters across transformer neutrals
- Replace station service supply transformers with two (2) new 500kVA kiosk transformers.
- Upgrade of the station service supply cabling and installation of new AC distribution board with auto-changeover scheme
- Replace ALL substation surge arrestors with new 22kV continuous voltage units for resonant network compatibility and 10hr 24kV TOV capability
- Development and Installation of the Master Earth Fault (MEF) and Neutral Bus Management Relay
  - Adoption of existing MEF function
  - Neutral Voltage supervision
  - Neutral Bus CB Management functions
- Development and Installation of the Station Earth Fault Management Relay
  - Operating mode selection
  - GFN remote controls
  - Automate fault detection handling
  - Request fault confirmations consistent with operating mode
  - Trip faulted zones consistent with operating mode
  - Bypass ASC
  - Provide local controls and indications
- Upgrade five (5) SEL-351S 22kV Feeder Protection Relays to IEC compatible units
- Install & Commission GFN control and RCC inverter cubicles
- Modification of existing Capacitor Bank
  - Remove HV earth from star point
  - Install new Current Balance protection
  - Install new CB Management relay incorporating overcurrent & earth fault functions
- Install new Elspec Power Quality Meter

- Modification of existing substations communications network configuration
  - Install new RSG 2100 Ethernet Switch
  - Install two (2) new Fortigate 60 Firewall units.

2.1 Primary plant requirements

The works associated with the installation of the CMN ASC is summarised in the following single line diagram.

Figure 1 CMN single line diagram



2.1.1 Arc suppression coil

Install Swedish Neutral - Ground Fault Neutraliser's Arc Suppression Coil (ASC) component. The ARC suppression coil is a paper wound copper coil wrapped around a solid iron core and immersed in oil. This arc suppression coil is of fixed reluctance but contains an array of capacitors in parallel that are switch as part of the tuning process of the coil. The coil also features an LV winding for coupling of these capacitors and the Residual Current Compensator.

Primary neutral and earth connections are via elbows.

As oil filled device, it shall be installed in a bunded area in accordance with current standards. The total volume of oil will be made available once the coil size has been confirmed.

The GFN ASC shall be installed between the existing 66kV and 22kV switchyards.

- install Ground Fault Neutraliser comprising of 200A ASC and residual current compensation module with maximum available tuning steps onto the provided pad mount within a newly established bunded area;
- the footing of the ASC shall reside on the installed 150mm steel beams fixed to the concrete pad; and

- install cable connections to and from the Neutral System.

2.1.2 Zone substation surge arrestors

The operating principle of the GFN uses a tuned reactance to choke fault current in the event of a single-phase-to-ground fault. As a result, displacement of the line-to-ground voltage occurs in the healthy phases. Whilst line-to-line voltages remain at 22kV, the line-to-ground voltage rises to 22kV, phase-to-ground, on the two healthy phase's subsequently stressing substation and distribution equipment. In the case of surge diverters, this displacement cannot be tolerated and as such the diverters require replacement.

To accommodate the GFN installation:

- replace all sub-standard zone substation surge arresters with a station class 22kV continuous voltage arrestor; and
- install station class 19kV surge arresters across the transformer neutrals.

2.1.3 Zone substation capacitor bank

The existing No.3 22kV Capacitor Bank comprises of two (2) 4.5MVAR externally fused banks with earthed neutrals. There is no existing neutral balance protection. CTs on the neutral feed into the MEF and BUEF relays.

To facilitate GFN installation, the earth must be removed from the capacitor bank. The star point shall be reconfigured as a floating neutral, and the neutral structure re-designed with a continuous insulation rating of 13kV in the case of a neutral rise during REFCL operation on ground fault.

2.1.4 Neutral system arrangement

A kiosk type Neutral Bus system shall be installed alongside the ASC. The neutral bus system comprises of four (4) circuit breakers to facilitate transformer neutral earthing while the ASC is out of service and as independent isolation of transformer neutrals in case of an internal fault.

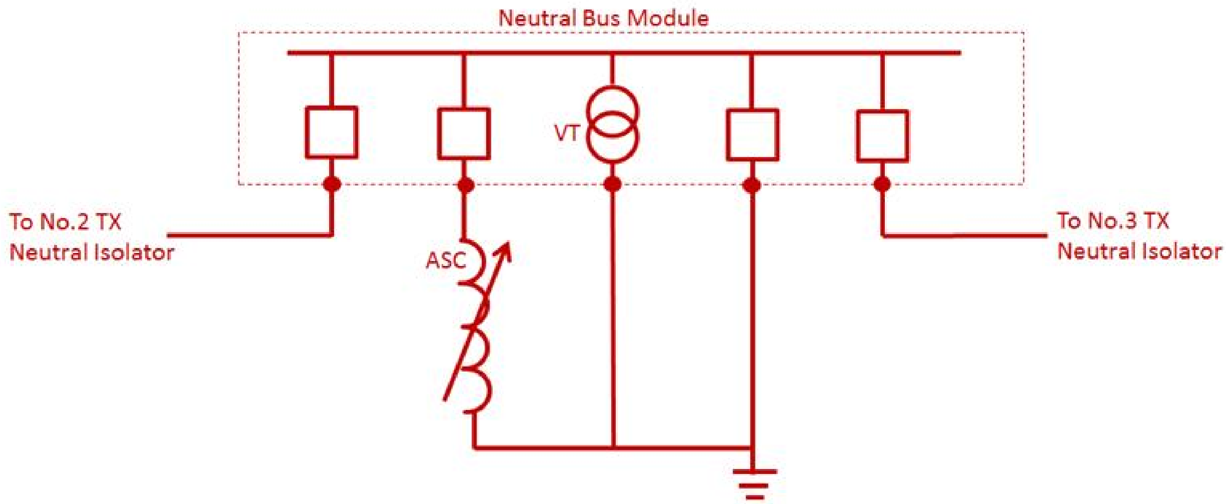
The purpose of this arrangement is to provide a simple switching configuration that offers the following combinations within one kit:

- solid grounding;
- ASC in service; and
- independently isolating each transformer neutral.

Neutral bus

A kiosk type Neutral Bus system shall be installed alongside the ASC. The neutral bus system comprises of four (4) circuit breakers to facilitate transformer neutral earthing while the ASC is out of service and as independent isolation of transformer neutrals in case of an internal fault.

Figure 2 Neutral bus module



Neutral Voltage Transformer

A neutral VT shall be included in each of the Neutral Bus modules. The neutral VT shall be 0.5M 1P at 15VA.

2.1.5 Transformer earthing

The two (2) 66/22kV 25/33 MVA transformers in service at CMN are delta/star connected with both neutrals solidly earthed.

The neutral earthing arrangement for each transformer shall be modified as to incorporate the following parallel connections:

- earth connection via isolation switch;
- surge diverter rated at 19kV (must be able to withstand 12.7kV neutral voltage under earth fault conditions); and
- neutral bus module connection via circuit breaker.

2.1.6 Neutral surge diverter

As the 66/22kV Transformers at CMN are outdoors, neutral surge diverters are to be installed.

Install and connect a Station Class 19kV surge diverter between the transformer neutral bus and the substation earth grid. The surge diverters should be connected as close to the transformer neutrals as possible.

2.2 Civil works requirement

For neutral systems:

- install concrete foundation pad for neutral system module;
- install neutral cable conduit, control cable conduit and provision for solid earth grid connections;
- install neutral cable conduits from transformers to neutral bus;
- install conduits to GFN system; and
- install conduits for secondary circuits.

For ASCs:

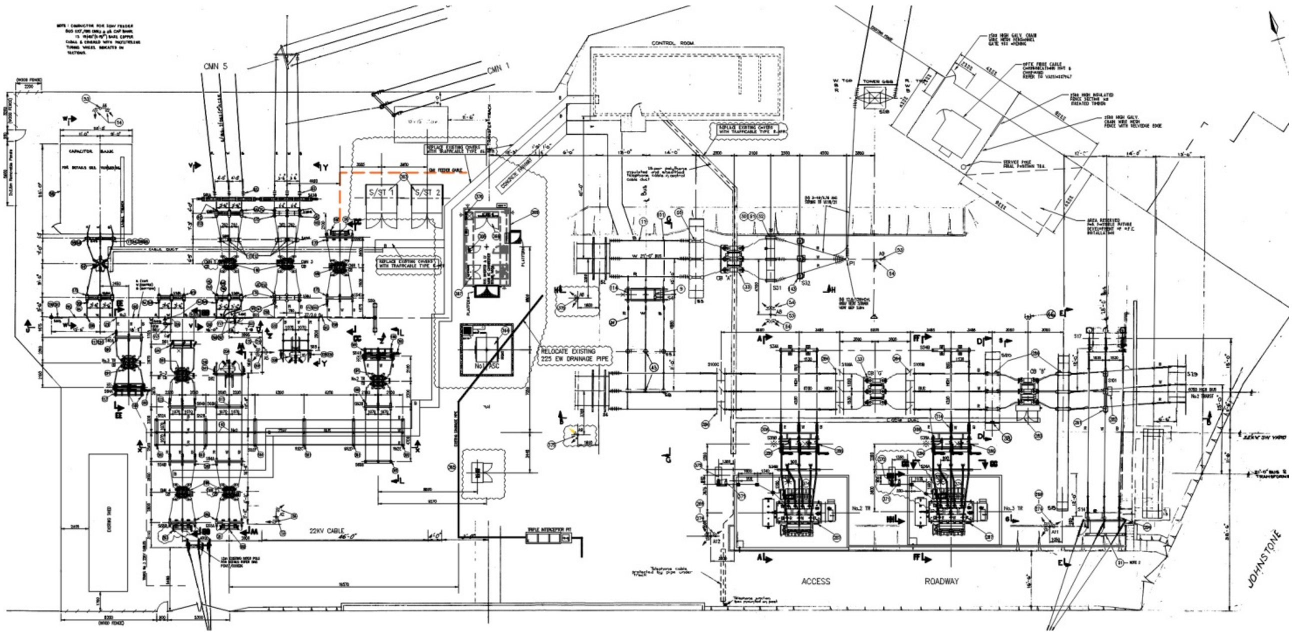
- install neutral cable conduit, control cable conduits and solid earth grid connections;

- pour concrete foundation;
- install steel beam, 150mm high at a width designed to accommodate the placement of the GFN Arc Suppression coil; and
- install bunding to EPA requirements.

For station service supplies:

- install concrete foundation pad for two (2) new 500kVA kiosk transformers;
- install conduits from No. 2 22kV bus to new station services transformer No.1;
- install conduits from No. 3 22kV bus to new station services transformer No.2;
- LV cables from each transformer to be run to the new AC changeover board; and
- concrete footing for new outdoor auto changeover board.

Figure 3 Proposed CMN substation layout



2.3 Secondary works

The following outlines the Protection and Control requirements.

All secondary drawings shall be in the wiring schematic format consistent with the existing suite of drawings for the station.

2.3.1 Protection Schemes

Cub 15 and 16 – 22kV Feeder Relays

CMN has five (5) old model SEL-315S Feeder Management Relays which are not IEC61850 compatible. Replace five (5) existing SEL-351S relays with new model SEL-351S relays which are IEC61850 compatible.

The new SEL-351S Feeder Management Relays shall have the following updates to their configuration:

- relays shall be configured with directional control capability for all phase, neutral and earth fault elements;

- relays shall be configured to receive external protection trip initiations from the GFN control unit via GOOSE; and
  - these GOOSE initiations shall drive auto reclose functionality direct to lockout through the internal 79DTL function.

22kV Feeder CT contributions are required by the GFN zero sequence bus admittance calculations.

To facilitate the GFN connection, install an extra set of neutral links on feeder link rack to permit the installation of the I0 connection off to the GFN controller.

Cub 17 – No.3 22kV Capacitor Bank Protection

The existing SEL-351S No.3 Cap Bank Prot & Mgmt Relay shall be subject to the following updates:

- relay shall be reconfigured with directional control capability for all phase, neutral and earth fault elements;
- relay shall be reconfigured to provide external protection trip initiations from the GFN control unit;
- relay shall be reconfigured (firmware upgraded) to enable IEC61850 settings to be applied to enable the GFN control unit to instruct breakers to trip if required; and
  - these GOOSE initiations shall drive auto-reclose functionality direct to lockout through the internal 79DTL function.

Existing CTs on the capacitor banks earthed star point shall be retired given that the capacitor bank will have a floating neutral under the new configuration.

Cub 18 - 22 kV CB Management

Cubicle No.18 contains the three (3) SEL-351S relays:

- No.2 Trans CB Management & X CB Fail Relay
- 2-3 BT 22kV CB Management & X CB Fail Relay
- No.3 Trans CB Management & X CB Fail Relay

Each of these relays shall be reconfigured (firmware upgraded) to enable IEC61850. 22kV Feeder CT contributions are required by the GFN zero sequence bus admittance calculations.

Cub 21 – Earth Fault Protection

X-MEF and Neutral Bus Management Relay

The existing 2C138 MEF relay shall be replaced with a modern IED relay, GE F-35, to allow flexible control of feeder earth protection.

A GE F-35 relay shall be installed and configured as the X MEF and Neutral Bus Management relay. The relay will execute and manage the following functions;

- Master Earth Fault relay for NER/direct earth in service applications
- Neutral Voltage Supervision
- Neutral CB Management

The new F-35 X-MEF and Neutral Bus Management shall be installed in the existing MEF and BUEF cubicle No.21.

Station Earth Fault Management Relay

Install a SEL-451 Station Earth Fault Management Relay in order to perform the automated control of the GFN's installed at the substation.

The relay will manage the following functions

- Operating mode selection
- GFN remote controls
- Automate fault detection handling
- Request fault confirmations consistent with operating mode
- Trip faulted zones consistent with operating mode
- Bypass ASC
- Provide local controls and indications

The new SEL-451 Station Earth Fault Management shall be installed in the existing MEF and BUEF cubicle No.21.

Y Master Earth Fault, Neutral Overvoltage and Common Backup Earth Fault Protection

The existing SEL-351 shall remain as the Y MEF and Common BUEF protection relay. The relay shall also incorporate station 22kV and neutral VTs and be configured to provide neutral voltage protection and supervision. BUEF shall be supressed when GFN is in service.

2.3.2 Ground Fault Neutraliser

Control Unit

The GFN control unit is a single cubicle comprising of:

- GFN Master Control module
- GFN Slave Control Module
- Windows Based PC utilising proprietary NM Term software
- All VT and feeder I0 CT terminations
- All trip link outputs
- RCC Inverter and ASC Interface
- Panel Meters

CMN zone substation will only require one (1) GFN controller as it will not require a split bus operation.

Powercor will request through their specification process that the control unit be constructed within a 850mm wide cubicle. Each cubicle will contain an interface controller in the form of a SEL-2440 DPAC control unit in the top 2U of this cabinet. This control unit will be used to interface controls to the Station Earth Fault Management relay.

VT Supplies (R,W,B & VN) are required from bus into the GFN controller along with Feeder and Transformer neutral summation (IN) circuits.

Inverter

The inverter to power the GFN shall be housed in an air-conditioned outdoor hut which includes isolation switches and grid balancing capacitors. The hut shall be located alongside the arc suppression coil.

The Residual Current Compensation technique used by the GFN requires an Inverter to inject current into the ASC via an auxiliary winding. The inverter must be sized to displace the full capacitive current drawn by the system and as a result requires significant power.

The performance specification calls for a 0.5A fault current sensitivity. GFN sensitivity is determined by two main factors:

- system damping; and

- capacitive dissymmetry.

According to Network Planning Load Estimates, the size and future growth of CMN does not suggest any issues in meeting this threshold with 1 ASC.

2.3.3 Protection settings

A protection review shall be undertaken by Network Protection and Control of all schemes within CMN zone substation with particular reference to earth fault schemes on the 22kV network:

- SEL-351S relays will have configuration changes to introduce:
  - directional SEF functionality;
  - GOOSE (via GFN) tripping capability;
  - auto reclose integration of GFN initiated trips;
  - GOOSE message isolation function;
- the station REF configuration shall be reviewed for GFN integration;
- the station MEF and BUEF schemes shall be reviewed for GFN integration; and
- review of transformer differential scheme.

An application for backup Voltage Displacement shall be considered.

2.3.4 Protection relay configurations

Powercor Network Protection and Control will make standard relay configuration files available to the Service Provider where appropriate. Given the nature of this project, the service provider must expect that this project will have non-standard requirements.

2.3.5 Metering requirements

Power Quality Meter

The existing ION 7700 Power Quality Meter is to remain undisturbed.

An ELSPEC Power Quality and Data recorder shall be installed in Cubicle 23.

This recorder is capable of recording 16 analogue & 32 digital channels of data at a sampling rate of 1000 samples per second. 12 months of data can be captured and stored internally using a patented algorithm.

The ELSPEC shall be installed to capture bus voltage, neutral voltage and bus incomer currents (ie transformer and bus tie contribution currents). The purpose of this recorder is to aid with GFN commissioning, long term monitoring and compliance reporting.

Cubicle 22 and 24 contains the existing No.2 and No.3 Low Impedance Bus Distance relays. Use the spare cubicle No.23 in close proximity to the distance protection CT circuits that may be utilised by the ELSPEC Power Quality meter.

Connectivity to the ELSPEC meter to be fibre 100BASE-FX Ethernet to a new switch in Cubicle 28.

2.3.6 Control and monitoring requirements

Remote Control and Monitoring of new:

- Modified SEL-351S Feeder Protection Relay Configurations
- X MEF, Neutral Voltage & Neutral System CB Management Relay UR F35
- GFN Controller
- ELSPEC Power Quality recorder

- Cap Bank CB Management Relay
- Transformer No. 2 22kV CB Management Relay
- Transformer No. 3 22kV CB Management Relay
- 22kV 2-3 BT CB Management Relay

Shall be via DNP 3.0 with DNP Maps provided to the SCADA group and produced by the service provider in conjunction with Network Protection and Control.

Powercor SCADA group are responsible for developing a suite of ENMAC control pages in conjunction with the Network Operations group and Network Protection and Control.

2.3.7 Communications Requirements

Ethernet Connectivity

All communications shall be over 100 BASE-FX (optic fibre) Ethernet back to the zone substation Sub-LAN RSG-2100 Ethernet switches. Preferably, devices maintain duplicated Ethernet connectivity either through an internally "switched" architecture or a preferred and failover arrangement.

Tripping from the GFN to the feeder CB's will be over IEC 61850 via an interface module built into the GFN control cubicle. For this reason, the architecture for Ethernet communications shall change to eliminate "loops" that emanate from the sub-LAN switch.

The CMN communications network shall be reconfigured to include:

- Install Gigabit backbone connection back to the existing CMN-RSG2100-01 and CMN-RSG2100-02
- Install fibre connections from GFN Interface controller (SEL-2440)
  - all Port 5A connections to CMN-RSG2100-01
  - all Port 5B connections to CMN-RSG2100-02
  - ensure relay configurations modified to Port Failover configuration
  - ensure Sub-LAN switch architecture configured to support fail over scenario's
- Two (2) new firewalls, CMN-IDG-01 and CMN-IDG-02, of identical hardware and firmware installed in cubicle No. 28 (existing CMN-IDG-01 to be retired to stores, this hardware is no longer available)
- New RSG2100 Ethernet switch, RSG2100-12, installed in cubicle No.28.
- Install Gigabit backbone connection back to the existing CMN-RSG2100-11 and CMN-RSG2100-12
- Point-to-point fibre connection between RSG2100-11 and RSG2100-12 through the following IEC-61850 enabled IEDs:
  - five (5) new SEL- 351S Feeder Management Relays
  - two (2) SEL-351S Trans 22kV CB Mgmt Relays
  - SEL-351S 22kV BT CB Mgmt Relay
  - SEL-351S 22kV Cap Bank CB Mgmt Relay
  - SEL-2440 GFN Interface Controller
  - F35 Station Earth Fault Management Relay

See figures below for further information.

Figure 4 Proposed communications system layout

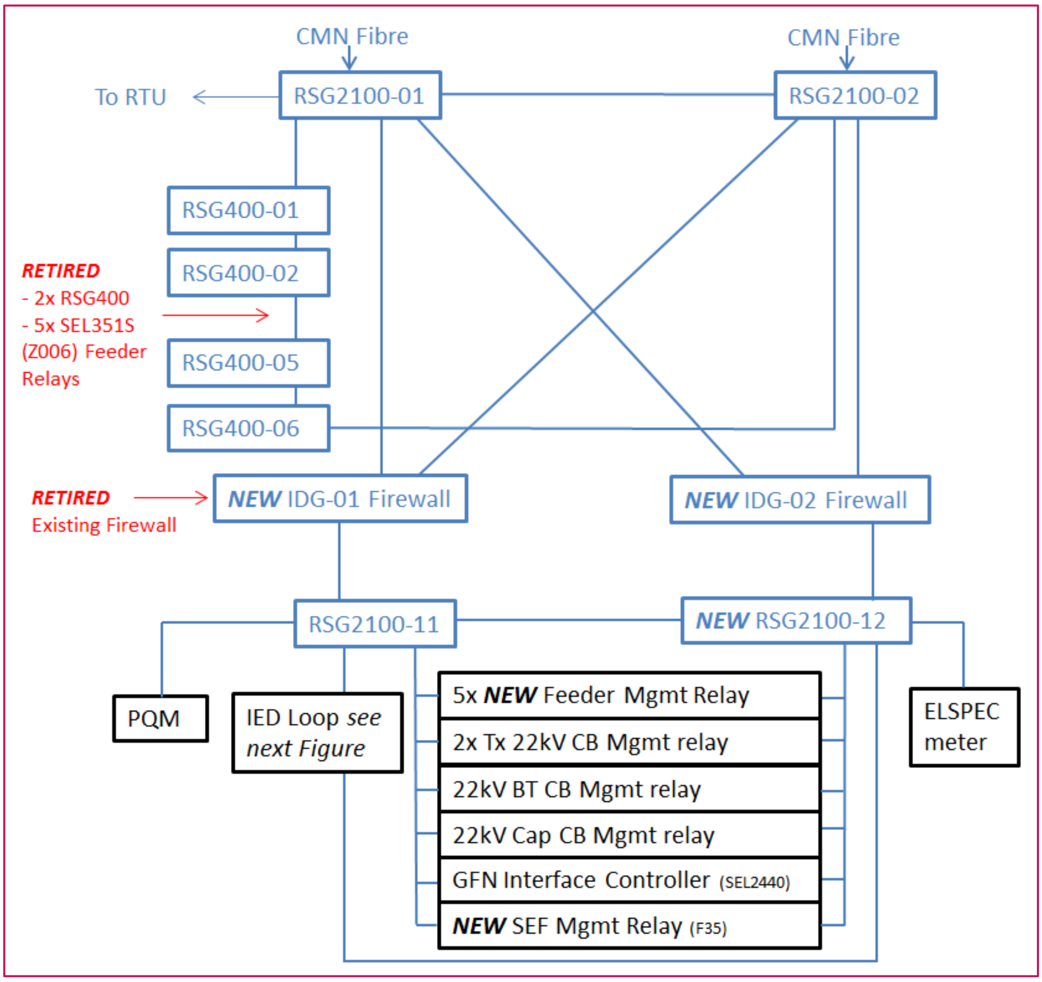
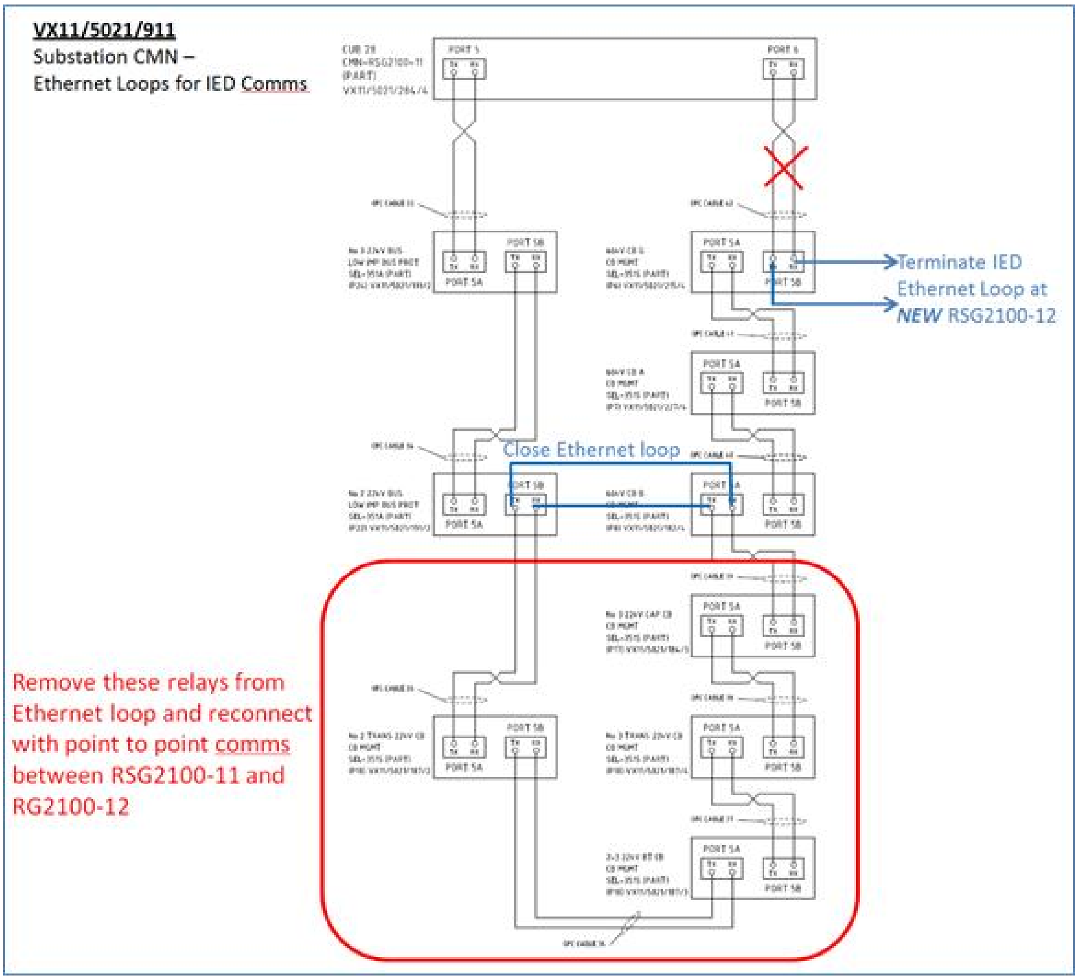


Figure 5 IED loop required changes



Engineering Access

Powercor SCADA shall ensure remote engineering access is available to select members of the Network Protection and Control group. Remote access is required to all sub-LAN connected devices including protection relays, data recorders and GFN controller.

Time Stamping

A new GPS clock shall be installed for use by the new Elspec meter.

2.3.8 415/240 AC supplies

The two (2) existing 63kVA station services supply transformers are located on the No. 2 and No.3 22kV outdoor buses.

The sizing of theses station service transformers is an inadequate capacity for the RCC inverters used to drive faulted phase voltage to zero via the Arc Suppression Coil.

Given CMN is a fully switched station, there must be capacity to supply the RCC from either the No.2 or No.3 22kV bus so that a single 22kV bus outage does not cause loss of RCC function. As such, both station services transformers shall be upgraded to 500kVA kiosks.

The following upgrades shall be made to the station services system:

- retire both existing 63kVA Station Services transformers
- take supply from No.2 22kV bus to new No.1 500kVA kiosk substation via underground cable
- take supply from No.3 22kV bus to new No.2 500kVA kiosk substation via underground cable
- upgrade existing station AC board, incoming mains and change over schemes such that they are compliant with existing standards.
- install AC supplies for the GFN inverter to meet its specifications.

A changeover board shall be such that secure supply is available for GFN Inverters. The AC Supplies shall be connected onto an AC Changeover supply board configured to detect loss of AC volts on the preferred supply and changeover automatically no longer than 500ms after supply loss is detected.

2.3.9 DC supplies

The battery capacities shall be verified as being of adequate capacity to supply the station standing load and any CB operations that could occur within a 10 hour period following loss of AC Station Service supplies.

Documentation must be provided that demonstrates the battery amp-hour rating chosen has been sized for the load and the duty of the load. Calculations and appropriate documentation must be provided to demonstrate compliance with IEEE – 485 "IEEE Recommended Practices for Sizing Lead Acid Batteries for Stationary Applications".

The existing 24V and 120V chargers will need to be shifted slightly towards the switch room door to make way for the GFN RCC Inverter cabinets which will sit either side of the Row 2 cable trench against the wall at the 22kV switch room end of the control room.

2.3.10 Station design

As a minimum the secondary design documentation shall include:

- 22kV Station Schematic Diagram
- Protection, Control, Instrumentation and Alarm data schedules
- Control room layout and elevation of cubicles
- Cubicle Layouts
- Wiring schematics/diagrams for individual protection, control and metering schemes
- DC supply schematics
- Remote control equipment and associated data schedules
- Labelling for cubicles and all slide link terminals
- Manufacturer and interface drawings for the Ground Fault Neutraliser equipment.

The latest modular design concepts shall be used as far as practical for this project.

2.3.11 Powercor control centre SCADA works

A new series of Control System Pages shall be created for the GFN interface. Consultation between SCADA, Operations and Network Protection and Control is required to establish these pages.

2.3.12 Fibre optic cable

Fibre optic patch leads are required for Zone Substation Sub-LAN Ethernet communications.

These optic fibres shall be of OM1 62.5/125um type.

2.3.13 Radio

No radio communications are required.

2.3.14 Building and property considerations

Yard lighting

Switch yard lighting shall be reviewed to ensure adequate coverage of the ASC, Neutral System.

Fire suppression

The ASC winding is immersed in oil. A review of its design and the amount of contained oil is required to determine if any fire suppression assets are required.

3 22 kV distribution feeder requirements

3.1 Surge diverters and insulation limitations

The operating principle of the GFN uses a tuned reactance to choke fault current in the event of a single-phase-to-ground fault. As a result, displacement of the line-to-ground voltage occurs in the healthy phases. Whilst line-to-line voltages remain at 22kV, the line-to-ground voltage rises to 22kV, phase-to-ground, on the two healthy phase's subsequently stressing substation and distribution equipment. In the case of surge diverters, this displacement cannot be tolerated and as such the diverters require replacement.

To accommodate the GFN installation:

- replace approximately 3,104 surge diverters across the 22kV three phase and single phase system. This covers all feeders ex CMN ZSS;
- surge arrestors beyond inter-station open points shall also be upgraded to permit transfer of loads with the GFN in service; and
- the replacement diverters should be of 22kV continuous rating with a 10 hour 24kV TOV rating.

CitiPower and Powercor standard surge diverters are the ABB MWK 20 and POLIM D 20 arresters. These do not meet the overvoltage requirement needed for use with a GFN and therefore the higher rated arresters are required.

These surge diverters will be a new standard, applicable to distribution systems with a GFN installed.

3.2 Distribution transformers

Operation of the GFN displaces the neutral voltage of the entire 22kV system from the bus to the outer extremities of the feeders. This is different from an NER arrangement, when displacement is at its highest for a fault on the 22kV bus, and decreases for faults occurring down the feeders.

During GFN commissioning, voltage offset testing will simulate the voltage displacement that will occur for a single-phase-to-ground fault (22kV phase-to-ground).

1. Some distribution transformers may not be in a condition to withstand the overvoltage and will subsequently fail during the voltage offset testing
2. Some distribution transformers may fail following repeated subjection to sustained over-voltages caused post commissioning due to normal operation of the GFN

At this time, experience from network resilience (voltage stress) testing at GSB and WND does not support a proactive replacement of any distribution transformers.

3.3 Line insulators

As is the case above for distribution transformers, line insulators are also susceptible to premature failure caused by the repetitive over-voltage stresses.

Similar to Distribution Transformers, at this time, experience from the network resilience testing does not support a proactive replacement of any line insulators.

3.4 Line regulators

Single phase open-delta-connected Cooper regulators displace the system neutral voltage by regulating line-line voltages on two phases as opposed to three.

Closed-delta independent regulator control schemes tap each regulator independently, a similar displacement to the neutral voltage occurs, as per the open-delta mode.

All regulator works shall be compliant with current CitiPower and Powercor standards for 22kV regulators.

For all regulators on the CMN network, controls shall be upgraded to a CL7 control unit such that:

- all units regulate and tap together in a master follower style scheme:
  - for ground mount option, a three phase CL7 module shall be employed;
  - for “adjacent pole option”, single phase CL7 running communicating over fibre optic can be used;
- each tank tap position is monitored and fed back into an out-of-step control circuit:
  - out-of-step logic shall lock out automatic control within 90 seconds of detection.

All alarms and controls shall be integrated into SCADA

The CMN 22kV distribution network contains three (3) 22kV regulating systems.

3.4.1 Strangways P8 Reg 1

Strangways P8 Regulator has two (2) single phase 100A regulators connected in an open delta configuration. The regulator scheme shall have a third 100A regulator tanks installed and be reconfigured as a closed delta system.

3.4.2 Chewton (Elphinstone) P115A Reg

Chewton P115 A and B Regulators have a single 200A regulator on each pole resulting in an open delta regulator configuration. The regulator scheme shall be upgraded to a closed delta configuration.

3.4.3 Newstead P175 Reg

Newstead P175 and P175A Regulators have a single 200A regulator on each pole resulting in an open delta regulator configuration. The regulator scheme shall be upgraded to a closed delta configuration.

3.5 Admittance balancing

The ground fault neutraliser uses a tuned inductance (Petersen Coil / Arc Suppression Coil) matched to the capacitance of the distribution system. The 3 phase 22kV distribution system from CMN zone substation contains approximately 766km of overhead conductor length (excluding SWER). Of this, 227km is single phase. Whilst planning philosophies have always attempted to balance the single phase system, inevitably this is difficult to achieve. In order to balance the capacitance of the three phase system such that the ASC can be correctly tuned, balancing substations will be placed at nodes on the system that utilise low voltage capacitors to inject the missing capacitance onto the system.

Note: Balance does not refer to the balancing of load. System balance is required from a capacitance-to-ground perspective and affected by route length and single phase connected distribution equipment.

A reconciliation of all 22kV overhead and underground lines routes shall be conducted to assess the scope of the network balancing requirements.

The following steps shall be outworked prior to GFN installation;

1. Consolidate all “Single Phase” and “unknown” conductor into the “BR”, “RW” or “WB” categories
   (i) validate “Single Phase” and “unknown” conductor where required
   (ii) spot check the validity of current phasing information
2. Consolidate all single phase transformers on the 22kV system and assign to one of the “BR”, “RW” or “WB” categories
3. Ascertain the construction types for all sections
   (i) indicate whether LV subsidiary exists
4. Consolidate all “1 Phase” and “unknown phase” 22kV cable and assign phase information

5. If single phase circuits are used underground, ascertain the design principles behind the single phase underground sections
   (i) conductor type, two or three core?
   (ii) treatment of the unused core (earthed or phase bonded)—if bonded, to what phase?

The course balance shall look at sections of the system in 'switchable blocks' and for any re-phasing and finite admittance balancing opportunities in order to balance out the single phase route lengths and large single phase spurs where the capacitance is fairly easy to approximate.

A tuneable balancing approach shall then look at the system again in switchable blocks for the application of 3-phase admittance balancing substations.

The use of 3-phase admittance balancing substations will provide accurate capacitive balancing in each section. Admittance balancing substations shall be placed at the following locations to enable switching of balanced blocks of the system. These locations are listed below:

Table 3 3-phase balancing unit locations

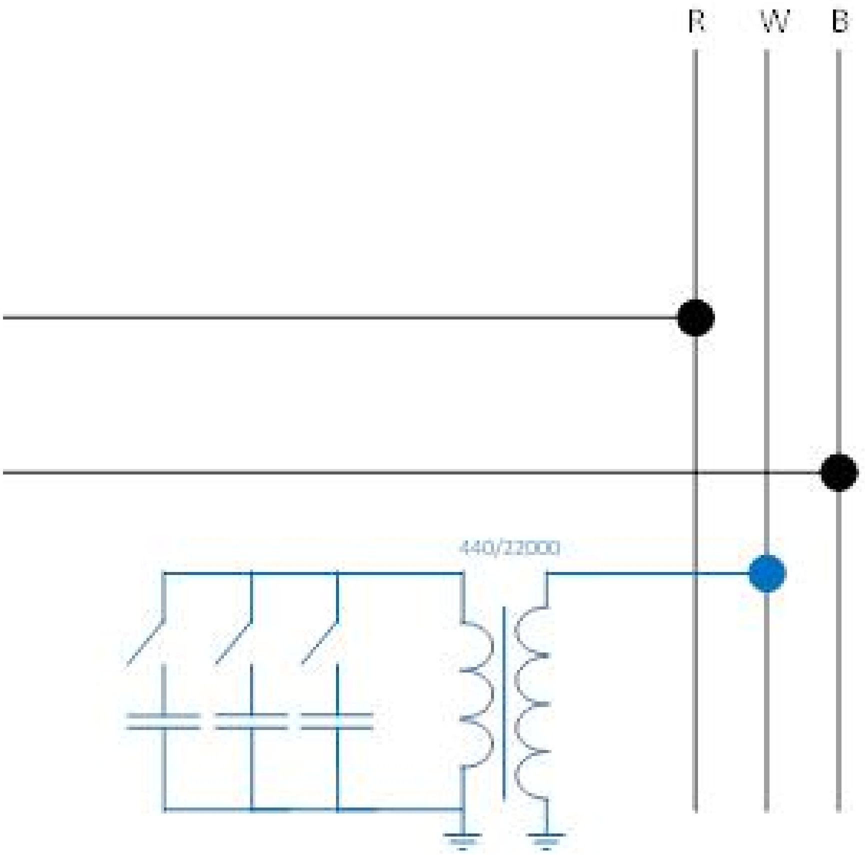
Location (1)	Location (2)	Location (3)
Chewton P1	CMN3 Feeder exit	Sutton Grange 1
Chewton P12	Harcourt P34	Metcalfe 6
Chewton P55	Industrial Tie P52	Franklinford 69
Guilford P20A	Newstead Maldon P1AE	Drummond North 1
Chewton P28	Newstead P28R	Harcourt 200
Guilford P69	Maldon P86	Drummond 21
Wattle Gully Chewton Tie	CMN5 Feeder exit	Harcourt 148
Newstead P1	Industrial P31	Maldon 180
Newstead P93	Butterworth CMN 2 Tie P3	Sutton Grange 35
Strangways P6	Newstead 93	South Harcourt 2

The design of these admittance compensating banks involves the use of the following:

- single phase 22kV/480V pole mount transformer:
  – one HV bushing to be solidly earthed and run at 12.7kV nominal;
  – SWER transformer considered but will not cope with the 22kV TOV requirements;
- control box consisting of:
  – appropriate MCB;
  – 400V LV capacitor cans, individually switched in series and/or parallel to achieve required capacitance; and

– required telemetry and monitoring over 3G.

Figure 6 Capacitive balancing unit



The blended approach to admittance balancing is designed to cater for the historical use of single phase spur lines, single phase cable and the variability in capacitive balancing. The number of re-phasing sites, single phase balancing units and 3 phase balancing units are also informed by experience of GSB and WND and scaled to the relative network parameter of this substation.

Table 4 Balancing requirements summary

Balancing concept	Number of sites
Re-phasing Sites	34
Single Phase Balancing Units	8
3 Phase Balancing Units	30

3.6 Automatic Circuit Reclosers (ACRs) and remotely controlled gas switches

Each RVE or VWVE ACR on the CMN network should be replaced with the current standard Schneider N27 ACR which has inbuilt voltage measurement.

Table 5 ACR replacements

Name	Operating voltage	Phase code	ACR model
Spring Gully P67C	22kV	RWB	VWVE27

Each ACR or remote controlled gas switch requires a modern control box which has required programmable functions and up to date firmware. ACR and gas switch control box replacements are required (for CAPM5 or GCR300 control boxes) in order to:

- automatically detect REFCL operation and prevent incorrect operations de-energising customers;
- provide advanced fault locating algorithms capable of detecting REFCL fault confirmation tests; and
- continue to operate in the traditional manner automatically when REFCL is not in operation.

Table 6 Control box replacements

Name	Control box model
MALMSBURY P139	PTCC-CAPM5
CARPENTER-SPR-GULLY P11A	PTCC-CAPM5
STRANGWAYS P6	PTCC-CAPM5

Table 7 ACR and control box requirements summary

Units	Number of sites
ACR replacements	1
Control box replacements	3

3.7 Fuse savers

HV Fuses pose a difficulty in operating a network with a REFCL. Maintaining capacitive balance is critical in the network, and scenarios that result in 1 or 2 out of 3 fuses blowing in a 3 phase section, such as phase-phase faults can result in large capacitive imbalances. This depends on the size of the downstream network. These imbalances can result in loss of REFCL sensitivity, REFCL maloperations resulting in widespread outages or REFCL backup schemes operating to remove the REFCL from service.

Fuse Savers are to be installed as a 3 phase ganged unit such that when any individual phase operates for a fault, all 3 phases open in unison de-energising a balanced section of the network regardless of the fault type.

Fuse Savers are required to operate for any fused section with a downstream network capacitive charging current of 540 mA or greater.

Table 8 Fuse saver requirements

Units	Number of sites
Fuse savers	40

3.8 HV underground cable

Experience from REFCL testing has shown that a percentage of HV underground cable is likely to experience failure due to elevated phase to earth voltages experienced in a resonant network. An allowance for cable failure is to be made for the transition to resonant earthing.

Table 9 HV underground cable requirements

Location	Length (m)
Cable failure length	626

3.9 Distribution switchgear

Overhead distribution switchgear has been shown to be largely resilient to the phase to earth over-voltages experienced in a resonant network. There is no planned replacement of these assets.

Resilience testing has shown that Felten and Guilleaume ground mounted kiosk switchgear is not capable of withstanding 24.2kV phase to earth voltages. The inherent design and construction of these units preclude them from any repair works and as such must be replaced.

Table 10 Felten and Guilleaume switchgear replacements

Location	Kiosk Size
Pyrenees-Rilens	315 kVA
Alanna Chapmans	315 kVA

3.10 HV customer isolation substations

The Electricity Distribution Code stipulates that at the point of connection to a customer on the 22kV network, the phase to earth voltage must be no greater than 80 per cent for up to 10 seconds.

In order to maintain compliance with the code, the installation of HV isolation substations is required.

The service provider is to ensure that the detailed design of these installations considers:

- a star-star-delta (Ynyn0d) vector group transformer with the load side star point earthed and source side star point unearthed is required to provide the isolation
- isolation substation to be sized appropriate for the total size of the customer's load, taking into account any generation
- voltage control requirements for the customer is likely to require tap changing capability for larger customers
- station service supply via the tertiary winding to provide supply to protection, metering and control circuitry
- appropriate HV source side protection to protect for faults in the substation transformer
- appropriate HV load side protection to protect for faults between the substation and customer protective devices
- note that customer protection is in some cases not at the point of connection and there is a risk of sensitive earth faults
- bunding and other environmental considerations for substations
- undergrounding of any electrical conductor between the isolation substation and customer connection

HV customer connection sizes are set out in table 11.

Table 11 Isolation Substations

Size	Quantity
2 MVA	4
10 MVA	1

4 Appendix A: primary works overview