CITIPOWER	**ELECTRICITY NETWORKS** **Asset Strategy and Performance** **Functional Scope**	Powercor AUSTRALIA

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Project RO	Dene Ward	Ex:	4747		
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Version	Date	Changes	Responsible Officer
1.0	31.03.2016	Original	V. Hadya
1.1	06.01.2017	Updated based on GSB and WND installations	V. Hadya

1 Project overview

This project scope covers the migration of the Colac zone substation (**CLC**) 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 Colac zone substation

Colac Zone Substation is located at the corner of Colac-Forrest Rd and Forest St, towards the eastern edge of the Victorian town of Colac. The substation was originally built as a 'banked' substation with no 22kV transformer or bus tie circuit breakers. The existing 22kV arrangement did not allow for future expansion into a 3 transformer fully switched substation without significant modifications. The substation was converted into a 'partially switched' substation with the installation of two new 25/33 MVA transformers in 2013.

Table 1 CLC: existing characteristics (zone substation)

Zone substation	Volume
Feeders	7
Zone substation transformers	3
22kV buses	3
Capacitor banks	2
Station service transformers	1
22kV circuit breakers (switching configuration)	9 (banked)

Table 2 CLC: existing characteristics (network)

Network	Volume
Total route length (km)	1,323
Underground cable length (km)	35
Overhead line length (km)	1,288
Underground network (%)	2.6
Overhead single phase (km)	567
Estimated network capacitance (A)	182
Distribution transformers	2,267
HV regulator sites	12

Network	Volume
Fuses	2,544
ACRs	19
Surge arrestor sites	2,467
HV customers	9

2 ZSS requirements

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

- establish ASC bunds;
- installation of two (2) Swedish Neutral GFN Arc Suppression Coils;
- modification of the 66/22kV transformer earthing arrangement:
  - installation of Transformer Neutral Isolators and Direct Earth Switches;
  - installation of 19kV surge diverters on transformer neutrals;
  - installation of Neutral Bus System:
    - bus CB's;
    - NER terminations;
    - ASC Terminations;
    - neutral VT Installation;
- upgrade station service supply to two (2) new 750kVA kiosk transformers with changeover board;
- upgrade of the station service supply cabling and installation of new AC distribution board;
  - install current limiting fuses on AC distribution boards;
- 22kV Bus Modifications:
  - installation of new 22kV 2-3 Bus Tie CB;
  - reconfigure existing No.1 Transformer CB to No.2 Transformer CB;
  - installation of 22kV Switchroom to house:
    - installation of new 22kV 1-2 Bus Tie CB;
    - installation of new No.1 Transformer CB;
    - installation of new No.1 Capacitor Bank CB;
- installation of two (2) new 22kV VT's;
- replace ALL substation surge arrestors with new 22kV continuous voltage units for resonant network compatibility and 10hr 24kV TOV capability;
- installation of Station Earth Fault Management control relay:
  - GFN Interface control;
  - operating mode management;
- installation of Neutral Bus Management Relay:
  - adoption of existing MEF function;
  - neutral Voltage supervision;
  - neutral Bus CB Management functions;
- install and Commission two (2) GFN control and two (2) RCC inverter cubicles;
- review and Modify secondary systems to accommodate split bus arrangement:
  - install new independent transformer and voltage control schemes;

- replacement of existing Capacitor Bank due to space constraints:
  - install new modular 12 MVAr Capacitor Bank;
  - install new Current Balance protection;
  - install new CB Management relay incorporating overcurrent and earth fault functions;
  - install new station VAR controller;
- installation of new CB Management relays:
  - 1-2 22kV Bus Tie CB;
  - 2-3 22kV Bus Tie CB;
  - No.2 Transformer CB;
- installation of Bus Protection Relays to accommodate split bus arrangement:
  - no.1 22kV Bus X Low Impedance Bus Protection;
  - no.1 22kV Bus Y Bus Distance Protection;
  - no.2 22kV Bus X Low Impedance Bus Protection;
  - no.2 22kV Bus Y Bus Distance Protection;
  - no.3 22kV Bus X Low Impedance Bus Protection;
  - no.3 22kV Bus Y Bus Distance Protection;
- modify existing HMI and HMI RTU; and
- install new Elspec Power Quality Meter.

2.1 Primary plant requirements

The works associated with the installation of the CLC ASC & NER arrangement is summarised in the following single line diagrams.

Figure 1 Existing Colac 22kV and neutral schematic

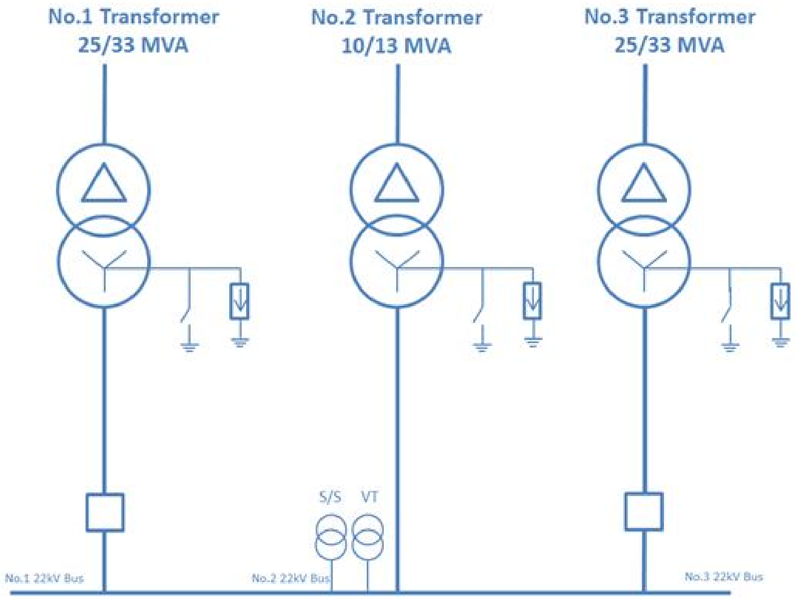
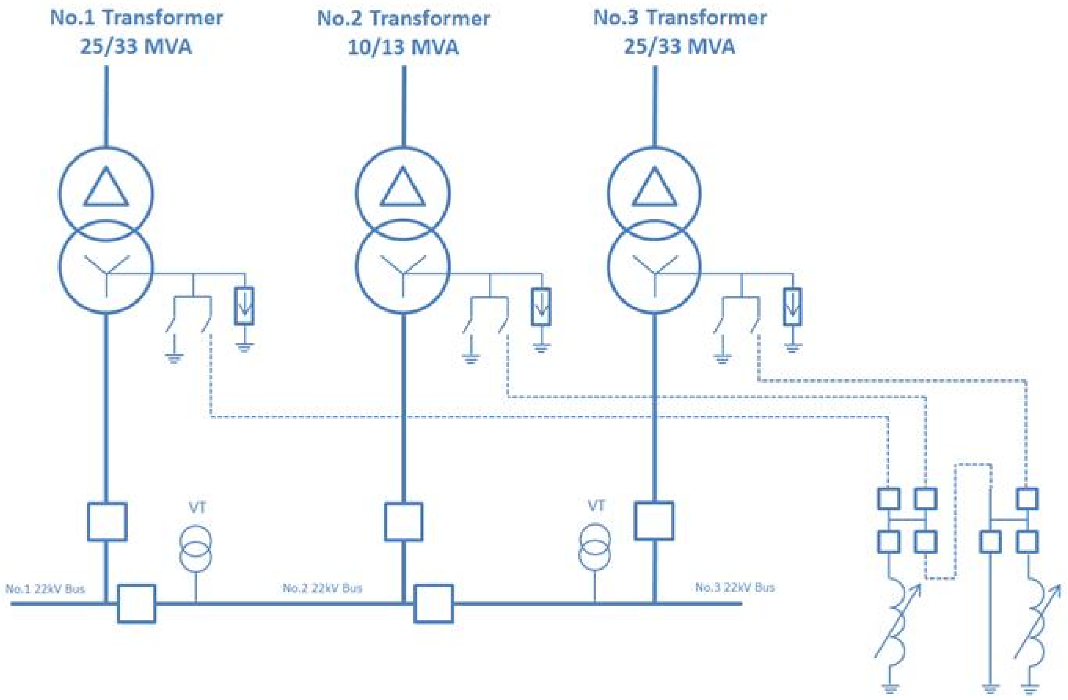


Figure 2 New Colac 22kV and neutral schematic



2.1.1 Ground bypass isolators

For each transformer neutral earthing, install a ground by pass isolators at the transformer. This is required in the case that the neutral bus is to be taken out of service, transformer neutrals can be earthed by closing these ground by pass isolators.

2.1.2 Arc suppression coil

Install two (2) 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 an 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's shall be installed in the location of the existing No.1 Capacitor Bank:

- install Ground Fault Neutraliser comprising of 2x 200A ASCs and residual current compensation modules 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.

2.1.3 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.

2.1.4 Zone substation capacitor bank

The existing No.1 22kV Capacitor Bank is located alongside the 22kV Outdoor Bus. This space was previously required for future bus extensions and is now required for REFCL components, the Arc Suppression Coils and Neutral Bus Modules. The Capacitor Bank also requires modification works to take it from a grounded star connection to an ungrounded star with an insulation rating of not less than 13kV. In addition to this, neutral balance CT's required replacement to ensure that current balance protection could be installed.

To accommodate GFN installation,

- replace existing No.1 Capacitor Bank with a new modular capacitor bank located alongside the existing No.3 Capacitor Bank; and
- the No.1 and No.3 Capacitor Banks are to be connected with the Station Service Transformers and as such require step switches on all 4 steps to ensure that CB switching of the capacitor bank does not result in station service outages. This will require an additional step switch for the No.3 Capacitor Bank.

2.1.5 Neutral system arrangement

A new kiosk type ground mounted Neutral Bus system shall be installed for each transformer neutral connection. The neutral bus system allows for integration of the ASC, a potential NER with bypass or direct earth onto the transformer neutral. In the case of CLC, connecting the bus systems in series allows for common and split 22kV bus operation.

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 (NER CB Open) on a common bus; and
- ASC in service (NER CB open) on a split bus (bus tie open).

Install 2 x Neutral Bus Modules – type A and type B1 alongside the Arc Suppression Coils.

Neutral Bus

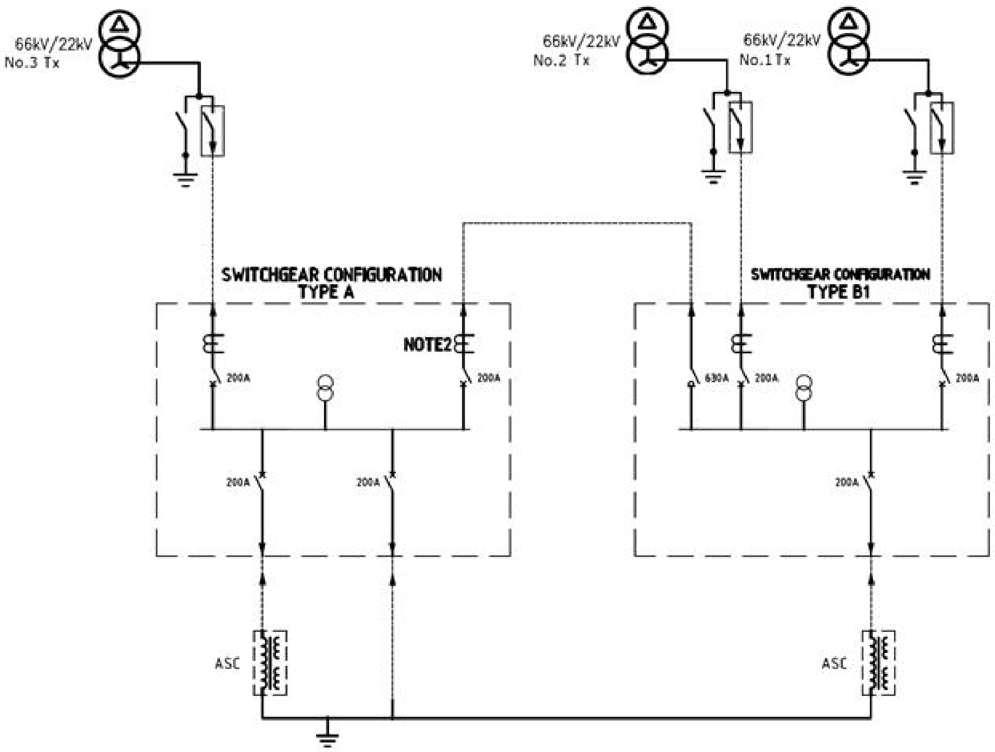
The connection to the Neutral Bus module shall be via elbow connections. Four (4) elbows are required per module for:

- transformer neutral connection;
- ASC connection;
- NER connection; and
- bus tie connection.

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.

Figure 3 Proposed CLC neutral system single line diagram



2.1.6 Transformer Earthing

The two 66/22kV, 25/33 MVA and the 10/13 MVA transformers in service at CLC are delta/star connected with the neutral of the star windings directly earthed.

The neutral earthing arrangement shall be modified to incorporate the new earthing arrangement (refer SLD) with connection to the ASCs. The transformer neutral shall have a new HV insulated single phase cable installed underground from the new Neutral Bus isolator (enclosed in a lockable cage) through to HV elbow connections on the Neutral Bus modules.

External earth receptacles are required if any air cable boxes are used.

2.1.7 Neutral surge diverter

As the 66/22kV Transformers at CLC 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.

2.1.8 22kV bus arrangement

GFN sensitivity

The Colac 22kV Network consists of an estimated 1,287km of overhead line and 34.7km of underground cable. This leads to a network charging current of approximately 180 amps. To meet the sensitivity requirements of the GFN, it is recommended that the network be limited to 120 amps. This is a result of a sensitivity analysis surrounding a number of unknown parameters in the CLC network. In order to achieve this, the 22kV network must be rearranged, to cater for the ability to 'split' the buses.

The following requirements are necessary to split the CLC 22kV buses:

- 22kV Bus Tie Circuit Breakers are required between each of the 3 22kV Buses to physically split the 22kV buses and provide CT measurements for bus protection zones required for the GFN fault detection schemes in a split bus arrangement;
- 22kV Transformer Circuit Breaker is required for the No.2 Transformer in order to complete the transformer and bus protection zones;
- 2 x 22kV VT's are required for transformer parallel control and GFN operation with the buses split; and
- 2 x Station Service Transformers are required to ensure that the GFN Inverter is available following any single fault. To prevent de-sensitising the bus protection scheme, these station service transformers shall be connected beyond the No.1 and No.3 Capacitor Bank CB's.

66kV works

In order to assist installation of the extended GFN Inverter room to the east of the 66kV Bus, the 66kV CDN Line Entry must be relocated:

- relocate CDN 66kV Line Entry as shown in the proposed General Arrangement in figure 5.

22kv works

In order to arrange the substation in such a way that the 22kV bus can be split, appropriate protection zones exist for the GFN fault detection schemes the following works are required.

<u>Extended GFN Inverter Room and Switchroom</u>

- Install extended GFN Inverter Room and 22kV Switchroom with 22kV Switchboard:

  - switchboard is to be sourced with 7 positions, (Bus-Tie CB, Joggle, Transformer CB, Cap Bank CB and 3 spare positions). Future developments at the substation must fund any additional equipment (feeder circuit breakers) if required; and
  - switchboard to be similar to current or recent standards for 22kV switchboards, refer Technical Standards Group.

Station Service and Capacitor Banks

- Install new 750kVA 22kV No.1 Station Service Kiosk Transformer alongside new No.1 Capacitor Bank:
  - Station Service Kiosk to include 3-way RMU to allow for cable in and cable out to Capacitor Bank;
  - Refer WND Station Service Transformer for specifications;
  - Connect to AC Changeover Board within GFN Inverter Room;
- Install new 750kVA 22kV No.3 Station Service Kiosk Transformer alongside existing No.3 Capacitor Bank
  - Station Service Kiosk to include 3-way RMU to allow for cable in and cable out to Capacitor Bank
  - Refer WND Station Service Transformer
  - Connect to AC Changeover Board within GFN Inverter Room
- Install new 22kV Cable to connect No.1 Station Service Kiosk to No.1 Cap Bank CB in new switchboard
- Install new 22kV Cable to connect No.1 Capacitor Bank to No.1 Station Service Kiosk
- Install new 22kV Cable to connect No.3 Station Service Kiosk to existing No.3 Cap Bank CB
- Install new 22kV Cable to connect No.3 Capacitor Bank to No.3Station Service Kiosk

Transformer and Bus Tie

- Install new 22kV Cable from No.1 Transformer to new No.1 Transformer 22kV CB in new switchboard
- Install new 22kV Cable from No.2 Transformer to existing outdoor No.1 Transformer 22kV CB
- Decommission existing No.1 Capacitor Bank CB
- Install new 22kV Cable from existing No.1 Bus Extension to new 1-2 Bus Tie CB in new switchboard
- Install new 22kV Voltage Transformer on existing No.1 Bus Extension with HV Fuses:
  - Construction: 5 limb, 3-phase
  - Vector group: YNyn0yn0
  - Ratio: 22000/110/110
  - Output: 100VA per phase per secondary
  - Accuracy: Class 0.5M1P
  - SAP material ID: 381684
- Install new 22kV Voltage Transformer on existing No.3 Bus with HV Fuses in place of the existing 2-3 Bus Tie Isolators
  - Construction: 5 limb, 3-phase
  - Vector Group: YNyn0yn0
  - Ratio: 22000/110/110
  - Output: 100VA per phase per secondary

  - Accuracy: Class 0.5M1P
  - SAP material ID: 381684
- Install new 22kV Bus Tie CB in the location of the existing 1-2 22kV Tie Bus (also called Service Bus)
  - Technical Specification ZT104.01 (22/33 Outdoor Dead Tank Circuit Breaker) to be followed
  - 2000A Continuous Rating, 20kA Fault Break Rating, 120V DC for CB Operation
  - 4 x 3 phase 1600/1200/900/600A : 5A Winding Ratio's
  - CT Class 0.2PL100R0.3 on 300/5
  - 2 CT's required on either side of CB
  - SAP Material ID: 354230 for Schneider VOX CB as an example

22kV bus naming

The large scale changes to the 22kV yard require that consideration is given to the naming of plant in the substation from an operational perspective. This is critical from a healthy and safety perspective as well as from an operational

Nameplates in the 22kV Yard must be reviewed and any that do not conform with the new naming of primary plant must be replaced.

- Review nameplates of all 22kV Circuit Breakers, Buses, Isolators, Disconnect Switches, Earth Points and Cables.

All Primary and Secondary drawings must be reviewed and any that do not conform with the new naming of primary plant must be updated.

- Review all drawings with references to 22kV Circuit Breakers, Buses, Isolators, Disconnect Switches, Earth Points and Cables.

No.1 22kV Bus

- The newly installed indoor bus shall be named the No.1 22kV Bus

No.2 22kV Bus

- The existing No.1 22kV Bus and No.1 22kV Bus Extension are to be renamed the No.2 22kV Bus and No.2 22kV Bus Extension

No.3 22kV Bus

- Removal of existing 2-3 Bus Tie Isolators results in the existing No.2 and No.3 22kV Buses being permanently connected and renamed No.3 22kV Bus

Particular attention shall be given to the naming of primary plant items in the operational systems to ensure that any naming changes in the field are updated in the operational software such that switching instructions are correct when printed. This requires coordination between the field works, the SCADA group and network operations.

Figure 4 Existing general arrangement

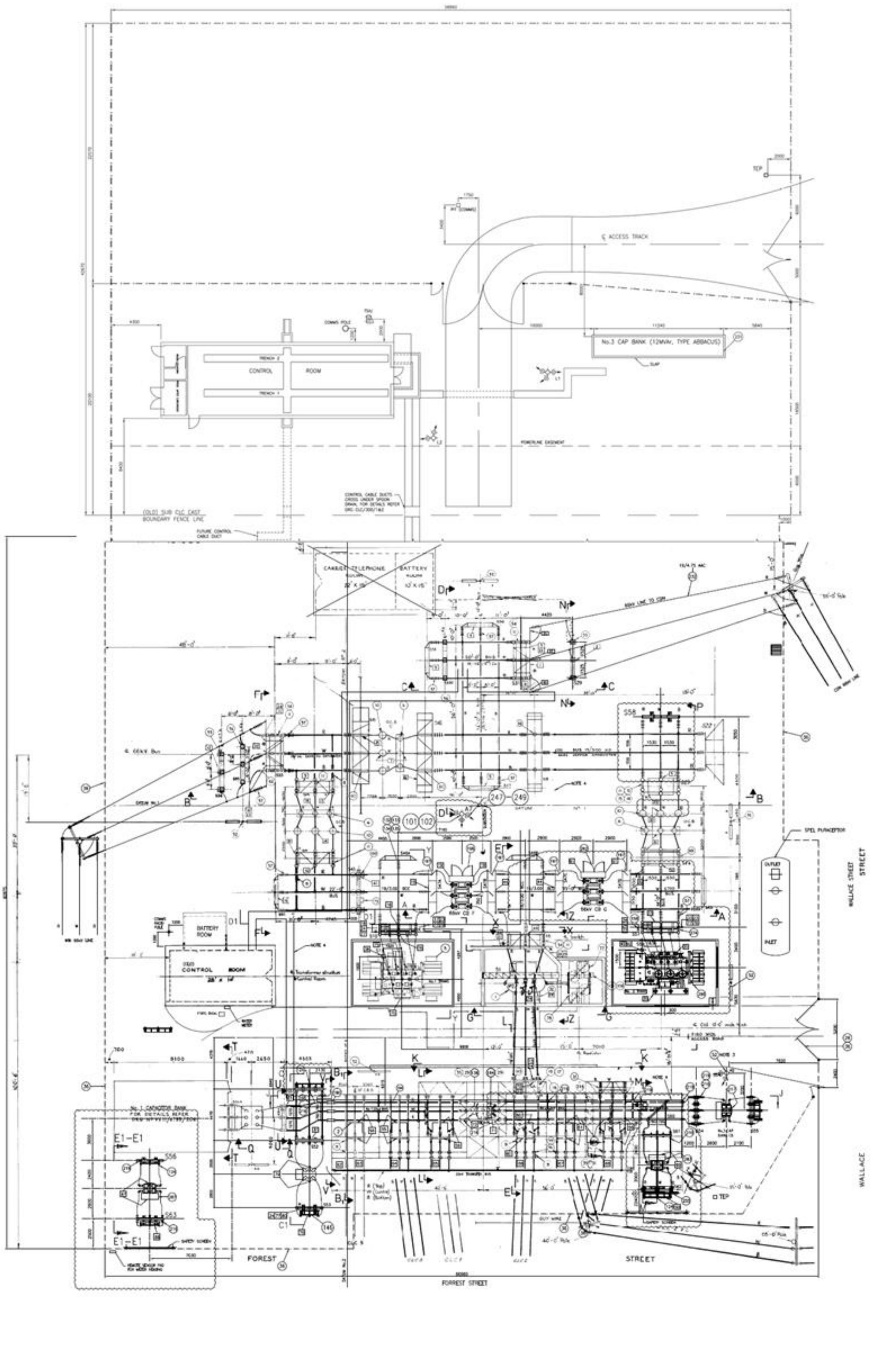
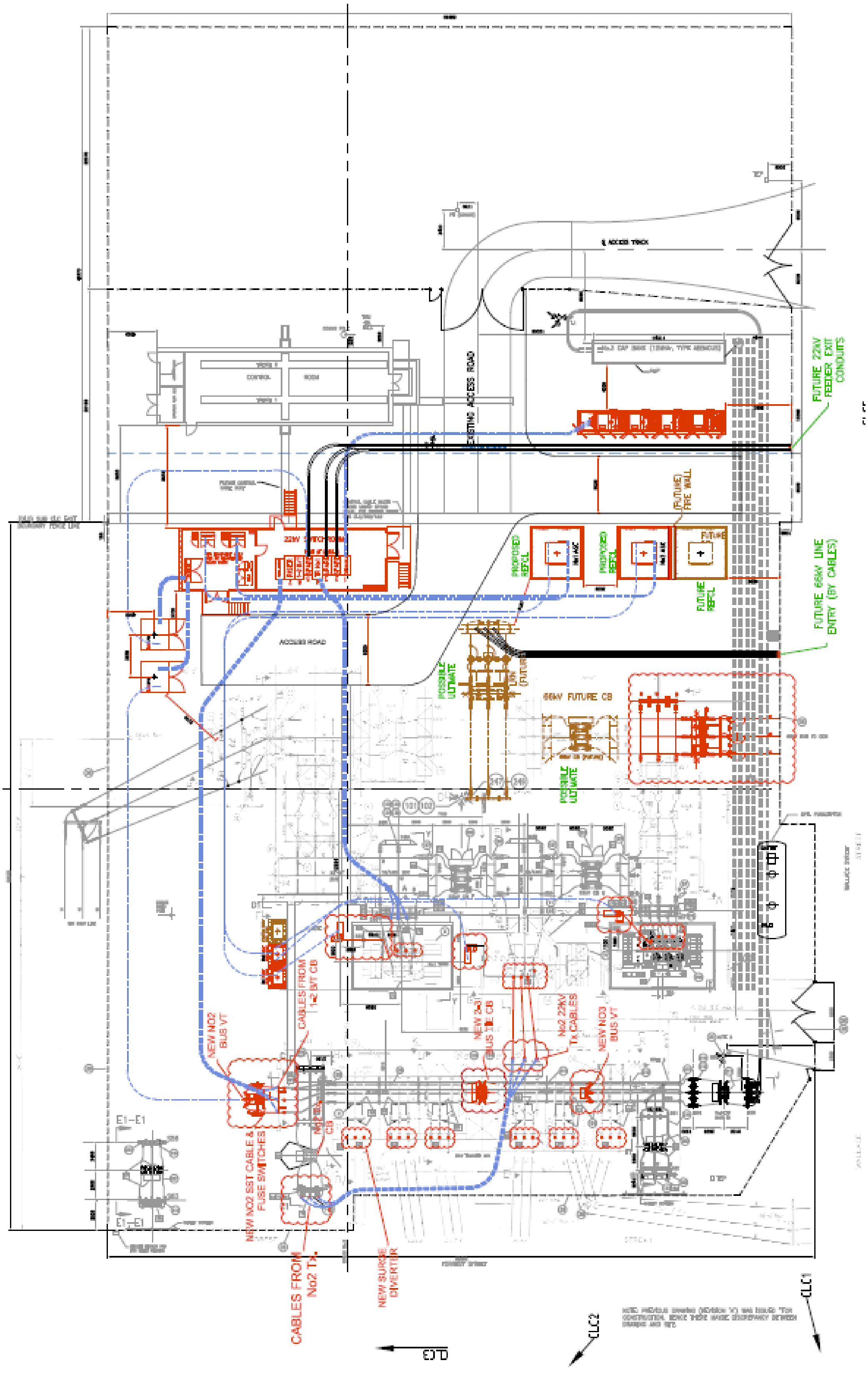


Figure 5 Proposed general arrangement



2.2 Civil works requirement

For neutral systems:

- install concrete foundation pad for neutral system modules
- install neutral cable conduit, control cable conduit and provision for solid earth grid connections
- install neutral cable conduits from transformers to neutral system modules
- install conduits to ASCs and solid earth grid connection
- 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
- install bunding to EPA requirements.

For station service supplies:

- install concrete foundation for new station service transformers
- install HV cable conduit to new No.1 Capacitor Bank
- install HV cable conduit to existing No.3 Capacitor Bank
- install HV cable conduit to new switchroom
- install HV cable conduit to existing No.3 Capacitor Bank CB

For new 22kV 2-3 Bus Tie CB:

- install concrete footings for new 22kV CB
- install control cable conduits for new 22kV CB

For new 22kV No.1 and No.3 Bus VTs:

- install concrete footings for new structures
- install control cable conduits for No.1 and No.3 22kV VT's

For capacitor bank:

- install concrete footings for new modular capacitor bank
- install control cable conduits for new modular capacitor bank

For extended GFN enclosure/switchroom:

- install concrete footings for new GFN Enclosure and switchroom
- land new GFN Enclosure and switchroom
- install HV cable conduits for No.1 Transformer Cable, No.1 Capacitor Bank, 1-2 Bus Tie Cable
- install control cable conduits to Control Room.

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 30 – No.1 Cap Current Balance Protection

The existing capacitor bank Neutral Balance protection must be modified to accommodate the removal of the No.1 Capacitor Bank earth connection from the neutral star point.

The existing 4 off relays performing RMS 2C138 Neutral Balance protection are to be replaced with 4 off Argus 7SR11 relays. These are to be installed in Cubicle 30 and configured to provide Current Balance protection. The service provider is responsible for the calculation of Current Balance settings in line with current standards for Current Balance protection on internally fused, unearthed star capacitor banks. The existing RTU cables are to be re-used for Current Balance alarms.

Cub 27 – X MEF and Neutral Bus Management relay

The existing RMS 2C138 relay in cubicle 27, currently performing X Master Earth Fault shall be replaced with a modern IED relay to allow flexible control of feeder earth protection and GFN integration. A GE F35 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 F35 MEF relay shall be installed in the existing No.1 and No.3 Capacitor Bank Current Balance protection cubicle, making use of existing space.

Cub 30 – SEL-451 Station Earth Fault Management

Install a SEL-451 Station Earth Fault Management relay in Cubicle (30) 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

Cub 23 and Cub 24 - 22 kV Feeder Protections

SEL-351S Feeder Protection Configuration:

- Relays shall be reconfigured with directional control capability for all phase, neutral and earth fault elements
- Relays shall be reconfigured to provide external protection trip initiations via IEC61850 GOOSE

- 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 5 – Transformer CB Management and CB Fail Relays

The installation of the new No.1 Transformer CB and repurposing of existing No.1 Transformer CB for No.2 Transformer requires modification/installation of the CB Management and CB Fail Relays for these two breakers.

- Review No.1 Transformer CB Management and CB Fail Relay (SEL-351S)
  - Connect to new No.1 Transformer 22kV CT's
  - Connect No.1 Bus VT
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-351S CB Management and CB Fail)
- Install No.2 Transformer CB Management and CB Fail Relay (SEL-351S)
  - Connect to No.2 Transformer 22kV CT's
  - Connect No.2 Bus VT
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-351S CB Management and CB Fail)

Cub 6 – No.1 Transformer Protection

The installation of the new No.1 Transformer CB requires modification of the No.1 Transformer protection to utilise the new CT contributions.

- Review No.1 Transformer Differential Protection (SEL-387E and 7UT612) and connect to new No.1 Transformer 22kV CT's

Cub 7 - No.2 Transformer Differential Protection

The existing 22kV Bus Protection is covered by the No.2 Transformer Differential Protection zone. This is to be modified to only cover the No.2 Transformer.

The introduction of the 22kV 1-2 Bus Tie CB impacts on the No.2 Transformer Differential Protection as it is currently configured to cover the entire 22kV bus as well as the No.2 Transformer. This must be modified to remove the No.1 22kV Bus CT contributions; utilising CT's in the new 22kV 1-2 Bus Tie CB.

- Review and reconnect No.2 Transformer Differential Protection (SEL-387E) to cover No.2 Transformer
  - Remove contribution from Feeder CT's and connect to No.2 Transformer CT
- Install No.2 Y Transformer Differential Protection (7UT612) to provide redundant protection for No.2 Transformer
  - Connect to 66kV CT's across 66kV CB F and 66kV CB 6 and across the No.2 Transformer CB

Cub 19 - No.1 Bus Protection

As mentioned above, the introduction of the 22kV 1-2 Bus Tie CB removes the No.1 22kV Bus from the No.2 Transformer Differential Zone. As such, new 22kV Bus protection is required.

- Install new cubicles in the cubicle 19, 20, 21 and 22 positions.
  - Cubicle 19 to be used for No.1 Bus Protection

- Cubicle 20 to be used for No.2 Bus Protection.
- Cubicle 21 to be used for No.3 Bus Protection.
- Cubicle 22 to be used for the new 1-2 Bus Tie CB Management and 2-3 Bus Tie CB Management relays.

- Install SEL-351A and associated MCB's and Link Rack in Cubicle 19 to perform Low Impedance Bus Protection
  - Summate feeder side CT's on any feeder CBs, transformer side CT on No.1 Transformer CB and cap bank side of No.1 Cap Bank CB as well as No.2 Bus Side CT of the new 1-2 Bus Tie CB. Use 900/5 CT ratio's on these CT's.
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-351A Low Impedance Bus Protection
- Provide No.1 22kV Bus Zero Sequence summation from the Low Impedance Bus Protection to the GFN Control Cubicles.
  - 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
- Install SEL-311C-1 relay and associated MCBs and link rack in Cubicle 19 to perform Single Zone Bus Distance Protection.
  - Summate transformer side CT on No.1 Transformer CB and No.2 Bus Side CT of the new 1-2 Bus Tie CB.
  - Connect No.1 Bus VT
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-311C-1 Single Zone Bus Distance.

Cub 20 – No.2 Bus Protection

The introduction of the 22kV 1-2 Bus Tie CB, 2-3 Bus Tie CB and No.2 Transformer CB necessitates the installation of redundant Bus Protection for the No.2 22kV Bus.

- Install SEL-351A and associated MCB's and Link Rack in Cubicle 20 to perform Low Impedance Bus Protection
  - Summate feeder side CT's on each feeder CB, transformer side CT on No.2 Transformer CB, No.1 Bus Side CT of the new 1-2 Bus Tie CB and No.3 Bus Side of the new 2-3 Bus Tie CB. Use 900/5 CT ratio's on these CT's.
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-351A Low Impedance Bus Protection
- Provide No.2 22kV Bus Zero Sequence summation from the Low Impedance Bus Protection to the GFN Control Cubicles.
  - 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
- Install SEL-311C-1 relay and associated MCBs and link rack in Cubicle 20 to perform Single Zone Bus Distance Protection.
  - Summate transformer side CT on No.2 Transformer CB, No.1 Bus Side CT of the new 1-2 Bus Tie CB and No.3 Bus Side CT of the new 2-3 Bus Tie CB.
  - Connect No.2 Bus VT
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-311C-1 Single Zone Bus Distance.

Cub 21 – No.3 Bus Protection

The introduction of the 22kV 2-3 Bus Tie CB necessitates the installation of Bus Protection for the No.2 22kV Bus.

- Install SEL-351A and associated MCB's and Link Rack in Cubicle 21 to perform Low Impedance Bus Protection
  - Summate feeder side CT's on each feeder CB, transformer side CT on No.3 Transformer CB and No.2 Bus Side of the new 2-3 Bus Tie CB. Use 900/5 CT ratio's on these CT's.
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-351A Low Impedance Bus Protection
- Provide No.3 22kV Bus Zero Sequence summation from the Low Impedance Bus Protection to the GFN Control Cubicles.
  - 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
- Install SEL-311C-1 relay and associated MCBs and link rack in Cubicle 21 to perform Single Zone Bus Distance Protection.
  - Summate transformer side CT on No.2 Transformer CB and No.2 Bus Side CT of the new 2-3 Bus Tie CB.
  - Connect No.2 Bus VT
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-311C-1 Single Zone Bus Distance.

Cub 22 – Bus Tie CB Fail and CB Management Relays

2 off SEL-351S CB Fail and CB Management relays shall be installed in Cubicle 22. They require the following to be wired to them—DC Supplies, Breaker DC Status (Breaker Statuses, Open, Closed, Safety Switch, Low Gas Alarm and Lockout etc.), Trip Circuit, Close Circuit, CT Circuit and Bus VT.

- Install 1-2 22kV Bus Tie CB Fail and CB Management Relay
  - Connect to CT's in the 1-2 22kV Bus Tie CB
  - Connect No.1 Bus VT
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-351S CB Management and CB Fail)
- Install 2-3 22kV Bus Tie CB Fail and CB Management Relay
- Connect to CT's in the 2-3 Bus Tie CB
  - Connect No.2 Bus VT
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-351S CB Management and CB Fail)

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 & feeder I0 CT terminations
- All trip link outputs
- RCC Inverter and ASC Interface

- Panel Meters

CLC zone substation will require two (2) of these controllers to permit 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.

The location of the GFN cubicle shall be in the vacant cubicle 31 and 32 positions.

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

Inverter

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 discussed earlier calls for a 0.5A fault current sensitivity. GFN sensitivity is determined by two main factors:

- system damping; and
- capacitive dissymmetry.

The current network size of CLC does not permit a 0.5A sensitivity using a single ASC. For CLC, two ASC's will be installed and the 22kV bus split when 0.5A sensitivity is required.

The inverter requirement is also quite large as it must have the power to counter balance the system damping and capacitance when in operation. Inverter sizing expected to be 320kVA for each ASC.

The inverters must be installed with appropriate cooling, and shall be housed within an air-conditioned enclosure, as indicated in the proposed general arrangement.

2.3.3 VT supplies

VT supplies from the new No.2 & No.3 Bus VT's are required to the GFN control units. For earth fault detection, an open delta (UN) input is required from the 22kV bus VT at 110V secondary. Swedish Neutral install internally to their control cubicle an open delta connected auxiliary transformer, as such no works beyond providing normal star connected VT supplies is required.

- Connect No.1 Bus VT to No.1 GFN
- Connect No.3 Bus VT to No.2 GFN

2.3.4 Protection settings

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

- SEL-351S relays will have configuration changes done by Network Protection and Control to introduce;
- GOOSE (via GFN) tripping capability
- Auto Reclose integration of GFN initiated trips
- GOOSE message isolation function

An application for backup Voltage Displacement shall be considered.

2.3.5 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.

2.3.6 Metering requirements

Cub 2 – Existing Power Quality Meter

The existing ION 7650 Power Quality Meter in Cubicle 2 is to be modified to meter the No.1 Bus Summation, removing the contributions from the No.2 and No.3 Transformers. This is to be done as the Cap Control RTU requires separate bus information to control the No.1 and No.3 Cap Banks in the split bus arrangement required at CLC zone substation.

SCADA must ensure that the Cap Control RTU scans this PQM, not the Station RTU.

Cub 2 – New Power Quality Meter

A new ION7650 Power Quality Meter is to be installed in Cubicle 2 as the No.2 and No.3 Bus Summation PQM. The CT circuits are to be wired such that this new No.2 and 3 Bus PQM summates the No.2 and No.3 Transformer currents.

SCADA must ensure that the Cap Control RTU scans this PQM, not the Station RTU.

Cub 3 – New ELSPEC Power Quality and Data Recorder

An ELSPEC Power Quality and Data recorder shall be installed in Cubicle 3.

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 (i.e. transformer and bus tie contribution currents). The purpose of this recorder is to aid with GFN commissioning, long term monitoring and compliance reporting.

Cubicle 3 contains the two ION 7650 PQM's as well as both bus VT's, use of these circuits is suggested for the ELSPEC Power Quality meter.

Connectivity to the ELSPEC meter to be fibre 100BASE-FX Ethernet to an RSG2100 sub-lan ethernet switch.

2.3.7 Transformer and Capacitor Bank (VAR) Control

The existing Transformer Control RTU and RMS-2V164-S Relays will not be able to handle the split bus arrangement required at Colac Zone Substation for the necessary sensitivity of earth fault detection. A SEL-451 Programmable Automation Controller shall be configured to perform independent voltage control of each bus in the split bus arrangement or traditional voltage control with the 22kV 1-2 Bus Tie closed. It will require installation of additional relays to provide the statuses, analogues as well as a pathway for controls.

The existing Cap Control RTU will be able to independently regulate the VAR's on each bus, however requires some modifications to be able to perform this. These are described in the following Capacitor Bank (VAR) Control section.

In order to enable the split bus arrangement, the following items will be required.

- 1 x SEL-451 Programmable Automation Controller (VRR & TX Parallel Control)
- 3 x SEL-2440 DPAC (Transformer Interface)

Cub 3 – VRR and TX Parallel Control

The SEL-451 Programmable Automation Controller shall be installed to control three transformers in either the traditional or split bus arrangement. It shall be installed in Cubicle 3.

The SEL-451 VRR and Transformer Parallel Control Relay will receive the following via IEC-61850 GOOSE Messaging:

- 22kV No.1 Bus Volts from
- 22kV No.2 Bus Volts from
- No.1 Trans CB Status from SEL-351S CB Management Relay
- No.2 Trans CB Status from SEL-351S CB Management Relay
- No.3 Trans CB Status from SEL-351S CB Management Relay
- 1-2 BT CB Status from SEL-351S CB Management Relay
- All CLC Feeder Loads from SEL-351S Feeder Management Relays
- Transformer No.1 Tap Change In Progress from new SEL-2440 Transformer Interface Controller
- Transformer No.2 Tap Change In Progress from new SEL-2440 Transformer Interface Controller
- Transformer No.3 Tap Change In Progress from new SEL-2440 Transformer Interface Controller
- Transformer No.1 Tap Position Indication from new SEL-2440 Transformer Interface Controller
- Transformer No.2 Tap Position Indication from new SEL-2440 Transformer Interface Controller
- Transformer No.3 Tap Position Indication from new SEL-2440 Transformer Interface Controller

It shall transmit the following via IEC-61850 GOOSE Messaging

- Transformer No.1 Raise Tap to the No.1 Transformer Interface Controller
- Transformer No.2 Raise Tap to the No.2 Transformer Interface Controller
- Transformer No.3 Raise Tap to the No.3 Transformer Interface Controller
- Transformer No.1 Lower Tap to the No.1 Transformer Interface Controller
- Transformer No.2 Lower Tap to the No.2 Transformer Interface Controller
- Transformer No.3 Lower Tap to the No.3 Transformer Interface Controller
- No.1 Transformer De-Ion Trip
- No.2 Transformer De-Ion Trip
- No.3 Transformer De-Ion Trip

The SEL-451 VRR and Transformer Control relay shall be programmed to perform Line Drop Compensation (LDC) calculations for each bus, and the station as a whole, and apply these values based upon the status of the 22kV 1-2 Bus Tie breaker.

Local Control of this Relay shall be via the existing station HMI, as such there shall be no manual controls or switches required on this panel.

Cub 4 – Transformer Interface Controllers

SEL-2440 DPAC units shall be installed in Cubicle 4 to convert signals to and from the transformers into IEC-61850 Goose Messages. This enables the SEL-451 to send and receive the appropriate signalling, raise/lower tap commands, TCIP signal and tap position indication.

Capacitor Bank (VAR) Control RTU

The existing SCD5200 Capacitor Bank Control RTU is capable of independently regulating 2 capacitor banks on separate buses. At present it regulates the single bus using both capacitor banks. The following modifications are required:

- Rewire existing ION-7650 PQM to perform as No.2 Bus PQM

- Install new ION-7650 PQM to perform as 3 Bus PQM
- SCADA to ensure that No.2 Bus PQM and No.3 Bus PQM are polled by SCD5200 Capacitor Control RTU
- Hard Wired status of 2-3 Bus Tie CB to be wired to Cap Control RTU

2.3.8 Station HMI and HMI RTU

The existing Human Machine Interface (HMI) is to be relocated to cubicle 3 and modified to accommodate new station controls:

- Single Line Diagram updated to match Substation Configuration
- New Transformer Controls

2.3.9 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
- SEL-451 Station Earth Fault Management
- GFN Controller
- ELSPEC Power Quality recorder
- 22kV 1-2 BT CB Management Relay
- 22kV Low Impedance Bus Protection (2 off)
- 22kV Bus Distance Protection (2 off)
- VRR and Transformer Control Relay
- Transformer Interface Control Relays

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 & Control.

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

2.3.10 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 for devices that are involved in this scheme.

Given the proximity of the devices to be connected, install a new RuggedCom RSG-2100 (CLC-RSG2100-13) switch at the top of the No.1 Bus Feeder Protection cubicle No.23 and a new RuggedCom RSG-2100 (CLC-RSG2100-14) switch at the top of No.2/3 Bus Feeder Protection cubicle No.24.

- Install Gigabit backbone connection back to the existing CLC-RSG2100-11 and 12 (connecting in loop)
- Install fibre Ethernet links from the 7 off SEL-351S Feeder Protection relays to each Ethernet switch

- Install fibre connections from GFN Interface controller (SEL-2440):
  - all Port 5A connections to CLC-RSG2100-13
  - all Port 5B connections to CLC-RSG2100-14
  - ensure relay configurations modified to Port Failover configuration
  - ensure Sub-LAN switch architecture configured to support fail over scenario's

Additionally, modify the substation ethernet topology to provide redundant communications:

- Install two new Fortigate 60C firewalls and return existing to store (redundant firewalls must be identical)
- Connect SCADA Ethernet radio to both firewalls
- Connect SCADA 3G Modem to both firewalls
- Connect both firewalls to CLC-RSG2100-11 and CLC-RSG2100-12

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

Install new Tekron TCG-01 GPS clock, antenna and ensure that earthing is performed carefully using the standard enclosure. This is to be used for time stamping all equipment. All NTP capable equipment shall synchronise with the CLC GPS NTP server.

All non NTP capable equipment is to be left as is.

2.3.11 415/240 AC Supplies

The existing station service supply transformer is located on the 22kV service bus.

The sizing of this station service transformer is inadequate for the RCC inverters used to drive faulted phase voltage to zero via the Arc Suppression Coil.

As the size of CLC network requires a split bus arrangement and 2 Arc Suppression Coils, one for Transformer No.1 and one for Transformers No.2 and 3, the AC Supplies must ensure capacity and reliability requirements are fulfilled.

Install new 750 KVA kiosk type station service transformers, location shown on proposed GA.

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.

2.3.12 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".

2.3.13 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.

2.3.14 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.

2.3.15 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.

2.3.16 Radio

No radio communications are required.

2.3.17 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 3,510 surge diverters across the 22kV three phase and single phase system on all feeders ex CLC ZSS.
- Surge arrestors beyond inter-station open points shall also be upgraded as part of the WIN GFN and CDN GFN projects to permit transfer of loads with the GFN in service.
- 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.

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.

The CLC 22kV distribution network contains 12 22kV regulating systems.

Table 3 CLC regulating systems

Feeder	Name	Manufacturer (reg)	Manufacturer (tap)	Phasing	Issue
CLC3	Beeac P133	Wilson Elec	Ferranti	RWB	No issue
CLC4	Wool Wool P16	Brentford Elec	Brentford Elec	RW	No issue
CLC5	CLC-LRN P159	Wilson Elec	ABB	RWB	No issue
CLC5	Lorne P317A (R/C)	Wilson Elec	ABB	RWB	No issue
CLC6	Gellibrand P192	Wilson Elec	Ferranti	RWB	No issue
CLC6	Gellibrand P354 (Beech Forest)	N/A	N/A	RWB	Independent voltage control
CLC6	Hordern Vale P39	Cooper	Cooper	BR	No issue
CLC6	Lavers Hill P3	Wilson Elec	Ferranti	RWB	No issue
CLC6	Swan Marsh P104	Cooper	Cooper	N/A	Open delta w/ indep voltage ctrl
CLC7	Barwon Downs P285	Wilson Elec	Ferranti	RWB	No issue
CLC7	Barwon Downs P78	Cooper	Cooper	RWB	Independent voltage control
CLC5	Lorne Line P409A	Cooper	Cooper	RW	Open delta w/indep voltage ctrl

3.4.1 Gellibrand P354 regulator

Gellibrand P354 regulator has 3 single phase regulators. They will need to tap independently, which will require a new CL7 control box as a minimum. If it is not possible for this to be fitted, a new 3 phase regulator may be required.

3.4.2 Swan Marsh P104 regulator

Swan Marsh P104 regulator is an open delta connected regulator; this artificially moves the neutral point of the line beyond it. This must be either replaced with a 3-phase ground type regulator, or a third single phase regulator installed on a neighbouring pole and a control scheme installed to ensure that all 3 phases tap in unison.

3.4.3 Barwon Downs P78

Barwon Downs P78 regulator has 3 single phase Cooper regulators. A CL7 control box will be required as per Gellibrand P354. Allowances should be made for a 3-phase ground type regulator in the event that it cannot be controlled with a CL7.

3.4.4 Lorne Line P409A

Lorne Line P409A regulator is an open delta connected regulator; this artificially moves the neutral point of the line beyond it. This must be either replaced with a 3-phase ground type regulator, or a third single phase regulator installed on a neighbouring pole and a control scheme installed to ensure that all 3 phases tap in unison.

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 ex CLC zone substations contains approximately 1,288km of overhead conductor length (excluding SWER). Of this 1,288 km, 567km (44 per cent) is single phase or unknown. 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 4 3-phase balancing unit locations

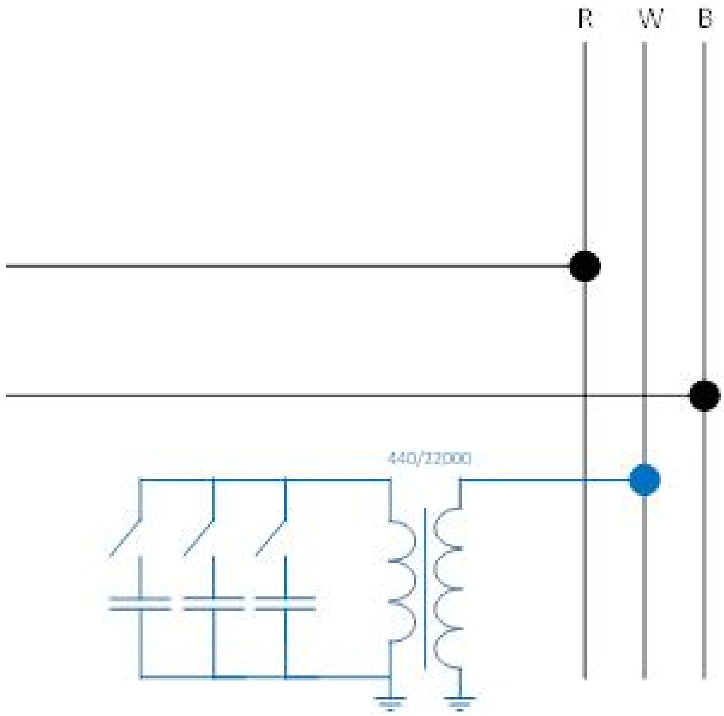
Location (1)	Location (2)	Location (3)
CLC1 Feeder Exit	Wongarra P18	Barwon Downs 332
CLC2 Feeder Exit	Gellibrand P527	Barwon Downs 392

Location (1)	Location (2)	Location (3)
CLC3 Feeder Exit	Gellibrand P503	Beeac 133
CLC4 Feeder Exit	Swan Marsh P1	Beeac 29
CLC5 Feeder Exit	Hordern Vale P5	CLC-LRN 216
CLC6 Feeder Exit	Lavers Hill P167A	CLC-LRN 2B
CLC7 Feeder Exit	Barwon Downs P149	CLC-LRN 3A
Carlisle P2	Cororooke P220	CLC-LRN 116
Gellibrand P246	Hamil P2	Cororooke Elliminyt Tie P8
Cororooke P14	Lorne Line P493	Elliminyt 19
Lavers Hill P2	Cororooke P104	Gellibrand 323
Gellibrand P353	CLC-CDN P684	Gellibrand 536
Beeac P173	Barwon Downs 21	Gellibrand 558
Barwon Downs P403	Barwon Downs 210	Gellibrand 454

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;
  - 415V LV capacitor cans, individually switched in series and/or parallel to achieve required capacitance; and
  - required telemetry and monitoring over 3G.

Figure 6 Admittance balancing concept



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 5 Balancing requirements summary

Balancing concept	Number of sites
Re-phasing Sites	46
Single Phase Balancing Units	9
3 Phase Balancing Units	42

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

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

Table 6 ACR replacements

Name	Operating voltage	Phase code	ACR model
Carlisle P2	22kV	RWB	RVE
Beeac P173	22kV	RWB	VWVE27

Name	Operating voltage	Phase code	ACR model
Swan Marsh P1	22kV	RWB	RVE
Anglesea P265	22kV	RWB	RVE

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 7 Control box replacements

Name/Location	Control box model
BARWON DOWNS P392	GCR-300
BEEAC P133A	GCR-300
GELLIBRAND 558	PTCC-CAPM5
LORNE LINE 441	GCR-300
HENDY MAIN RD P1A	PTCC CAPM5
COROROOKE P220	PTCC CAPM5
COROROOKE P14	PTCC CAPM5
WONGARRA P18	PTCC CAPM5
LAVERS HILL P2	PTCC CAPM5
LAVERS HILL P167A	PTCC CAPM5
GELLIBRAND P353	PTCC CAPM5
BARWON DOWNS P149	PTCC CAPM5
LORNE LINE P342	PTCC CAPM5
GELLIBRAND P246	PTCC CAPM5
BARWON DOWNS P403	PTCC CAPM5

Name/Location	Control box model
GELLIBRAND P503	PTCC CAPM5
GELLIBRAND P527	PTCC CAPM5

Table 8 ACR and control box requirements summary

Units	Number of sites
ACR replacements	4
Control box replacements	17

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. 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 9 Fuse saver requirements

Units	Number of sites
Fuse savers	56

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 10 HV underground cable requirements

Location	Length (m)
Cable failure length	1,576

3.9 HV aerial bundled cable

The elevated phase to earth voltage during REFCL operation, up to 24.2kV, will accelerate the pitting of non-metallic screened HV ABC. The failure of this cable to earth due to an elevated phase voltage will cause the REFCL inverter to trip and a cross-country earth fault resulting in a large earth fault current and significant fire and public safety risk. These sections of HV ABC are to be replaced.

CLC zone substation has four (4) bays of HV ABC.

Table 11 HV ABC replacement requirements

Location	Length (m)
CLC004 - Christies Road P10 to Christies Road P13	287
CLC005 - Armytage St Spur Wallace P34 to George Wallace P2	90
CLC007 - Riverside Dve P5E to Riverside-Boulevarde P4	293
CLC007 - Wongarra Line P172 to Wongarra Line P186	606

3.10 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 12 Felten and Guilleaume switchgear replacements

Location	Kiosk Size
Erskine House	1,000 kVA
Ocean-Armytage	500 kVA
Ocean-Bay	500 kVA
Summerhills Hazel	315 kVA

3.11 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 13.

Table 13 Isolation substation requirements

Size	Quantity
2 MVA	5
5 MVA	4