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

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System Planning Engineer					
Protection and Control Engineer					
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Version	Date	Changes	Responsible Officer
1.0	01.03.2017	Original	V.Hadya

1 Project overview

This project scope covers the migration of the Eaglehawk zone substation (**EHK**) 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 Eaglehawk zone substation

EHK is a banked zone substation that supplies the township of Bendigo and extending into surrounding rural areas. EHK comprises of two 20/30MVA 66/22kV transformers supplying eight 22kV feeders. The estimated total system capacitance of the EHK 22kV network is approximately 174A.

Table 1 EHK: existing characteristics (zone substation)

Zone substation	Volume
Feeders	8
Zone substation transformers	2
22kV buses	2
Capacitor banks	1
Station service transformers	1
22kV circuit breakers (switching configuration)	10 (banked)

Table 2 EHK: existing characteristics (network)

Network	Volume
Total route length (km)	935
Underground cable length (km)	44
Overhead line length (km)	891
Underground network (%)	4.6
Overhead single phase	338
Estimated network capacitance (A)	174
Distribution transformers	1,470
HV regulator sites	6
Fuses	1,662

Network	Volume
ACRs	10
Surge arrestor sites	2,021
HV customers	9

2 ZSS requirements

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

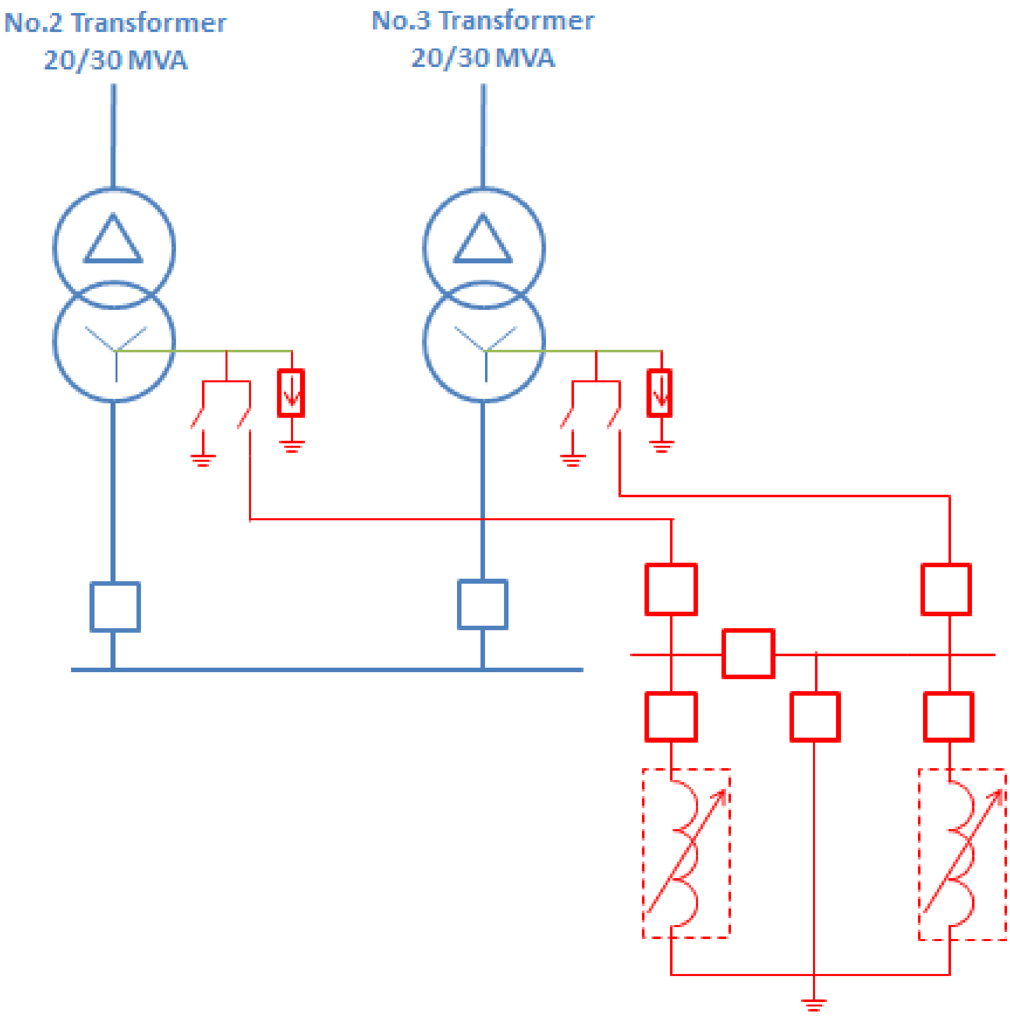
- Establish Arc Suppression Coil (ASC) bunds;
- Installation of two (2) Swedish Neutral GFN Arc Suppression Coils;
- Modification of the 66/22kV transformer earthing arrangement;
  - Installation of Neutral Bus System;
    - Transformer neutral CB's;
    - Ground terminations;
    - ASC Terminations;
    - Neutral VT Installation;
- Upgrade station service supply transformers with two (2) new 750kVA kiosk transformers;
- Upgrade of the station service supply cabling and installation of new AC distribution board;
- Replace ALL substation surge arrestors with new 22kV continuous voltage units for resonant network compatibility and 10hr 24kV TOV capability;
- Install 66kV CB 'C' and associated isolators and structures;
- Install 22kV 2-3 Bus Tie CB and associated isolators and structures;
- Install No 1 22kV Capacitor Bank CB and associated isolators and structures;
- Establish No 1 22kV Bus and associated structures;
  - No 1 22kV Bus to remain 'unswitched' and treated as extension of No 2 22kV Bus;
- Install duplicate 66kV Bus Protection;
- Install duplicate 66/22kV Transformer protection;
- Install duplicate 22kV Bus Protection;
- Install No 1 Capacitor Bank Protection;
- 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 Bus CB Management;
- Install a SEL-451 Station Earth Fault Management relay to perform the automated control of the GFN. 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;
- Install & Commission two (2) GFN control and two (2) RCC inverter cubicles;
- Modification of existing Capacitor Bank;
  - Remove HV earth from star point;
  - Install new CB Management relay incorporating overcurrent & earth fault functions;
  - Install new station VAR controller; and
- Install new Elspec Power Quality Meter.

2.1 Primary plant requirements

The works associated with the installation of the EHK ASC and neutral arrangement is summarised in the following single line diagram.

Figure 1 EHK single line diagram



2.1.1 Ground Bypass Isolators

For each transformer neutral earthing, install direct ground bypass 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 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 in the location east of the future No.1 Transformer and No.1 Bus:

- install Ground Fault Neutraliser comprising of 2x 200A ASC 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
- install station class 19kV surge arrestors across the transformer neutrals

2.1.4 Zone substation capacitor bank

The existing No.3 22kV Capacitor Bank is connected in grounded star. The bottom modules of the stack reside on a 22kV insulated structure.

To facilitate GFN installation, the earth must be removed from this Capacitor Bank:

- the neutral structure shall be modified such that the earth connection be removed and the neutral point floating with a continuous insulation rating of not less than 13kV;
- install station class 19kV surge arrestor between the floating star-point and earth;
- remove the Cap Bank Neutral CTs (used for Backup Earth Fault and Master Earth Fault); and
- install Neutral VT for monitoring of the capacitor bank imbalance.

New No.1 22kV Capacitor Bank

The station loading at EHK will require capacitive VAR support on both sides of the split bus arrangement. The existing No.3 Capacitor Bank will not be able to support voltage on the No.2 Bus with the REFCL in operation and the 2-3 22kV

Bus Tie CB open. An additional capacitor bank is required on the No.2 bus to regulate the VAR loading on the No.2 66/22kV Transformer.

2.1.5 Neutral system arrangement

A new kiosk type ground mounted Neutral Bus system shall be installed with the ASCs. The neutral bus systems allows for integration of the ASCs onto the transformer neutral.

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 (solid ground CB open).

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

Neutral Bus

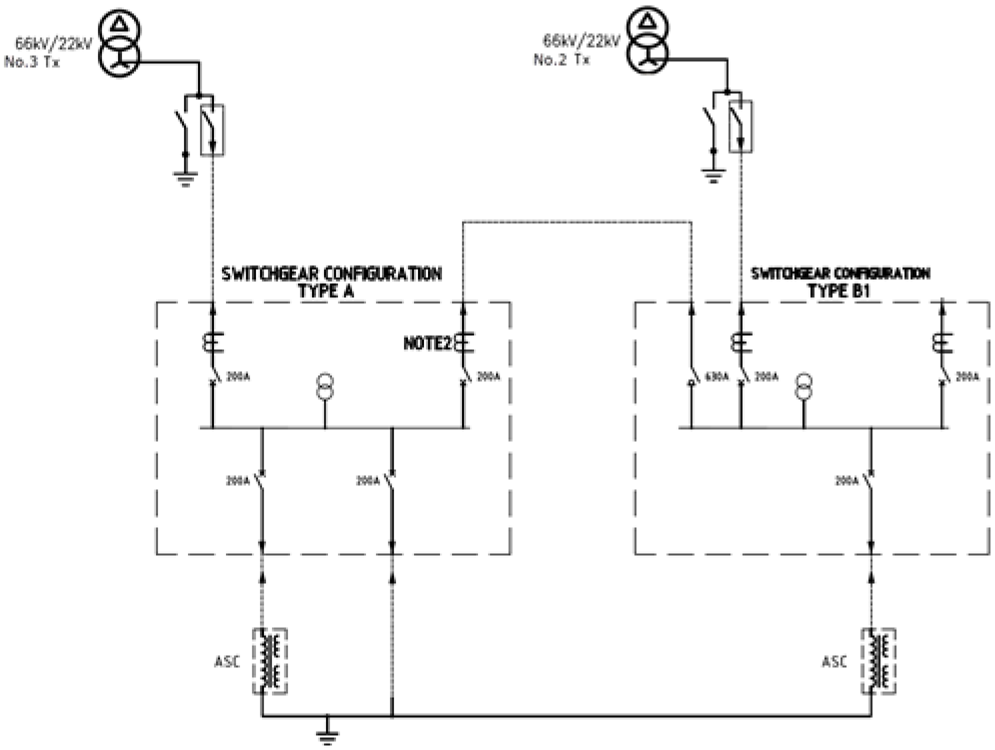
The connection to the Neutral Bus module shall be via elbow connections. Four (4) elbows are required per module for:

- transformer neutral connection;
- neutral bus tie connection;
- ASC connection; and
- solid ground 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 2 Proposed EHK neutral system single line diagram



2.1.6 Transformer Earthing

The two 66/22kV, 20/30 MVA transformers in service at EHK are delta/star connected with the neutral of the star windings solidly earthed.

The neutral earthing arrangement shall be modified to incorporate the new earthing arrangement (refer SLD) with connection to the ASCs. The transformer neutrals from each transformer shall be extended using a HV insulted single phase cable installed underground from the existing transformer neutral earthing point to the HV CB (via the elbow connections) on the Neutral Bus modules (RMU).

2.1.7 22kV Bus Modifications

The location of the No 1 capacitor bank and its requisite circuit breaker necessitate establishment of the No.1 22kV Bus. These works are summarised as follows:

- No 1 22kV bus requires the installation of structures for a 1-2 22kV Bus Tie Isolator:
  - install No 1 22kV bus support structures as per latest modular design concepts;
  - install No 1 22kV bus conductor as per standard;
  - install 1-2 22kV Bus Tie Isolator;
  - install No 1 22kV Capacitor Bank CB Isolator;
  - install No 1 22kV Capacitor Bank CB; and
    - install Install associated supplies and control cabling for circuit breaker.

Electrically the No 1 22kV Bus is to be treated as an extension of the No 2 22kV bus (i.e. no installation of additional Circuit Breakers, Protection and Control etc), until in future when either of the following works may occur;

- installation of the No 1 66/22kV Transformer at EHK; and
- installation of additional feeders at EHK.

2.1.8 22kV Bus VT

The existing VT is located on the 22kV Service Bus which is to be replaced with the 2-3 22kV Bus Tie CB. When the 22kV bus is split, separate VT's are required on both 22kV buses for protection (bus distance) and control (voltage regulation) schemes.

Install on the 22kV No.2 Bus Structure a new 22kV Voltage Transformer:

- 3-Phase 5 Limb construction
- Frequency – 50Hz
- Ratio - 22,000/110/110V
- Connection - STAR/STAR/STAR.
- Vector Group - YNyn0yn0.
- Output - 100VA per phase per secondary winding
- Accuracy class - CLASS 0.5M1P per secondary winding
- Confirm suitability of the stock item, SAP ID – 381684

Install on the 22kV No.3 Bus Structure a new 22kV Voltage Transformer with the following specification:

- 3-Phase 5 Limb construction
- Frequency – 50Hz

- Ratio - 22,000/110/110V
- Connection - STAR/STAR/STAR.
- Vector Group - YNyn0yn0.
- Output - 100VA per phase per secondary winding
- Accuracy class - CLASS 0.5M1P per secondary winding
- Confirm suitability of the stock item, SAP ID – 381684

2.1.9 Neutral Surge Diverter

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 system:

- 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; 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;
- install bunding to EPA requirements.

For station service supplies:

- install concrete foundation for new No.3 station service transformer & No.2 station service transformer;
- install HV cable conduits from EHK31 Feeder CB & EHK24 Feeder CB to station service transformers;
- install LV cable conduits from No.3 station service transformer & No.2 station service transformer to GFN Enclosure.

For GFN Enclosure:

- install concrete foundation for GFN Enclosure;
- land new GFN Enclosure;
- install control cable conduits to Control Room.

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 No.1 22kV Bus:

- install concrete footings for overhead bus structures.

For new No.1 Capacitor Bank:

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

For new No.1 Capacitor Bank CB:

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

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

No.2 Transformer 22kV CB Management and CB Fail

Transformers No.2 already has a circuit breaker installed at EHK, however not wired for protection. The voltage control scheme under a split bus operation requires metering from Transformer CBs and the REFCL protection scheme requires bus and transformer tripping schemes and as such the site requires installation of the CB Management and CB Fail Relays for this circuit breaker.

- Install SEL-351S and associated MCB's and Link Rack to perform No.2 Transformer CB Management and CB Fail
  - Connect to new 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)

No.3 Transformer 22kV CB Management and CB Fail

Transformers No.2 already has a circuit breaker installed at EHK, however not wired for protection. The voltage control scheme under a split bus operation requires metering from Transformer CBs and the REFCL protection scheme requires bus and transformer tripping schemes and as such the site requires installation of the CB Management and CB Fail Relays for this circuit breaker.

- Install SEL-351S and associated MCB's and Link Rack to perform No.3 Transformer CB Management and CB Fail
  - Connect to No.3 Transformer 22kV CT's
  - Connect No.3 Bus VT
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-351S CB Management and CB Fail)

2-3 22kV Bus Tie CB Management and CB Fail

The splitting of the EHK 22kV Bus requires installation of a 2-3 22kV Bus Tie CB. This CB Management relay is required for tripping of bus zones via the GFN control scheme as well as providing info to the split bus voltage control scheme and providing remote control and cb fail protection of the new circuit breaker.

- Install SEL-351S and associated MCB's and Link Rack to perform 2-3 22kV Bus Tie CB Management and CB Fail
  - Connect to new 2-3 22kV Bus Tie CTs
  - Connect No.2 Bus VT

  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-351S CB Management and CB Fail)

No.1 22kV Capacitor Bank Overcurrent, Earth Fault, CB Management and CB Fail Relay

The installation of the new No.1 Capacitor Bank requires protection; standard capacitor bank overcurrent protection is to be provided via this relay.

- Install SEL-351S and associated MCB's and Link Rack to perform No.1 22kV Capacitor Bank OC, EF, CBM and CB Fail
  - Connect to new No.1 Capacitor Bank CT
  - Connect No.2 Bus VT
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-351S Capacitor Bank OC, EF, CB Management and CB Fail)
  - 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

No.3 22kV Capacitor Bank Overcurrent, Earth Fault, CB Management and CB Fail Relay

The existing No.3 Capacitor Bank is protected by a SEL-351S Protection Relay. This relay is to be configured to provide neutral voltage monitoring of the capacitor bank. This is as the bank is externally fused and there are no neutral CT's to provide current balance protection.

- Review No.3 22kV Capacitor Bank OC, EF, CBM and CB Fail Relay (SEL-351S)
  - Connect No.3 Capacitor Bank Neutral VT
  - 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
- Upgrade Firmware to current standard R516 – Z106.

No.2 22kV Bus Protection

Splitting the 22kV buses at EHK to achieve the mandated REFCL sensitivity requires installation of 22kV Bus Protection on the No.2 22kV bus. The existing protection of the No 2 22kV Bus is via the station differential scheme. This cannot be used as we require the current measurements to be bus-based in order to provide the GFN control scheme with bus neutral current.

- Install SEL-351A and associated MCB's and Link Rack to perform Selective Bus Overcurrent
  - Summate feeder side CT's on transformer side CT on No.2 Transformer CB and cap bank side of No.1 Cap Bank CB as well as No.3 Bus Side CT of the new 2-3 Bus Tie CB. Use 1200/5 CT ratio's on these CT's.
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-351A Selective Bus Overcurrent
  - IEC-61850 GOOSE Messaging is to be utilised to provide "Relay Start" from each of the Feeder Protection schemes.
- 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 to perform Single Zone Bus Distance Protection.
  - Summate transformer side CT on No.2 Transformer 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.

No.3 22kV Bus Protection

Splitting the 22kV buses at EHK to achieve the mandated REFCL sensitivity requires installation of 22kV Bus Protection on the No.3 22kV bus. The existing protection of the No 3 22kV Bus is via the station differential scheme. This cannot be used as we require the current measurements to be bus-based in order to provide the GFN control scheme with bus neutral current.

- Install SEL-351A and associated MCB's and Link Rack to perform Selective Bus Overcurrent
  - Summate feeder side CT's on transformer side CT on No.3 Transformer CB and cap bank side of No.3 Cap Bank CB as well as No.2 Bus Side CT of the new 2-3 Bus Tie CB. Use 1200/5 CT ratio's on these CT's.
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-351A Selective Bus Overcurrent
  - IEC-61850 GOOSE Messaging is to be utilised to provide "Relay Start" from each of the Feeder Protection schemes.
- 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 to perform Single Zone Bus Distance Protection.
  - Summate transformer side CT on No.3 Transformer CB and No.2 Bus Side CT of the new 2-3 Bus Tie CB.
  - Connect No.3 Bus VT
  - Connections to be consistent with CitiPower and Powercor Application Guide (Whitebook) for SEL-311C-1 Single Zone Bus Distance.

No.2 Transformer Protection

The REFCL control scheme in a split bus operation requires segregated protection zones for transformers and as such the existing station differential scheme is to be retired. Installation of duplicate transformer differential protection on the No.2 Transformer is required.

- Install No.2 X Transformer Differential and Restricted Earth Fault Protection (SEL-787) to provide redundant protection of No.2 Transformer. This protection scheme also provides X protection of the No1 and 2 66kV Bus.
  - Connect to No 2 Trans 66kV CT
  - Connect to No 2 22kV bus side CT of the No 2 Trans 22kV CB
- Provide No.2 Transformer Zero Sequence Summation from the REF current circuit 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 No.2 Y Transformer Differential Protection (GE – T60) to provide redundant protection for No.2 Transformer
  - Connect to No 2 Trans 66kV CT
  - Connect to No 2 22kV bus side CT of the No 2 Trans 22kV CB

No.3 Transformer Protection

The REFCL control scheme in a split bus operation requires segregated protection zones for transformers and as such the existing station differential scheme is to be retired. Installation of duplicate transformer differential protection on the No.3 Transformer is required.

- Install No.3 X Transformer Differential and Restricted Earth Fault Protection (SEL-787) to provide redundant protection of No.3 Transformer. This protection scheme also provides X protection of the No 3 66kV Bus.
  - Connect to No 3 Trans 66kV CT
  - Connect to No 3 22kV bus side CT of the No 3 Trans 22kV CB
- Provide No.3 Transformer Zero Sequence Summation from the REF current circuit 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 No.3 Y Transformer Differential Protection (GE – T60) to provide redundant protection for No.3 Transformer
  - Connect to No 3 Trans 66kV CT
  - Connect to No 3 22kV bus side CT of the No 3 Trans 22kV CB

22kV Feeder Protection

The existing SEL-351S Feeder Protection was installed in 2010 as part of a relay replacement project. These relays are suitable for REFCL control schemes and require only a firmware upgrade.

- Review 22kV Feeder Protection Relay wiring
  - 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
- Upgrade Firmware to current standard R516 – Z106.

X-MEF and Neutral Bus Management

The existing RMS 2C137 X MEF relay is to be retired as it is not capable of intelligent master earth fault interlocking depending on whether the network is in a resonant or solidly earthed state.

The management of conversion between resonant and solidly earthed networks through the use of the 2 x Neutral Buses is performed by a Neutral Bus Management Relay. This relay is also responsible for providing the interlocking master earth fault signal when the network is in a solidly earthed arrangement. This is a standard and key item installed in all REFCL substations.

- Retire RMS 2C137 X MEF Relay
- Install GE-F35 relay and associated MCB’s and link rack to perform X MEF and Master Earth Fault.
  - Connect No.1 and No.2 Trans neutral CT’s directly, internal relay logic will perform summation for X-MEF.
  - Connect Neutral VTs from each of the Neutral Bus RMU’s

Y-MEF and Backup Earth Fault Protection

The existing backup earth fault scheme is to be modified to ensure it is appropriately interlocked by the state of the NER CB as well as is staged to isolate any faults via 22kV Bus Tie tripping followed by appropriate transformer/bus tripping.

- Modify existing BUEF On/Off selection and indication circuit using status of the BUEF Inhibit from the Neutral Bus Management Relay

- Modify existing SEL-351A Y-MEF and Common Backup Earth Fault protection relay wiring to trip new bus tie C and initiate stage 2 relays
- Install new RMS-2C138 and associated MCB and link rack to perform Stage 2 tripping of No.2 Bus
- Install new RMS-2T105 and associated MCB and link rack to perform Stage 3 tripping of No.2 Transformer
- Install new RMS-2C138 and associated MCB and link rack to perform Stage 2 tripping of No.3 Bus
- Install new RMS-2T105 and associated MCB and link rack to perform Stage 3 tripping of No.3 Transformer

Station Earth Fault Management

The automated control of the GFN's installed at EHK is performed by the Station Earth Fault Management Controller. 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

Install SEL-451 relay and associated MCB to perform Station Earth Fault Management:

- Connect serial fibre (ST) from SEL-451 to SEL-2505 in GFN Inverter Enclosure to provide smoke alarm, MCB trip alarms, and indication of inverter.
- Connect DC to DC monitor terminals such that station DC can be monitored remotely

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

EHK 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 standard cubicle. The cubicle will contain an interface controller in the form of a SEL-2440 DPAC control unit in this cabinet. This control unit will be used to interface controls to the Station Earth Fault Management relay.

The GFN cubicles shall be located in the control room in the vacant cubicle 15 and 16 positions.

VT Supplies (R,W,B and VN) are required from the bus into the GFN controller along with Feeder 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
- Capacitive Dissymmetry

For EHK, two ASC's will be installed one for each transformer 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 enclsoure, as indicated in the proposed general arrangement.

2.3.3 VT supplies

VT supplies from the new 22kV Bus VT is required to the GFN control unit. For earth fault detection, an open delta (UN) input is required from the 22kV bus VT at 110V secondary. To achieve this, Swedish Neutral has provided an auxiliary transformer in their GFN control cubicles:

- connect No.3 Bus VT to No.3 GFN; and
- connect No.2 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 EHK 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; and
- 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

Existing Power Quality Meter

In a split bus arrangement, power quality and summation metering is to be measured by independent power quality meters as is common practice across the CitiPower and Powercor networks. The existing ION7650 is to be reconfigured to perform power quality and summation metering of the No.2 Bus.

New Power Quality Meter

An ION-6200 PQM is to be installed to perform power quality and summation metering of the No.3 Bus. This smaller PQM is connected to the existing ION-7650 which will in turn provide total station summation as well as individual bus reporting back via SCADA and to the PQM server.

New ELSPEC Digital Fault Recorder

This recorder is capable of recording 16 analogue and 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 currents). The purpose of this recorder is to aid with GFN commissioning and long term monitoring and compliance reporting.

Connectivity to the ELSPEC meter to be via copper RJ45 100 base-tx using an SFP in the vacant port of any of RSG2100-11 through to 14.

2.3.7 Station Voltage and VAR Control

Splitting the 22kV Bus requires that the voltage and VAR flow on the 22kV bus must be regulated independently and also capable of being regulated in parallel.

Voltage Regulation and Transformer Control

A 61850 based voltage regulation scheme is to be installed at EHK, utilising metering quantities from Transformer CB Management Relays, Feeder CB Management Relays and status of the Bus Tie CB Management Relay along with controls and status from Transformer Interface Controllers. This means that a minimum amount of wiring is required and only the installation of the VRR and Transformer Control Relay along with 2 Transformer Interfaces are required.

- Install new SEL-451 and associated MCB to perform VRR and Transformer Control
- Install new SEL-2440 and associated MCB and link rack in appropriately IP-rated enclosure alongside No.2 Transformer to function as No 2 Transformer I/O Controller
  - Re-terminate No 2 Transformer I/O to this link rack
  - Motorised AC MCB to be installed to provide Out Of Step Tripping of No 2 Transformer
- Install new SEL-2440 and associated MCB and link rack in appropriately IP-rated enclosure alongside No.3Transformer to function as No.3 Transformer I/O Controller
  - Re-terminate No 2 Transformer I/O to this link rack
  - Motorised AC MCB to be installed to provide Out Of Step Tripping of No 3 Transformer
- Retire existing Transformer Control Panel

VAR Control

The existing SCD5200 Capacitor Bank Controller logic is to be modified to control 2 Capacitor Banks.

2.3.8 Control and monitoring requirements

Remote Control and Monitoring of new:

- SEL-351S Capacitor Bank Protection Relay Configurations
- SEL-351S CB Management Relay Configurations
- SEL-451 Station Earth Fault Management
- SEL-451 Station VRR and Transformer Control
- SEL-787 Transformer Differential Protection Relay Configurations
- GE-T60 Transformer Differential Protection Relay Configurations
- SEL-351A Low Impedance Bus Protection Relay Configurations
- GE-F35 X MEF & Neutral System CB Management Relay
- GFN Controllers
- ELSPEC Power Quality recorder

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.

2.3.9 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.

Each pair of Ruggedcomm switches provides a set of fourteen (14) 100-base FX connections. Connectivity at EHK requires 26 connections including existing unchanged RS400 connections. 4 total RSG-2100's are required and there is 1 existing. Given the proximity and quantity of the devices to be connected, three (3) new RuggedCom RSG-2100 sub-lan switches are required at EHK.

- Install Gigabit backbone connection between the 3 new Ethernet switches and the existing RSG2100-11 sub-lan switch in a ring formation.
- All 61850 connected relays are to be connected 'point-to-point' between RSG-2100 sub-lan switches. The relays requiring this connection are;
  - SEL-351S Feeder Protection Relays (8)
  - SEL-351S Capacitor Bank Protection Relays (2)
  - SEL-351S CB Management Relays (3)
  - SEL-787-3 X Transformer Protection Relays (2)
  - SEL-451 Station Earth Fault Management (1)
  - SEL-451 VRR and Trans Control (1)
  - SEL-2440 Transformer I/O Control (2)

- SEL-2440 GFN I/O Control (2) [Note: This relay is provided by Swedish Neutral – not by Powercor, however connectivity is performed by Powercor]

- Remaining ethernet connections may be in a ring between 2 ports on 2 different RSG-2100's
- Install fibre Ethernet links from the SEL-351S Feeder Protection relays, Cap Bank protection relay, 66kV CB management relays, Station EF relay, ELSPEC PQM, Station PQM, GFN DPAC to each Ethernet switch

Firewall

Secure sub-lan ethernet, SCADA, Engineer Access, PQM and ELSPEC connectivity is provided via redundant firewalls. Firewalls are to be installed as a cluster pair and as such the existing Fortigate 60C is to be replaced with 2 identical Fortigate 60C firewalls.

Install two (2) x Fortigate 60C Firewalls and associated MCBs and configure as a cluster to ensure that connectivity to the substation is not lost for the failure of a firewall.

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 SNTP capable equipment shall synchronise with the EHK GPS SNTP server.

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

2.3.10 AC Supplies

The existing station service supply transformer is located on the 22kV service bus. This bus is to be retired to allow installation of the 2-3 22kV Bus Tie CB.

The sizing of the existing 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 EHK network requires a split bus arrangement and 2 Arc Suppression Coils, one for Transformer No.2 and one for Transformer No.3 the AC Supplies must ensure capacity and reliability requirements are fulfilled. The two inverters draw 320kVA each, for this reason two (2) 750kVA kiosk type station service transformers are to be installed. This ensures that for a feeder outage there is no long term loss of GFN availability.

Install new 750 KVA kiosk type station service transformers, location shown on proposed GA and connect to beyond the 22kV Feeders as shown on the proposed single line diagram.

Install new AC changeover board with current limiting fuses and review existing station AC board, incoming mains and any change over schemes such that they are compliant with existing standards.

Install AC supplies for the GFN inverter to meet its specifications.

2.3.11 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".

Exposed DC Bus

The exposed 'clothes line' style DC busses in the control room are to be retired as they are a health and safety risk to personnel working within the control room. New DC supply terminals are to be installed at the rear of each cubicle and linked together as is the standard practice across the Powercor network.

2.3.12 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 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.

2.3.13 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.

2.3.14 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.

2.3.15 Radio

No radio communications are required.

2.3.16 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 3,690 surge diverters across the 22kV three phase and single phase system. This covers all feeders ex EHK 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.

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 EHK distribution network contains six 22kV regulating systems:

Table 3 EHK regulating systems

Feeder	Name	Manufacturer	Phasing	Issue
EHK023	Bagshot P221	Wilson	RWB	None
EHK024	Bridgewater P307	Cooper	R,W,B	Control Box Required to ensure 3 phase tapping
EHK024	Glenalbyn P374	Cooper	R	Balancing works to accommodate neutral current caused by the tapping of this unit
EHK024	Prairie P297	Wilson	RWB	None
EHK024	Sebastian Reg	Wilson	RWB	None
EHK024	Prairie P412	Cooper	R,W	3rd phase to be installed in ground mount substation

3.4.1 Bagshot P221

Bagshot P221 regulator is installed in an acceptable configuration. A condition assessment is required to satisfy the ten minute 22kV TOV requirement.

3.4.2 Bridgewater P307

Bridgewater P307 is a Cooper Reg with three single phase 100A Regs with independent controls. The existing CL6 control schemes are installed on each phase and as such are controlled separately.

The controls shall be updated to a CL7 control unit such that;

- all units regulate and tap together in a master follower style scheme;
- 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; and
- all alarms and controls shall be integrated into SCADA.

3.4.3 Glenalbyn P374

Glenalbyn P374 regulator is a single phase regulator on a single phase line. The imbalance caused by this regulator cannot be rectified via regulator upgrade works unless significant line works are carried out to provide three phase supply to the area. A single phase balancing unit is to be installed at the nearest upstream three phase section and configured to provide supplementary capacitance to cater for approximately the midpoint of voltage dissymmetry induced capacitive imbalance from this regulator.

3.4.4 Prairie P297

Prairie P297 regulator is installed in an acceptable configuration. A condition assessment is required to satisfy the ten minute 22kV TOV requirement.

3.4.5 Sebastian Reg

Sebastian regulator is installed in an acceptable configuration. A condition assessment is required to satisfy the ten minute 22kV TOV requirement.

3.4.6 Prairie P412

Prairie P412 is a pole mounted regulator (two units regulator across two poles) and connected in open delta. Existing CL6 control schemes control each regulator separately.

This regulator scheme shall have a third phase installed and be reconfigured as a closed delta system.

The controls shall be updated to a CL7 control unit such that:

- all units regulate & 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; and
- all alarms and controls shall be integrated into SCADA.

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 EHK zone substation contains approximately 891km of overhead conductor length (excluding SWER). Of this, 338km (38 per cent) 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 4 3-phase balancing unit locations

Location (1)	Location (2)	Location (3)
EHK21 feeder exit	Inglewood P127A ACR	Inglewood P63 (EHK024)
EHK22 feeder exit	Prairie P94 ACR	Serpentine P167 (EHK024)
EHK23 feeder exit	Calivil P2 ACR	Nelson P3 (EHK031)
EHK24 feeder exit	Prairie P348 AS	Havliah Moran 7 (BET/EHK032)
EHK31 feeder exit	Inglewood P334 ACR	Nolan St P60 (EHK033)
EHK32 feeder exit	Serpentine P3 ACR	Barnard-Mercy P3 (EHK034)
EHK33 feeder exit	Kennington P145 (EHK021)	Inglewood 413
EHK34 feeder exit	Sandy Creek P1 (EHK022)	Neilborough 1
Muskerry P2 ACR	Bobs P34 (EHK022)	Muskerry 19 to Sommerville
Elmore P222A ACR	Elmore P111 (EHK023)	-
Prairie P3 ACR	Midland P47 (EHK023)	-

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	36
Single Phase Balancing Units	8
3 Phase Balancing Units	31

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

Each RVE or VWVE ACR on the EHK 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
MUSKERRY P2 ACR	22kV	RWB	VWVE27
ELMORE P222A ACR	22kV	RWB	RVE
CALIVIL P2 ACR	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	Control box model
INGLEWOOD P334 ACR	PTCC-CAPM5
CROWTHER P134 ACR	PTCC-CAPM5
PRAIRIE P298	PTCC-CAPM5

Table 8 ACR and control box requirements summary

Units	Number of sites
ACR replacements	3
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. 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	26

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	1,266

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 11 Felten and Guilleaume switchgear requirements

Location	Kiosk size
Holdsworth Manor Aged Care	1,000 kVA
Corner-Midland	500 kVA
Water-Coliban Water	500 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;

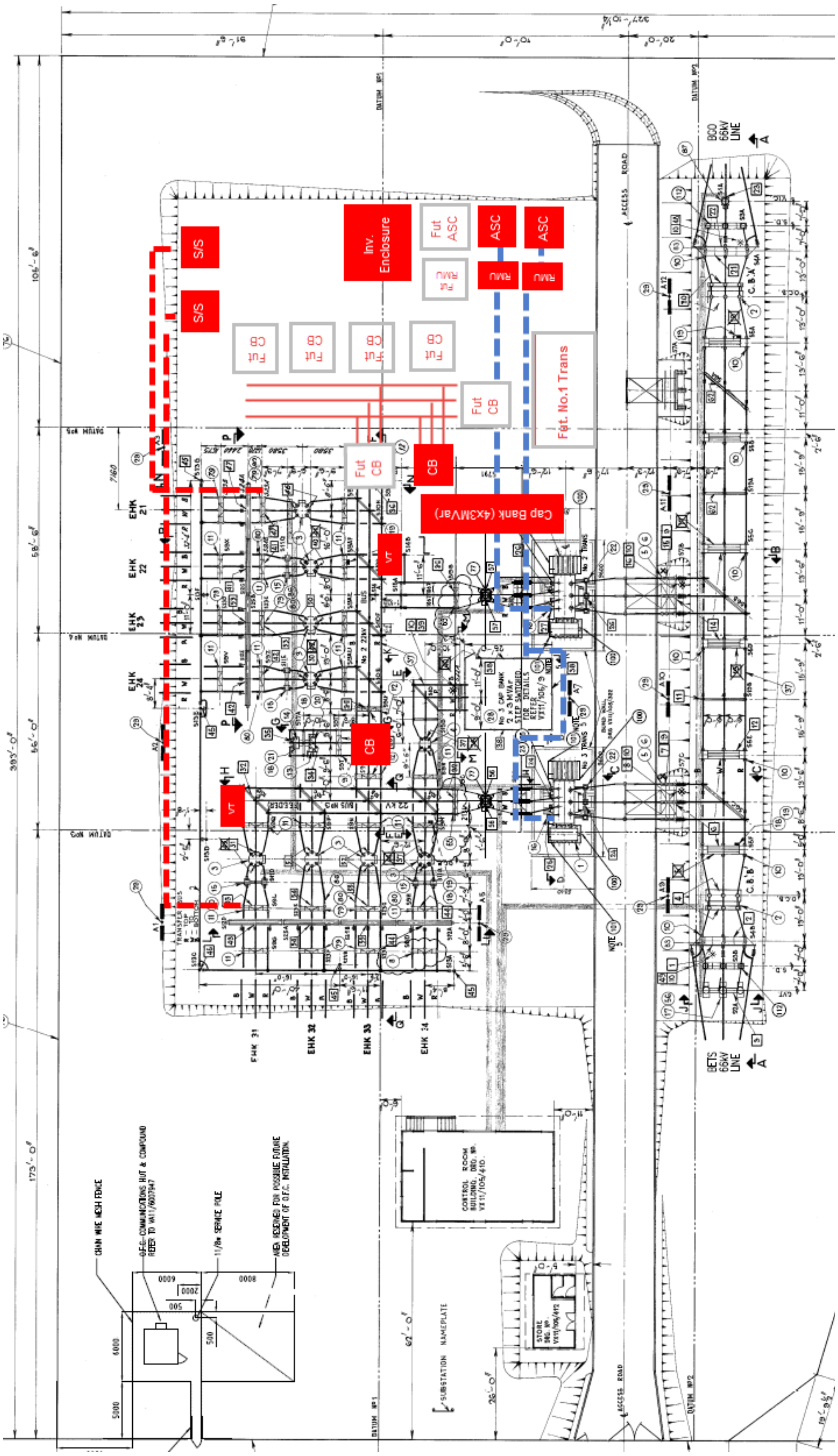
- voltage control requirements for the customer is likely to require tap changing capability for larger customers;
- station service supply via the tertiary winding to provide supply to protection, metering and control circuitry;
- appropriate HV source side protection to protect for faults in the substation 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; and
- undergrounding of any electrical conductor between the isolation substation and customer connection.

HV customer connection points are set out in table 12.

Table 12 Isolation substation requirements

Size	Quantity
2 MVA	6
5 MVA	3

4 Appendix Proposed Site General Arrangement



5 Appendix Proposed Substation Single Line Diagram