Functional Scope Created	**10/07/2019**	**By**	Danny Jutrisa		
		Ex:	6656		
Project RO	Danny Jutrisa	**Ex:**	6656		
Project Title	Merbein (MBN) ZSS REFCL Installation				
Network No. and F/C					
Last Update	15/08/2019	**By**	Vikram Hadya	**Version**	1.0
Related Scopes					
Project Engineer					
System Planning Engineer	Danny Jutrisa				
Protection and Control Engineer	Vikram Hadya				
Plant and Stations Engineer					
Asset Strategy Engineer					
Required Quote Date					
System Requirement Date	30 April 2023				

Revision History:

Version	Date	Changes	Responsible Officer
0.1	11/07/2019	Initial Scope	D. Jutrisa
0.2	30/07/2019	Added secondary requirements	V.Hadya
1.0	15/08/19	Final scope	V.Hadya

1 Project overview

This project scope covers the migration of the Merbein zone substation (**MBN**) 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
- 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
- the low voltage (**LV**) system.

1.1 Background

To meet the Victorian Government Bushfire Mitigation Regulations performance standards for detection and limiting of arc fault energy on high voltage (**HV**) overhead assets in high bushfire consequence, rapid earth fault current limiters (**REFCLs**) can be used.

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 to mitigate against fire ignition.

The Bushfire Mitigation Regulations mandate the following performance criteria (for a phase-to-ground fault on a polyphase electric line with a nominal voltage between 1 kV and 22 kV):

- 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.

1.2 Merbein zone substation

Merbein 66/22 kV zone substation is a partially switched station consisting of two 10/13.5 MVA transformers and one 20/33 MVA transformers and six 22 kV feeders.

It is located at Merbein and largely supplies along the Murray River between Mildura and Lake Cullulleraine.

To permit the transfer of loads from adjacent zone substations with the GFN in service the 22kV feeder requirements in section 3 of this scope must also be applied to the portion of the feeders that can be transferred to MBN. MDA023, MDA032, MDA033 and MDA034 are the feeders that can be transferred to MBN.

The switch zones are as follows:

- MDA023 → MBN032
  - Between RCTS - MDA No.1 P140 GV Switch (SW# 20017), Benetook – Fifteenth P8A Kiosk Switch (SW# 67151), Karadoc X 15-Dairtnunk P11 Gas Switch (SW# 48446), RCTS - MDA No.1 P121 GV Switch (SW# 19695), and RCTS - MBN P194 Gas Switch (SW# 61571)
- MDA032 → MBN023 and MBN012
  - MBN023 - Between Ontario 13th Kiosk Switch (SW# 30079) and Walnut – Ontario P27 Switch (SW# 46031)
  - MBN012 - Between Walnut P2 GV Switch (SW# 11745) and MDA032 Feeder CB
- MDA033 → MBN023, between Ontario – Walnut P27 Gas Switch (SW# 35391) and MDA033 Feeder CB
- MDA034 → CRO021, between Etiwanda – Riverside P10 Switch (SW# 13101) and MDA034 Feeder CB

Table 1 MBN: existing characteristics (zone substation)

Zone substation	Volume
Feeders	6
Zone substation transformers	3
22kV buses	3
Capacitor banks	1
Station service transformers	2
22kV circuit breakers (switching configuration)	9 (Partially Switched)

Table 2 MBN: REFCL network to be hardened

Network	Volume MBN only	Volume for transfers	Volume MBN + Transfers
Total route length (km)	366	83	449
Underground cable length (km)	26.5	14.0	40.5
Overhead line length (km)	339	69	409
Underground network (%)	7.25%	16.78%	9.02%
Overhead single phase	9.3	2.0	11.4
Estimated network capacitance (A)	92.4	41.6	134.0
Distribution transformers	855	259	1,114

Network	Volume MBN only	Volume for transfers	Volume MBN + Transfers
HV regulator sites	2	0	2
Fuses	964	141	1,105
ACRs	4	2	6
Surge arrestor sites	3,309	1,272	4,581
HV customers	2	0	2

2 ZSS requirements

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

- establish ASC bunds for one (1) REFCLs
- installation of one (1) Swedish Neutral GFN Arc Suppression Coil (ASC)
- 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 Systems
    - bus CB's
    - NER terminations
    - ASC terminations
    - neutral VT Installation
- install two (2) new core balance CTs on the cable head poles for the MBN031 and MBN032
- install four (4) new 22kV feeder post type CTs on MBN012, MBN013, MBN014 and MBN021
- upgrade station service supplies to two (2) new 500kVA kiosk transformer
- upgrade of the station service supply cabling and installation of new AC distribution board
  - install current limiting fuses on AC distribution board
- replace two (2) 22kV Bus VT (on Bus No.1-2 and Bus No.3)
- replace ALL substation surge arrestors with new 22kV continuous voltage units for resonant network compatibility and 10hr 24kV TOV capability
- test existing No.1 Capacitor Bank.
- reconfigure and replace CTs
- test all underground 22kV feeder exits (on MBN014, MBN031 and MBN032), and replace as required
- extend station yard and earth grid as required
- install weather station

Secondary requirements

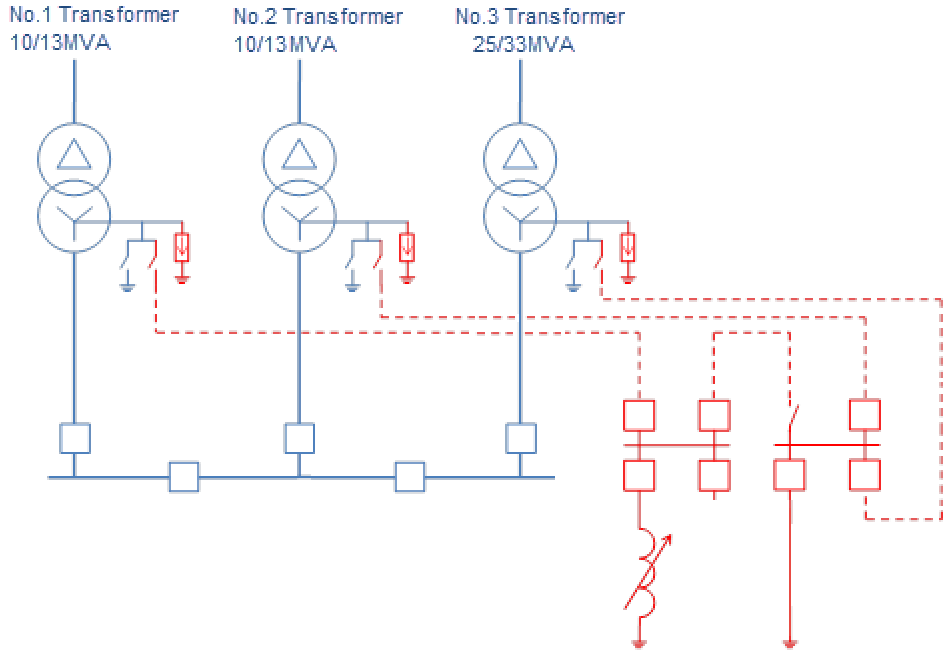
- firmware upgrades and new settings for recently installed devices
  - feeder protection relays
  - CB 'G' CB management relay
  - capacitor bank protection
- utilising existing cubicle space to install the following cubicles
  - X Protection Ethernet communication cubicle
  - REFCL cubicle
  - Earth Fault Management cubicle

- HMI cubicle
- CB Management cubicle
- Backup Earth Fault and Digital Fault Recorder cubicle
- PQM and VAR Control cubicle

2.1 Primary plant requirements

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

Figure 1 MBN Proposed Neutral Diagram



2.1.1 Arc suppression coil

Install one (1) x 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 GFN ASC shall be installed in the west location of the yard;

- install Ground Fault Neutraliser comprising of one (1) x 17-200A 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
- install cable connections to and from the Neutral System.

2.1.2 GFN inverter room

Install one (1) GFN inverter hut in the west end of the yard.

2.1.3 Zone substation surge arrestors

In a non-effectively earthed system, the voltage displacement caused under earth fault conditions results in the healthy phases experiences full line-to-line voltage on a line-to-ground basis. Surge arrestors used in Powercor substations do not have the Temporary Overvoltage Capability required for these conditions.

To accommodate transition to a resonant network, replace all sub-standard zone substation surge arresters with a station class (class 2) 22kV continuous voltage arrestor (ABB MWK22 or equivalent).

2.1.4 Zone substation capacitor bank

The existing No.2 capacitor bank is connected in grounded star with CTs which require replacement. To make this existing capacitor bank with resonant network requirements:

- the neutral star-point earth shall be removed from the No. 2 22kV capacitor bank:
  - neutral (star-point) structure must provide sufficient insulation to allow for continuous neutral displacement (12.7kV + 10%) under system earth fault conditions
  - the primary designer shall review the existing design to ensure the neutral point is fit for continuous operation at 13.97kV
  - the star point shall be reconfigured as a floating neutral, and the neutral structure re-designed if necessary
- replace CTs on capacitor bank with new REFCL compliant CTs.

2.1.5 22kV Underground exits

Given the underground failure rate seen on current REFCL networks, following from testing, there may be a requirement to replace of all underground 22kV feeder exits (i.e. on MBN014, MBN031 and MBN032). The replacement exit cables are to be 300mm2 Cu cables.

2.1.6 Neutral system arrangement

Install a Neutral Bus system comprised of:

- two (2) new kiosk type ground mounted modules as per Powercor technical standard ZD081
  - one (1) new type A comprising of four (4) CBs
  - one (1) new type B1 comprising of three (3) CBs and one (1) 22kV switch
- transformer neutral connection assets
  - HV neutral cable
  - neutral bus connection isolator
- system earth connection.

The Neutral Bus system facilitates simple use of the different earthing methodologies and permits isolation of the transformer neutral in case of access or internal fault.

The Neutral Bus system and all connection assets shall be continuously rated to 13.97kV:

- the Type A neutral bus module has CTs on two (2) of the CBs. Connection to one (1) transformer neutral and to the Type B1 neutral bus module is to be via a CB with CT at the neutral bus module end
- the Type B1 neutral bus module has CTs on two (2) of the CBs. Connection to each of the remaining two (2) transformer neutrals are to be via a CBs with CT at the neutral bus module end.

Neutral Bus

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

- Type A neutral bus:
  - transformer neutral connection (1 x transformers)

- – ASC connection
- – solid ground connection will **<u>not</u>** be used
- – neutral bus tie connection

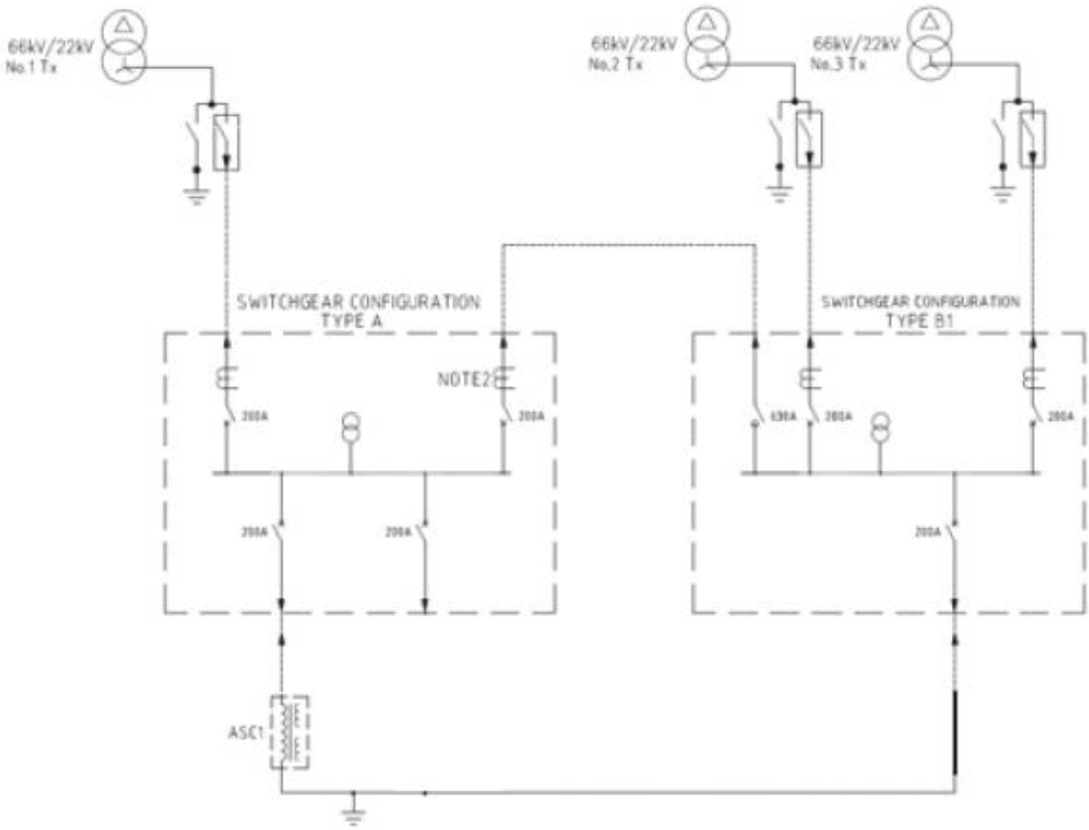
- Type B1 neutral bus:
  - – Transformer neutral connection (2 x transformers)
  - – ASC connection
  - – Neutral bus tie connection.

Neutral Voltage Transformer

A neutral VT shall be included in each of the Neutral Bus modules, connected directly to the bus.

- 22000 √3 ⁄ 110 √3
- Class 0.5M1P
- Output: 15VA
- Frequency: 50 Hz
- Voltage Factor: 1.9 for eight (8) hours
- Dielectric Insulation Level: 24/50/150kV
- Australian Standard: AS 60044.2.

Figure 3 Proposed MBN neutral system single line diagram



2.1.7 Transformer Earthing and Ground Bypass Isolators

The three (3) 66/22kV, (i.e. 1 x 25/33MVA and 2 x 10/13MVA) transformers in service at MBN are delta/star connected with the neutral of the star windings directly earthed.

The neutral earthing arrangement for each transformer shall be modified to permit connection to the Neutral Bus system. For each transformer neutral connection point:

- insulate the neutral conductor and install independent Neutral Bus/Direct Ground isolators
    - this is required so that if the neutral bus is to be taken out of service the transformer neutrals can be earthed by closing these ground by-pass isolators
- install single phase HV cable and cable terminations between the new Transformer Neutral Bus Isolators and the relevant Neutral Bus CB via elbow connections on the Neutral Bus RMU.

2.1.8 Neutral surge diverter

Install a Station Class (Class 2) 19kV surge diverter between the transformer neutral bus and the substation earth grid, as close to the transformer neutrals as possible (ABB MWK19 or equivalent).

2.1.9 22kV Bus VT

Replace the existing No.1 and No.3 22kV bus VTs with the following specification:

- Frequency: 50Hz
- Ratio: 22,000/110/110V
- Connection: Star/Star/Star
- Vector Group: YNyn0yn0
- Neutral for HV and 2 LV Windings: Solidly Earthed
- Output: 100VA Per Phase Per Secondary Winding
- Accuracy: Class 0.5M1P per secondary winding at the specified voltage factor
- Voltage Factor: 1.9 for 8 Hours
- Category B

2.1.10 Station service transformer

Replace the existing two (2) 63kVA 22kV Station Service Transformer from the No.1-2 and No.3 22kV bus.

Install two (2) new 500kVA 22kV Station Service Kiosk Transformer:

- the general arrangement drawing shows the suggested location for this kiosk in the south end of the yard
- connect the two (2) new station service transformer to:
    - the north end of No.1 22kV bus, protected by HV fuses on the bus
    - the west end of No.3 22kV bus, protected by HV fuses on the bus.

2.1.11 Adjacent non-REFCL ZSS 22kV feeder transfers

To identify where surge arrestors need to be replaced and how much of the network needs to be surveyed to hardened and balanced the network so that non-REFCL network can be transferred onto a REFCL network.

The following switching zone which is the transfers from non-REFCL subs that need to be considered

- MDA023 → MBN032

- CLOSE RCTS - MDA No.1 P140 GV Switch (SW# 20017)
- OPEN Benetook – Fifteenth P8A Kiosk Switch (SW# 67151)
- OPEN Karadoc X 15-Dairtnunk P11 Gas Switch (SW# 48446)
- OPEN RCTS - MDA No.1 P121 GV Switch (SW# 19695)
- OPEN RCTS - MBN P194 Gas Switch (SW# 61571)

- MDA032 → MBN023 and MBN012
  - CLOSE Between Ontario 13th Kiosk Switch (SW# 30079)
  - OPEN Walnut – Ontario P27 Switch (SW# 46031)
  - CLOSE Walnut P2 GV Switch (SW# 11745)
  - OPEN MDA032 Feeder CB
- MDA033 → MBN023
  - CLOSE Ontario – Walnut P27 Gas Switch (SW# 35391)
  - OPEN MDA033 Feeder CB
- MDA034 → CRO021
  - CLOSE Etiwanda – Riverside P10 Switch (SW# 13101)
  - OPEN MDA034 Feeder CB

2.1.12 22kV insulators

Replace all existing under rated pin insulators with 24kV rated station post insulators

2.1.13 22kV Feeder CTs

The existing feeder CT specifications are outlined below.

Table 3 Feeder CT information

Feeder	CT Spec	Required Action
MBN012	0.2PX 100 R0.3 300/5	Not suitable for sensitivity requirements, require new CT installation.
MBN013	0.2PX 100 R0.3 300/5	Not suitable for sensitivity requirements, require new CT installation.
MBN014	0.2PX 100 R0.3 300/5	Not suitable for sensitivity requirements, require new CT installation.
MBN023	0.2PX 100 R0.3 300/5	Not suitable for sensitivity requirements, require new CT installation.
MBN031	0.2PX 100 R0.3 300/5	Not suitable for sensitivity requirements, require new CT installation.
MBN032	0.2PX 100 R0.3 300/5	Not suitable for sensitivity requirements, require new CT installation.

The 22kV feeder CTs require testing to determine their suitability for REFCL fault detection and feeder balancing. A process is currently underway to determine the performance of different CTs across the Powercor network to further guide REFCL scoping requirements. Horizon breakers have been identified to have appropriate accuracy, but still require testing.

The performance requirements do not align to any conventional standard and must be confirmed through a particular set of tests.

At MBN, two (2) 22kV feeder CTs require newly installed core balance CTs 600-300/5A 40-20VA class 0.1 inbuilt with to the new feeder CBs (MBN031 and MBN032).

The remaining four (4) 22kV feeder CTs (MBN012, MBN013, MBN014 and MBN021) require newly installed post mounted metering CTs 600-300/5A 40-20VA class 0.1 RITZ Outdoor Current Transformer - GIFS36-42 50Hz (refer to quote 18305R REV03). Note that these are the same CTs used at EHK CT mounting structure in each feeder bay that requires new CT's.

2.1.14 Other considerations

Other considerations required are:

- replacement of 66/22kV transformers if they fail tests
- lighting study/review
- replacement of neutral structures if there any clearance or quality issues
- asbestos and contaminated soil
- cable duct replacement for new cable installation
- earth grid extension.

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 system module
  - install conduits to ASC and solid earth grid connection
  - install conduits for secondary circuits
- For ASC:
  - 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
  - review station service transformer foundations and enclosure for upgrade to 750kVA. Note the existing station services are 63kVA
- For new 22kV No.1 and No.3 Bus VTs:
  - install concrete footings for new structures
  - install control cable conduits for both 22kV VT.

2.3 Secondary works

2.3.1 22kV Control Room Works

Station RTU cubicle

- Install one (1) SEL-3505-4 RTACs for RTU & High Voltage Customer NVD comms
- Install one (1) Tekron GPS Clock
- Install station I/O Controllers (SEL-2440) for HW connections to non-DNP devices
- Note:
  - RTAC to be used for establishing DNP session to 22kV relays
  - RTAC NVD to be used for new neutral displacement blocking scheme for 22kV connected generators

SubLAN X & Y Protection A Loop cubicle

- Install standard 23" protection cubicle
- Install two (2) RST-2228 Ethernet Switches for
  - X RST-2228-21 SubLAN
  - X RST-2228-22 SubLAN
- Note: Y Protection Ethernet switches are not required at this stage however the design should cater for future installation

SubLAN X & Y Protection B Loop cubicle

- Install standard 23" protection cubicle
- Install two (2) RST-2228 Ethernet Switches for:
  - X RST-2228-41 SubLAN
  - X RST-2228-42 SubLAN
- Note: Y Protection Ethernet switches are not required at this stage however the design should cater for future installation

REFCL Cubicle

- Install standard Swedish Neutral GFN cubicle with associated devices for GFN control
- Note: the design party to advise of the preferred cubicle construction type to advise procurement of the GFN requirements

Station Earth Fault and Neutral Bus Management cubicle

- Install standard 23" protection cubicle
- Install one (1) SEL-451 relay for Station Earth Fault Management (SEFM)
- Install one (1) GE-F35 relay for Neutral Bus Management & X MEF

HMI Inverter Cubicle

- Install one (1) SEL-3505-4 RTAC with HMI for dedicated station HMI
- Install one (1) DC-AC inverter for supply to station HMI PC
- Install one (1) DC-DC converter for 24V DC distribution

- Install emergency lighting controls
- Install audible controls
- Note: establish red GPO on operator desk for connection of station HMI

66kV X CB Management cubicle

66kV CB 'G' CB management relay (SEL-351S) is adequate and does not require replacement. It requires a firmware and setting configuration upgrade.

- Install standard 23" protection cubicle
- Install two (2) SEL-351S X CB Management and X CB Fail relays for
    - 66kV CB A
    - 66kV CB B
- Note: these are to be configured for tripping from the REFCL for in-station faults.

66/22kV Trans Protection cubicles

The existing No1 and 2 Transformer Differential Relay (SEL-387E) is adequate and does not require replacement, as tripping of this zone is to be performed by tripping of the 66kV CB Management relays.

The existing No3 Transformer Differential Relay (SEL-387E) is adequate and does not require replacement, as tripping of this zone is to be performed by tripping of the 66kV CB Management relays.

Note: The following are not required at this stage but the panel layout must allow for the future installation of:

- one (1) GE-T60 relay for No1 Trans Y Differential and Y REF Protection
- one (1) SEL-2414 relay for No1 Transformer Mechanical Protection and monitoring

Backup Earth Fault and Disturbance Fault Recorder cubicle

- Install standard 23" protection cubicle
- Install one (1) GE-F35 relay for Backup Earth Fault (BUEF) protection
- Install one (1) Elspec G5 Black Box for 22kV Digital Fault Recorder (DFR)

Feeder Protection cubicles

The existing feeder protection relays (SEL-351S) are adequate for REFCL works. These relays will require firmware upgrades and new relay configurations. Feeder protection settings are to be reviewed.

- Upgrade six (6) SEL-351S relays for:
    - MBN012 feeder protection
    - MBN013 feeder protection
    - MBN014 feeder protection
    - MBN023 feeder protection
    - MBN031 feeder protection
    - MBN032 feeder protection
- Note: neutral CT ratio to be considered in relay setting. In addition rating of CTs and settings must consider handover between sensitive earth fault protection and inverse time earth fault protection.

PQM, VRR & VAR Control cubicle

- Install standard 23" protection cubicle
- Install one (1) ION-9000 relay for Station Summation PQM
- Install one (1) SEL-2411 relay for No1 Cap Bank VAR Control

Capacitor Bank Protection Cubicle

The existing capacitor bank protection relay (SEL-351S) is adequate for REFCL works. This relay will require firmware upgrades and new relay configurations. Protection settings are to be reviewed.

Note: neutral CT ratio to be considered in relay setting.

2.3.2 IEC61850 Configuration

- IEC61850 Design Integration Spreadsheet
  - prepare new IEC-61850 design integration spreadsheet
  - add and configure all new relays performing functions through IEC-61850
  - map and re-configure signals to new and existing relays as per relevant Scheme Documents
- IEC61850 Architect & GE UR Setup
  - configure CID files for all new relays performing functions through IEC-61850 as per Design Integration Spreadsheet
  - prepare station 'SCD' file as per Design Integration Spreadsheet
- IEC61850 Scheme document drawings
  - produce scheme document drawings to match configured Design Integration Spreadsheet.

2.3.3 GPS Clock

Establish time synchronisation to new relays

2.3.4 SCADA works

- Update Single Line Diagram to accommodate new SLD
- Update Alarm Pages to include new relays and retire old relays
- New configurations required for SEL RTACs

2.3.5 Fibre Optic works

- Establish new Fibre connections to new control room, inverter hut
- X & Y Fibre paths are to be diverse

2.3.6 DC Distribution

Install X & Y DC Distribution Wall boxes as per current standard.

2.3.7 AC Station service supplies

Install AC distribution as per current standard.

2.3.8 Building access control system

Install building access control system and intrusion detection as per current standard

2.3.9 Fire System & Indication

Install fire system as per current standard.

2.3.10 AC Charger & DC System

Load calculation for DC System to be attached in RESIS

2.3.11 Fibre Patch Panel

- Install X fibre patch panel/wall box
- Y fibre patch box to be installed at rear of any Y protection cubicle
- Fibre paths are to be diverse and Multimode OM3 (Aqua) fibre to be utilised

2.3.12 Operator Desk

- Install Station HMI PC, mouse, keyboard, monitor on operators desk
- Refer Protection & Control group for procurement and setup of these device

2.3.13 Station HMI works

- Create SLD and control pages
- Create IEC61850 status pages

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 surge diverters across the 22kV three phase and single phase system
- This covers all feeders ex MBN ZSS as well as surge arrestors on the MDA023, MDA032, MDA033 and MDA034 transfers
- All surge arrestors except 'Type A' Bowthorpes, will need to be replaced with the new ABB polim D 22kV arrestor
- The replacement diverters should be of 22kV continuous rating with a 10 hour 24kV TOV rating.

Table 4 Surge arrestor replacement volumes

Surge arrestors	Volume (sites)	Volume (arrestors)
Surge arrestor sites (single phase)	148	296
Surge arrestor sites (three phase)	1040	3120

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 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 MBN distribution network contains two (2) 22kV regulating systems and none on the transfer feeders:

Table 5 MBN regulating systems

Feeder	Name	Manufacturer	Phasing	Scope of works
MBN031	LAKE CULLULLERAINE 249 REG 1	Unknown – 3 x 200A Ground mounted	RWB	Require a new CL7 control box required to tap all phases together
MBN031	LAKE CULLULLERAINE P355 REG	Unknown – 2 x 100A pole mounted	Unknown	Require a new 3 x 100A 3 x 1∅ reg and CL7 control box required to tap all phases together

The table below summarises the replacements.

Table 6 Regulator works

HV regulators	Volume (sites)
Regulator sites	2
Regulator replacement	1
Control box upgrade	1

3.5 Capacitive 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 supplied from ART zone substation contains a significant amount of single phase lines. Whilst planning philosophies have always attempted to balance the single phase system, inevitably this is difficult to achieve and the objective has been load balancing rather than capacitive balancing. In order to balance the capacitance of the three phase system such that the ASC can be correctly tuned, balancing substations that utilise low voltage capacitors to inject the missing capacitance onto the system are to be placed at selected locations on the 22kV distribution system in addition to courser balancing by altering phase connections of single phase lines.

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.

As the existing phase connections of single phase lines and single phase transformers is largely unknown a detailed scope of works cannot be produced without visual inspection on site. This scope thus includes estimated quantities of the required balancing works with a subsequent detailed scope of works to be produced following a field audit to be conducted as described below.

A reconciliation of all 22kV overhead and underground lines routes (including the portion of HTN005 and STL005 covered by this scope) shall be conducted to enable a more detailed balancing design scope of the network balancing requirements to be produced.

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
    a. Perform field audits to validate “Single Phase” and “unknown” conductor where required
    b. Perform field audit to 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
    a. 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
    a. Conductor type, two or three core?
    b. Treatment of the unused core (earthed or phase bonded)
        i. If bonded, to what phase
6. Provide this data so that the network can be modelled with correct balancing study and a detailed balancing scope can be produced.

The data will be assessed and an action plan for a “course balance” will be developed as part of the separate detailed balancing design scope. The course balance will look at sections of the system in “switchable blocks” and for any re-phasing opportunities in order to balance out the single phase route lengths.

A finite balancing approach will then look at the system again in “switchable blocks” for the application of admittance balancing substations.

Prior to completion of this additional scope the estimated quantities are provided in the table below.

The number of rephasing sites, single phase balancing units and 3 phase balancing units are based on the experience of Tranche 1 and Tranche 2.

Table 7 Balancing requirements summary

Balancing concept	Number of sites MBN + transfers
Re-phasing Sites	10
Single Phase Balancing Units	2
3 Phase Balancing Units	11
RC Gas Switches	0

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

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

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
- continue to operate in the traditional manner automatically when REFCL is not in operation.

SWER transformer supplies for ACRs have been proven to fail.

Replace all ACRs SWER supply transformers.

Table 8 ACR sites

Feeder	Name	Operating voltage	Phase code	Control Box Model	ACR model
MBN013	WENTWORTH P57 ACR	22kV	RWB	CAPM5	N24
MBN014	RIVER AVE P43 ACR	22kV	RWB	ADVC	N24
MBN031	LAKE CULLULLERAINE P264 ACR	22kV	RWB	ADVC	unknown
MBN031	LOCK NINE P95A ACR	22kV	RWB	CAPM5	N24
MDA023	BENETOOK P32 ACR	22kV	RWB	ADVC	N24
MDA033	DEAKIN-HUNTER P61 ACR	22kV	RWB	ADVC	N24

Table 7 ACR and control box requirements summary

Units	Number of sites
ACR replacements	1
Control box replacements	2

3.7 Fusesavers

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

Fusesavers 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.

Fusesavers are required to operate for any fused section with a minimum downstream network capacitive charging current of 150mA for the 40A model, 500 mA for the 100A model and 1A for the 200A model. If fault levels are too high, then alternative solutions are required (e.g. augmentation works, network rearrangement, etc).

The table below shows the number of sites where fusesavers will be required.

Table 8 Fusesaver requirements

Units	Number of sites MBN + transfers
Fusesavers	18

3.8 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.

Based on our tranche one experience, we will replace 100% of the ABB and F&G switchgear as well as 6 per cent of all other distribution switchgear. Table 9 Switchgear replacements

Unit	Volume
Distribution switchgear	30

3.9 HV underground cable

Experience from REFCL testing has shown that HV underground cable can fail due to a number of flaws. Manufacturing techniques in the past have relied on steam curing of XLPE cables which can in the presence of higher voltages, result in extensive water treeing and subsequent failure. Additionally, joints and other terminations produce higher stress and can be a point of failure. The following lengths of cable are required to be replaced.

Table 10 HV underground cable requirements

Location	Length (m)
Cable failure length	4,176

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 variations in the distribution code (section 4.2.2) no longer applies during a REFCL condition.

For HV customers, this means that they need to ensure that their network can tolerate these conditions. Given this, all HV customers will now have an ACR installed at their supply point. HV customers which generate and export onto the 22kV system require additional signalling to coordinate with the REFCL operation.

Table 11 HV customer

Units	Volume
HV customer sites with generation	0
HV customer sites without generation	2
Total HV customer sites	2

4 Appendix

4.1 Proposed Site General Arrangement