

Functional Scope Created	13/06/2019	By	Danny Jutrisa		
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Project Title	Stawell (STL) ZSS REFCL Installation				
Network No. and F/C					
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Related Scopes					
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System Planning Engineer	Danny Jutrisa				
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Plant and Stations Engineer					
Asset Strategy Engineer					
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Revision History:

Version	Date	Changes	Responsible Officer
0.1	13/06/2019	Initial scope	D. Jutrisa
0.2	25/06/2019	Added secondary requirements	V.Hadya
1.0	13/08/19	Final review	V.Hadya

## 1 Project overview

This project scope covers the migration of the Stawell zone substation (**STL**) 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 Stawell zone substation

Stawell 66/22 kV zone substation is a banked station consisting of two (2) 10/13.5 MVA transformers and two (2) capacitor banks of 1 x 6Mvar and 1 x 3Mvar. It is located on the western outskirts of Stawell. It was established in 1964 and supplies the city of Stawell and the rural areas north to Rupanyup, east to Landsborough and south to Halls Gap. The Halls Gap tourist area is the main growth area with some growth occurring in Stawell town.

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 STL. ART031, HSM001 and MRO005 are the feeders that can be transferred to STL.

The switch zones are as follows:

- ART031 → STL007, between Great Western P760A Gas Switch (SW# 50356) and ART031 Feeder CB
- HSM001 → STL006, between Murtoa P178 Gas Switch (SW# 38857) and Murtoa P178 ACR (SW# 80573)
- MRO005 → STL007, between Fused GV Switch P349 Moonambel Line (SW# 49680) and Switch P222 Moonambel Line (SW# 47245)

Given MRO005 has already been hardened and ART031 will be hardened as part of the tranche 2 works, only the HSM001 transfer blocks will need to be hardened as part of this scope.

**Table 1** STL: existing characteristics (zone substation)

Zone substation	Volume
Feeders	4
Zone substation transformers	2
22kV buses	3
Capacitor banks	2
Station service transformers	1
22kV circuit breakers (switching configuration)	8 (Banked)

Table 2 STL: network characteristics

Network	Volume STL only	Volume with transfer
Total route length (km)	541	581
Underground cable length (km)	2.3	2.8
Overhead line length (km)	539	583
Underground network (%)	0.43%	0.47%
Overhead single phase	168	177
Estimated network capacitance (A)	42	46
Distribution transformers	659	702
HV regulator sites	4	5
Fuses	785	794
ACRs	11	12
Surge arrestor sites	1,665	1,787
HV customers	2	2

## **2 ZSS requirements**

This functional scope sets out the STL 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 one (1) new control room
- install one (1) new amenities room
- install four (4) feeder CTs (on STL004, STL005, STL006 and STL007)
- upgrade station service supply to one (1) 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 one (1) 22kV Bus VT
- replace ALL substation surge arrestors with new 22kV continuous voltage units for resonant network compatibility and 10hr 24kV TOV capability
- install new No.1 and No.3 Capacitor Banks:
  - install new two (2) x 3MVar modular system on Bus No.1
  - install new one (1) x 3MVar modular system on Bus No.3
- extend station yard and earth grid as required
- install weather station

### **Secondary requirements**

- Within the existing control room
  - retire and declare out of service
    - feeder protection relays
    - transformer differential
    - capacitor bank protection relays
    - Master and Backup Earth Fault relays
  - install interface equipment to concentrate and display operator alarms

- Install the following cubicles within the new control room
  - uplink communication and substation LAN cubicle
  - Station Remote Terminal Unit (RTU) cubicle
  - X Protection Ethernet communication cubicle
  - REFCL cubicle
  - Earth Fault Management cubicle
  - HMI cubicle
  - CB Management cubicle
  - Station Differential cubicle
  - Backup Earth Fault and Digital Fault Recorder cubicle
  - No1 Bus Feeder Protection cubicle
  - No2 Bus Feeder Protection cubicle
  - Capacitor Bank Protection cubicle
  - PQM and VAR Control cubicle.

## 2.1 Primary plant requirements

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

Figure 1 STL existing Neutral Diagram

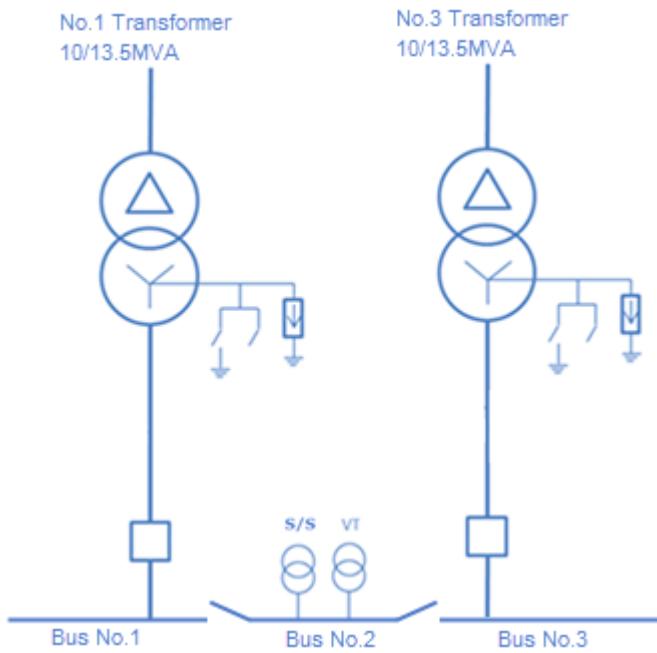
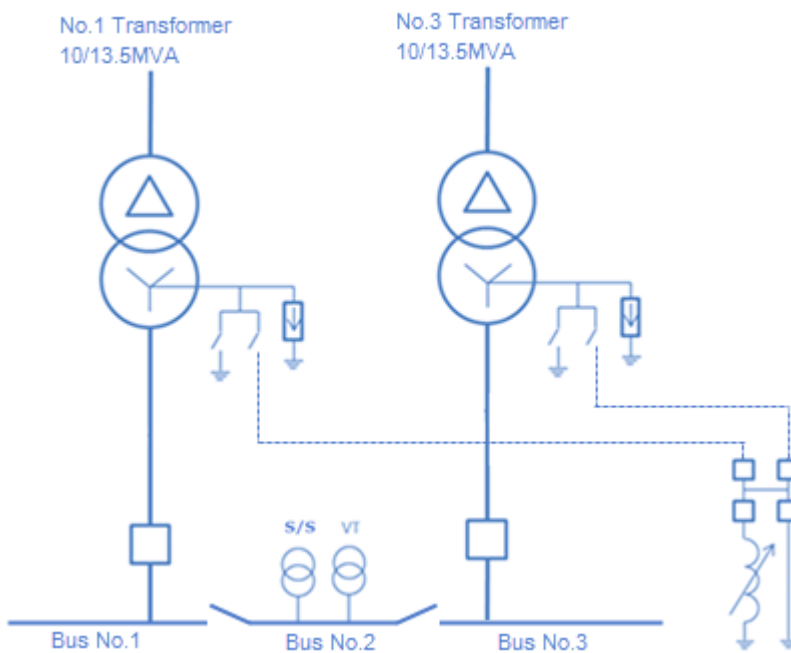


Figure 2 STL proposed Neutral Diagram



### **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 switched 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 location of the existing Capacitor Bank No.3:

- 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 south east corner 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 arrestors with a station class (class 2) 22kV continuous voltage arrestor (ABB MWK22 or equivalent).

### **2.1.4 Zone substation capacitor bank**

The existing No.1 and No.3 22kV capacitor banks are connected in grounded star with tuning reactors and CTs which require replacement. The current capacitor banks have a limitation with the inrush reactor and therefore our ability to make it compliant.

Retire the existing No.1 (1 x 3MVAR) and No.3 22kV (1 x 6MVAR) capacitor banks, then to provide reactive support, install two (2) new capacitor banks is required on the No.1 and No.3 buses.

- For Bus No.1 install new two (2) x 3.0MVAR ABB Abbacus modular capacitor banks and associated protection
- For Bus No.3 install new one (1) x 3.0MVAR ABB Abbacus modular capacitor banks and associated protection
- New cabling from the existing capacitor back CBs to the control room is required. Underground cable to the switch room is to be 3 x 630mm<sup>2</sup> 1/c Al HV cable.

The two new capacitor banks are to be located in the south east corner of the yard.

### **2.1.5 Neutral system arrangement**

A neutral bus system comprised of:

- one (1) new kiosk type ground mounted modules as per Powercor technical standard ZD081
  - Type A comprising of four (4) circuit breakers
- 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 each of the two (2) transformer neutrals is to be via a CB with CTs 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:

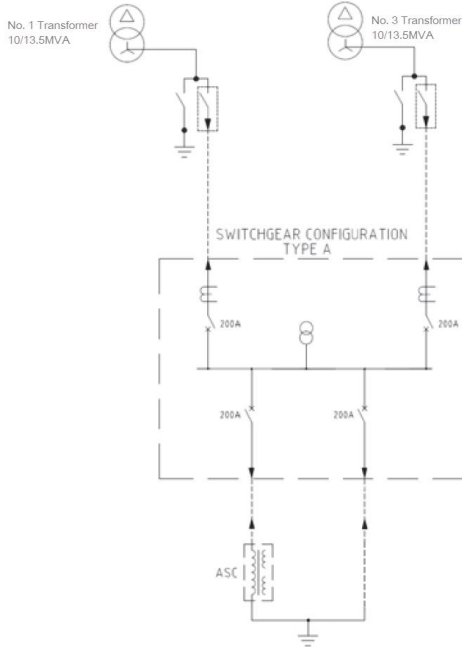
- Transformer neutral connection (2 x transformers)
- ASC connection
- Solid ground connection
- Neutral bus tie connection

#### **Neutral Voltage Transformer**

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

- 22000  $\sqrt{3}$  / 110  $\sqrt{3}$
- 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 4 Proposed STL neutral system single line diagram**



### 2.1.6 Transformer Earthing and Ground Bypass Isolators

The two (2) 66/22kV, 10/13.5MVA transformers in service at STL 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.

### 2.1.7 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).

### 2.1.8 22kV Bus VT

Replace the existing No. 3 22kV bus VT with a VT 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

**2.1.9 Station Service Transformer**

Retire the existing 63kVA 22kV Station Service Transformer from the No.2 22kV bus.

Install a new 500kVA 22kV Station Service Kiosk Transformer:

- the general arrangement drawing shows the suggested location for this kiosk in the south east end of the yard
- connect the new station service transformer to the No.1 22kV bus, protected by HV fuses on the bus.

**2.1.10 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 to non-REFCL subs that need to be considered:

- HSM1 → STL6
  - CLOSE Murtoa P381 SW#38857
  - OPEN Murtoa P178 ACR SW#80573

**2.1.11 22kV Insulators**

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

**2.1.12 22kV Feeder CTs**

The existing feeder CT specifications are outlined below.

Table 3 Feeder CT information

Feeder	CT Spec	Required Action
STL004	10P100 300/5	Not suitable for sensitivity requirements, require new CT installation.
STL005	10P100 300/5	Not suitable for sensitivity requirements, require new CT installation.
STL006	0.2PL100 R0.3 300/5	Not suitable for sensitivity requirements, require new CT installation.
STL007	0.2PL100 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 STL, all four (4) 22kV feeder CTs 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 CTs.

#### 2.1.13 Other considerations

Other considerations required are:

- replacement of CBs if they fail tests
- 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
- vegetation removal.

## 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 service is 63kVA
- For new 22kV No.2 Bus VT:
  - install concrete footings for new structures
  - install control cable conduits for No.2 22kV VT
  - review concrete footings for replaced one (1) VT
- New control room and amenities/storage room:
  - build to be determined by design.

## **2.3 Secondary Works**

### **2.3.1 Existing control room works**

#### **Alarm aggregation**

- Install three (3) Station I/O Controllers to digitise hardwired signals
  - SEL-2440 for hard wired signals and alarms
  - SEL-2440 for hard wired signals and alarms
  - SEL-2411 for analog signals
- 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 one (1) Advantech Panel PC for limited alarm point display and to direct operator to new control room
- Note:
  - all alarms must be observable via the HMI within the new control room
  - the existing control room HMI must display station alarms from the existing control room and direct the operator to new control room for full visibility.

### **2.3.2 22kV control room works**

#### **Uplink Communication & SubLAN Control Loop cubicle**

- Install standard 23" protection cubicle
- Install two (2) Fortigate 60E firewalls
- Install one (1) MDS SD9 radio device
- Install one (1) 3G modem
- Install one (1) EKI-2525 Ethernet switch
- Install two (2) RST-2228 SubLAN switches
- Note:
  - this is to be configured to communicate with existing control room and Powercor System Control Centre (PSCC)
  - MDS radio unit device type and part no. is to be confirmed by the comms group
  - the SubLAN switches in this cubicle are to be ordered with 4x RJ45 ports.

#### **Station RTU cubicle**

- Install standard 23" protection 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**

- 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 cubicle**

- Install standard 23" protection cubicle
- Install one (1) SEL-787 relay for Station X Differential
  - In future this is to be reutilised for No1 Trans X Differential and X REF Protection
- 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)

#### **No1 Bus 22kV Feeder Protection cubicle**

- Install standard 23" protection cubicle
- Install two (2) SEL-351S relays for:
  - STL007 Feeder protection
  - STL005 Feeder protection
- Note:
  - Space to be reserved for future feeder protection relays (STL003 and STL001)
  - 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

#### **No2 Bus 22kV Feeder Protection cubicle**

- Install standard 23" protection cubicle
- Install two (2) SEL-351S relays for:
  - STL004 Feeder protection
  - STL006 Feeder protection
- Note:
  - Space to be reserved for future feeder protection relays (STL002 and STL008)
  - 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 No2 Cap Bank VAR Control



#### **Capacitor Bank Protection cubicle**

- Install standard 23" protection cubicle
- Install two (2) SEL-351S relay for:
  - No1 Capacitor Bank OC, EF & Management
  - No3 Capacitor Bank OC, EF & Management
- Note: neutral CT ratio to be considered in relay setting

#### **2.3.3 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 TRG Scheme document drawings
  - produce scheme document drawings to match configured Design Integration Spreadsheet

#### **2.3.4 GPS Clock**

Establish time synchronisation to new relays.

#### **2.3.5 SCADA works**

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

#### **2.3.6 Fibre Optic works**

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

#### **2.3.7 DC Distribution**

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

#### **2.3.8 AC Station service supplies**

Install AC station service, AC changeover & AC distribution as per current standard

#### **2.3.9 Building access control system**

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

#### **2.3.10 Fire System & Indication**

Install fire system as per current standard

#### **2.3.11 AC Charger & DC System**

- Install X & Y Battery Charger as per current standard
- Install X & Y DC Systems as per current standard
- Load calculation for DC System to be attached in RESIS

#### **2.3.12 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

#### **2.3.13 Operator Desk**

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

#### **2.3.14 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 STL ZSS as well as surge arrestors on the HSM001 transfer. It excludes the section of STL between Landsborough P144 ACR and the MRO005 open point (at Moonambel Line P349 Switch) as it was done as part of MRO works. It also excludes the MRO005 and ART0031 transfers as they will be done as part of their respective station scopes
- 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)	184	368
Surge arrestor sites (three phase)	249	747

#### 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 STL distribution network contains four (4) 22kV regulating systems as well as one (1) 22kV regulating system on the HSM001 transfer feeder:

Table 5 STL regulating systems

Feeder	Name	Manufacturer	Phasing	Scope of works
STL005	HALLS GAP P107 REG	Unknown – 2 x 200A pole mounted	Unknown	Require a new 3 x 200A 1Ø reg and CL7 control box required to tap all phases together
STL006	GLENORCHY P185 REG	Unknown – 2 x 200A pole mounted	Unknown	Require a new 3 x 200A 3 x 1Ø reg and CL7 control box required to tap all phases together
STL006	GLENORCHY P394 REG	Unknown – 3 x 100A ground mounted	RWB	Require new CL7 control box only to tap all phases together.
STL007	LANDSBOROUGH P215A P215B REG	Unknown – 3 x 100A pole mounted	RWB	No issue (done as part of MRO005 works)
HSM001	MURTOA REG	Unknown – 1 x 2MVA ground mounted	RWB	No issue

The table below summarises the replacements.

Table 6 Regulator works

HV regulators	Volumes (sites)
Regulator sites	4
Regulator replacement	2
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.



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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
Re-phasing Sites	30
Single Phase Balancing Units	4
3 Phase Balancing Units	15

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

Each RVE or VWVE ACR on the STL 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
STL005	MOUNT WILLIAM P1 ACR	22kV	RWB	ADVC	N24
STL005	HALLS GAP P13 ACR	22kV	RWB	ADVC	W27
STL005	POMONAL P4 ACR	22kV	RWB	CAPM5	N24
STL005	HALLS GAP P121 ACR	22kV	RWB	CAPM5	N24
STL006	GLENORCHY P31 ACR	22kV	RWB	CAPM5	N24
STL006	MARNOO P1A ACR	22kV	RWB	CAPM5	N24
STL006	MINYIP P1 ACR	22kV	RWB	CAPM5	N24
STL006	GLENORCHY P125 ACR	22kV	RWB	ADVC	VWVE27
STL006	HOTS-STL P397 ACR	22kV	RWB	CAPM5	N27
STL007	LANDSBOROUGH P144 ACR	22kV	RWB	ADVC	N24
STL007	LANDSBOROUGH P35 ACR	22kV	RWB	ADVC	N27
STL007	LANDSBOROUGH P56 (Switch)	22kV	RWB	ADVC	Switch
HSM001	MURTOA P178 ACR	22kV	RWB	CAPM5	N24

Table 7 ACR and control box requirements summary

Units	Number of sites
ACR replacements	1
Control box replacements	7

### 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
Fuse savers	39

### 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	9

### 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)
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Location	Length (m)
Cable failure length	164

### 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**

