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| CitiPower | **ELECTRICITY NETWORKS**<br>**Asset Strategy and Performance**<br>**Functional Scope** | Powercor Australia |

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|---|---|---|---|---|---|
| Functional Scope Created | 30/10/18 | **By** | Danny Jutrisa | | |
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| Project RO | | **Ex:** | | | |
| Project Title | Ararat (**ART**) REFCL Installation | | | | |
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| Related Scopes | | | | | |
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| System Requirement Date | | | | | |

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| Version | Date | Changes | Responsible Officer |
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| 0.1 | 02/11/2018 | Original | D. Jutrisa |
| 0.2 | 05/12/2018 | Site visit update – revised protection and control requirements | L. Venn |
| 0.3 | 05/12/2018 | Minor updates for Tech Peer Review submission | D. Jutrisa |
| 0.4 | 13/12/2018 | Minor tech peer review updates | D. Jutrisa |
| 0.5 | 18/12/2018 | Update of SST connection and 22kV CT specs | D. Jutrisa |
| 1.0 | 20/12/2018 | Update FS purpose and Neutral Bus naming convention | D. Jutrisa |

# 1 Project overview

This project scope covers the migration of the ART system to a resonant earthed network through the installation of the Ground Fault Neutraliser (GFN). The GFN is an adaptation to tradition Petersen Coil / Arc Suppression coil systems where a tuned reactance is placed in the substation neutral. The GFN system employs further technology through the use of an inverter to apply residual compensation into the system neutral in order to fully compensate system earth faults by nullifying the faulted phase voltage to near zero. Migration to a resonant network requires significant upgrade of system components (to withstand full system displacement) and realignment of network management strategy and policy.

## 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 ART zone substation

The ART zone substation is located in Ararat, Victoria and consists of two (2) transformers, four x (4) 22kV feeders and one (1) capacitor bank. It supplies the region to Elmhurst, Lake Bolac and towards the Grampians national park.

The two transformers are in a banked arrangement and a fault on any one transformer or 22kV busbar will cause a station black.

To permit the transfer of loads from adjacent zone substations with the GFN in service the 22kV feeder requirements in section D of this scope must also be applied to the portion of the feeders that can be transferred to ART. HTN005, MRO008, STL005 and TRG002 are the feeders that can be transferred to ART.

The switch zones are as follows:

- HTN005 → ART033, between Ballarat Rd P460 ACR (SW22661) and Ballarat Rd P60A ACR (SW47789)
- TRG002 → ART033, between Lake Bolac P279 ACR (SW32540) and Woorndoo P27 ACR (SW24064)
- MRO008 → ART023, between GV Switch P502 Avoca Line (SW15101) and Avoca P289 ACR (SW34445)
- STL005 → ART031, between Gas Switch P760A Great Western (SW50356) and GV Switch Great Western P10 (SW24242)

Given MRO008 has already been hardened and TRG002 will be hardened as part of the Tranche 2 works, only the HTN005 and STL005 transfer blocks will need to be hardened as part of this scope.

**Table 1 ART existing characteristics (zone substation)**

| Zone substation | Volume |
|---|---|
| Feeders | 4 |
| Zone substation transformers | 2 |
| 22kV buses | 2 |
| Capacitor banks | 1 |
| Station service transformers | 1 |
| 22kV circuit breakers (switching configuration) | 5 |

**Table 2 ART: existing characteristics (network)**

| Network | Volume |
|---|---|
| Total route length (km) | 796 |
| Underground cable length (km) | 4 |
| Overhead line length (km) | 792 |
| Underground network (%) | 0.5 |
| Overhead single phase | 465 |
| Estimated network capacitance (A) | 64 |
| Distribution transformers | 850 |
| HV regulator sites | 6 |
| Fuses | 1,050 |
| ACRs | 5 |
| Surge arrestor sites (3 phase) | 345 |
| Surge arrestor sites (1 phase) | 643 |
| HV customers | 1 |

# 2 ART zone substation functional requirements

The functional scope sets out the ART zone substation requirements, including the following:

- install and commission one (1) GFN system and its subcomponents
  - install one (1) 17-200A ASC
  - install one (1) 320kVA RCC Inverter
- modification of the 22/66kV transformer earthing arrangement
  - installation of Neutral Bus Bypass Isolators on the new Transformer Neutral Connection
  - insulate and surge protect transformer neutral and connection assets
  - installation of one (1) Neutral Bus System (Type 'A' configuration per Powercor ZD081 technical standard)
    - transformer and Neutral Bus Tie CB's
    - ASC and Direct Ground Connections
- replace existing station service supply with one (1) new 500kVA kiosk transformer
  - upgrade station service supplies including installing a new AC distribution board
- replace one (1) existing 22kV VT
- replace four (4) 22kV feeder CTs.
- replace all substation surge arrestors with new station class units
- HV customer requires neutral displacement block
- install weather station

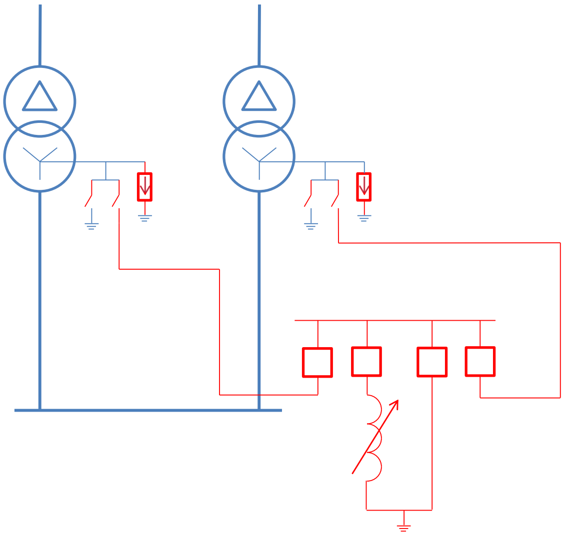
**Secondary requirements**

- install new Elspec Power Quality Meter
- install new MEF and Neutral Bus Management Relay GE F35
- install new Station Earth Fault Management Relay SEL-451
- install Station Differential protection relay SEL787-3
- install new 66kV CB Management relays SEL351S

## 2.1 Primary plant requirements

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

Figure 1 : ART single line diagram



### 2.1.1 Ground bypass isolators

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

### 2.1.2 Arc suppression coil

Install one (1) 17-200A Swedish Neutral – Ground Fault Neutraliser 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 this is an oil filled device, it shall be installed in a bunded area in accordance with current standards (AS2067). The total volume of oil is approximately 1320 litres.

The proposed location for the GFN ASC installation is adjacent to the control room in the north-west corner (refer to the proposed general arrangement drawing in the appendix). Suitability shall be evaluated within the Detailed Design Scope (DDS) and confirmed prior to the first Construct, Operate and Maintain (COM1) on site.

- install Ground Fault Neutraliser comprising of one (1) 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.

### 2.1.3 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 using ABB MWK22 or equivalent

### 2.1.4 Zone substation capacitor bank

ART ZSS has one (1) 22kV Capacitor Bank.

The existing No.3 22kV Capacitor Bank is ungrounded so no changes are required.

### 2.1.5 Station service transformer

Retire the existing 25kVA 22kV Station Service Transformer from the No.3 22kV bus.

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

- the general arrangement drawing in the appendix shows suggested locations for this kiosk
- connect the new station service transformer to the No.3 22kV bus, protected by HV fuses on the bus. Note that the VT is to remain connected via the original fuses.

### 2.1.6 Neutral system arrangement

Install 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 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 at one module for:

- transformer Neutral connection (2 transformers)
- Neutral Bus Tie
- ASC Connection
- solid ground connection.

**Neutral Voltage Transformer**

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

- $\frac{22000/\sqrt{3}}{110/\sqrt{3}}$
- 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.

**Transformer Earthing and Ground Bypass Isolators**

The two (2) 66/22kV transformers in service at ART are delta/star connected with the neutral of the 22kV star winding solidly earthed.

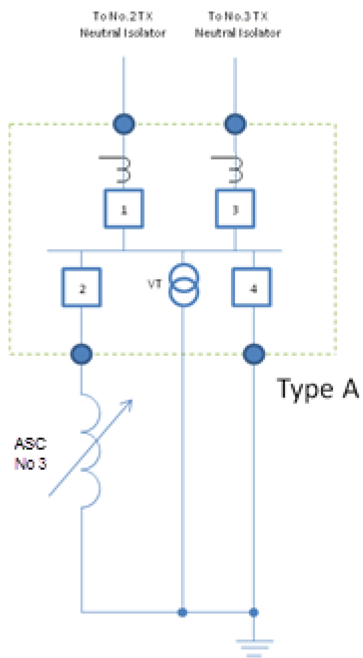
The neutral earthing arrangement for each transformer shall be modified to permit connection to the Neutral Bus system. For each transformer neutral connection point:

- 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.

**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, using ABB MWK19 or equivalent.

Figure 2 Proposed ART neutral system single line diagram



#### 2.1.7 22kV bus VT

Replace the existing No. 3 22kV bus VT with a VT with the following specification (SAP ID 310661):

- 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.
- Dielectric Insulation Level: 24/50/150kV.
- Australian Standard: AS 60044.2.

This existing VT (TWS Controls – SAP # 381684) requires replacement as it has a voltage factor of 1.9 for 30 sec, and a voltage factor of 1.9 for 8 hours is required.

#### 2.1.8 Feeder protection current transformers

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 ART, 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.

#### 2.1.9 22kV insulators

Replace all existing unrated 22kV pin insulators with station post insulators.

#### 2.1.10 ZSS general arrangement considerations

Consideration is required for all elements of the ART ZSS possible ultimate plan as per its System Design Sheet.

**22kV feeder rearrangement**

There are no feeder rearrangement requirements.

**22kV bus naming**

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

Nameplates in the 22kV yard must be reviewed and any that do not conform with the new naming of primary plant must be replaced. Nameplates for all 22kV circuit breakers, buses, isolators, disconnect switches, earth points and cables must also be reviewed.

All Primary and Secondary drawings must be reviewed and any that do not conform with the new naming of primary plant must be updated. Drawings with references to 22kV circuit breakers, buses, isolators, disconnect switches, earth points and cables must be reviewed.

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

## 2.2 Civil works requirement

- For Neutral Systems:
  - install concrete foundation pad for neutral system modules
  - install neutral cable conduit, control cable conduit and provision for solid earth grid connections
  - install neutral cable conduits from transformers to neutral system modules
  - install conduits to ASCs and earth grid connection
  - install conduits for secondary circuits
- For ASCs:
  - install neutral cable conduit, control cable conduits and solid earth grid connections
  - pour concrete foundation
  - install steel beam, 150mm high at a width designed to accommodate the placement of the GFN Arc Suppression coil
  - install bunding to EPA requirements and AS2067 requirements
- For Station Service Supplies:
  - install concrete foundation for new station service 500kVA kiosk transformer with associated conduits and cables.
- For new 22kV No.3 Bus VT:
  - modify or replace as necessary the existing structure to accommodate the new 22kV VT
    - additional weight requirements
    - additional clearance requirements
- For control room:
  - assess the load bearing capability of the floor to accommodate the new GFN control cubicle.

## 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

**Panel 3 - Station HMI**

- Install 19” rack panel inserts
- Install one (1) new panel insert
- Install relocate existing station HMI (AVANTECH) from panel 17

**Panel 4 – 66kV CB B & F Management Relays**

- Retire Existing 66kV mimic
- Install 19” Rack panel inserts
- Install Two (2) SEL351S CB Management relays for 66kV CB B & F
- Note:
  - relays to have CB failure protection set.
  - the 66kV CB management relay shall be configured to provide external protection trip initiations via IEC61850 GOOSE
  - this is required to enable GOOSE tripping from the GFN controller to the next zone up (failure of the feeder CB operation will enable tripping of the next zone feeders.

**Panel 8 & 9 – No.2 & No.3 Bus Feeder Protection Relays**

SEL-351S Feeder Protection Configuration:

- Relays shall be reconfigured with directional control capability for all phase, neutral and earth fault elements
- Relays shall be reconfigured to provide external protection trip initiations via IEC61850 GOOSE
  - these GOOSE initiations shall drive auto reclose functionality direct to lockout through the internal 79DTL function
- The CB fail functionality of the feeder CBs will be provided by the GFN controller. In this case the 66kV CB management relays will be tripped by GOOSE trip initiations from the GFN controller.

22kV Feeder CT contributions are required by the GFN zero sequence bus admittance calculations. To facilitate the GFN connection, install an extra set of neutral links on feeder link rack to permit the installation of the $I_0$ connection off to the GFN controller.

**Panel 10 – X MEF, Y MEF & BUEF and No.3 Cap Bank OC & EF Protection**

- Retire existing RMS 2C138 MEF Relay

**Panel 11 – Alarms Panel**

- Retire all equipment and make panel spare

**Panel 17 – Station HMI & Cap Bank VAR Control**

- Install one (1) new SEL RTAC 3530-4
- Install one (1) EKI2525M Cooper/Fibre Converter

- Note:
  - new RTAC to be configured for blocking of Neutral Voltage Displacement protection of HV customers that are supplied from ART
  - station HMI is being moved from this panel to panel 3.

**Panel 20 – Alarms and Comms Equipment**

- Retire existing Fortigate 60D Firewall
- Install two (2) new Fortigate 60E Firewalls
- Install one (1) EKI2525M Cooper/Fibre Converter
- Install one (1) new RSG 2100 Ethernet Switch
- Note EKI2525M is required to allow the building access controller to connect to both firewalls.

**Panel 26 – Transformer Protection**

- Retire existing station differential protection relays (DUO-BIAS)

**Panel 30 – Station Differential Protection**

- Install One (1) new SEL787-3 Station Differential protection relay
- Note feeder and cap bank CTs to be connected in star as the neutral current is required by the GFN.

**Panel 31 – Station Earth Fault Management**

- Install one (1) new SEL-451 Station Earth Fault Management relay
- Install one (1) new GE F35 MEF and Neutral Bus Management relay
- Install one (1) new RSG 2100 Ethernet Switch

For MEF & Neutral Bus Management relay (F35):

- GE F35 station Earth Fault management relay shall provide the following functions:
  - X Master Earth Fault relay
  - Backup Neutral Over Voltage Protection
  - Neutral Voltage Supervision
  - Neutral CB Management
- GE F35 relay shall provide the X Master Earth Fault relay scheme and shall be configured with sensitive ground CT options. The F35 shall then send a hard wired inhibit to the Y MEF relay (SEL351A)
- the relay shall also incorporate the station 22kV and neutral VT’s and be configured to provide neutral voltage protection & supervision
- this relay will also incorporate CB Management functions of the Neutral Earth & ASC CB arrangement.

### 2.3.2 Ground Fault Neutraliser

**Control Unit**

The GFN control unit is a single cubicle comprising of:

- GFN Master Control module
- GFN Slave Control Module

- Windows Based PC utilising proprietary NM Term software
- All VT & feeder $I_0$ CT terminations
- All trip link outputs
- RCC Inverter and ASC Interface
- Panel Meters

ART Zone substation will only require one (1) GFN controller as it won't require a 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 the top 2U of this cabinet. This control unit will be used to interface controls to the Station Earth Fault Management relay.

The GFN specification will be developed separately from this scope.

The GFN cubicle shall be in panel 16 position.

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

The size and future growth of ART does not suggest any issues in meeting this threshold with one ASC.

The inverter requirement is also quite large as it must have the power to counter balance the system damping and capacitance when in operation. Inverters in the order of 300-400kVA is expected.

The inverters shall be installed in a separate air conditioned hut in the switchyard. Inverter AC Supplies to be supplied of the new station service transformer.

### 2.3.3 VT Supplies

**Auxiliary transformer for GFN**

VT supplies from the new 22kV Bus VT is required to the GFN control unit. For earth fault detection, an open delta ($U_N$) 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 cubicle.

### 2.3.4 Protection settings

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

- SEL-351S relays will have configuration changes to introduce;
  - Directional SEF functionality
  - GOOSE (via GFN) tripping capability
  - Auto Reclose integration of GFN initiated trips

– GOOSE message isolation function

- The station MEF and BUEF schemes shall be reviewed for GFN integration (there is no REF protection at ART)
- Transformer protection settings to be reviewed with the new larger size station transformer in service which is in the transformer protection zone.

### 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

**Panel 16 – Summation Metering & Power Measure System**

- Install one (1) new ELSPEC Power Quality Meter and Data recorder

**ELSPEC Power Quality Meter**

- This recorder is capable of recording 16 analogue & 32 digital channels of data at a sampling rate of 1000 samples per second. 12 months of data can be captured and stored internally using a patented algorithm.
- The ELSPEC shall be installed to capture bus voltage, neutral voltage and bus incomer currents (ie transformer currents). The purpose of this recorder is to aid with GFN commissioning and long term monitoring.
- Connectivity to the ELSPEC meter to be fibre 100BASE-FX Ethernet to a new RS 2100 switch in Panel 16

### 2.3.7 Transformer Control

No changes required as only one GFN is being installed.

### 2.3.8 Station HMI and HMI RTU

Updated existing Cap Control HMI to full station HMI.

### 2.3.9 Control & monitoring requirements

Remote Control and Monitoring of new:

- X MEF & Neutral System CB Management Relay UR F35
- Station Earth Fault Management Relay SEL-451
- GFN Controller
- ELSPEC Power Quality recorder
- Station Differential Relay SEL787-3
- 66kV CB Management Relays SEL351S

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

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

### 2.3.10 Communications requirements

**Ethernet Connectivity**

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

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

- Install Gigabit backbone connection between the new and existing Ethernet switches
- Install fibre Ethernet links from the Station EF relay, MEF & Neutral Bus Management relay, Station Differential Relay, 66kV CB Management Relays, ELSPEC PQM, GFN DPAC to each Ethernet switch.
- Reconfigure all existing relays to be connected to the new and existing Ethernet switch.
- Ensure relay configurations modified to Port Failover configuration
- Ensure Sub-LAN switch architecture configured to support fail over scenario's

A suggested Ethernet connection diagram is included in the appendix.

**Engineering access**

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

**Time stamping**

The existing Tekron TCG-01 GPS Clock is to be used for time stamping all equipment. All NTP capable equipment shall synchronise with the ART GPS NTP server. All non NTP capable equipment is to be connected to the ART GPS IRIG-b loop.

### 2.3.11 415/240 AC supplies

The existing 25 KVA station service supply transformer is located in the switchyard and is supplied of the 22kV bus. The size of this station service transformer will not be adequate for the RCC inverter used to drive faulted phase voltage to zero via the Arc Suppression Coil.

This station service transformer shall be replaced with a 500kVA kiosk type station service transformer with LV mains upgraded accordingly (subject to space constraints).

Since the station service transformer is supplied off the 22kV bus, there is no need for a second station service transformer or an AC changeover scheme.

The AC supplies must ensure capacity and reliability requirements are fulfilled for a single ARC Suppression Coil.

- Install current limiting fuses to be installed on distribution AC board supplies
- Upgrade existing station AC board and incoming mains such that they are compliant with existing standards
- Install AC supplies for the GFN inverter to meet its specifications.

### 2.3.12 DC Supplies

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

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

#### 2.3.13 Station Design

As a minimum the secondary design documentation shall include:

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

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

#### 2.3.14 Powercor control centre SCADA works

At CitiPower and Powercor’s Control Centre, a new series of Control System Pages shall be created for the GFN interface. Consultation between SCADA, Operations and Network Protection & Control is required to establish these pages.

#### 2.3.15 Fibre Optic Cable

Fibre optic patch leads are required for zone substation sub-LAN Ethernet communications.

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

#### 2.3.16 Radio

No radio communications are required.

#### 2.3.17 Building and property considerations

**Yard Lighting**

Switch yard lighting shall be reviewed to ensure adequate coverage of the ASCs and the Neutral cubicle.

**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.

**Recoveries**

The following items are to be fully recovered and returned to stores for consideration:

- 25kVA station service transformers
- Existing No.3 22kV bus VT
- SEL311B relay
- RMS 2C138 relay

**Health and Safety**

The asbestos register shall be consulted and any occurrences validated on-site. The register should be updated following completion of the project.

# 3 22 kV distribution feeder requirements

The 22kV distribution works is to include all ART feeders and the part of HTN005 and STL005 are the feeders that can be transferred to ART as specified in section A.

## 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 includes all ART feeders and the part of HTN005 and STL005 which can be temporarily supplied from ART
- Surge arrestors beyond inter-station open points, in the part of HTN005 and STL005, shall be upgraded in addition to those on all ART feeders to permit the transfer of loads with the GFN in service
- 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 3 Surge arrestor replacement volumes

| Surge arrestors | Volume (sites) | Volume (arrestors) |
|---|---|---|
| Surge arrestor sites (single phase) | 406 | 812 |
| Surge arrestor sites (three phase) | 347 | 1041 |

## 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).

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

Experience from network resilience (voltage stress) testing at GSB and WND has suggested that there is a low likelihood of distribution transformer failure, and any that fail are likely to fail due to poor condition rather than as a result of inappropriate rating. This project scope does not include the proactive replacement of any distribution transformers.

## 3.3 Line insulators

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

Similar to distribution transformers, experience from the network resilience testing has suggested that there is a low likelihood of line insulator failure. This project scope does not include the 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 causing a similar displacement to the neutral voltage occurs as for the open-delta mode.

All regulator works shall be compliant with current CitiPower & Powercor standards for 22kV regulators. For all single phase Cooper regulators on the ART network the controls shall be upgraded to 3 single phase units with 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
- All alarms and controls shall be integrated into SCADA

The ART 22kV distribution network contains six (6) 22kV regulating systems.

Table 4 ART regulating systems

| Fdr | Name | Regulator Make | Phasing | Control Box | Issue/Work Required |
|---|---|---|---|---|---|
| ART033 | MOYSTON P75 REG | Cooper – 2 x 50 Amps | RWB | CL 6A | One unit at pole 75 & one unit at pole 76. Replace Regulator with 3 x 100A ground mounted and new CL7 controller. |
| ART031 | ART-STL P678A REG | Cooper – 2 x 200 Amps | RWB | CL 6A | Two units at pole 678A. Replace Regulator with 3 x 200A ground mounted and new CL7 controller. |
| ART033 | WICKLIFFE P2 REG | Unknown – 1 x 0.3MVA | RW | No control box | One unit at pole 2. Solution to be determined with balancing scope. Solution will most likely involve reconductoring and retiring existing reg. |
| ART033 | WILLAURA P212 REG | Cooper – 3 x 200 Amps | RWB | CL 6A | Three units at pole 212. Replace controller with new CL7 controller. |
| ART033 | WILLAURA P332 REG | Wilson – 1 x 3.75MVA | RWB | 2V164JUMX | One unit at pole 332. Replace controller with new CL7 controller. |
| ART033 | STREATHAM P114A REG | Wilson – 1 x 1.0MVA | RWB | Unknown | One unit at pole 114A. Replace controller with new CL7 controller. |

The table below summarises the replacements.

Table 5 Regulator works

| HV regulators | Volume (sites) |
|---|---|

| HV regulators | Volume (sites) |
|---|---|
| Regulator sites | 6 |
| 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.

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 6 Balancing requirements summary**

| Balancing concept | Number of sites |
|---|---|
| Re-phasing sites | 44 |
| Single Phase Balancing Units | 19 |
| 3 Phase Balancing Units | 17 |

## 3.6 Automatic Circuit Reclosers (ACRs)

The ART 22kV distribution network currently has 26 in service Automatic Circuit Reclosers (ACR's). Of these one (1) are RVE or VWVE model and four (4) are Nulec N24 model ACRs.

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

**Table 7 ART ACR sites**

| Name | Operating voltage | Phase code | Control Box Model | ACR model |
|---|---|---|---|---|
| ELMHURST P129 ACR | 22kV | RWB | ADVC | N24 |
| ELMHURST P8 ACR | 22kV | RWB | ADVC | N24 |
| ART-STL P589 ACR | 22kV | RWB | ADVC2 | N24 |
| LAKE BOLAC P2 ACR | 22kV | RWB | ADVC2 | N24 |
| WILLAURA P344 ACR | 22kV | RWB | ADVC | 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
- continue to operate in the traditional manner automatically when REFCL is not in operation.

Table 8 Control box replacements

| Name/Location | Control box model |
|---|---|
| Nil | Nil |

Table 9 Total replacements

| Units | Number of sites |
|---|---|
| ACR replacements | 1 |
| Control box replacements | 0 |

## 3.7 HV 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 10 Fusesavers

| Units | Number of Sites |
|---|---|
| Fusesavers | 35 |

## 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 11 Switchgear replacements

| Unit | Volume |
|---|---|
| Distribution switchgear | 8 |

## 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 12 HV underground cable requirements

| Location | Length (m) |
|---|---|
| Cable failure length | 1,448 |

## 3.10 HV customers

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 13 HV customers

| Units | Volume |
|---|---|
| HV customer sites with generation | 1 |
| HV customer sites without generation | 0 |
| Total HV customer sites | 1 |

# 4 Appendix

**Figure 3 Existing ART ZSS general arrangement (drawing VX11/66/6)**

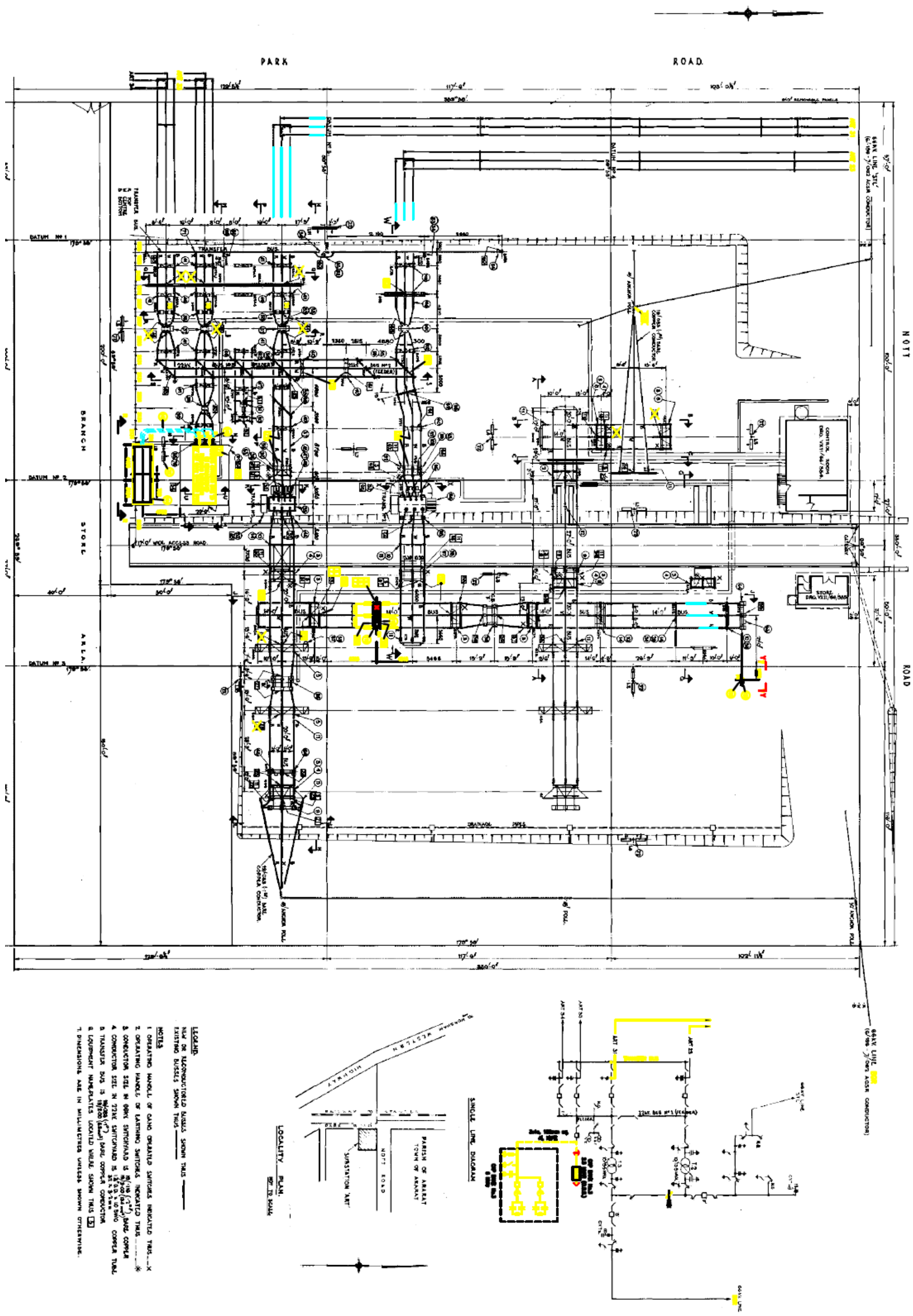


**Figure 4 Proposed ART ZSS general arrangement (drawing VX11/66/6)**