CitiPower	ELECTRICITY NETWORKS Asset Strategy and Performance Functional Scope	Powercor Australia

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1.0	14.04.2016	Original	G. Squires
1.1	13.12.2016	Revised	G. Squires
1.2	23.12.2016	Revised for secondary requirements for 22kV buses	G. Squires
1.3	10.01.2017	Revised	G. Squires

1 Project overview

This project scope covers the migration of the Winchelsea zone substation (**WIN**) system to a resonant earthed network. Migration to a resonant network requires the installation and operation of a ground fault neutraliser (**GFN**). This changes the electrical operating characteristics of a zone substation and its distribution network as follows:

- full voltage displacement occurs on the system for operation of the GFN;
- this significantly stresses equipment on the system and may lead to failure;
- this equipment has been identified and included in this scope for replacement as part of the GFN installation; and
- other limitations will dictate part of the operational protocols that will be developed by Electricity Networks.

The GFN provides potential benefits to single-phase-to-ground faults on the 22kV three phase system. It provides no benefit on the following:

- the 12.7kV Single Wire Return System (**SWER**);
- the 66kV sub-transmission system; and
- the low voltage (**LV**) system.

1.1 Background

The Victorian Government has introduced changes to the Bushfire Mitigation Regulations that require distribution businesses with high voltage (**HV**) overhead assets in high bushfire consequence areas to meet new performance standards for detection and limiting of arc fault energy. These standards can only be achieved using rapid earth fault current limiters (**REFCLs**).

A REFCL is a network protection device, normally installed in zone substations that significantly reduce the arc fault energy generated during a phase to ground fault. The reduction in arc fault energy can be so effective that earth fault fire ignition on 22kV three phase networks is almost eliminated.

The Bushfire Mitigation Regulations mandate that REFCLs must provide the required capacity—required capacity means, in the event of a phase-to-ground fault on a polyphase electric line, the ability:

- to reduce the voltage on the faulted conductor in relation to the station earth when measured at the corresponding zone substation for high impedance faults to 250 volts within 2 seconds; and
- to reduce the voltage on the faulted conductor in relation to the station earth when measured at the corresponding zone substation for low impedance faults to:
  - 1900 volts within 85 milliseconds; and
  - 750 volts within 500 milliseconds; and
  - 250 volts within 2 seconds; and
- during diagnostic tests for high impedance faults, to limit:
  - fault current to 0.5 amps or less; and
  - the thermal energy on the electric line to a maximum I^2t value of 0.10;

  where:

- high impedance faults means a resistance value in ohms that is equal to twice the nominal phase-to-ground network voltage in volts;
- I^2t means a measure of the thermal energy associated with the current flow, where I is the current flow in amps and t is the duration of current flow in seconds;

- low impedance faults means a resistance value in ohms that is equal to the nominal phase-to-ground network voltage in volts divided by 31.75; and
- polyphase electric line means an electric line comprised of more than one phase of electricity with a nominal voltage between 1 kV and 22 kV.

1.2 Winchelsea zone substation

WIN zone substation is located in cleared country to the north of the Otway Ranges supplying over 3,330 customers. The peak usage recorded in 2013 was 7.42 MVA. The substation consists of 2 transformers and three 22kV feeders.

One of the transformers is currently a fixed tap transformer, with a separate 22kV regulator. This combination is currently being replaced with a tapping transformer. Once completed, the station will consist of two transformers with separate voltage control systems. This means the station in its current configuration can only be operated with one of the transformers in service at any time.

The three 22kV feeders are Cooper VWVE27 ACR's with Nulec ADVC controllers that operate independently and external to the zone substation via 3G modems. The recent transformer works means that one of these ACR's is now included within the zone substation earth grid area, but it is still independently controlled.

Two of the 22kV feeders extend towards the south into the Otway Ranges, where there has been some recent undergrounding of both 22kV single and three phase, and 12.7kV SWER lines to reduce the risk of fire starts. The undergrounding of the 22kV network has increased significantly the phase to ground capacitance on the network that introduces difficulties for sizing a GFN.

Table 1 WIN: existing characteristics (zone substation)

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

Table 2 WIN: existing characteristics (network)

Network	Volume
Total route length (km)	479
Underground cable length (km)	114
Overhead line length (km)	365
Underground network (%)	23.8

Network	Volume
Overhead single phase (km)	199
Estimated network capacitance (A)	336
Distribution transformers	869
HV regulator sites	-
Fuses	957
ACRs	3
Surge arrestor sites	736
HV customers	-

2 ZSS requirements

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

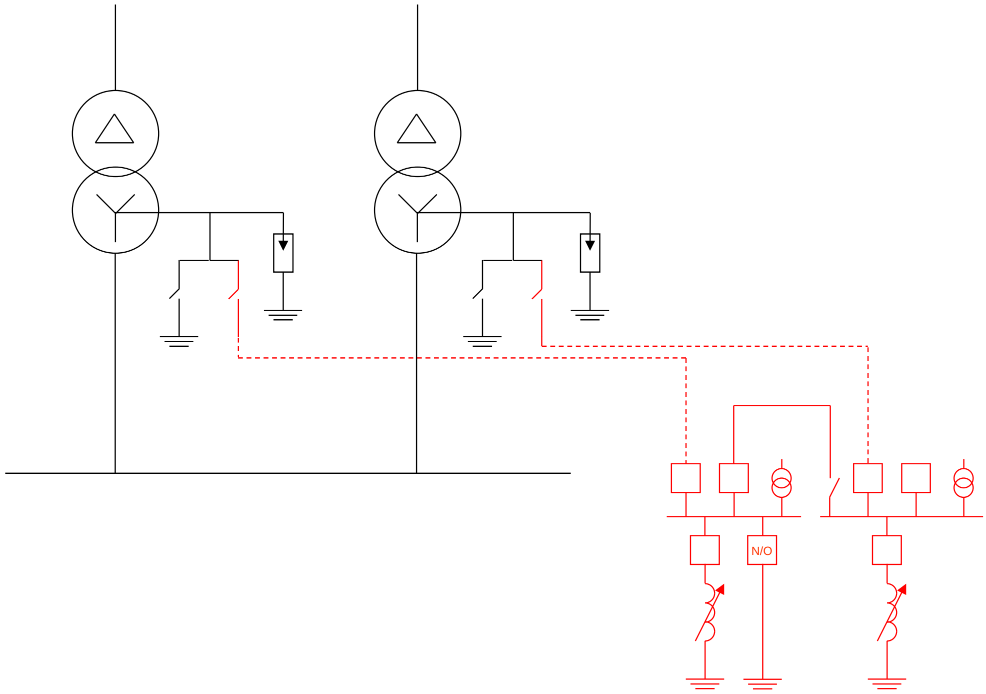
- establish ASC bunds;
- installation of two (2) Swedish Neutral GFN Arc Suppression Coils;
- modification of the 66/22kV transformer earthing arrangement:
  - installation of Transformer Neutral Isolators and Direct Earth Switches;
  - installation of 19kV surge diverters on transformer neutrals;
  - installation of Neutral Bus System:
    - bus CB's;
    - NER terminations;
    - ASC Terminations;
    - neutral VT Installation;
- upgrade station service supply to two (2) new 750kVA kiosk transformers with changeover board;
- upgrade of the station service supply cabling and installation of new AC distribution board;
  - install current limiting fuses on AC distribution boards;
- 22kV Bus Modifications:
  - installation of 22kV Switchroom to house:
    - installation of new 22kV 1-2 Bus Tie CB;
    - installation of new No.1 Transformer CB;
    - installation of new No.2 Transformer CB;
    - installation of new WIN11 Feeder CB
    - installation of new WIN22 Feeder CB
    - installation of new WIN23 Feeder CB
    - GFN inverters and grid isolation cabinets
- replace ALL substation surge arrestors with new 22kV continuous voltage units for resonant network compatibility and 10hr 24kV TOV capability;
- installation of Station Earth Fault Management control relay:
  - GFN Interface control;
  - operating mode management;
- installation of Neutral Bus Management Relay:
  - adoption of existing MEF function;
  - neutral Voltage supervision;
  - neutral Bus CB Management functions;
- install and Commission two (2) GFN control and two (2) RCC inverter cubicles;
- review and Modify secondary systems to accommodate split bus arrangement:

  - install new independent transformer and voltage control schemes;
- installation of new CB Management relays:
  - 1-2 22kV Bus Tie CB;
  - No.1 Transformer CB;
  - No.2 Transformer CB;
- installation of Bus Protection Relays to accommodate split bus arrangement:
  - no.1 22kV Bus X Low Impedance Bus Protection;
  - no.1 22kV Bus Y Bus Distance Protection;
  - no.2 22kV Bus X Low Impedance Bus Protection;
  - no.2 22kV Bus Y Bus Distance Protection;
- installation of new feeder protection relays:
  - WIN11 Feeder
  - WIN22 Feeder
  - WIN23 Feeder
- install new Elspec Power Quality Meter.

2.1 Primary plant requirements

The works associated with the installation of the WIN ASC arrangement (two GFN's) is summarised in the following single line diagram.

Figure 1 WIN 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 two Swedish Neutral - Ground Fault Neutraliser's Arc Suppression Coil (ASC) component. The ARC suppression coil is a paper wound copper coil wrapped around a solid iron core and immersed in oil. This arc suppression coil is of fixed reluctance but contains an array of capacitors in parallel that are switch as part of the tuning process of the coil. The coil also features an LV winding for coupling of these capacitors and the Residual Current Compensator.

Primary neutral and earth connections are via elbows.

As an oil filled device, it shall be installed in a bunded area in accordance with current standards. The total volume of oil will be made available once the coil size has been confirmed.

The GFN ASCs shall be installed in a location to be determined:

- install 2 Ground Fault Neutralisers comprising of 200A ASC and residual current compensation module with maximum available tuning steps onto the provided pad mount within a newly established bunded area;
- the footing of the ASC shall reside on the installed 150mm steel beams fixed to the concrete pad; and
- install cable connections to and from the Neutral System.

2.1.3 Zone substation surge arrestors

The operating principle of the GFN uses a tuned reactance to choke fault current in the event of a single-phase-to-ground fault. As a result, displacement of the line-to-ground voltage occurs in the healthy phases. Whilst line-to-line voltages remain at 22kV, the line-to-ground voltage rises to 22kV, phase-to-ground, on the two healthy phase’s subsequently stressing substation and distribution equipment. In the case of surge diverters, this displacement cannot be tolerated and as such the diverters require replacement.

To accommodate the GFN installation:

- replace all sub-standard zone substation surge arresters with a station class 22kV continuous voltage arrestor; and
- install station class 19kV surge arresters across the transformer neutrals.

2.1.4 Neutral system arrangement

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

The purpose of this arrangement is to provide a simple switching configuration that offers the following combinations within one kit:

- solid grounding; and
- ASC in service (solid ground CB open).

Neutral Bus

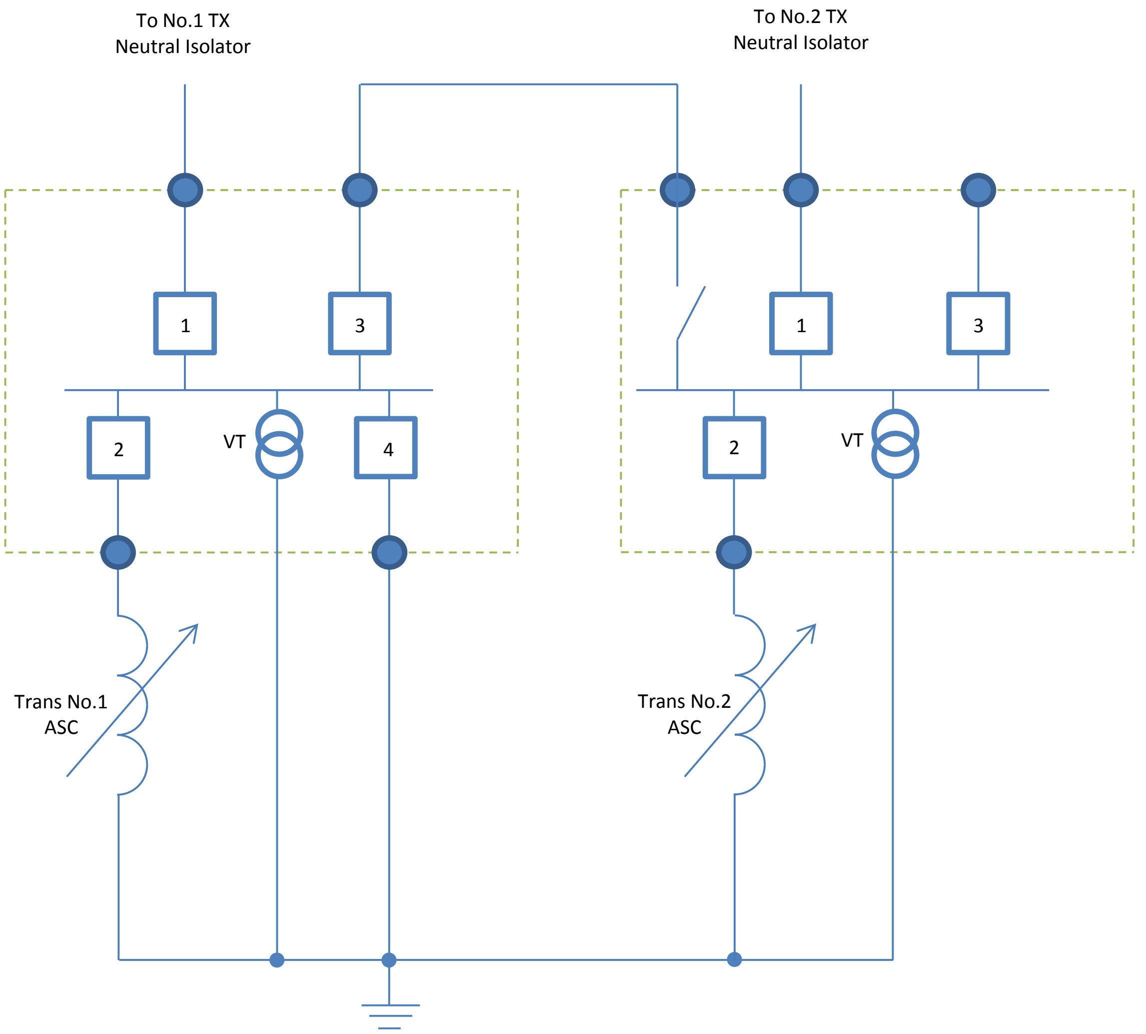
The connection to the Neutral Bus module shall be via elbow connections. Four (4) elbows are required per module for:

- transformer no.1 neutral connection;
- neutral bus tie;
- ASC connection; and
- solid ground Connection (Trans 1) or neutral bus tie (Trans 2).

Neutral Voltage Transformer

A neutral VT shall be included in each of the Neutral Bus modules. The neutral VT shall be 0.5M 1P at 15VA.

Figure 2 Proposed WIN neutral system single line diagram



2.1.5 Transformer earthing

The two 66/22kV transformers in service at WIN are delta/star connected with the neutral of the star windings solidly earthed.

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

2.1.6 Neutral surge diverter

As the 66/22kV Transformers at WIN are outdoors, neutral surge diverters are to be installed.

Install and connect a Station Class 19kV surge diverter between the transformer neutral bus and the substation earth grid. The surge diverters should be connected as close to the transformer neutrals as possible.

2.2 Civil works requirement

The location for installing all civil works is to be determined to allow for the ultimate site requirements. WIN has recently had the site extended for a transformer replacement project that means there is sufficient space available for the GFN and associated equipment.

For neutral systems:

- install concrete foundation pad for neutral system module;
- install neutral cable conduit, control cable conduit and provision for solid earth grid connections;
- install neutral cable conduits from transformers to neutral bus;
- 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:

- review station service transformer foundations and enclosure for upgrade to 2 off 500kVA (note the existing station service is 100kVA);

For 22kV indoor switchgear:

- install indoor switchroom and switchgear, allowing sufficient space for future station requirements; and
- only install CB's for current requirements.

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

Master earth fault, neutral overvoltage and neutral bus management

A GE F35 relay shall be installed and configured with the sensitive ground CT option and provide the facility for a Master Earth Fault relay scheme. 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 and ASC CB arrangement.

Station X MEF and Neutral Bus Management relay (GE-F35)

- The relay will execute and manage the following functions:
  - Master Earth Fault relay for direct earth in service applications
  - Neutral Voltage Supervision
  - Neutral CB Management
- The relay shall provide the X Master Earth Fault relay.

- The relay shall also incorporate the station 22kV and neutral VT's and be configured to provide neutral voltage protection & supervision
- The relay will incorporate CB Management functions of the Neutral Earth & ASC CB arrangement.

Station earth fault management

Station Earth Fault Management relay (SEL-451):

- The relay shall provide the following functions:
  - Operating mode selection
  - GFN remote controls
  - Automate fault detection handling
  - Request fault confirmations consistent with operating mode
  - Trip faulted zones consistent with operating mode
  - Bypass ASC
  - Provides remote and local controls, and indications

22 kV feeder protection

Feeder Protection & CB Management relays (SEL-351S):

- Install 3 off relays, 1 per 22kV feeder
- The relays shall provide the following functions:
  - OC & EF protection
  - Auto reclose
  - CB management, including local and remote controls
  - Integration with GFN protection for detecting compensated earth faults

Remote IO in Feeder CB's (SEL-2506)

- Install 1 off relay in each CB (as per TNA design)
- Connect mirrored bits to SEL-351S

22 kV CB management

CB Management relays (SEL-351S)

- Install 3 off relays on the following CB's:
  - Transformer 1, 22kV CB
  - Transformer 2, 22kV CB
  - 1-2 Bus-Tie 22kV CB
- The relays shall provide the following functions:
  - CB management, including local and remote controls

Remote IO in CB's (SEL-2506)

- Install 1 off relay in each CB (as per TNA design)
- Connect mirrored bits to SEL-351S

Transformer differential protection

Transformer Differential relays (SEL-787)

- Existing transformer differential relay that was installed to cover both transformers is to be reconfigured to only cover transformer 1
- Install 1 off new transformer differential relay to cover transformer 2
- The relays shall provide the following functions:
  - Transformer differential protection
  - REF protection (new)

22 kV bus protection

22kV Low Impedance Bus Protection and Voltage Supervision relay (SEL-751)

- Install 2 off relays, 1 per 22kV bus
- The relays shall provide the following functions:
  - Low impedance protection
  - UV/OV supervision
- Trips shall be sent by IEC61850 to CB Management Relays

22 kV bus distance protections

22 kV 2 Zone Bus Distance Protection relays (SEL-311C-1)

- Existing 22kV 2 zone bus distance relay is to be reconfigured to now only cover 22kV bus 2
- Install 1 off new 22kV 2 zone bus distance relay to cover 22kV bus 1
- The relays shall provide the following functions:
  - 2 zones of distance protection for protecting the 22kV bus and providing 22kV feeder backup

2.3.2 Control schemes

22 kV voltage control

Voltage Regulating Relays (REG-D)

- Retire 2V164 VRR
- Install 2 off relays, 1 per transformer
- The relays shall provide the following functions:
  - voltage control
  - line drop compensation
  - manage parallel and independent control

22 kV UV/OV supervision

22kV Undervoltage and Overvoltage Supervision relays (RMS-2V67)

- Existing UV/OV relay shall be retired
- UV/OV Supervision shall be performed in SEL-751 22kV bus relays

- The relays shall provide the following functions:
  - UV/OV voltage supervision
  - VRR interlocking

CB control

Backup CB control (GE-C60)

- Install 1 relay in each of 22kV transformer CB's for backup control of all CB's on the bus
- Configure relays as per TNA design

RTAC RTU

Install RTAC RTU for new HMI

HMI

Install desk based HMI (maay require inverter to be installed if unit runs off AC).

2.3.3 Metering schemes

22 kV PQM

Power Quality Meter (ION-7650 & ION-7450)

- Existing ION-7650 PQM reconfigured to now be on transformer 1
- Install new ION-7450 PQM on transformer 2
- Note: Station controls next to existing PQM will need to be moved down to accommodate new PQM.

GFN PQM

Power Quality Meter and Data Recorder (Elspec)

- Install Elspec PQM & data recorder
- Installed for GFN monitoring

2.3.4 Ground Fault Neutraliser

Control Unit

The GFN control unit is a single cubicle comprising of;

- GFN Master Control module
- GFN Slave Control Module
- Windows Based PC utilising proprietary NM Term software
- All VT & feeder I0 CT terminations
- All trip link outputs
- RCC Inverter and ASC Interface
- Panel Meters

WIN zone substation will require two (2) of these controllers.

Powercor will request through their specification process that the control unit be constructed within a 850mm wide cubicle. Each cubicle will contain an interface controller in the form of a SEL-2440 DPAC control unit in the top 2U of this cabinet. This control unit will be used to interface controls to the Station Earth Fault Management relay.

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

Inverter

The Residual Current Compensation technique used by the GFN requires an Inverter to inject current into the ASC via an auxiliary winding. The inverter must be sized to displace the full capacitive current drawn by the system and as a result requires significant power.

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

- system damping; and
- capacitive dissymmetry.

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

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

2.3.5 VT supplies

Auxiliary transformer for GFN

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

2.3.6 Protection settings

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

Feeder protection relays will have configuration to introduce:

- directional SEF functionality;
- the station BUEF scheme shall be reviewed for GFN integration;
- an application for backup Voltage Displacement shall be considered; and
- transformer protection settings to be reviewed with the new larger size station transformer in service which is in the transformer protection zone.

2.3.7 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.

2.3.8 Metering requirements

Power quality meter

The existing ION 7650 Power Quality Meter is to be reconfigured for transformer 1 only.

The new ION-7450 is to be configured for transformer 2.

An ELSPEC Power Quality and Data recorder shall be installed:

- this recorder is capable of recording 16 analogue and 32 digital channels of data at a sampling rate of 1000 samples per second. 12 months of data can be captured and stored internally using a patented algorithm;

- the ELSPEC shall be installed to capture bus voltage, neutral voltage and bus incomer currents (i.e. transformer currents). The purpose of this recorder is to aid with GFN commissioning and long term monitoring; and
- connectivity to the ELSPEC meter to be fibre 100BASE-FX Ethernet.

2.3.9 Control and monitoring requirements

Remote Control and Monitoring of new:

- X MEF, Neutral Voltage & Neutral System CB Management Relay UR F35
- 22kV Feeder Protection Relays (SEL-351S)
- 22kV CB Management Relays (SEL-351S)
- Transformer Differential Relay (SEL-787E)
- 22kV 2 Zone Bus Distance Relay (SEL-311C-1)
- Voltage Regulating Relays (REG-D)
- GFN Controller
- Transformer PQM (ION-7450)
- ELSPEC Power Quality recorder

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

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

2.3.10 Communications requirements

Ethernet connectivity

A second zone substation Sub-LAN RSG-2100 Ethernet switch shall be installed. GFN controls shall utilise IEC61850, so redundant Ethernet paths shall now be required.

All communications shall be over 100 BASE-FX (optic fibre) Ethernet back to the zone substation Sub-LAN RSG-2100 Ethernet switches.

Engineering access

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

Time stamping

The existing Tekron TCG-01 GPS clock is to be used for time stamping all equipment. All NTP capable equipment shall synchronise with the WIN GPS NTP server

All non NTP capable equipment is to be connected to the WIN GPS IRIG-b loop.

2.3.11 AC supplies

The existing 100 KVA station service supply transformer is located in the switchyard and is supplied off 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 2 off 500kVA kiosk type station service transformers with LV mains upgraded accordingly (subject to space constraints).

The AC Supplies must ensure capacity and reliability requirements are fulfilled for the ARC Suppression Coils.

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.

It is expected that the additional equipment being installed will require an additional parallel battery string.

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;

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

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

2.3.14 Powercor control centre SCADA works

A new series of Control System Pages shall be created for the GFN interface. Consultation between SCADA, Operations and Network Protection and Control is required to establish these pages.

A new series of Control System Pages shall be created for the site. 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 ASC and Neutral System.

Fire suppression

The ASC winding is immersed in oil. A review of its design and the amount of contained oil is required to determine if any fire suppression assets are required.

3 22 kV distribution feeder requirements

3.1 Surge diverters and insulation limitations

The operating principle of the GFN uses a tuned reactance to choke fault current in the event of a single-phase-to-ground fault. As a result, displacement of the line-to-ground voltage occurs in the healthy phases. Whilst line-to-line voltages remain at 22kV, the line-to-ground voltage rises to 22kV, phase-to-ground, on the two healthy phase's subsequently stressing substation and distribution equipment. In the case of surge diverters, this displacement cannot be tolerated and as such the diverters require replacement.

To accommodate the GFN installation:

- replace approximately 827 surge diverters across the 22kV three phase and single phase system on all feeders ex WIN ZSS; and
- surge arrestors beyond inter-station open points shall also be upgraded to permit transfer of loads with the GFN in service.

The replacement diverters should be of 22kV continuous rating with a 10 hour 24kV TOV rating.

CitiPower and Powercor standard surge diverters are the ABB MWK 20 and POLIM D 20 arresters. These do not meet the overvoltage requirement needed for use with a GFN and therefore the higher rated arresters are required.

These surge diverters will be a new standard, applicable to distribution systems with a GFN installed.

3.2 Distribution transformers

Operation of the GFN displaces the neutral voltage of the entire 22kV system from the bus to the outer extremities of the feeders. This is different from an NER arrangement, when displacement is at its highest for a fault on the 22kV bus, and decreases for faults occurring down the feeders.

During GFN commissioning, voltage offset testing will simulate the voltage displacement that will occur for a single-phase-to-ground fault (22kV phase-to-ground).

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

At this time, experience from network resilience (voltage stress) testing at GSB and WND does not support a proactive replacement of any distribution transformers.

3.3 Line insulators

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

Similar to Distribution Transformers, 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 WIN 22kV distribution network contains no 22kV regulating systems.

3.5 Admittance balancing

The ground fault neutraliser uses a tuned inductance (Petersen Coil / Arc Suppression Coil) matched to the capacitance of the distribution system. The 3 phase 22kV distribution system ex WIN zone substation and referring to contains approximately 362km of overhead conductor length (excluding SWER). Of this 362km, 196km (54 per cent) is single phase. Whilst planning philosophies have always attempted to balance the single phase system, inevitably this is difficult to achieve. In order to balance the capacitance of the three phase system such that the ASC can be correctly tuned, balancing substations will be placed at nodes on the system that utilise low voltage capacitors to inject the missing capacitance onto the system.

Note: Balance does not refer to the balancing of load. System balance is required from a capacitance-to-ground perspective and affected by route length and single phase connected distribution equipment.

A reconciliation of all 22kV overhead and underground lines routes shall be conducted to assess the scope of the network balancing requirements.

The following steps shall be outworked prior to GFN installation;

1. Consolidate all “Single Phase” and “unknown” conductor into the “BR”, “RW” or “WB” categories
   (i) validate “Single Phase” and “unknown” conductor where required
   (ii) spot check the validity of current phasing information
2. Consolidate all single phase transformers on the 22kV system and assign to one of the “BR”, “RW” or “WB” categories
3. Ascertain the construction types for all sections
   (i) indicate whether LV subsidiary exists
4. Consolidate all “1 Phase” and “unknown phase” 22kV cable and assign phase information
5. If single phase circuits are used underground, ascertain the design principles behind the single phase underground sections
   (i) conductor type, two or three core?
   (ii) treatment of the unused core (earthed or phase bonded)—if bonded, to what phase?

The course balance shall look at sections of the system in 'switchable blocks' and for any re-phasing and finite admittance balancing opportunities in order to balance out the single phase route lengths and large single phase spurs where the capacitance is fairly easy to approximate.

A tuneable balancing approach shall then look at the system again in switchable blocks for the application of 3-phase admittance balancing substations.

The use of 3-phase admittance balancing substations will provide accurate capacitive balancing in each section. Admittance balancing substations shall be placed at the following locations to enable switching of balanced blocks of the system. These locations are listed below:

Table 3 3-phase balancing unit locations

Location (1)	Location (2)	Location (3)
WIN11 Wintown P1 ACR (Feeder Exit)	WIN12 Modewarre P1 Gas Switch	Fultons Lane 2
WIN11 Boundary P23 AS	WIN13 Shelford P3 ACR (Feeder Exit)	Deans Marsh 1

Location (1)	Location (2)	Location (3)
WIN11 Ingleby P71 AS	Ingleby 71	Buckley 25
WIN12 Gherang P1 ACR (Feeder Exit)	Ricketts Marsh 1	-
WIN12 Gherang P33	Inverleigh 5	-

The blended approach to admittance balancing is designed to cater for the historical use of single phase spur lines, single phase cable and the variability in capacitive balancing. The number of re-phasing sites, single phase balancing units and 3 phase balancing units are also informed by experience of GSB and WND and scaled to the relative network parameter of this substation.

Table 4 Balancing requirements summary

Balancing concept	Number of sites
Re-phasing Sites	14
Single Phase Balancing Units	12
3 Phase Balancing Units	13

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

The WIN 22kV Distribution Network currently has 3 in service RVE or VWVE Automatic Circuit Reclosers (ACR's). As all of these are feeder exits from WIN, these are to be replaced with feeder circuit breakers for GFN integration (and as such do not require to be addressed as ACR replacements).

There are no gas switches or ACRs on the WIN network with either CAPM5 or GCR300 control boxes.

Table 5 ACR and control box requirements summary

Units	Number of sites
ACR replacements	-
Control box replacements	-

3.7 Fuse savers

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

Fuse Savers are to be installed as a 3 phase ganged unit such that when any individual phase operates for a fault, all 3 phases open in unison de-energising a balanced section of the network regardless of the fault type.

Fuse Savers are required to operate for any fused section with a downstream network capacitive charging current of 540 mA or greater.

Table 6 Fuse saver requirements

Units	Number of sites
Fuse savers	32

3.8 Capacitive current reducing isolation substations

The installation of 2 GFN's at Winchelsea and splitting the 22kV bus results in a capacitive charging current in excess of 200A on the Bus 1 GFN and approximately 110A on the Bus 2 GFN.

The cause of the large capacitance on WIN11 is significant undergrounding works as part of bushfire mitigation programs. There are 2 sections of the Winchelsea network on the WIN11 feeder that if electrically removed can significantly reduce the network capacitance, to within the Powercor design threshold for REFCL networks. This is required to meet the performance specification of reliable 25.4 kOhm fault detection on WIN11.

Table 7 WIN capacitive current reducing isolation substations

Network spur	Size
Fultons Lane P51A	2 MVA
Bambra P48	2 MVA

These 2 cable networks are to be isolated using HV Isolation Substations, these are to be fully enclosed Kiosk type substations with an internal source side circuit breaker, star-star-delta 22/22kV 2MVA transformer, and duplicate circuit breakers on the load side. Voltage regulation is required as the downstream network being entirely cable is likely to give rise to excessive voltages; as such the transformer is required to have a range of tapping positions. Two sites are to be procured within the vicinity (less than 1 km) of these spurs and HV underground cable is to be installed from this site to the spur.

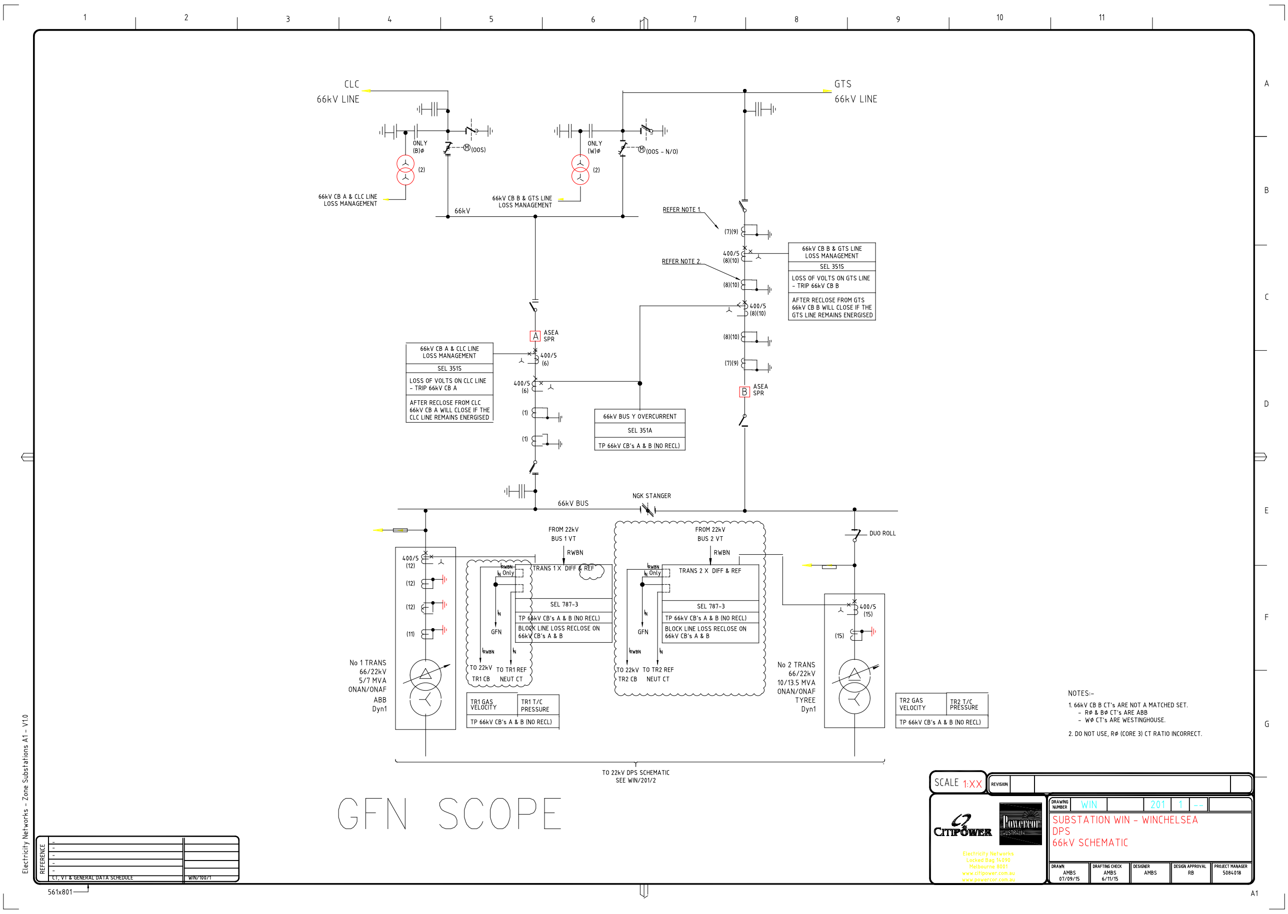
3.9 HV underground cable

Experience from REFCL testing has shown that a percentage of HV underground cable is likely to experience failure due to elevated phase to earth voltages experienced in a resonant network. An allowance for cable failure is to be made for the transition to resonant earthing.

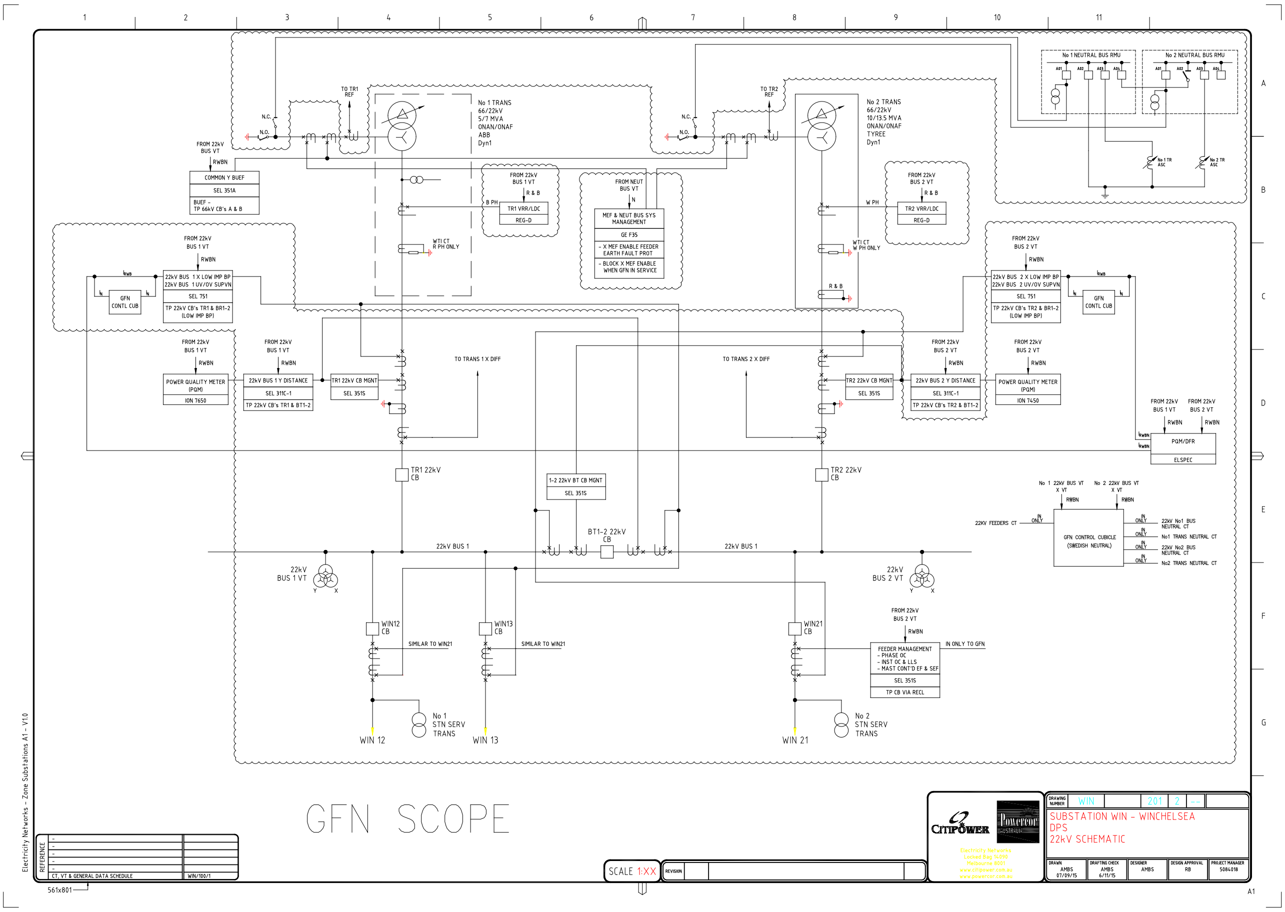
Table 8 HV underground cable requirements

Location	Length (m)
Cable failure length	352

4 Appendix A: 66kV DPS



5 Appendix B: 22kV DPS



6 Appendix C: cubicle layout