



Corio zone substation REFCL

**PAL BUS 6.10 - Corio supply area - Jan2020 -
Public**

Regulatory proposal 2021–2026

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Business	Powercor
Title	Corio zone substation REFCL
Project ID	PAL BUS 6.10 - Corio supply area - Jan2020 - Public
Category	Augmentation capital investment
Identified need	The identified need addressed by this investment is to ensure that Corio zone substation meets the capacity requirements in the Amended Bushfire Mitigation Regulations within the mandated timeframes.
Recommended option	To install Rapid Earth Fault Current Limiter at Corio zone substation to comply with the Amended Bushfire Mitigation Regulations.
Proposed start date	2020
Proposed commission date	2022
Supporting documents	PAL ATT094 - Bushfire mitigation plan - Dec2019 - Public

Source: Powercor

1 Overview

Powercor currently has an obligation to install Rapid Earth Fault Current Limiters at the Corio (**CRO**) zone substation under both sections 113B and 120M of the Electricity Safety Act 1998 (Vic) (**ESA**), with the breach of these sections being an offence punishable by financial penalty and liable to a pecuniary penalty of \$2 million per point.

Powercor's obligations under the ESA to install REFCLs at each of its zone substations listed in Schedule 2 to the Bushfire Mitigation Regulations is a regulatory obligation or requirement associated with the provision of standard control services, as it is a distribution system safety duty, being a requirement under the ESA, the ESA being an act relating to the safe distribution of electricity in Victoria.¹

Accordingly, the AER is under an obligation to allow Powercor's efficient and prudent expenditure.

This document provides an overview of the works required to migrate the Corio zone substation system to a resonant earthed network. Migration to a resonant network requires the installation and operation of a REFCL, as set out in the regulations.

The forecast capital and operating expenditure requirements for the 2021–2026 regulatory control period, to comply with the obligation is outlined in the table below.

Table 1 Expenditure forecasts for preferred option (\$ million, 2021)

Expenditure forecast	2021	2022	2023	2024	2025	2026	Total
Capital expenditure		28.98					28.98
Operating expenditure		-					
Total		28.98					28.98

Source: Powercor

In terms of the timing of works, design and procurement of materials for Corio will commence by July 2020, with construction beginning by February 2021. Construction will start by February 2021 and is expected to take around 21 months. The works will must be completed by November 2022, to ensure we meet the 1 May 2023 regulatory deadline. The expenditure modelling used for this matter is a simplified representation of our proposed expenditure where construction activity is assigned to only one year, irrespective of whether the works are conducted over more than one year.

¹ National Electricity Law, section 2(1) definition of 'distribution system safety duty' and section 2D definition of 'regulatory obligation or requirement'.

2 Background

Powercor currently has an obligation to install REFCLs at the Corio zone substation under both sections 113B and 120M of the ESA.

A REFCL is a network protection device, normally installed in a zone substation, which can reduce the risk of a fallen powerline starting a fire. A REFCL is capable of detecting when a powerline has fallen to the ground and (almost instantaneously) reducing the voltage on the fallen line to limit the risk of fire. Currently the only type of REFCL considered suitable for limiting bushfire risk in Victoria is the Ground Fault Neutraliser (**GFN**).

2.1 Legislative requirement

The management of bushfire risk by major electricity companies is governed by the Electricity Safety Act 1998 (Vic) (**ESA**). Powercor as an electricity distributor is, by definition, a ‘major electricity company’ for the purposes of the ESA.

Under the ESA, we have a general duty to design, construct, operate, maintain and decommission its supply network to minimise so far as practicable the hazards and risks to any person arising from the supply network, the hazards and risks to the property of any person arising from the supply network, and the bushfire danger arising from the supply network.² We must submit an Electricity Safety Management Scheme (**ESMS**), which specifies the safety management system by which we will comply with this general duty and other prescribed safety matters including a plan for the mitigation of bushfire danger, periodically to Energy Safe Victoria (**ESV**) for acceptance.³ We must comply with an accepted ESMS for the supply network.⁴

We also have an obligation to submit a bushfire mitigation plan (**BMP**), which specifies our plan for the mitigation of bushfire risk on our supply network, periodically to the ESV for acceptance.⁵ The BMP must include the prescribed particulars.⁶ We must comply with an accepted BMP for our supply network.⁷

The *Electricity Safety (Bushfire Mitigation) Regulations 2013* prescribe particulars for BMPs.

On 1 May 2016, the Victorian Government introduced amendments to the Bushfire Mitigation Regulations so as to implement certain of the VBRC recommendations including in relation to REFCLs (**Amended Bushfire Mitigation Regulations**). Those Regulations introduced the following new prescribed particulars:⁸

7 Prescribed particulars for bushfire mitigation plans—major electricity companies

(1) For the purposes of section 113A(2)(b) of the Act, the following are the prescribed particulars—

...

(ha) details of the preventative strategies and programs referred to in paragraph (h) (including details in relation to timing and location) by which the major electricity company will ensure that—

(i) in its supply network, each polyphase electric line originating from a selected zone substation has the required capacity; and

² ESA, section 98.

³ ESA, section 99.

⁴ ESA, section 106(2).

⁵ ESA, section 113A.

⁶ ESA, section 113A(2).

⁷ ESA, section 113B(2).

⁸ Bushfire Mitigation Regulations, r7(1)(ha)-(hc) & (n)(vii), and (3).

(ii) on and from 1 May 2023, in its supply network, each polyphase electric line originating from every zone substation specified in Schedule 2 has the required capacity;

(hb) details of testing that will be undertaken before the specified bushfire risk period each year by which the major electricity company will ensure that its supply network can operate to meet the required capacity in relation to each polyphase electric line in accordance with paragraph (ha);

(hc) details of the preventative strategies and programs referred to in paragraph (h) (including details in relation to timing and location) by which the major electricity company will ensure that, on and from 1 May 2016, within an electric line construction area, each electric line with a nominal voltage of between 1 kV and 22 kV that is constructed, or is wholly or substantially replaced, in its supply network is a covered or underground electric line;

(n) details of the processes and procedures by which the major electricity company will—

...

(vii) before the specified bushfire risk period each year, report to Energy Safe Victoria the results of testing undertaken in that year in accordance with regulation 7(1)(hb);

...

(3) For the purposes of subregulation (1)(ha)(i)—

(a) the major electricity company must select a sufficient number of zone substations so that—

(i) at 1 May 2019, the points set out in column 6 of the Table in Schedule 2 in relation to each zone substation selected, when totalled, are not less than 30; and

(ii) at 1 May 2021, the points set out in column 6 of the Table in Schedule 2 in relation to each zone substation selected, when totalled, are not less than 55; or

(b) if there are an insufficient number of zone substations (specified in Schedule 2) in a major electricity company's supply network for the major electricity company to comply with paragraph (a)(i) or (ii), the major electricity company must ensure that each polyphase electric line originating from every zone substation that is specified in Schedule 2 and is in its supply network has the required capacity.

As a consequence, section 6.5.1 of our current ESV accepted BMP details its plans for the installation of REFCLs on our network, as required by the ESA and the above provisions of the Amended Bushfire Mitigation Regulations.

In addition, on 16 May 2017, the ESA was amended to include new Part 10A (Additional bushfire mitigation requirements for major electricity companies) so as to implement certain of the VBRC recommendations including in relation to REFCLs. Section 120M relevantly reads:

(1) A major electricity company must ensure that—

(a) for the initial period, a sufficient number of zone substations in its supply network are complying substations so that the total number of allocated substation points prescribed in respect of all of the complying substations is not less than 30 (the period 1 minimum points); and

(b) for the intermediate period, a sufficient number of zone substations in its supply network are complying substations so that the total number of allocated substation points prescribed in respect of all of the complying substations is not less than 55 (the period 2 minimum points); and

(c) on and after 1 May 2023, or if Energy Safe Victoria specifies a later date under section 120X, that date, all zone substations in its supply network are complying substations.

...

(5) *In this section—*

initial period means—

(a) *the period beginning 1 May 2019 and ending 30 April 2021; or*

(b) *if Energy Safe Victoria specifies a later period under section 120X, that period;*

intermediate period means—

(a) *the period beginning 1 May 2021 and ending 30 April 2023; or*

(b) *if Energy Safe Victoria specifies a later period under section 120X, that period.*

This clause also contains a civil penalties scheme which includes financial penalties of up to \$2 million per point for any difference between the total number of required substation points prescribed in the amended Bushfire Mitigation Regulations and that actually achieved. The scheme also includes a daily penalty up to \$5,500 per point for each day that a contravention with the amended Bushfire Mitigation Regulations continues.

Schedule 2 to the Amended Bushfire Mitigation Regulations specifies the points that are ascribed to each zone substation; a certain number of points are required to be met at milestone dates between 2019 and 2023.⁹

Corio zone substation is listed in Schedule 2, and it is ascribed one point.

Therefore, the ESA read with the Amended Bushfire Mitigation Regulations now requires REFCLs to be installed at prescribed zone substations by certain dates.¹⁰

2.2 Project scope

This document covers the migration of the Corio zone substation (**CRO**) 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.

⁹ ESA, section 120M; Bushfire Mitigation Regulations, Schedule 2.

¹⁰ ESA, sections 113B and 120M; Bushfire Mitigation Regulations, Schedule 2.

2.2.1 REFCL technical specifications

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, REFCL 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.

2.3 Corio zone substation

Corio 66/22 kV zone substation is a fully switched station consisting of two 20/27 MVA transformers and ten 22 kV feeders. It is located in an industrial area within North Shore and supplies the heavy industrial area around the Port of Geelong as well as north towards the regional town of Anakie.

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 CRO. FNS011, FNS012, FNS032 and GB031 are the feeders that can be transferred to CRO. GL024 can also be transferred across to CRO, however, this transfer will be factored in as part of the GL REFCL scope of works.

The switch zones are as follows:

- FNS011 → CRO034, between Station St P36 Gas Switch (SW# 43614) and FNS011 Feeder CB
- FNS012 → CRO034, between Walpole – Nelson P8 ACR (SW# 22053) and FNS012 Feeder CB
- FNS032 → CRO032, between SRC to CRO P29 GV Switch (SW# 67035) and FNS032 Feeder CB
- GB031 → CRO021, between Edols St P54 Gas Switch (SW# 18157) and GB031 Feeder CB

Table 2 CRO: existing characteristics (zone substation)

Zone substation	Volume
Feeders	10
Zone substation transformers	2
22kV buses	3
Capacitor banks	2
Station service transformers	2
22kV circuit breakers (switching configuration)	15 (Fully Switched)

Table 3 CRO: REFCL network to be hardened

Network	Volume CRO only	Volume for transfers	Volume CRO + transfers
Total route length (km)	217	157	375
Underground cable length (km)	8.3	15.6	23.9
Overhead line length (km)	209	142	351
Underground network (%)	3.81%	9.90%	6.37%
Overhead single phase	77	28	106
Estimated network capacitance (A)	35.6	50.5	86.1
Distribution transformers	468	398	866
HV regulator sites	1	0	1
Fuses	498	419	917
ACRs	6	6	12
Surge arrestor sites	1,713	1,813	3,514
HV customers	6	4	10

3 Zone substation requirements

This functional scope sets out the CRO 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 CBs
 - NER terminations
 - ASC terminations
- neutral VT Installation
- install one (1) new control room and demolish old control room
- install one (1) new amenities room
- install three (3) new 22kV feeder CBs with inbuilt core balance CTs on CRO013, CRO014 and CRO024
- install seven (7) new 22kV feeder post type CTs on CRO021, CRO022, CRO023, CRO031, CRO032, CRO033, CRO034
- convert Bus No.1 existing rack structure feeder exits to underground cable exits (for CRO013 and CRO014)
- upgrade station service supplies to two (2) new 500kVA kiosk transformer
- upgrade of the station service supply cabling and installation of new AC distribution board
 - install current limiting fuses on AC distribution board
- replace two (2) 22kV Bus VT (on Bus No.1 and Bus No.3)
- replace ALL substation surge arrestors with new 22kV continuous voltage units for resonant network compatibility and 10hr 24kV TOV capability
- replace existing No.1 and No.3 capacitor banks
- replace all underground 22kV feeder exits (on CRO021, CRO024 and CRO033)
- install & commission one (1) GFN control and one (1) RCC inverter cubicles
- install two (2) new Elspec Power Quality Meter
- install two (2) new ION7350 Power Quality meters
- install one (1) new ION7400 Power Quality meter
- extend station yard and earth grid as required
- install weather station

Secondary requirements

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
- No2 Transformer Differential Cubicle
- No3 Transformer Differential Cubicle
- Backup Earth Fault and Digital Fault Recorder Cubicle
- No1 Bus Feeder Protection Cubicle
- No2 Bus Feeder Protection Cubicle
- No3 Bus Feeder Protection Cubicle
- Capacitor Bank Protection Cubicle
- PQM and VAR Control Cubicle

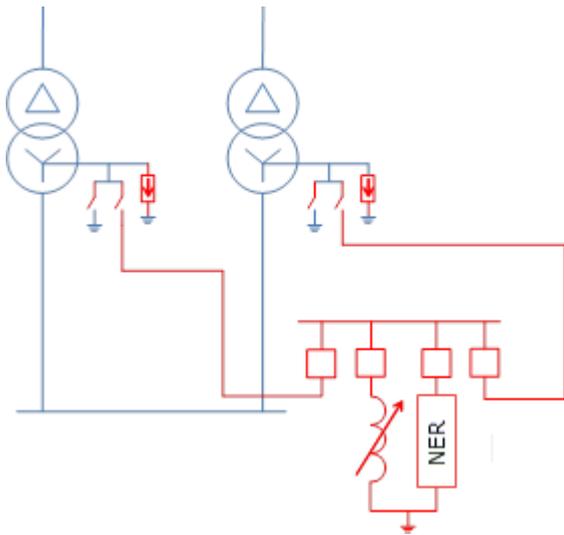
Within the existing control room:

- 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

3.1 Primary plant requirements

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

Figure 1 CRO Proposed Neutral Diagram



3.1.1 Arc suppression coil

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

Primary neutral and earth connections are via elbows.

As oil filled device, it shall be installed in a bunded area in accordance with current standards.

The GFN ASC shall be installed in the south west location of the yard;

- install Ground Fault Neutraliser comprising of one (1) x 17-200A ASC and residual current compensation modules with maximum available tuning steps onto the provided pad mount within a newly established bunded area;
- the footing of the ASC shall reside on the installed 150mm steel beams fixed to the concrete pad; and
- install cable connections to and from the Neutral System.

3.1.2 GFN inverter room

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

3.1.3 Control room

Install one (1) new control room to the east of the existing control room. Note that this will need to be built prior to decommissioning the existing control room

3.1.4 Amenities shed

Install one (1) new amenities shed where the existing control room is located.

3.1.5 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 arrester (ABB MWK22 or equivalent).

3.1.6 Zone substation capacitor bank

The existing No.1 and No.3 capacitor banks are connected in grounded star and will require replacement. Retire the existing No.1 (1 x 6.25MVar) and No.3 22kV (4 x 3MVar) capacitor banks, then to provide reactive support, install two (2) new capacitor banks 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 four (4) 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 630mm² 1/c Al HV cable.

The two new capacitor banks are to be located near the existing capacitor banks.

3.1.7 22kV Bus

Convert Bus No.1 existing rack structure feeder exits to underground cable exits (for CRO013 and CRO014).

3.1.8 22kV underground exits

Given the underground failure rate seen on current REFCL networks, replacement of all underground 22kV feeder exits (i.e. on CRO021, CRO024 and CRO033) will be required. The replacement exit cables are to be 300mm² Cu cables.

3.1.9 22kV feeder CBs

The existing three (3) 22kV feeder CBs which require replacement, will need to be 1250A rated CBs i.e. for the following feeders (CRO013, CRO014 and CRO014). Note that these new CBs will require new inbuilt core balance CTs.

3.1.10 Neutral system arrangement

Install a Neutral Bus system comprised of:

- one (1) new kiosk type ground mounted modules as per Powercor technical standard ZD081
 - one (1) new type A comprising of four (4) CBs
- 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 transformer neutral (i.e. transformer No.2 and No.3).

Neutral Bus

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

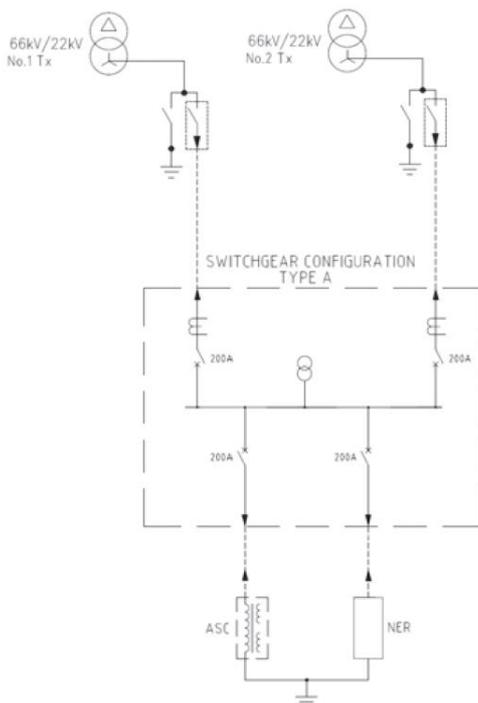
- transformer neutral connection (2 x transformers)
- ASC connection
- solid ground connection via the existing NER.

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 3 Proposed CRO neutral system single line diagram



3.1.11 Transformer earthing and Ground Bypass Isolators

The two (2) 66/22kV, 20/27MVA transformers in service at CRO 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

3.1.12 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).

3.1.13 22kV bus VT

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

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

3.1.14 Station Service Transformer

Replace the existing two (2) 25kVA 22kV Station Service Transformer from the No.1 and No.2 22kV bus.

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

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

3.1.15 Adjacent non-REFCL ZSS 22kV feeder transfers

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

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

- FNS011 → CRO034
 - CLOSE Station St P36 Gas Switch (SW# 43614)
 - OPEN FNS011 Feeder CB
- FNS012 → CRO034
 - CLOSE Walpole – Nelson P8 ACR (SW# 22053)
 - OPEN FNS012 Feeder CB
- FNS011 → CRO032
 - CLOSE SRC to CRO P29 GV Switch (SW# 67035)
 - OPEN FNS032 Feeder CB
- GB031 → CRO021
 - CLOSE Edols St P54 Gas Switch (SW# 18157)
 - OPEN GB031 Feeder CB

3.1.16 22kV Insulators

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

3.1.17 22kV feeder CT's

The existing feeder CT specifications are outlined below.

Table 4 Feeder CTs

Feeder	CT Spec	Required Action
CRO013	2.5 P150	Not suitable for sensitivity requirements, require new CT installation
CRO014	2.5 P150	Not suitable for sensitivity requirements, require new CT installation
CRO021	0.5M/1P	Not suitable for sensitivity requirements, require new CT installation
CRO022	0.5M/1P	Not suitable for sensitivity requirements, require new CT installation
CRO023	0.5M/1P	Not suitable for sensitivity requirements, require new CT installation
CRO024	5P60 300/5	Not suitable for sensitivity requirements, require new CT installation
CRO031	0.5M/1P	Not suitable for sensitivity requirements, require new CT installation
CRO032	0.5M/1P	Not suitable for sensitivity requirements, require new CT installation
CRO033	0.5M/1P	Not suitable for sensitivity requirements, require new CT installation
CRO034	0.5M/1P	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 CRO, three (3) 22kV feeder CTs require newly installed core balance CTs 600-300/5A 40-20VA class 0.1 inbuilt with to the new feeder CBs (CRO013, CRO014 and CRO024).

The remaining seven (7) 22kV feeder CTs (CRO021, CRO022, CRO023, CRO031, CRO032, CRO033 and CRO034) require newly installed post mounted metering CTs 600-300/5A 40-20VA class 0.1 RITZ Outdoor Current Transformer - GIFS36-42 50Hz (refer to quote 18305R REV03). Note that these are the same CTs used at EHK CT mounting structure in each feeder bay that requires new CT's.

3.1.18 Other considerations

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

3.2 Civil works requirement

- For Neutral System:
 - install concrete foundation pad for neutral system module
 - install neutral cable conduit, control cable conduit and provision for solid earth grid connections
 - install neutral cable conduits from transformers to neutral system module
 - install conduits to ASC and solid earth grid connection
 - install conduits for secondary circuits
- For ASC
 - install neutral cable conduit, control cable conduits and solid earth grid connections
 - pour concrete foundation
 - install steel beam, 150mm high at a width designed to accommodate the placement of the GFN Arc Suppression coil
 - install bunding to EPA requirements
- For Station Service Supplies
 - install concrete foundation for new station service transformers
 - review station service transformer foundations and enclosure for upgrade to 750kVA. Note the existing station services are 25kVA
- For new 22kV No.1 and No.3 Bus VTs
 - install concrete footings for new structures
 - install control cable conduits for both 22kV VT
- New control room and amenities shed:
 - build to be determined by design.

3.3 Secondary works

3.3.1 Existing Control Room Works

Alarm aggregation

In the existing control room:

- 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
- Note: 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

3.3.2 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 three (3) SEL-351S X CB Management and X CB Fail relays for
 - 66kV CB A
 - 66kV CB B
 - 66kV CB D
- Note: these are to be configured for tripping from the REFCL for in-station faults.

66/22kV No 2 Trans Protection cubicle

- Install standard 23" protection cubicle
- Install one (1) SEL-787 relay for

No 2 Trans X Differential

- 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 No2 Trans Y Differential and Y REF Protection
 - one (1) SEL-2414 relay for No2 Transformer Mechanical Protection and monitoring

66/22kV No 1 Trans Protection cubicle

- Install standard 23" protection cubicle
- Install one (1) SEL-787 relay for No 3 Trans X Differential
- 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 No3 Trans Y Differential and Y REF Protection
 - one (1) SEL-2414 relay for No3 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:
 - CRO013 Feeder protection
 - CRO014 Feeder protection
- Note:
 - Space to be reserved for future feeder protection relays (CRO011 and CRO012)
 - 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 four (4) SEL-351S relays for:
 - CRO021 Feeder protection
 - CRO022 Feeder protection
 - CRO023 Feeder protection
 - CRO024 Feeder protection
- Note: neutral CT ratio to be considered in relay setting. In addition, rating of CTs and settings must consider handover between sensitive earth fault protection and inverse time earth fault protection

No3 Bus 22kV Feeder Protection cubicle

- Install standard 23" protection cubicle
- Install four (4) SEL-351S relays for:
 - CRO031 Feeder protection
 - CRO032 Feeder protection
 - CRO033 Feeder protection
 - CRO034 Feeder protection
- Note: neutral CT ratio to be considered in relay setting. In addition, rating of CTs and settings must consider handover between sensitive earth fault protection and inverse time earth fault protection

PQM, VRR & VAR Control cubicle

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

3.3.3 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 Scheme document drawings
 - Produce scheme document drawings to match configured Design Integration Spreadsheet

3.3.4 GPS clock

Establish time synchronisation to new relays

3.3.5 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

3.3.6 Fibre optic works

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

3.3.7 DC Distribution

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

3.3.8 AC Station service supplies

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

3.3.9 Building access control system

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

3.3.10 Fire System & Indication

Install fire system as per current standard

3.3.11 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

3.3.12 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

3.3.13 Operator Desk

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

3.3.14 Station HMI works

- Create SLD and control pages
- Create IEC61850 status pages

4 22kV distribution feeder requirements

4.1 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 CRO ZSS as well as surge arrestors on the FNS011, FNS012, FNS032 and GB031 transfers.
- All surge arrestors except 'Type A' Bowthorpes, will need to be replaced with the new ABB polim D 22kV arrestor
- The replacement diverters should be of 22kV continuous rating with a 10 hour 24kV TOV rating.

Table 5 Surge arrestor replacement volumes

Surge arrestors	Volumes (sites)	Volume (arrestors)
Surge arrestor sites (single phase)	92	184
Surge arrestor sites (three phase)	889	2,667

4.2 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

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

4.3 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.

4.4 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 CRO distribution network contains one (1) 22kV regulating systems and none on the transfer feeders:

Table 6 CRO regulating systems

Feeder	Name	Manufacturer	Phasing	Scope of works
CRO013	ANAKIE P155 REG	Unknown – 2 x 100A pole mounted	RW	Require a new 3 x 100A 3 x 1 $\frac{1}{2}$ reg and CL7 control box required to tap all phases together

The table below summarises the replacements.

Table 7 Regulator works

HV regulators	Volume (sites)
Regulator sites	1
Regulator replacement	1
Control box upgrade	0

4.5 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
 - (i) Perform field audits to validate “Single Phase” and “unknown” conductor where required
 - (ii) 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
 - (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), and 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 8 Balancing requirements summary

Balancing concept	Number of sites including transfers
Re-phasing Sites	20
Single Phase Balancing Units	2
3 Phase Balancing Units	20
RC Gas Switches	0

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

Each RVE or VWVE ACR on the CRO 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 9 ACR sites

Feeder	Name	Operating voltage	Phase code	Control Box Model	ACR model
CRO013	ANAKIE RD P47 ACR	22kV	RWB	AVDC	Kyle
CRO013	PALEY-GOLDSWORTHY P1 ACR	22kV	RWB	AVDC	N24
CRO021	COWIE-EDOLS P8 ACR	22kV	RWB	AVDC	N24
CRO022	THOMPSON RD P62 ACR	22kV	RWB	CAPM5	N24
CRO022	COX-ANAKIE P7 ACR	22kV	RWB	AVDC	N24
CRO022	RESERVE RD P4 ACR	22kV	RWB	CAPM5	N24
FNS011	BACCHUS MARSH RD P50 ACR	22kV	RWB	AVDC	N24
FNS012	FLINDERS AVE P171 ACR	22kV	RWB	CAPM5	N24
FNS012	FOREST RD STH P81A ACR	22kV	RWB	AVDC	unknown
FNS012	WALPOLE - NELSON P8 ACR	22kV	RWB	AVDC	N24
FNS012	PATULLOS RD P153 ACR	22kV	RWB	AVDC	unknown
FNS032	AVALON P56 ACR	22kV	RWB	CAPM5	N24

Table 10 ACR and control box requirements summary

Units	Number of sites
ACR replacements	3
Control box replacements	4

4.7 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 11 Fusesaver requirements

Units	Number of sites with transfers
Fuse savers	18

4.8 Distribution switchgear

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 12 Switchgear replacements

Unit	Volume
Distribution switchgear	20

4.9 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 13 HV underground cable requirements

Location	Length (m)
Cable failure length	1,181

4.10 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 14 HV customer

Units	Volume
HV customer sites with generation	0
HV customer sites without generation	10
Total HV customer sites	10

