CITIPOWER	**ELECTRICITY NETWORKS** **Options assessment**	Powercor AUSTRALIA

Title	REFCL project: GL zone substation re-design
Project ID	5108027 (REFCL_GL)
Category	Zone substation
Background	The Geelong 66/22 kV zone substation (**GL**) is encompassed between the Midland Highway (Ballarat Road), Ebden Street and Gibb Street. It is a switched station consisting of two 20/40 MVA transformers and a 12MVAr capacitor bank. It supplies nine distribution feeders which supply mostly urban residential areas, and some rural areas to the west including the townships of Bannockburn, Lethbridge and Meredith as well as part of the Geelong CBD on Corio Bay. Rapid Earth Fault Current Limiters (**REFCL**s) are considered effective in reducing bushfire risk due to the ability to reduce the energy into a fault via rapidly neutralising fault current and voltage at the fault site. When an earth fault occurs, the power system becomes unbalanced and a current path to earth is initiated that can create extremely high currents, typically in the many hundreds or thousands of amps if the transformer neutral is solidly grounded. A REFCL is an adjustable inductor installed between the zone substation transformer neutral point and earth which self-adjusts (tunes) to resonate with the total distribution network capacitance at 50Hz so the neutral voltage can float and allow the voltage of any wire on the network to be set to zero with respect to ground. Calculations of feeder capacitive charging current shows two REFCLs are required.
Identified need	On 1 May 2016, the Victorian Government amended the Electricity Safety (Bushfire Mitigation) Regulations 2013 (**Amended Bushfire Mitigation Regulations**). The Amended Bushfire Mitigation Regulations now require the Powercor bushfire mitigation plan (**BMP**) to include details of the preventative strategies and programs by which we will ensure each polyphase electric line originating from selected zone substations in our network meet specified capacity requirements, which can only be provided by the installation of REFCLs. The GL REFCL is part of the Powercor Tranche 2 installations.
Options	**Option 1:** convert one 22 kV bus to an indoor switch room arrangement to provide enough physical space for two REFCLs. **Option 2:** convert the outdoor switchyard to an indoor switch room arrangement to provide enough physical space for two REFCLs. **Option 3:** bring forward the future Bannockburn zone substation and transfer the relevant GL feeders onto Bannockburn, install one REFCL.
Recommended option	**Option 1:** convert one 22 kV bus to an indoor switch room arrangement to provide enough physical space for two REFCLs.
Proposed start date	2019
Proposed commission date	2020

1 Geelong REFCL project

The requirement of the REFCL to be capable of detecting an earth fault of impedance up to 25,400 ohms requires the network size to be limited. Calculations indicate that a limit of 130 A of capacitive charging current is a suitable sized distribution network for REFCL operation. The total network capacitance is a function of the overhead line length and underground cable length. The figures of 0.068 A/km and 2.73 A/km are used for overhead line and underground cable after tests at the Gisborne (**GSB**) and Woodend (**WND**) zone substations where REFCL units have been installed.

For Geelong there is 561km of overhead line and 41km of underground cable for an estimated network capacitance of 145 amps requiring two REFCLs. To ensure the REFCL operating performance, 22kV circuit breaker switching is required at the zone substation to be able to segment the network.

Bus tie circuit breakers

Splitting the 22 kV bus is done with the installation of bus-tie circuit breakers. To reduce the capacitive charging current of the network to a manageable level for effective REFCL operation the 22 kV bus needs to be split. These open bus tie CBs create two smaller distribution networks and lower the capacitive charging current that needs to be controlled by each REFCL. The buses remain switchable (not permanently split) so that the N-1 load carrying rating of a station is not reduced throughout the year. A bus tie circuit breaker is required to separate all buses and this is already installed at Geelong.

Feeder circuit breakers

The REFCL control scheme must have access to feeder protection CTs in order to ascertain what feeder the fault is in, and controls to trip the feeder in the event of a fault. Geelong has circuit breakers on all existing nine distribution feeders.

Transformer circuit breakers

In order to differentiate between faults within the zone substation transformers, or on the zone substation 22 kV bus, 22 kV circuit breakers with current transformers (**CT**s) are required. Geelong already has necessary transformer circuit breakers in order for the REFCL proprietary schemes to function.

Fitting two REFCLs at Geelong requires dismantling one bus of the existing outdoor 22 kV switchyard and moving to an indoor switch room arrangement which has a smaller footprint.

The scope of the project is to:

- install two REFCLs on the transformers and operate the zone substation as a split bus arrangement in 2020;
- rearrange two of the existing 22 kV distribution feeders between the No 1 and No 2 22 kV bus;
- retire one existing 22 kV outdoor bus plant due to space and clearance limitations; and
- install an indoor 22 kV switch room for the retired 22 kV bus and re-terminate the 22 kV distribution feeders.

The result at GL zone substation will be a bus arrangement with two single transformer groups, split by an open 22 kV bus tie whilst the REFCL is in operation.

The GL zone substation is currently physically constrained and significant works will be required for this project. The project needs to conform to the CitiPower/Powercor technical standards for zone substations.

Retaining the full existing outdoor 22 kV bus is not an option due to the unavailability of the required space to install the REFCL equipment (ARC suppression coils, neutral bus modules, inverter equipment) and upgraded station service transformers at the zone substation.

Any bus extensions on the existing 22 kV bus are not workable as the site boundaries impede on the footprint required for the extensions. It is not viable to purchase further land on either side as all sides are bound by road reserves.

Isolating transformers

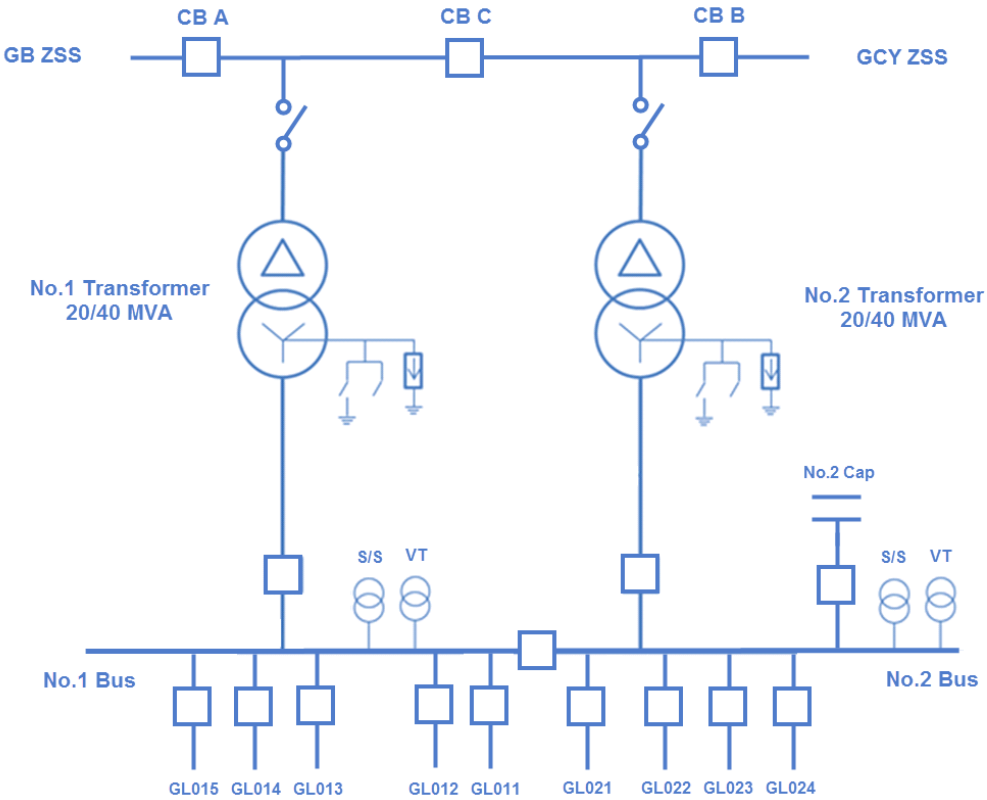
Geelong zone substation has predominantly an overhead network with some small dispersed sections of underground network. Due to the lack of appropriate sections of underground cable, it is not economically viable to use isolating transformers to reduce the network size at Geelong so that only one REFCL is required.

2 Background

The GL zone substation is encompassed between the Midland Highway (Ballarat Road), Ebden Street and Gibb Street. GL is served by two sub-transmission lines from Geelong B (GB) and Geelong City (GCY) zone substations. It is a switched station consisting of two 20/40 66 kV/22 kV transformers and a 12MVAr capacitor bank. There are two 22 kV buses and nine distribution feeders which supply mostly urban residential areas, and some rural areas to the west including the townships of Bannockburn, Lethbridge and Meredith as well as part of the Geelong CBD on Corio Bay.

The zone substation is operated with all transformers on load and a closed 22 kV buses. The transformers are operated by a voltage regulating relay to control the 22 kV bus volts. The REFCL project would split the zone substation into two sections; all transformers operating in parallel on load with a normally open 22 kV bus-tie.

Figure 1 - Existing Single Line Diagram



To the north and west of Geelong, towards and beyond the towns of Bannockburn, Inverleigh and Meredith are the high bushfire consequence areas.

Figure 2 - Geographic area supplied by Geelong

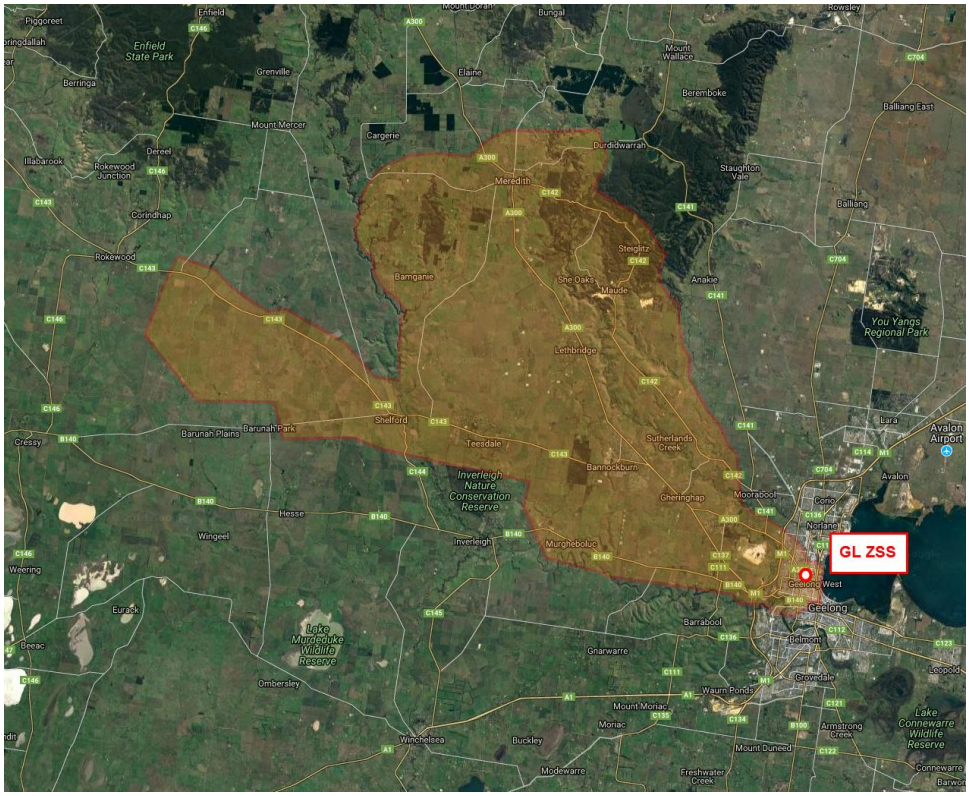


Figure 3 - Components of a REFCL

Arc Suppression Coil | Residual Current Compensator | Control Panel

3 Identified need

Regulatory obligation – REFCLs are required to comply with the recent changes to the Electricity Safety (Bushfire Mitigation) Regulations.

4 Options analysis

This section considers options which could address the identified need. These options consider both the required zone substation re-design and options at an alternate site.

Option 1: Convert one outdoor bus to an indoor switch room, rearrange two feeders and install two REFCLs

Establish a new 22 kV switch room for one 22 kV bus. Dismantle one existing outdoor 22 kV switchyard bus. Locate two REFCLs in the former outdoor switchyard bus area. Rearrange the GL015 22 kV feeder on No 1 22 kV bus with the GL024 22 kV feeder on No 2 22 kV bus.

Purchase seven new 22 kV indoor circuit breakers to replace the one outdoor bus 22 kV circuit breakers with an indoor switchboard. The indoor switchboard is to house the required transformer circuit breaker, bus tie circuit breaker, and five 22 kV feeder circuit breakers.

Table 1 Advantages and disadvantages of Option 1

Advantages	Disadvantages
Indoor switch room for safety and operability	Half the outdoor 22 kV bus converted to an indoor switch room
Cost effective option and compliant with legislation	Changes to the existing Geelong zone substation site
	Two REFCLs required

Option 2: Convert the entire 22kV outdoor switchyard to an indoor switch room, rearrange two feeders and install two REFCLs

Establish a new 22 kV switch room for both 22 kV buses. Dismantle the existing outdoor 22 kV switchyard buses. Locate two REFCLs in the former outdoor switchyard bus area. Rearrange the GL015 22 kV feeder on No 1 22 kV bus with the GL024 22 kV feeder on No 2 22 kV bus.

Fourteen new 22 kV indoor circuit breakers to be purchased as all the outdoor 22kV circuit breakers are being replaced with an indoor switchboard.

Table 2 Advantages and disadvantages of Option 1

Advantages	Disadvantages
Indoor switch room for safety and operability	More costly than Option 1
	Extensive changes to the existing Geelong zone substation site
	Two REFCLs required

Option 3: Establish Bannockburn zone substation with one REFCL and transfer feeders GL012 and GL015 onto Bannockburn

Establish a new single 25/33 MVA transformer 66/22 kV zone substation on a new site, with a new 66 kV outdoor switchyard and indoor 22 kV switch room. One REFCL located on the new site. Establish a new 66 kV sub-transmission line from Geelong terminal station (GTS) to the new Bannockburn (BBN) zone substation. Rearrange the majority of the existing GL012 and GL015 22 kV feeders onto 3 new 22 kV feeders from the new zone substation.

Purchase seven new 22 kV indoor circuit breakers for the indoor 22kV switchboard and one new 66 kV outdoor circuit breaker for the 66 kV switchyard. The indoor switchboard is to house the required transformer circuit breaker, bus tie circuit breaker, capacitor bank circuit breaker and four 22 kV feeder circuit breakers.

Table 3 Advantages and disadvantages of Option 3

Advantages	Disadvantages
One REFCL required	Would require exemption from ESV and change to the Bushfire Mitigation legislation
No changes to the existing Geelong zone substation site	Requires the purchase or lease of a new site. A willing land owner, council rezoning and Foreign Investment Review Board approval may be required.
Increases both zone substation capacity and 22 kV feeder capacity in the area	Involves the bring forward of a future zone substation which currently is not supported based on demand forecasts and not economically justifiable

Table 4 Estimated cost of each option

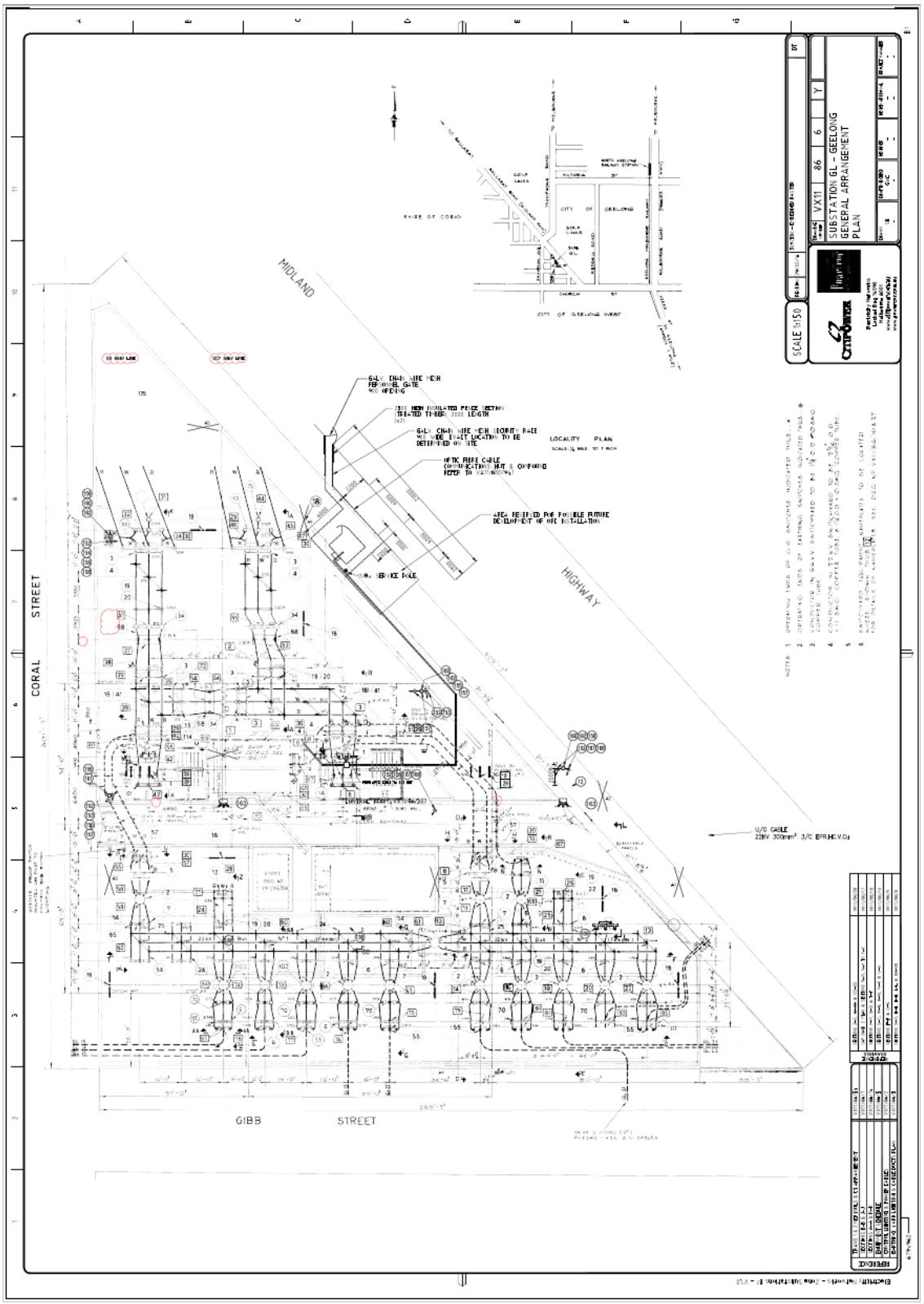
	Options	Cost ($m)
1	Convert one outdoor bus to an indoor switch room, rearrange two feeders and install two REFCLs	$18.1m
2	Convert the entire 22kV outdoor switchyard to an indoor switch room, rearrange two feeders and install two REFCLs	$21.9m
3	Establish Bannockburn zone substation with one REFCL and transfer feeders GL012 and GL015 onto Bannockburn	$28.0m

5 Recommendation

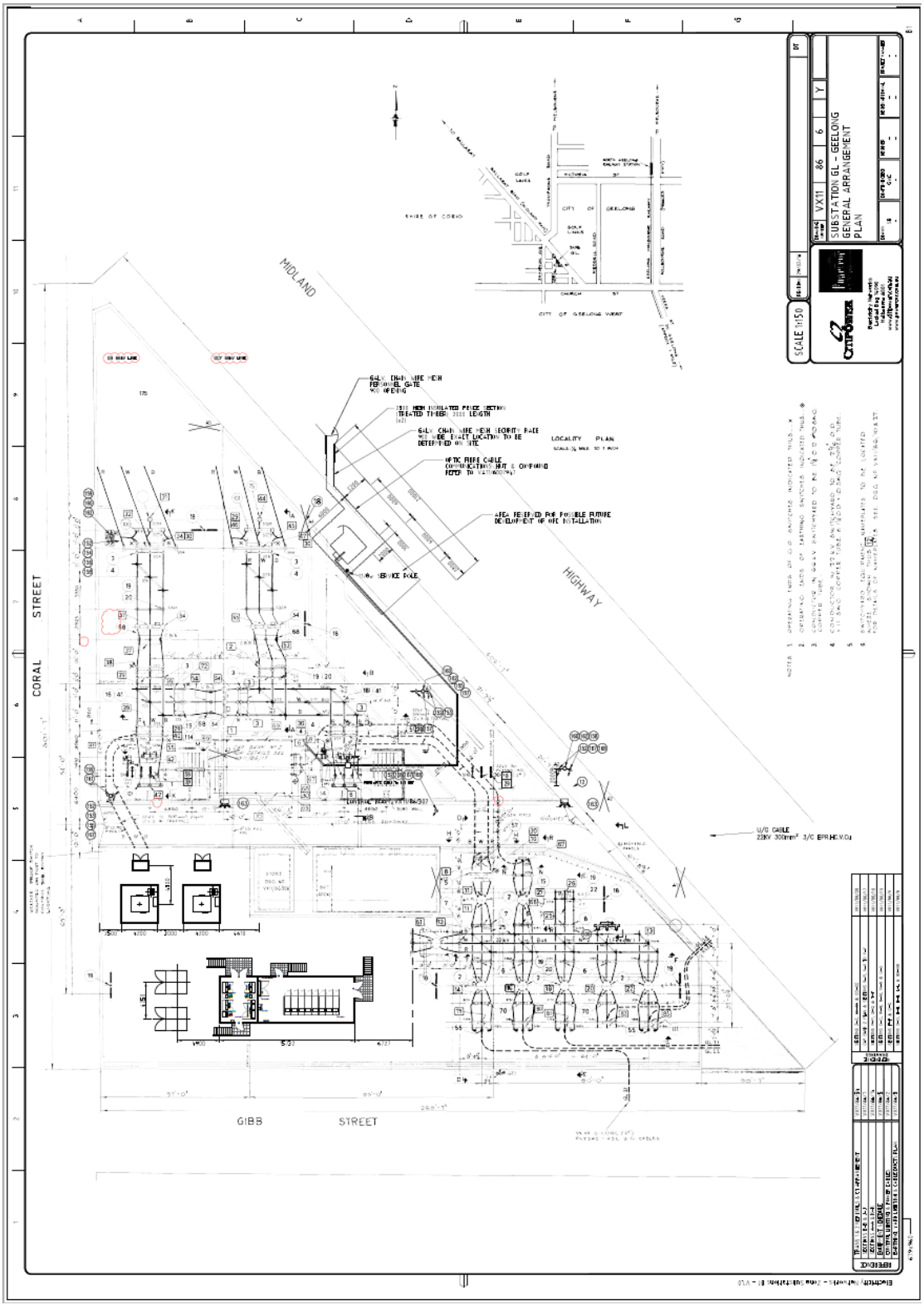
It is recommended to proceed with option 1: convert one outdoor bus to an indoor switch room, rearrange two feeders and install two REFCLs.

6 Appendix

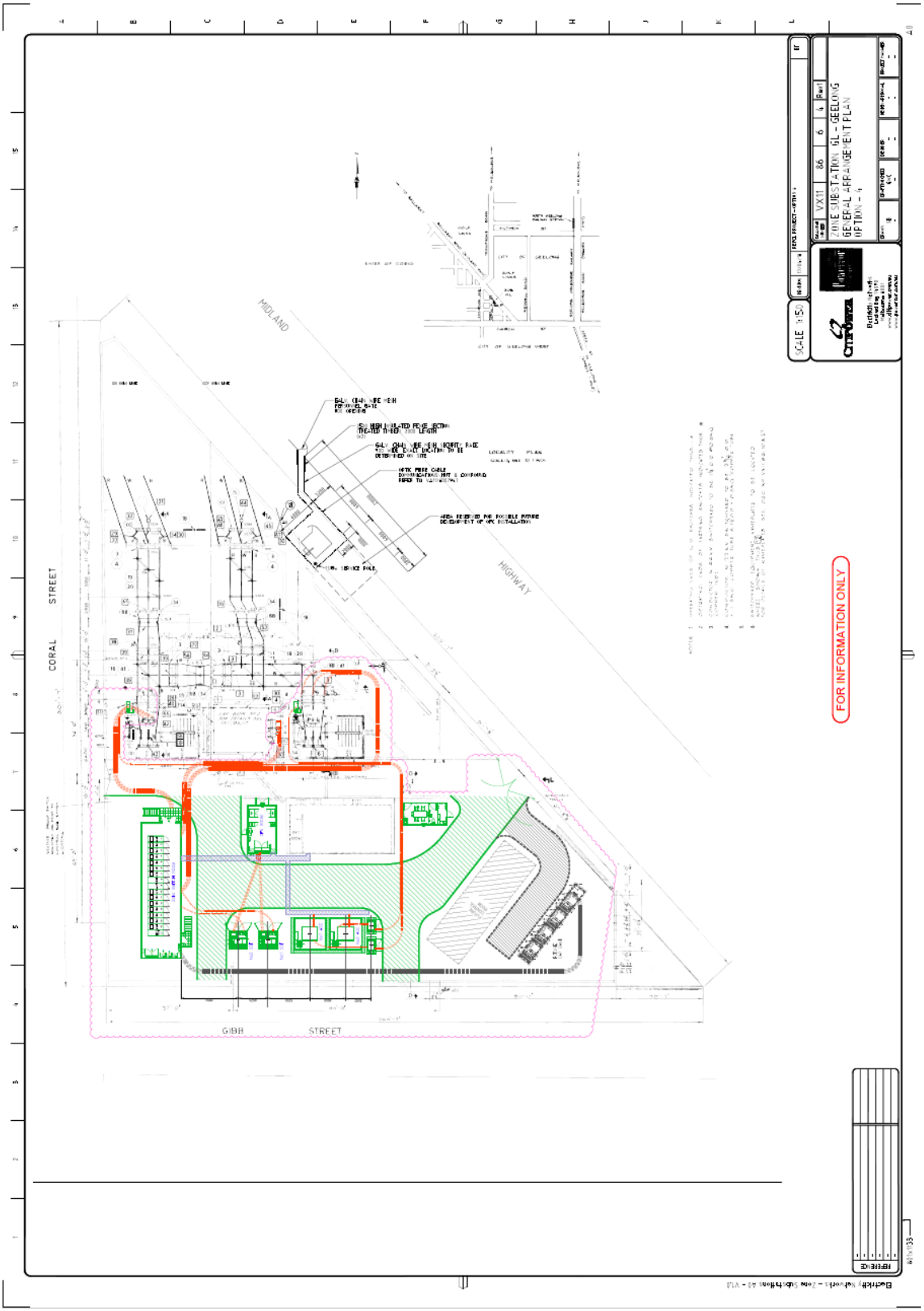
Existing Geelong (GL) zone substation General Arrangement



Option 1: One outdoor 22kV bus conversion to indoor switch room



Option 2: Convert both outdoor 22kV buses to indoor switch room



Option 3: Overview of potential new Bannockburn zone substation site