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

Title	REFCL project: WIN zone substation re-design
Project ID	5102403 (REFCL_WIN)
Category	Zone substation
Background	The Winchelsea zone substation (**WIN**) consists of a 10/13 MVA and 5/7 MVA 66/22kV transformer in banked configuration supplying a single 22 kV bus with three distribution feeders controlled by ACR's. The No 2 10/13 MVA Transformer has an ACR on the secondary side connection to the 22 kV strung bus. The No 1 5/7 MVA transformer is on hot standby and has an arc chute switch on the secondary side connection to the 22 kV strung bus. The WIN zone substation supplies the township of Winchelsea, Inverleigh, Moriac, Deans Marsh and surrounding areas. Rapid Earth Fault Current Limiters (**REFCLs**) are considered effective in reducing bushfire risk due to their 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 as it is at WIN. 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 passed legislation—the Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016 (**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 WIN REFCL is part of the Powercor Tranche 1 installations.
Options	These options consider the required zone substation re-design only: **Option 1:** Install two REFCLs and indoor switchboard North East (Gladman St) side. Install two Isolating transformers on WIN 11 22 kV feeder. **Option 2:** Install two REFCLs and outdoor switchyard East side. Install two Isolating transformers on WIN 11 22 kV feeder. **Option 3:** Install one REFCL and outdoor switchyard East side. Install three isolating transformers on WIN 11 and two isolating transformers on WIN 12 22 kV feeder.
Recommended option	**Option 1:** Install two REFCL's and indoor switchboard North East (Gladman St) side. Install two Isolating transformers on WIN 11 22 kV feeder.
Proposed start date	2017
Proposed commission date	2018

1 Winchelsea 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 120 A of capacitive charging current is a suitably sized distribution network for REFCL operation. The total network capacitance is a function of the overhead line length and underground cable length. An estimate of 0.06 A/km and 2.4 A/km had (which is the industry standard) been used for overhead line and underground cable respectively but after actual tests at the GSB and WND zone substations where REFCL units have been installed, the figures were revised to be 0.068 A/km and 2.73 A/km for overhead line and underground cable due to inaccuracies with the original estimates.

For Winchelsea there is 365 km of overhead and 114 km of underground for an estimated network capacitance of 336 A requiring two REFCL's. To ensure the REFCL operating performance, 22kV circuit breaker switching is required at the zone substation to be able to segment the network into protection zones for operation.

The 22 kV Circuit Breakers required for two REFCL operation are as follows:

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. This open bus tie CB creates two smaller distribution networks and lowers the capacitive charging current that needs to be controlled by each REFCL. This is done such that the buses remain switchable (not permanently split) as this would reduce the N-1 load carrying rating of a station throughout the year. A bus tie circuit breaker is required to separate all buses, hence for two bus's at Winchelsea there is a requirement for one 22 kV bus tie circuit breaker.

Feeder circuit breakers

Winchelsea does not have feeder circuit breakers, and currently deploys ACR's. It has no Master Earth Fault protection (MEF). The GFN control scheme must have access to feeder protection CT's in order to ascertain what feeder the fault is in, and controls to trip the feeder in the event of a fault. With the existing protection and control functionality of the ACR's on the 3 feeders at WIN, any permanent fault detected and compensated by the GFN would be unable to be detected on an individual feeder basis. In this case, existing reliability would be compromised as the entire WIN zone substation would need to be tripped by the GFN controller to clear a compensated fault. There would also be no indication available of which feeder the fault has occurred on. The distribution feeder ACRs do not have the operating duty (closing coil and ph-ph insulation) and protection functions suitable for REFCL operation.

Winchelsea therefore requires three 22 kV feeder circuit breakers which have in-built CTs. By replacing and relocating the 3 ACRs with circuit breakers within the zone substation earth grid boundary, standard feeder protection packages can be installed on all feeders that could be integrated with the GFN controls and implement MEF protection.

Transformer circuit breakers

In order to differentiate between faults within the zone substation transformers, or on the zone substation 22 kV Bus, additional 22 kV circuit breakers with current transformers (CTs) are required. The transformers at Winchelsea have an ACR and arc chute switch on the secondary sides. Transformer circuit breakers would be fitted to each transformer for REFCL operation.

To fit a REFCL at Winchelsea on each transformer (2 x REFCL) requires a re-arrangement of the 22 kV switchyard arrangements. The scope of the project is to:

- install a REFCL on each transformer and operate the zone substation as a split bus arrangement in 2019; and
- install an indoor 22 kV switchroom and re-terminate the three 22 kV distribution feeders.

Isolating transformers

Winchelsea zone substation has predominantly an overhead network with some large sections of underground network. To ensure the regulations are met, the capacitive charging current of the network being protected should be kept within 93 A -130A. Powercor has settled on a design figure of 120A. One method of reducing the size of the

network is to isolate large sections using isolating transformers. The application of isolating transformers is only applicable to sections of the system with 100 per cent underground cable, as any overhead section would lead to non-compliance with the regulations.

The use of isolating transformers has been included in all the options considered.

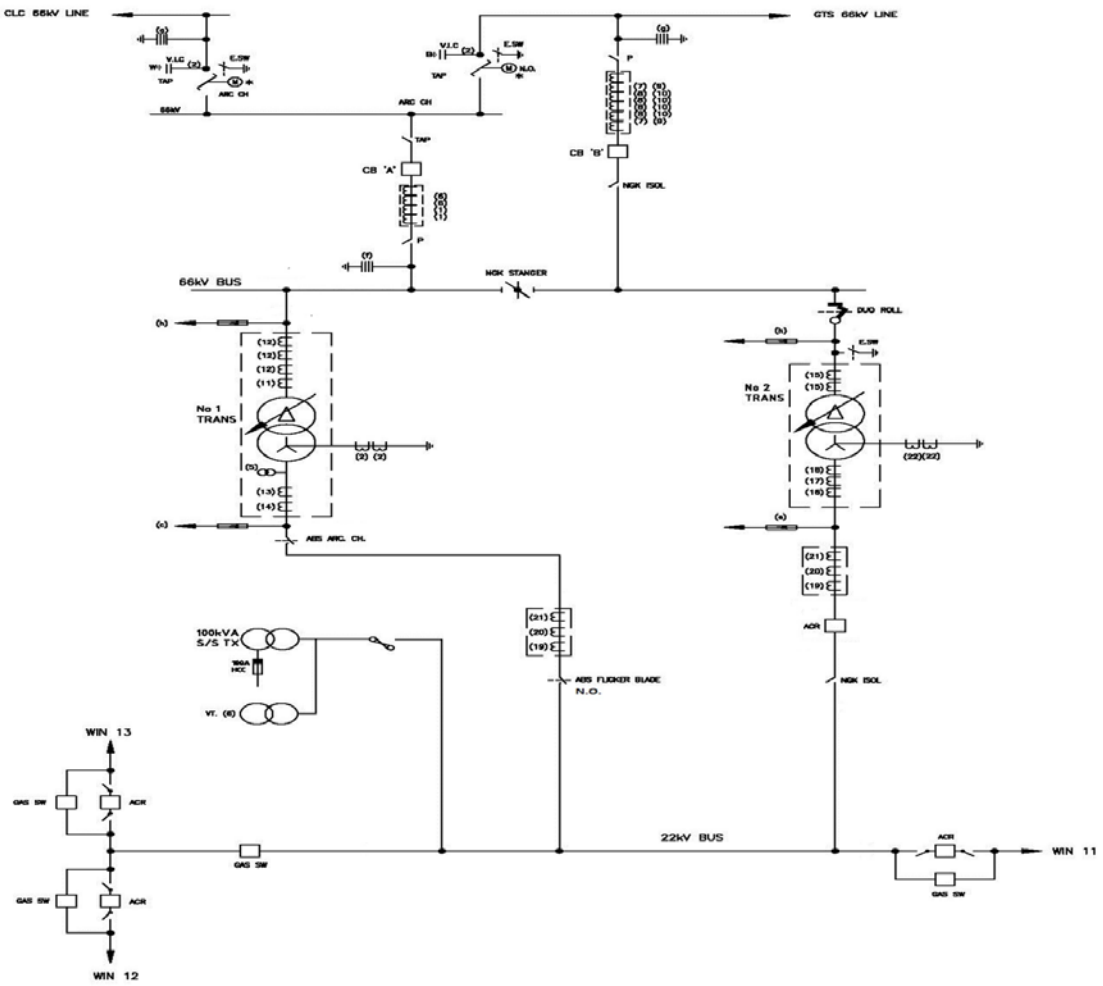
This project will conform to the CitiPower/Powercor technical standards for zone substations.

2 Background

The WIN zone substation is located on the corner of Princes Highway and Gladman Street on the east side of the Winchelsea township. WIN is served by two sub-transmission lines from the Geelong Terminal Station (GTS) and Colac (CLC) zone substation. It consists of a 10/13 MVA and 5/7 MVA 66 kV/22 kV transformer supplying a 22 kV bus and three distribution feeders controlled by ACR's.

The zone substation is operated normally with the 10/13 MVA transformer on load and the 5/7 MVA transformer on hot standby. Both have independent voltage control.

Figure 1 Existing Single Line Diagram



The REFCL project would incorporate both transformers operating in parallel on load with the normally open 22 kV bus-tie.

There are no works required with the 66 kV switchyard with this project. Longer term plans are for the 66 kV switchyard to be reconstructed as a 66 kV ring bus to cater for a future additional 66 kV line from GTS and a proposed 66 kV wind farm project.

To the south of Winchelsea is a high bushfire consequence area with a large SWER underground network (Figure 1).

Figure 2 WIN Distribution showing significant 22 kV underground spurs in high consequence bushfire areas (purple shaded)

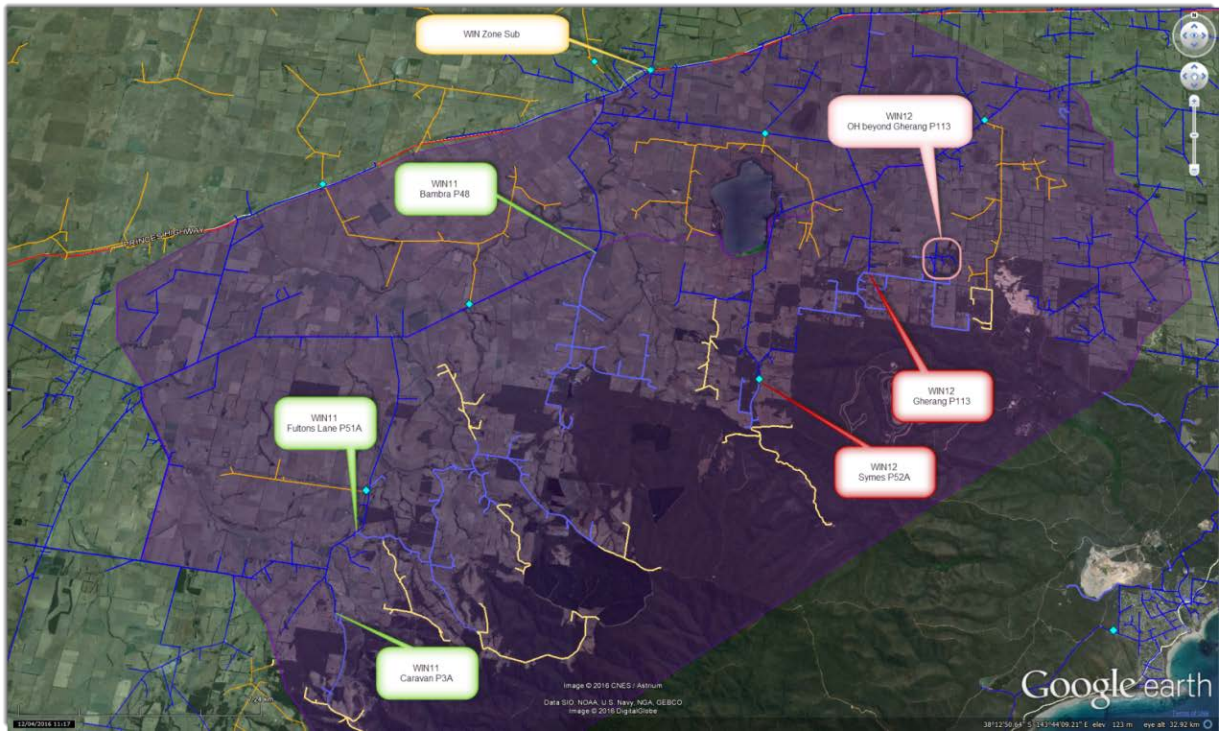


Figure 3 Components of a REFCL

Arc Suppression Coil

Residual Current Compensator

Control Panel

3 Identified need

Regulatory obligation—the REFCL is 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 the required zone substation re-design only.

Option 1

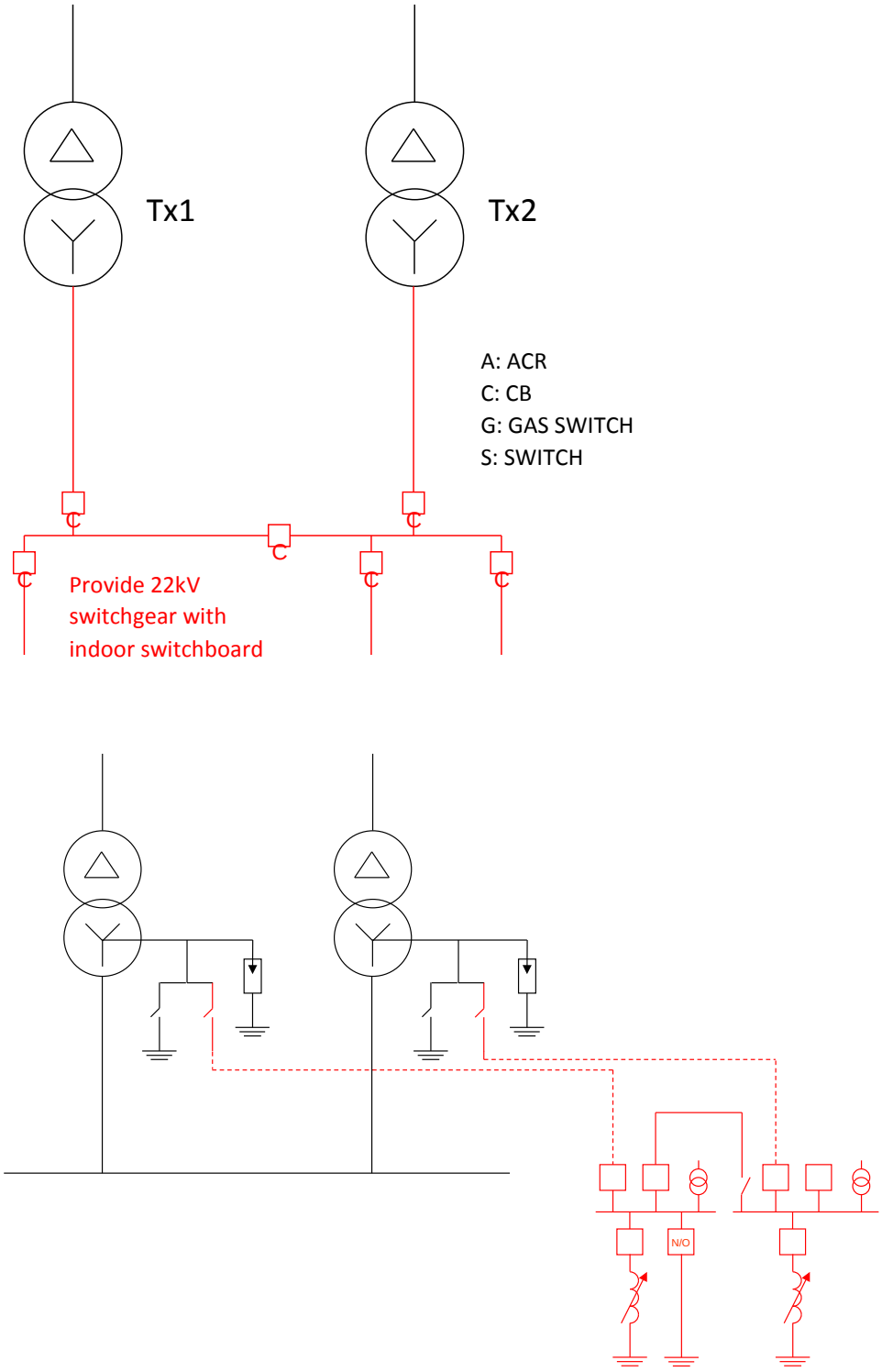
Install two REFCL's and indoor switchboard North East (Gladman St) side, and two Isolating transformers on WIN 11 22 kV feeder

Disestablish the existing strung 22 kV bus arrangement and unsuitable feeder ACR's. Install an indoor 22 kV switchboard with transformer CB's, Bus-tie CB, and three feeder CB's. This enables the transformers to be operated in switched configuration for REFCL operation with a normally open bus tie. Install two Isolating transformers on the existing high voltage underground network on WIN 11 22 kV feeder.

Seven new 22kV indoor circuit breakers to be purchased, six are required for REFCL functionality (2 x transformer circuit breakers, 1 x bus tie circuit breaker and 3 x feeder circuit breakers), and one is for a future distribution feeder. The circuit breaker for the future distribution feeder is to be purchased so that no issues occur at the time the feeder is required with attempting to purchase potentially outdated or equipment that is no longer manufactured.

Advantages	Disadvantages
Indoor switchroom for safety and operability	
Less 22 kV feeder underground feeder exits works	
REFCL's closer to transformers	
Lowest overall cost	

Figure 4 Proposed simplified Single Line Diagram



Option 2

Install two REFCLs and outdoor switchyard East side, and two isolating transformers on WIN 11 22 kV feeder

Disestablish the existing strung 22 kV bus arrangement and unsuitable feeder ACR's. Install an outdoor 22 kV switchyard with transformer CB's, Bus-tie CB, and three feeder CB's. This enables the transformers to be operated in switched configuration for REFCL operation with a normally open bus tie. Install two Isolating transformers on the existing high voltage underground network on WIN 11 22 kV feeder.

Seven new 22kV outdoor circuit breakers to be purchased, six are required for REFCL functionality (2 x transformer circuit breakers, 1 x bus tie circuit breaker and 3 x feeder circuit breakers), and one is for a future distribution feeder. The circuit breaker for the future distribution feeder is to be purchased so that no issues occur at the time the feeder is required with attempting to purchase potentially outdated equipment that is no longer manufactured.

The outdoor option requires more labour work hours and cost for construction and installation, which is in the order of 20 per cent more costly than the indoor option.

Advantages	Disadvantages
Caters for existing and future feeder requirements	Takes up more switchyard space.
	Visual impact for future housing in area
	Does not align with PAL zone substation 22 kV zone substation standard

Option 3

Install one REFCL and outdoor switchyard East side, and three isolating transformers on WIN 11 and two isolating transformers on WIN 12 22 kV feeder

Disestablish the existing strung 22 kV bus arrangement and unsuitable feeder ACR's. Install an outdoor 22 kV switchyard with provision for future transformer CB's, provision for future Bus-tie CB, and three feeder CB's. This enables the transformers to be operated in banked configuration for REFCL operation.

Install three Isolating transformers on WIN 11 and two Isolating transformers on WIN 12 22 kV feeder.

Four new 22kV outdoor circuit breakers to be purchased, 3 are required for REFCL functionality (3 x feeder circuit breakers), and one is for a future distribution feeder. The circuit breaker for the future distribution feeder is to be purchased so that no issues occur at the time the feeder is required with attempting to purchase potentially outdated equipment that is no longer manufactured.

Advantages	Disadvantages
Caters for existing and future feeder requirements	Takes up more switchyard space.
	Visual impact for future housing in area
	Does not align with PAL zone substation 22 kV zone substation standard

Summary of options—zone substation re-design

	Options	Cost ($m)
1	Install two REFCLs and indoor switchboard North East (Gladman St) side. Install two Isolating transformers on WIN 11 22 kV feeder.	$5.19
2	Install two REFCLs and outdoor switchyard East side. Install two Isolating transformers on WIN 11 22 kV feeder.	$5.83
3	Install one REFCL and outdoor switchyard East side. Install three isolating transformers on WIN 11 and two isolating transformers on WIN 12 22 kV feeder.	$6.60

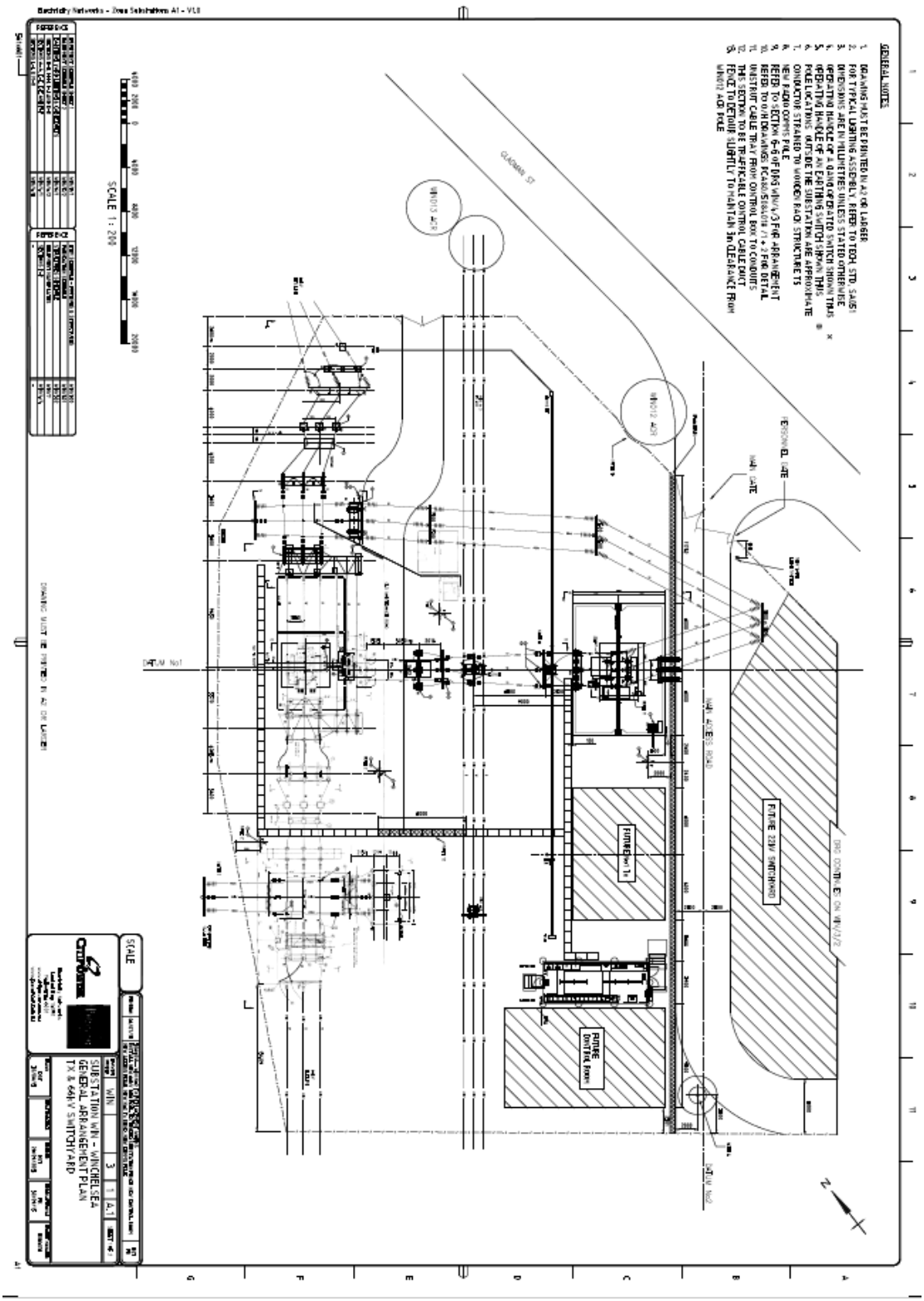
5 Recommendation

It is recommended to proceed with option 1.

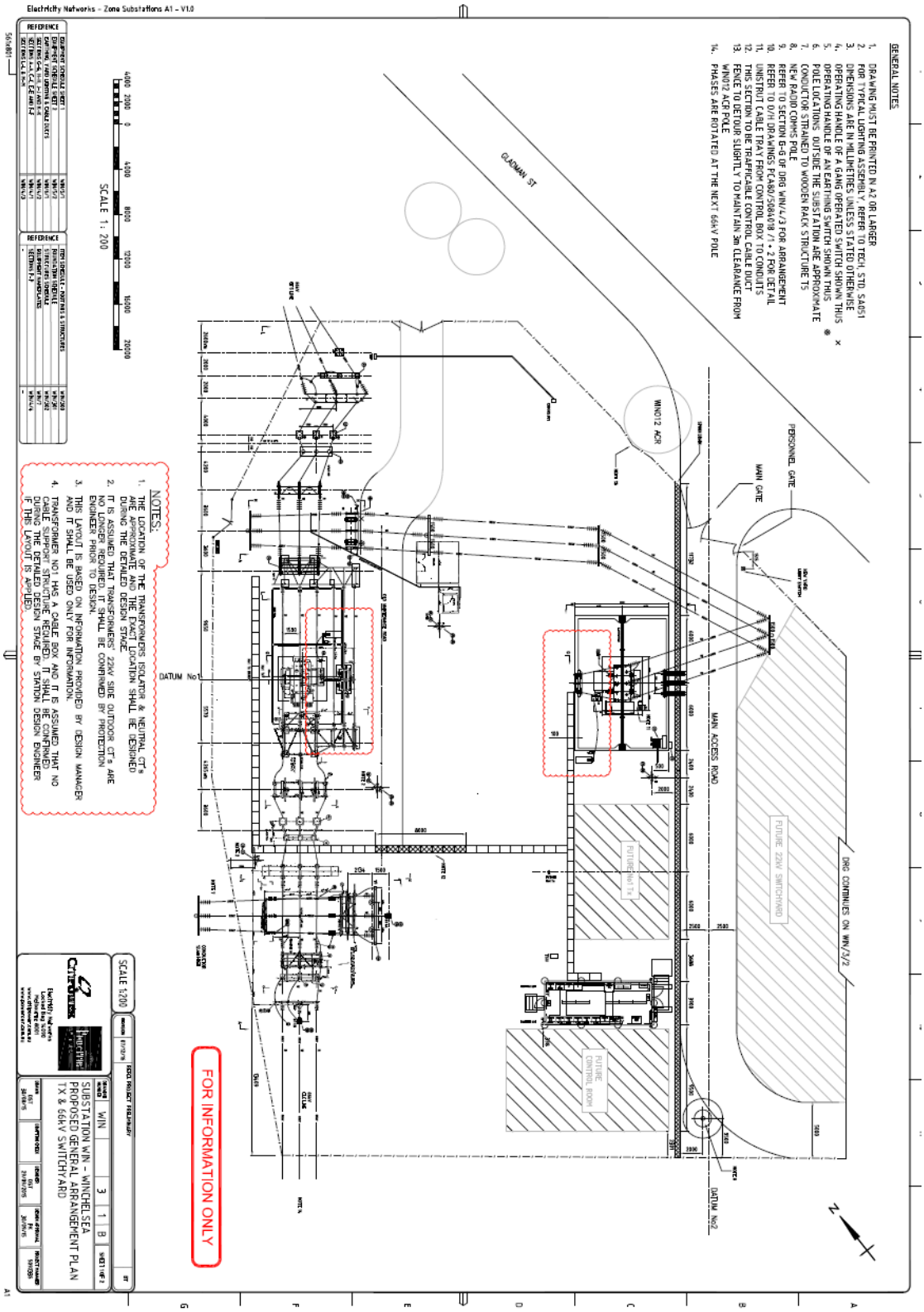
Install two REFCL's and indoor switchboard North East (Gladman St) side. Install two Isolating transformers on WIN 11 22 kV feeder.

APPENDIX

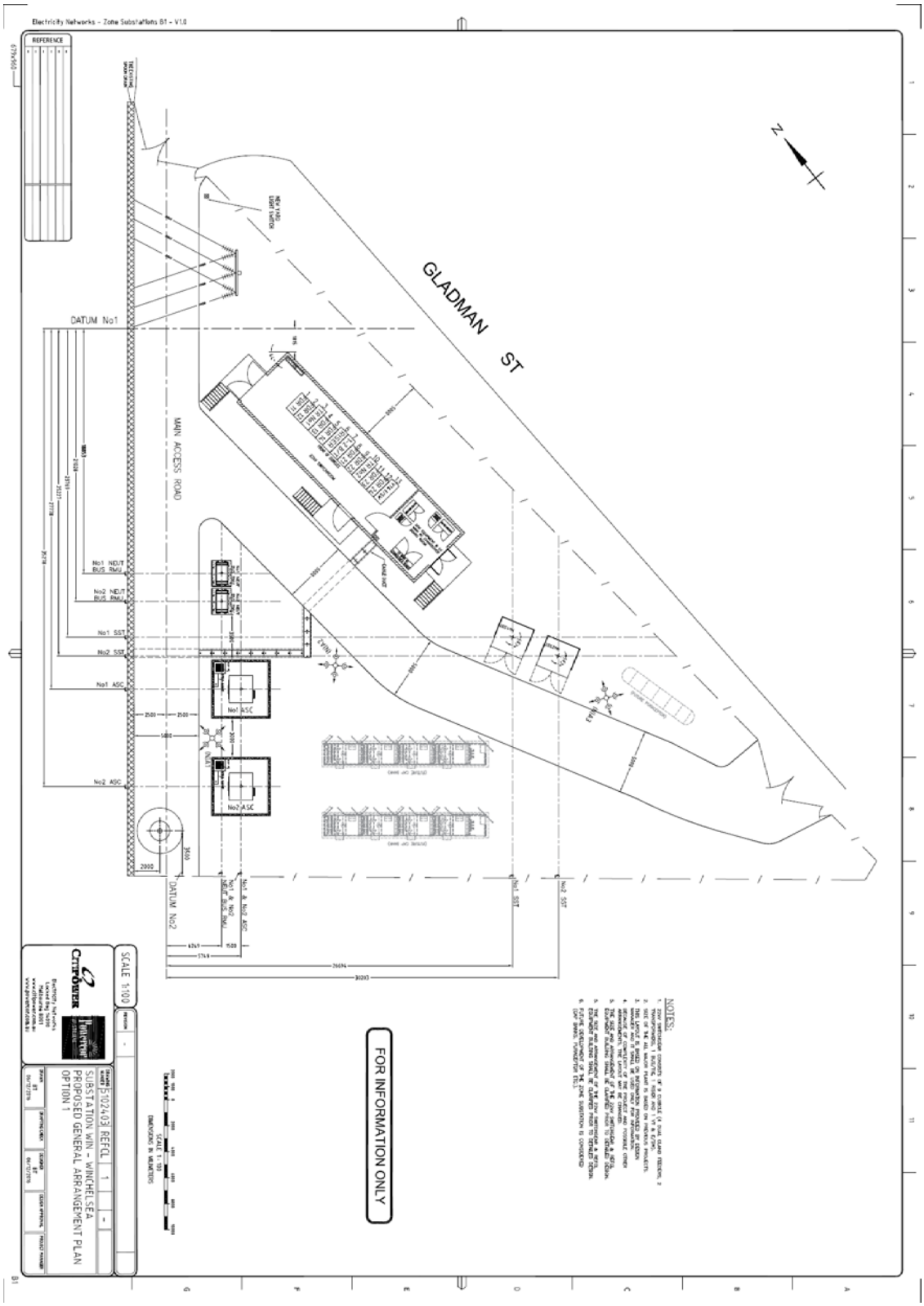
Existing 66 kV/22kV Switchyard (no planned works for REFCL project)



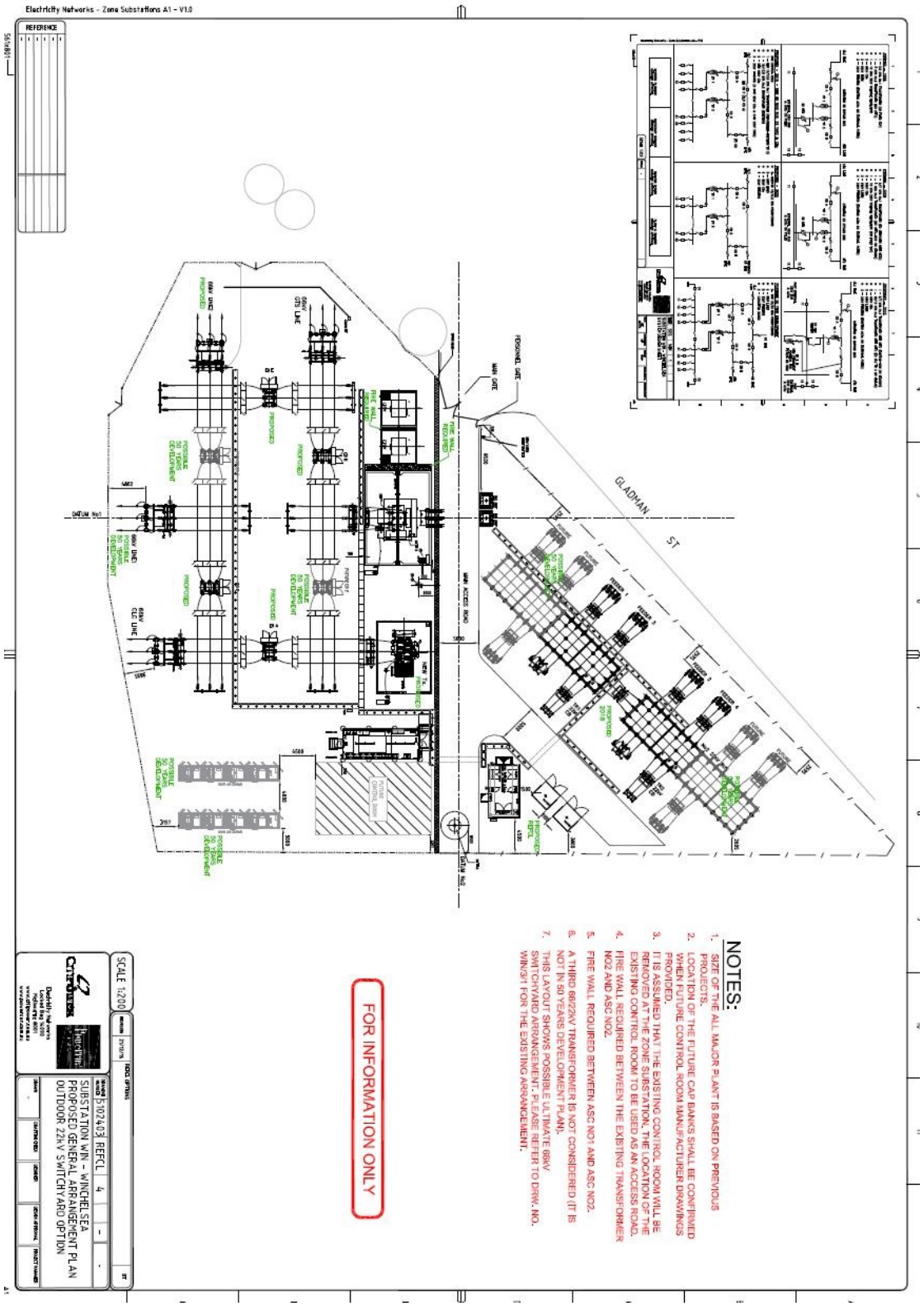
Proposed 66 kV Switchyard for all 3 options



Option 1 Install two REFCLs and indoor switchboard North East(Gladman St) side



Option 2 Install two REFCLs and outdoor switchyard East side



Option 3 Install one REFCL and outdoor switchyard East side. Three Isolating transformers on WIN 11 and two Isolating transformers on WIN 12 22 kV feeder.