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

Title	REFCL project: CLC zone substation re-design
Project ID	5102398 (REFCL_CLC)
Category	Zone substation
Background	The Colac zone substation (CLC) consists of two 25/33, and a 10/13 MVA 66/22kV transformer in partially switched configuration supplying three 22 kV bus's and seven distribution feeders. The transformers are switched by 66 kV CB's on the primary side. The two 25/33 MVA transformers have 22 kV CB's and the 10/13 MVA has a 22 kV switch on the secondary side. There are no bus tie CB's in the 22 kV bus's. Colac zone substation supplies the township of Colac, Lorne, Apollo Bay, Beeac, Gellibrand, Forrest and surrounding areas in the Otways. Rapid Earth Fault Current Limiters (REFCLs) 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 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 CLC REFCL is part of the Powercor Tranche 1 installations.
Options	These options consider the required zone substation re-design only: **Option 1:** New 22 kV indoor switchroom and two REFCL's. Feeder exits on east side of switchroom. **Option 2:** Install indoor switchroom for No 1 22 kV bus (north east side), and relocate Cap Bank. Install two REFCL's (south side) and relocate 66 kV line. **Option 3:** Install two REFCL's and relocate Cap Banks. Establish indoor switchboard on south side.
Recommended option	**Option 2:** Install indoor switchroom for No 1 22 kV bus (north east side), and relocate Cap Bank. Install two REFCL's (south side) and relocate 66 kV line.
Proposed start date	2017
Proposed commission date	2017

1 Colac 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 120 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. 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 Gisborne (GSB) and Woodend (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 Colac there is 1,288 km of overhead and 35 km of underground for an estimated network capacitance of 182 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.

To fit two REFCL's at Colac requires a rearrangement of the 22 kV switchyard.

The following 22 kV Circuit Breakers are required for two REFCL operation:-

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, hence at Colac there is a requirement for two 22 kV bus tie circuit breakers.

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. Colac has circuit breakers on all existing seven distribution feeders.

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. Colac does not have 22 kV CTs for the No 2 transformer and therefore requires this circuit breaker in order for the REFCL proprietary schemes to function.

The scope of the project is to:

- install two REFCLs on the transformers and operate the zone substation as a split bus arrangement in 2018;
- install an indoor 22 kV switchroom for No 1 22 kV bus and re-terminate the 22 kV distribution feeders; and
- rearrangement of existing plant (e.g. Cap Banks) due to space and clearance limitations.

The result at CLC zone substation will be a bus arrangement with a two transformer group and a single transformer group, split by an open 22kV bus tie. Whilst the REFCL is in operation, one bus tie will be open and the other closed.

The CLC 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.

An outdoor 22kV bus option has not been pursued due to the unavailability of the required space to install the additional 22kV circuit breakers at the physically constrained zone substation. There is not enough space in the existing 22kV outdoor bus yard to install the required two bus ties circuit breakers and transformer circuit breaker, as well as the other equipment required for a split bus arrangement (another voltage transformer and station service transformer).

Any bus extensions on the existing 22kV 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 the northern side is an established business and the southern side is road reserve.

Isolating transformers

Colac zone substation has predominantly an overhead network with some small dispersed 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 % underground cable, as any overhead section would lead to non-compliance with the regulations.

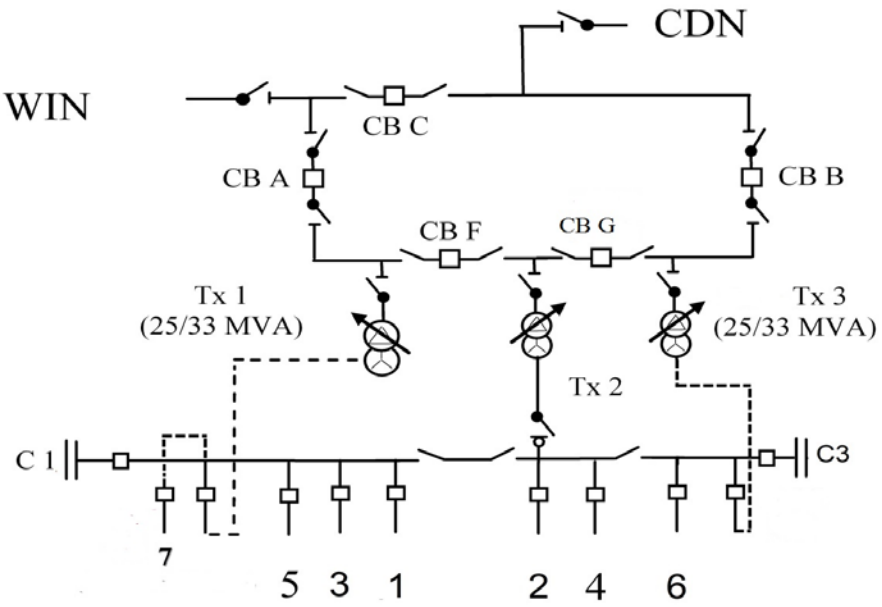
It is not economically viable to consider the use of Isolating transformers to reduce the requirement at Colac zone substation down to one REFCL being required. There is not enough underground in large sections from the Colac zone substation to reduce the capacitive charging current down to 120A using a limited amount of Isolating transformers. The capacitive charging current would need to be reduced by 62 A. There is currently 35km of underground available of which 26km would need Isolating transformers to reduce the capacitive current by 62A. The largest section of suitable underground for an Isolating transformer is only approximately 2.5km. The sections of underground than reduce in size considerably and to get the required 26km the number of Isolating transformers would be in the tens. Another option with the overhead capacitive charging current at 0.068A/km an estimated amount of 912 km of overhead network including substations would need to be converted to underground and isolated to get the required 62A reduction. Any hybrid option of undergrounding sections of overhead in combination with existing underground still isn't viable due to the lack of large sections of underground in close proximity of one another. Isolating transformers are only suitable on systems with large sections of underground cable and Colac zone substation does not have the levels of underground required.

2 Background

The CLC zone substation is located on the corner Wallace Street and Forrest Street on the east side of the Colac township. CLC is served by two sub-transmission lines from the Camperdown(CDN) and Winchelsea(WIN) zone substations. It consists of two 25/33 MVA and a 10/13 MVA 66 kV/22 kV transformer supplying three 22 kV bus's and seven distribution feeders.

The zone substation is operated with all transformers on load and a closed 22 kV bus's. 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 three sections comprising a 25/33 MVA, 10/33 MVA, and 25/33 MVA transformer, all transformers operating in parallel on load with a normally open 22 kV bus-tie.

Figure 1 Existing Single Line Diagram



There are minor works to the 66 kV switchyard due to space limitations and clearance issues accommodating plant items.

To the south of Colac is the Otways Ranges forest containing high bushfire consequence areas.

Figure 2 Geographical area supplied by Colac zone substation

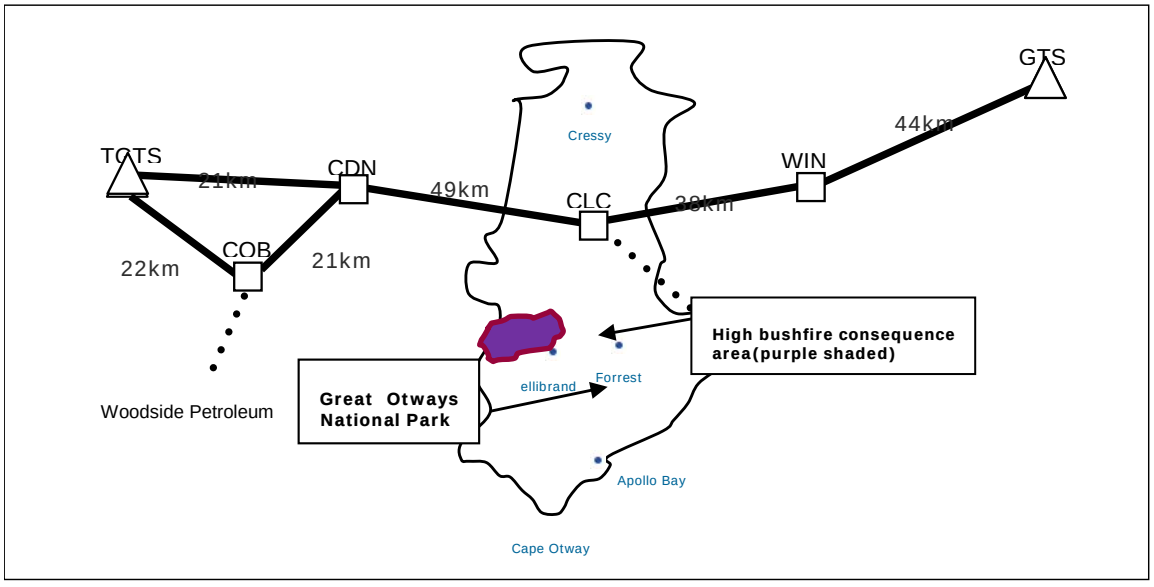


Figure 3 Components of a REFCL

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

New 22 kV indoor switchroom and two REFCL's. Feeder exits on east side of switchroom.

New 22 kV switchroom. Disestablish existing outdoor 22 kV switchyard. Two REFCL's located in Ex 22 kV outdoor switchyard area. Relocate Cap Bank.

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

Advantages	Disadvantages
Indoor switchroom for safety and operability	Reduction in reliability due to loss of transfer bus capability
	Cost of undergrounding all existing 22 kV feeder exits

Option 2

Install indoor switchroom for No 1 22 kV bus (north east side), and relocate Cap Bank. Install two REFCL's (south side) and relocate 66 kV line.

1 new 22kV indoor switchboard to be purchased, 1 outdoor 22kV circuit breaker as a tie between the existing outdoor No 2 and 3 buses (required for REFCL functionality). Indoor 22kV circuit breakers installed as part of the No 1 22kV bus

only. The indoor switchboard is to house the required transformer circuit breaker, bus tie circuit breaker, second station service transformer supply and replace existing capacitor bank circuit breaker to allow for room for the equipment to tie the outdoor bus with the indoor switchroom.

Advantages	Disadvantages
Joint switchroom building for 22 kV Bus and REFCL equipment	Cost of undergrounding some existing 22 kV feeder exits
Indoor switchroom for safety and operability	Some building demolition works for space
Less underground cable works	

Option 3

Install two REFCL's and relocate Cap Banks. Establish indoor switchboard on south side.

Locate two REFCL's and relocate Cap Banks. New 22 kV switchroom on south side. Disestablish existing outdoor 22 kV switchyard. Relocate 66 kV line.

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

Advantages	Disadvantages
Indoor switchroom for safety and operability	Reduction in reliability due to loss of transfer bus capability
Less underground cable works	Cost of undergrounding all existing 22 kV feeder exits
Easier construction with station in service	

Summary of options—zone substation re-design

	Options	Cost ($m)
1	New 22 kV indoor switchroom and two REFCL's. Feeder on exits east side of switchroom.	$6.22
2	Install indoor switchroom for No 1 22 kV bus (north east side), and relocate Cap Bank. Install two REFCL's (south side) and relocate 66 kV line.	$5.28
3	Install two REFCL's and relocated Cap Banks. Establish indoor switchboard on south side.	$5.65

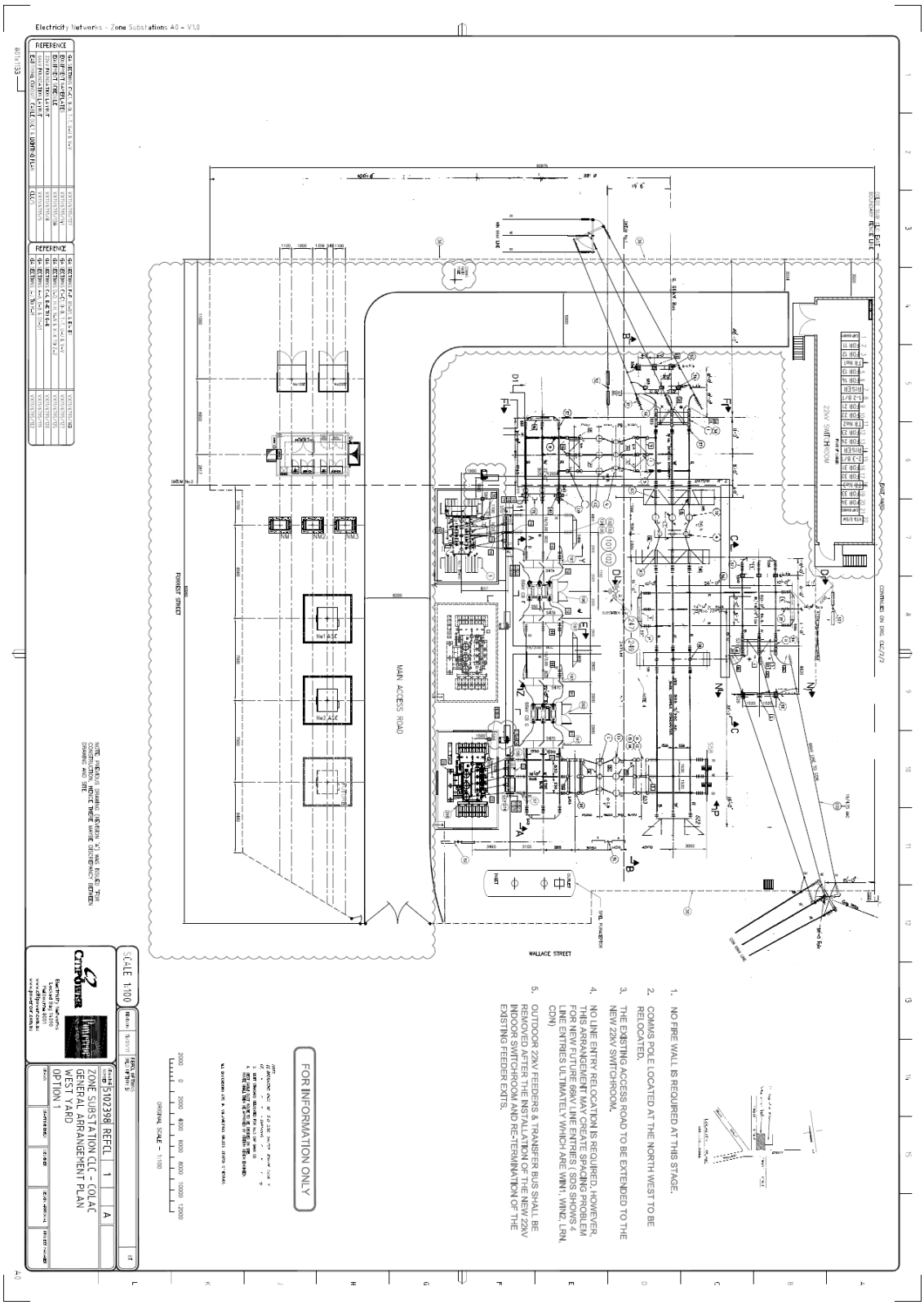
5 Recommendation

It is recommended to proceed with option 2.

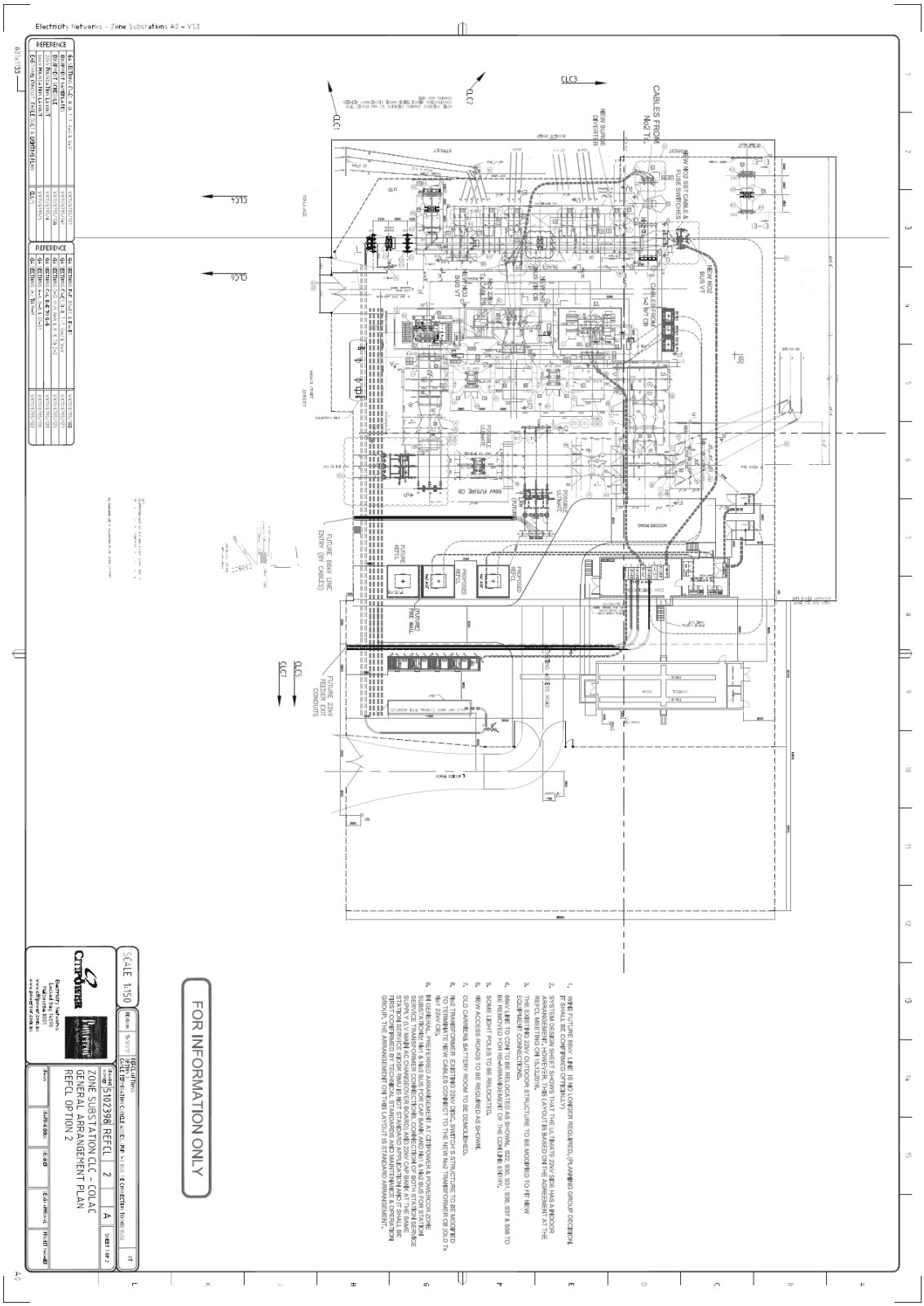
Install indoor switchroom for No 1 22 kV bus (north east side), and relocate No 1 Cap Bank. Install two REFCL's (south side) and relocate 66 kV line.

APPENDIX

Option 1: New 22 kV indoor switchroom and two REFCL's. Feeder exits on east side of switchroom.



Option 2: Install indoor switchroom for No 1 22 kV bus (north east side), and relocate Cap Bank. Install two REFCL's (south side) and relocate 66 kV line.



Option 3: Install two REFCL's and relocate Cap Banks. Establish indoor switchboard on south side.