Rapid Earth Fault Current Limiter (REFCL) Program

KLO Zone Substation Functional Scope

Document Details	
Document Number:	REF 70-27
Version number:	1.0
Author:	Youssef Ali
Status:	Published
Approver:	Hannah Williams
Date of approval	27 May 2019

REVISION HISTORY

Issue Number	Date	Description	Author
1.0	27 May 2019	Published	Y. Ali

Contents

1 Project overview 4

1.1 Background 4

1.2 Selected REFCL zone substations 5

1.3 Kalkallo zone substation overview 6

1.4 KLO ZSS assets 7

1.5 KLO ZSS single line diagram 8

1.6 KLO 22kV network 9

2 Zone substation requirements 11

2.1 Primary systems 11

2.2 Civil infrastructure 14

2.3 Secondary systems 15

2.4 KLO proposed single line diagram 17

3 22 kV distribution feeder requirements 19

3.1 Network hardening 19

3.2 Capacitive balancing 20

3.3 Compatible equipment 21

3.4 HV customers 22

4 Proposed Site Plan 24

5 Referenced Documents 26

1 Project overview

This project scope covers all aspects involved in the conversion of the Kalkallo (**KLO**) zone substation (**ZSS**) from a low impedance earthed network to a resonant earthed network that can meet the performance requirements as set out in the *Electrical Safety (Bushfire Mitigation) Regulations 2013* as amended by the *Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016* which came into effect on 1 May 2016.

Conversion to resonant earthing changes the electrical characteristics of the zone substation and the network it supplies. Resonant earthing significantly reduces single phase to ground fault currents. Phase to ground voltages on the faulted phase are reduced significantly whilst phase to phase voltages remain unaffected. The neutral voltage is raised to normal phase to ground voltage and the two healthy phases have their phase to ground voltages increase to phase to phase voltage levels.

Resonant earthing is only being applied to the 22 kV network. As such the resonant earthing does not affect (or protect) the following adjacent network, namely:

- 66 kV sub-transmission system;
- 12.7 kV Single Wire Earth Return System (**SWER**);
- High Voltage (**HV**) Customers with an Isolating Transformer installed; and
- Low Voltage (**LV**) supplies.

1.1 Background

AusNet Services' network operates in a geographical location which is exposed to extreme bushfire risk. These conditions warrant significant investment to mitigate the risk of bushfires as a result of earth faults on the distribution network.

The Victorian Bushfire Royal Commission, established in 2009, made several recommendations with respect to fires initiated from electricity distribution networks. Subsequently, the Victorian Government established the Powerline Bushfire Safety Taskforce (**PBST**) to investigate new cost efficient and effective technologies and operational practices to reduce catastrophic bushfire risk.

The PBST identified Rapid Earth Fault Current Limiters (**REFCLs**) installed in zone substations as an efficient and effective technology.

The *Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016* (**Amended Bushfire Mitigation Regulations**) which came into operation on 1 May 2016 set out new requirements for major electricity companies including the requirement for Polyphase Electric Lines (defined as multiphase distribution between 1 kV and 22 kV) at selected zone substations to have the following abilities:

- to reduce the voltage on the faulted conductor for high impedance faults to 250 volts within 2 seconds
- to reduce the voltage on the faulted conductor for low impedance faults to
    i. 1900 volts within 85 milliseconds; and
    ii. 750 volts within 500 milliseconds; and
    iii. 250 volts within 2 seconds; and
- Demonstrate during diagnostic tests for high impedance faults to limit
    i. Fault current to 0.5 amps or less; and
    ii. The thermal energy on the electric line to a maximum I^2t value of 0.10;

The Amended Bushfire Mitigation Regulations define the low and high impedance faults as follows:

- High impedance = a resistance value in Ohms that is twice the nominal phase-to-ground voltage. This is equal to 25.4 kOhms or a fault current of 0.5 amps on a 22 kV network.
- Low impedance = resistance value in Ohms that is the nominal phase-to-ground network voltage divided by 31.75. This is equal to 400 Ohms or a fault current of 31.75 Amps on a 22 kV network.

1.2 Selected REFCL zone substations

Schedule 2 of the Amended Bushfire Mitigation Regulations lists the selected zone substations to be REFCL enabled. For AusNet Services, 22 zone substations have been selected.

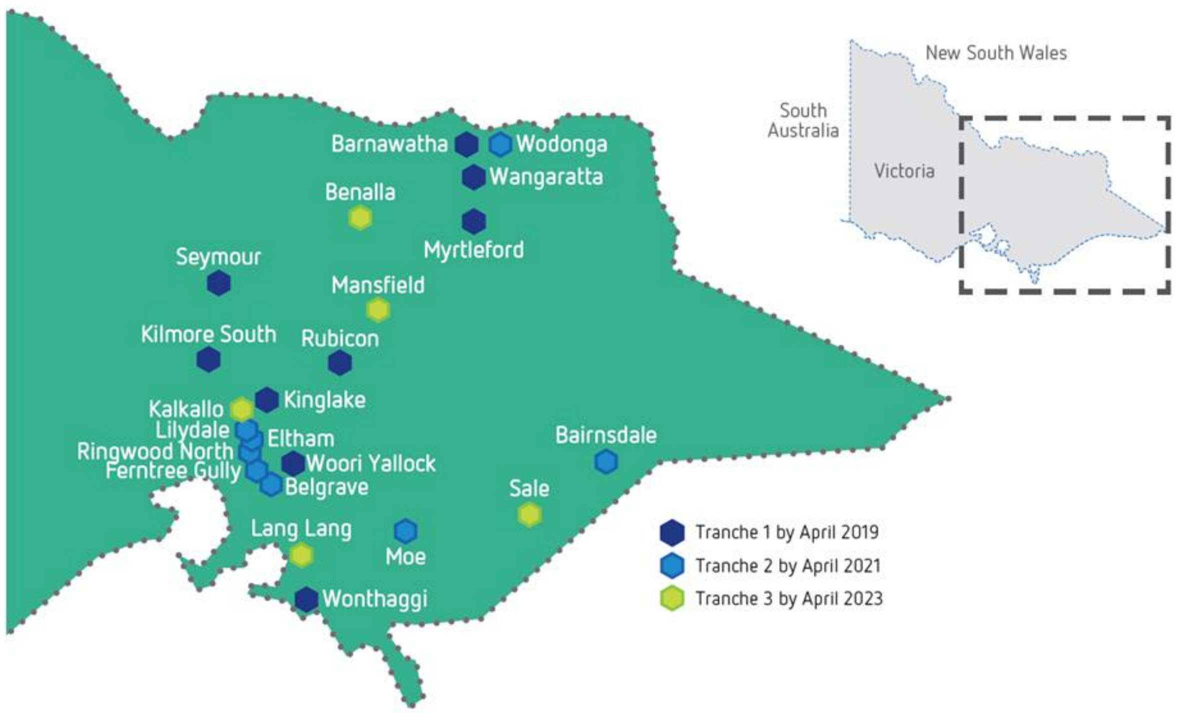
Schedule 2 assigns a number of points to each of the selected zone substations. The Amended Bushfire Mitigation Regulations require AusNet Services to ensure:

- at 1 May 2019, the points set out in Schedule 2 in relation to each zone substation upgraded, when totalled, are not less than 30;
- at 1 May 2021, the points set out in Schedule 2 in relation to each zone substation upgraded, when totalled, are not less than 55; and
- on and from 1 May 2023, each polyphase electric line originating from every AusNet Services zone substation specified in Schedule 2 has the required capacity.

AusNet Services REFCL Program has been structured into three separate tranches in order to achieve the ‘points’ requirement by the mandated dates.

The following figure shows the specified zone substations by tranche.

Figure 1: AusNet Services selected REFCL Zone Substations



Source: AusNet Services

1.3 Kalkallo zone substation overview

The KLOZSS is included in Tranche 3 of the AusNet Services REFCL Program.

KLO ZSS is located approximately 50 km north of Melbourne at Donnybrook Road, Kalkallo, 3064.

This zone substation was established in 2010 and supplies approximately 9,400 customers by means of two (2) 20/33/49.5 MVA transformers and seven (7) 22kV distribution feeders, 4 underground and 3 overhead.

The KLO electricity distribution area consists of primarily residential and light industrial areas in and around Kalkallo, Wallan, Woodstock and Wandong. These suburbs are undergoing intensive land development as they are situated in the main growth corridor in Melbourne's Northern region. In particular, the Merrifield's estate is expected to add a load of approximately 30MVA within the next four years. This load will be comprised of residential load, a large commercial shopping centre and multiple industrial sites.

Capacitive current is a major consideration for the technical solution to be employed at the KLO ZSS. Capacitive current does not increase in direct proportion to load growth. It is heavily influenced by the presence of underground High Voltage (**HV**) cable. There is a much higher percentage of underground cable on networks located closer to Melbourne than those in rural areas and the KLO ZSS network is currently comprised of 20% underground cable. Likewise, future extensions to this network will be predominantly underground cable further exacerbating capacitive current growth.

The existing total capacitive current of the KLO ZSS 22kV network is 321Amperes (**A**). As the capacitive current able to be accommodated by a single GFN is 101A, there will be four (4) REFCLs required to cater for the existing capacitive current.

1.3.1 Key issues and challenges

ZSS space constraints

The KLO ZSS has limited area for the installation of REFCL primary equipment to support the conversion to resonant earthing.

Control room

The control room within the existing KLO ZSS site is unsuitable for the installation of the REFCL technology and the associated 22 kV protection equipment.

Jemena 22kV feeders

Three (3) of the feeders fed from the KLO zone substation are owned by Jemena Electricity Network (**Jemena**) and lines hardening and balancing work will need to be undertaken collaboratively to ensure the lines can withstand, and support, REFCL operations.. The funding for lines works on these Jemena Electricity Network feeders has been excluded from the AusNet Services Contingent Project Application and the costs are to be borne by Jemena Electricity Network).

Underground cable and high network capacitance

The KLO ZSS feeders consist of long lengths of underground cables to supply Melbourne's northern growth corridor and these underground cables produce a high level of capacitive current.

The KLO ZSS cannot support the capacitance current produced by the KLO feeders. AusNet Services and the supplier of the GFNs do not have a solution to synchronise three (3) GFNs within a ZSS, therefore the requirement of four (4) GFNs in a zone substation appears to be unachievable.

Network capacitance forecasts are indicating that the KLO network capacitive current by 2025 will be in the vicinity of 466A which will require 5 GFNs and, by 2030, the forecast network capacitive current will increase to 1,644A which will Require 17 GFNs.

Intercepting this capacitive current growth is critical in order to prevent the ongoing expenditure that will be required to maintain REFCL compliance at KLO ZSS post Tranche 3.

Proposed solution

The proposed solution to be employed at KLO ZSS is to transfer four (4) fully underground feeders to a new separate zone substation and, through the use of isolation transformers, remove 100A of capacitive current from the remaining three overhead feeders.

All future 22kV load growth will be supplied from the new zone substation and be constructed entirely of underground cable.

This proposed solution will enable the existing KLO ZSS to be reduced to a two GFN site and to remain so into the future. Refer to section 2.2.1 of this document for an overview of the options analysis.

Whilst the proposed solution is the currently preferred option, a joint AusNet Services/Jemena network planning engagement has commenced, conducted by a third party, to confirm the least cost, technically acceptable solution for both Jemena and AusNet Services.

The forecast expenditure to implement the new ZSS has been included in the AusNet Services Tranche 3 contingent project application.

1.4 KLO ZSS assets

The following table provides an overview of the current assets located at the KLO ZSS.

Table 1: KLO Zone Substation – current assets

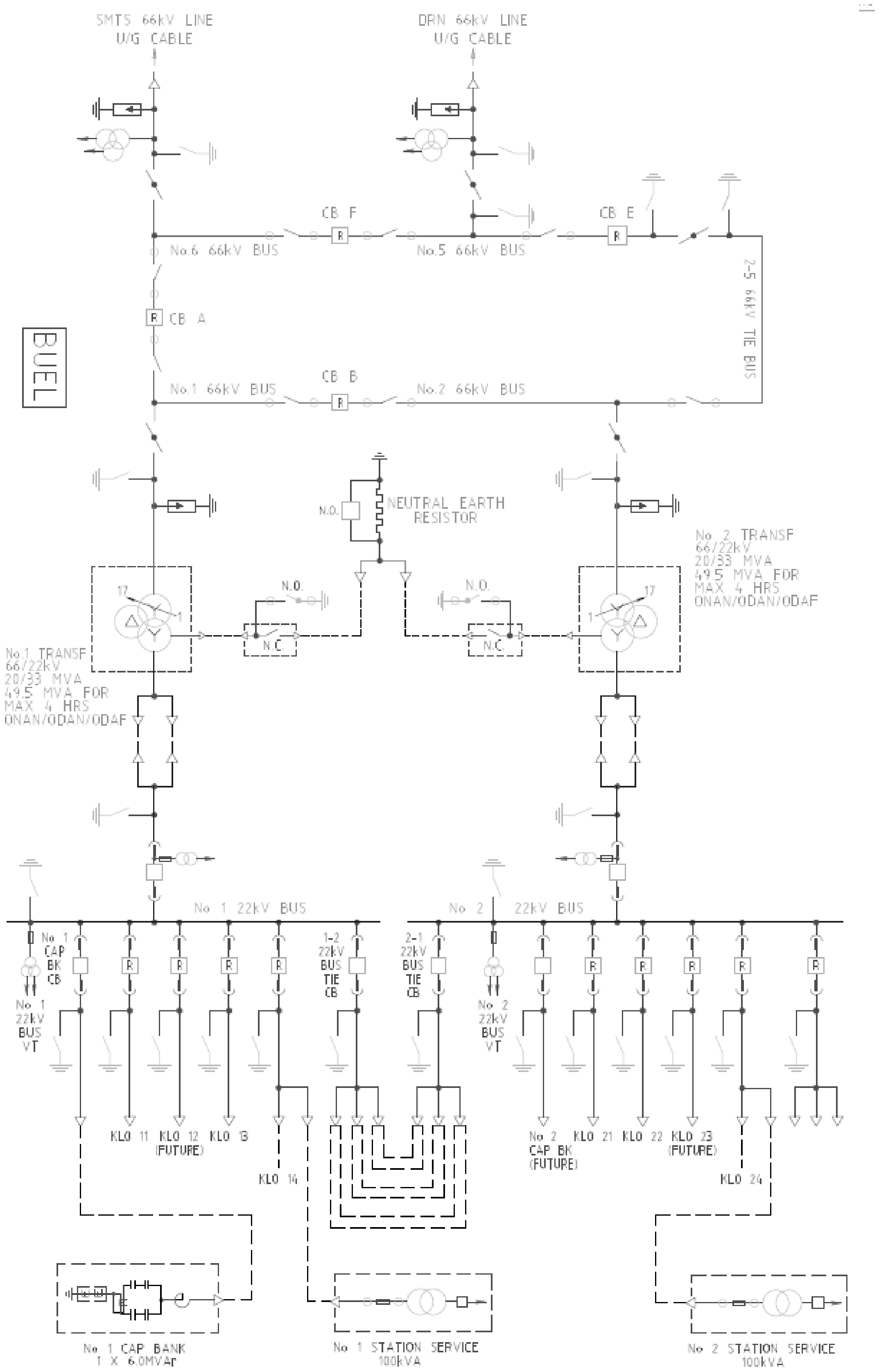
Zone Substation	Details
Location	50 km North of Melbourne on Donnybrook Road, Kalkallo
Established	2010
Supply Area	Kalkallo, Wallan, Woodstock and Wandong
Customers	9,406
Zone Substation transformers	2 x 20/33/49.5 MVA
22 kV Buses	2
Capacitor Banks	1 x 6 MVAr
Feeders	7 (4 x UG, 3 x OH) Jemena feeders are KLO13, 21 & 22
Station services transformers	2 x 100 kVA (22/0.415 V)
Schedule 2 points allocation	3

Source: AusNet Services

1.5 KLO ZSS single line diagram

The following figure represents the current single line diagram of the KLO ZSS.

Figure 2: KLO Current Single Line Diagram



Source: AusNet Services

1.6 KLO 22kV network

The following table provides an overview of the 22kV network originating from the KLO ZSS.

Table 2: KLO 22kV Network – current configuration[1]

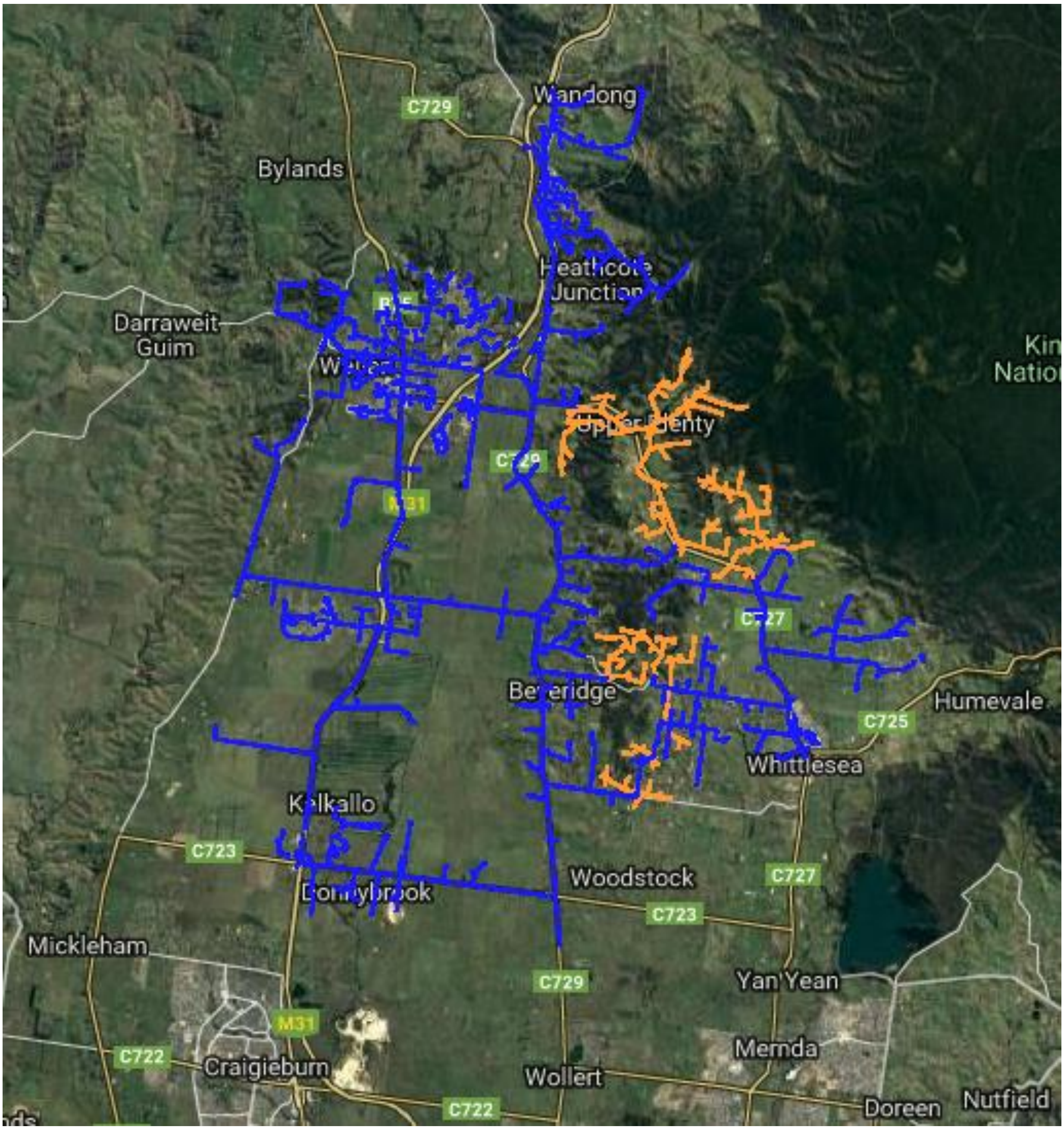
Network	Details
Total Network Length (km)	301.9
Aerial Bundled Cable (**ABC**) Length (km)	0.6
Underground (**U/G**) 3 phase (**ph**) Cable Length (km)	50.3
U/G 1ph Cable Length (km)	0.0
Overhead 3ph Line Length (km)	132.1
Overhead 1ph Line Length (km)	118.9
Estimated network capacitance (Amps (**A**))	321A
HV Customer Connections	3 (Jemena feeders)
Automatic Circuit Reclosers (**ACRs**)	3
Sectionalisers	12
HV Regulator sites	2
Surge Arrestor Sites	185

Source: AusNet Services

[1] Not including SWER or Transfer feeders

The following figure shows an aerial view of the 22kV feeders originating from the KLO ZSS.

Figure 3: AusNet Services KLO 22kV feeders shown in Blue (SWER lines in yellow)



Source: AusNet Services

2 Zone substation requirements

The successful implementation of resonant earthing requires a number of changes at the zone substation including the installation of the resonant earthing equipment, installation of supporting infrastructure and replacement of equipment that cannot tolerate the elevated voltages introduced by the transition to resonant earthing.

The scope of works for the installation of REFCL equipment, supporting infrastructure and asset hardening at KLO ZSS is summarised in the following sections of this functional scope document.

2.1 Primary systems

2.1.1 Options analysis

Given the capacitive current challenges at KLO ZSS, the following options were considered:

- **Do nothing;**
- **Option 1: Install 2 GFNs, a new ZSS and 5 isolation transformers** (Relocate four (4) underground feeders to a new ZSS and install five (5) isolation transformers to reduce the station capacitive current from the large underground estates down to ~130A);
- **Option 2: Install 4 GFNs and new ZSS** (Requires a new ZSS on separate earth grid as the GFN software is unable to tune when more than 2 GFNs are on the same earth grid); and
- **Option 3: Install 2 GFNs and 8-9 isolation transformers**

The do nothing option does not allow the installation of REFCL technology at KLO ZSS and therefore does not meet the requirements of the regulations.

After careful consideration, Option 2 was considered unviable as AusNet Services and the GFN supplier do not have a solution on how to synchronise 4 GFNs within a ZSS. In addition, given the forecast load and network capacitance growth within the northern suburbs, AusNet Services anticipates the site will require more than 4 GFNs post 2023.

Option 3 was also considered unviable as finding land for 8-9 isolating transformers is considered impractical.

Therefore, option 1 is the preferred option. This option will require AusNet Services to relocate four (4) underground 22kV feeders (KLO11, KLO12, KLO13, KLO21) to a new ZSS at least 120m away from the existing ZSS for earthing reasons. Given the four (4) feeders are completely underground, AusNet Services will be seeking a scope exemption to not install REFCLs in the new ZSS.

The remaining three (3) 22kV feeders supplied by the KLO ZSS are comprised of overhead and underground cables, with approximately 231A of network capacitive current which requires three (3) GFNs to meet the REFCL performance criteria. Operating three (3) GFNs within one ZSS has yet to be implemented within Victoria therefore, the installation of five (5) isolation transformers to isolate five (5) large underground residential developments supplied on KLO14, KLO22 and KLO24 is proposed.

By isolating the underground residential developments, the network capacitive current at KLO ZSS will be reduced to 130A and will require only two GFNs to be installed. This option also means that all future load and network capacitance growth for the KLO region will be accommodated by the new ZSS and not lead to the continual installation of GFNs into the future to maintain compliance.

2.1.2 REFCL Equipment

Taking into account the network size, dissymmetry and damping originating from the KLO ZSS, two (2) Arc Suppression Coils (**ASC**) are required to be installed at KLO ZSS. [2]

- Installation of two (2) Ground Fault Neutraliser (**GFN**) primary equipment, including:
  - Two (2) ASC;
  - Two (2) Residual Current Compensator Inverter (**RCC**);
  - Two (2) Grid Balancing Unit; and
  - Two (2) Control Cabinet.

2.1.3 Neutral Bus

A neutral bus system must be installed to control the neutral earthing arrangements allowing change of operational mode during fault management. [3]

- Installation of two (2) Neutral Bus kiosk at existing KLO ZSS.

2.1.4 Primary Cables

- Installation of 22kV cable (6 x 500mm2 IC CU) from:
  - No.1 Transformer to No.1 22kV Switchboard(300m); and
  - No.2 Transformer to No.2 22kV Switchboard(300m).
- Installation of the following 22kV 3C 185 mm^2, AL XLPE, from:
  - No.1 Station Service Transformer to No.1 Switchboard (40m);
  - No.2 Station Service Transformer to No.2 Switchboard (40m);
  - No.1 Cap bank to No.1 22kV Switchboard (40m); and
  - No.2 Cap bank to No.2 22kV Switchboard (40m);
- Installation of the following single core 185 mm^2, AL XLPE 22 kV neutral cables, from:
  - No. 1 Transformer neutral isolator to No. 1 Neutral Bus kiosk (50m);
  - No. 2 Transformer neutral isolator to No. 2 Neutral Bus kiosk (50m);
  - Neutral Earthed Resistor to No. 1 Neutral Bus kiosk (80m);
  - Neutral Earthed Resistor to No. 2 Neutral Bus kiosk (80m);
  - No. 1 GFN to No. 1 Neutral Bus kiosk (20m);
  - No. 2 GFN to No. 2 Neutral Bus kiosk (20m); and
  - No.1 Neutral bus Kiosk to No. 2 Neutral bus kiosk (20m).
- Relocate and replace four (4) 22kV feeder exit cables(KLO11, KLO12, KLO13,KLO21) from the existing KLO ZSS to the new ZSS with 22kV 3C 300 mm2, AL XLPE (1450m).

2.1.5 Circuit Breakers and Isolators

- None required.

---

2 For further information on the ARC sizing refer to REF 30-04 REFCL Program Arc Suppression Coil Sizing Policy

3 For further information refer to REF 30-16 REFCL Program Operating Modes Policy

2.1.6 Station Service Transformers

The two existing 100kVA (22/0.415 kV) Station Service Transformers do not have adequate rating to supply the RCC during fault compensation and must be replaced with a suitably rated transformer.

- Installation of two (2) 750 kVA (22/0.415V) transformers; and
- Removal of the existing Station Service Transformers.

2.1.7 AC Supplies

The existing AC supply boards cannot supply the current required by the RCC and handle the fault level introduced by the new station service transformer.

- Installation of one (1) AC 415V REFCL change over boards rated for 750 kVA each and suitable for the REFCL equipment.
- Installation of one (1) AC 415V station services change over board rated for 750kVA and suitable to supply the station AC supplies.

2.1.8 Surge Arrestors

- Installation of two (2) single phase surge arrestors for the neutral structures for the transformer due to various scenarios leading to excessive overvoltage at the neutral point.

2.1.9 Isolation Transformer

- Installation of five (5) 10MVA isolation transformers on KLO14, KLO22 and KLO24 to isolate large residential and light industrial estates that are wholly underground to avoid the need to install multiple GFNs as described in options analysis in section 2.1.1.

2.1.10 Instrument Transformers

Current Transformers (CTs)

- Replacement of two (2) neutral CTs for the two (2) transformers due to the condition and the incompatibility with REFCL operations.

Zero Sequence CTs

Zero Sequence (Core Balance) CTs are required to measure the individual imbalance on each feeder and any change in balance due to network modification or switching.

- Installation of seven (7) zero sequence CT; three (3) for the feeder exit cables, two (2) for the capacitor banks and two (2) for the station service transformers.

2.1.11 22 kV Cabling

22 kV transformers, capacitors and feeder exit cables are critical assets within the zone substation, failures in service may result in significant customer outages. To minimise this likelihood of failure, offline cable testing is to be undertaken and any issues identified will be addressed.

Transformer tests including partial discharge (**PD**) testing, power transformer condition monitoring test and REFCL operational test on each transformer (there are 2 x supply power transformers).

If testing identifies any issues, it is likely to result in full cable replacements due to the short lengths of these cables.

Offline partial discharge and high potential tests are required to be performed on the following cables:

- No. 1 Transformer 22 kV cables;
- No. 2 Transformer 22 kV cables;
- KLO14 Feeder exit cable;
- KLO22 Feeder exit cable;
- KLO24 Feeder exit cable; and
- No.1 Capacitor Bank cable.

2.1.12 Capacitor Banks

The existing Capacitor Bank is 1 x 6.0 MVAr stepped grounded star arrangement. The existing Capacitor Bank will be modified to achieve an ungrounded star arrangement.

- Replacement of one (1) 6 MVAr capacitor bank reactor.
- Replacement of five (5) insulators at the base of the Capacitor Bank Reactor.
- Install one new 2x3 MVAr capacitor bank (GFN compliant).

2.1.13 Neutral Earthing Resistor (NER)

- Replacement one (1) NER.

2.1.14 Earth Grid Design

- The existing earth grid design shall be reviewed to ensure the earthing system will continue to adequately protect personnel, plant and the public post the introduction of resonant earthing.

2.2 Civil infrastructure

A number of civil infrastructure installations and modifications are required to support the REFCL installation.

2.2.1 ASC

- Installation of two (2) footings, neutral cable conduit and oil bunds.

2.2.2 Station Service Transformer

- Installation of two (2) footings and cable conduits.

2.2.3 Neutral Bus

- Installation of two (2) footings and cable conduits.

2.2.4 REFCL control room

The existing site control room at the KLO ZSS does not have the physical space for the required installation of REFCL technology, namely the RCC unit , REFCL control panels, protection and communications equipment, network monitoring and switchgear interface relays. Therefore, a single large REFCL control room is to be installed requiring the following civil items:

- Design, construction, delivery and installation of one (1) large control room to house all the REFCL equipment; and
- Temporary security during delivery and installation.

2.2.5 Cable trench

- Installation of additional cable trenches for connection from the existing cable trench system to the following locations (allowance of 100m):
  - REFCL control room;

- ASCs;
- Neutral Buses;
- Cap Banks;
- NER;
- New Station Service Transformers; and
- Feeder exit cables.

2.2.6 Earth Grid

- Extension of the earth grid to protect the REFCL control room, ASCs, Neutral Buses, Station Service Transformers and other installed equipment as required.

2.2.7 Switchyard Surfacing

- Restoration of the disturbed switchyard surfaces.

2.2.8 NER

- Install one (1) footing for new NER

2.2.9 Lighting

- Produce lighting design and establish outdoor switchyard lighting to relevant standard.

2.3 Secondary systems

A number of secondary systems need to be added or modified to support the installation of REFCL equipment at the station.

2.3.1 GFN Control System

The GFN product includes a control panel containing the master and slave control modules, HMI computer, VT and CT inputs and trip outputs and ASC and RCC interfaces.

The GFN vendor will install a free issued GE C30 relay RUGGEDCOM Ethernet switch and C-VT410 Voltage transformer (110V/63.5V 25VA Class1enclosed multi tapped with ratios 36V, 48V, 63.5V and 110V for the Auxiliary VT push button test circuit) to allow AusNet Services control the operational mode of the GFN system.

- Installation of two (2) GFN control system panel as part of two GFN product; and
- GE C30 relays, RUGGEDCOM RSG2488 Ethernet Switches and Auxiliary VT push button test circuit transformers (1 per GFN) shall be free issued for installation in their GFN control system panels.

2.3.2 Neutral Control System

- Installation of two (2) neutral bus interface control system panel including:
  - No. 1 Neutral Bus X ABB REF630 controller relay;
  - No. 1 Neutral Bus Y GE30 controller relay;
  - No. 2 Neutral Bus X ABB REF630 controller relay; *and*
  - No. 2 Neutral Bus Y GE30 controller relay.

2.3.3 Fault Recording and Switchgear Interface Panels

Fault location and diagnosis can be significantly more difficult with resonant earthed networks.

To assist with GFN commissioning, annual compliance testing and fault investigation activities, additional network monitoring relays must be installed to capture bus voltage, neutral voltage and bus current waveforms.

To interface status and control signal wiring between the switchgear and the GFN system, one (1) control relays is required per 22 kV bus.

- Installation of two (2) network monitoring and switchgear interface panels. Each panel includes:
  - 2 x ELSPEC Network Monitoring relays; and
  - 1 x C30 control relays.

2.3.4 Protection Systems

Protection review required for transformers, feeders, Master Earth Fault (**MEF**) & Back Up Earth Fault (**BUEF**), Bus and 66/22 TX's addressing protection sensitivity, settings and time grading between stages when NER is in service;

- 66kV CB failure protection is required if the distance protection settings review comes up short;

Standard protection and control schemes may require modifications to suit specific site conditions. Any such modification should be carried out in consultation with Technical Standards and Services.

Transformer Protection

- Replace two (2) Transformer X and Y protection relays due to incompatibility with REFCL operations.

Feeder Protection

- Replacement of three (3) feeder protection relays for GFN operation suitability.

Station Master Earth Fault (MEF), Backup Earth Fault (BUEF) and PQM

- The existing REF630 Master Earth Fault relay will require a firmware upgrade and wiring changes.
- Replacement of one (1) Back Up Earth Fault relay and one (1) Power Quality Meter (**PQM**) as the existing are not compatible with the GFN operations.

Capacitor bank protection and control

- Replace one (1) capacitor bank Relay (F650) with a standard REF (630) for REFCL compatibility.
- Install one (1) new REF630 relay for the new Capacitor bank.

2.3.5 Communications

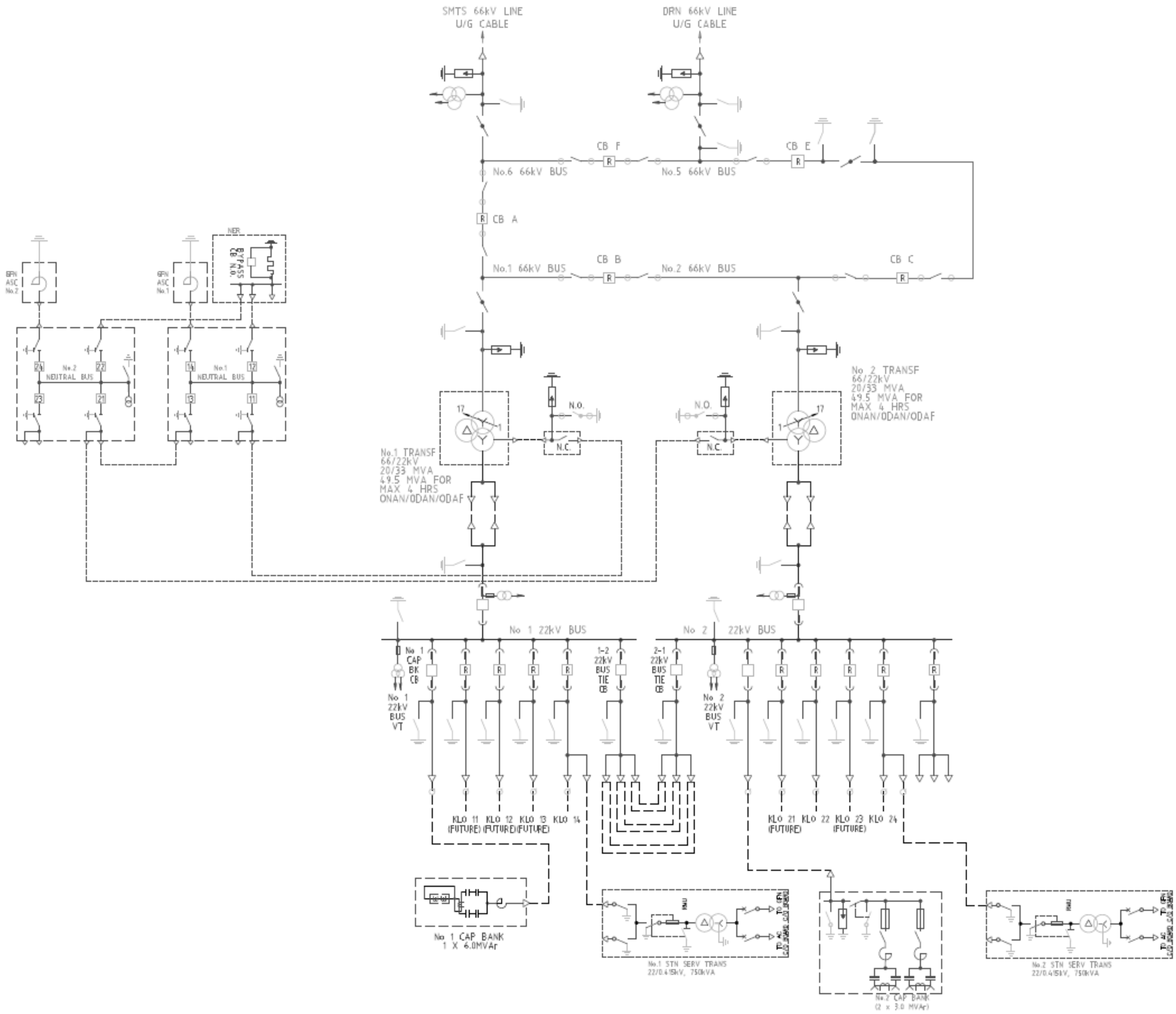
The new equipment in the REFCL control room requires connection to the existing Digital Interface Cubicle (**DIC**).

- Upgrade tele-protection equipment and communications:
- Install 1x RS2488 switch;
- Install 1x 2488 clock;
- Install one (1) HMI; and
- SCADA modifications.

2.4 KLO proposed single line diagram

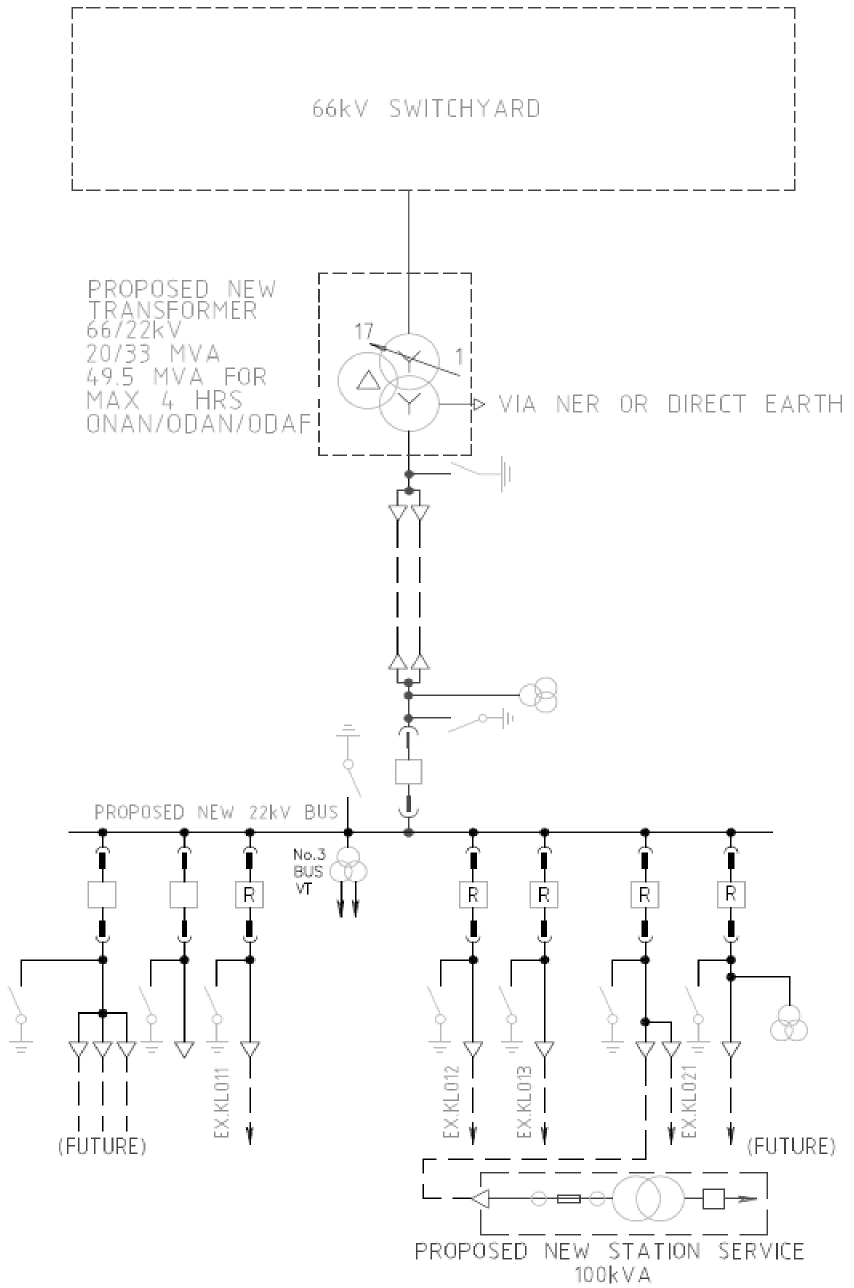
The following figure represents the proposed single line diagram of the KLO ZSS following the installation of the GFN and associated compatible equipment.

Figure 4A: KLO proposed single line diagram



Source: AusNet Services

Figure 4B: New Zone Substation proposed single line diagram



Source: AusNet Services

3 22 kV distribution feeder requirements

The suitability of the assets on the feeders supplied by a REFCL equipped zone substation is critical to ensure successful operation of the technology without undue reliability or safety consequences.

These assets must be able to sustain the additional phase to ground voltage stress introduced by the REFCL technology, be balanced with regards to capacitance to ensure the REFCL technology works at the regulated performance levels and operate normally during REFCL fault compensation.

To achieve these outcomes, three programs address equipment that does not meet the above criteria, namely:

- Network hardening;
- Capacitive balancing; and
- Compatible equipment.

Additionally, customers connected directly to the 22 kV supply network need to ensure their electricity assets can withstand REFCL voltages. If the HV customer assets are not hardened to withstand REFCL voltages, they must be isolated from the REFCL protected network.

3.1 Network hardening

Operation of resonant earthing, on which the REFCL technology is based, introduces periods of increased phase to ground voltages.

This increased voltage can cause issues for existing assets specified for a solidly grounded operational profile.

AusNet Services has assessed its assets and determined that network assets most impacted by the increased voltages are:

- Surge arrestors; and
- High Voltage (**HV**) cables.

3.1.1 Surge arrestors

Surge arrestors are a voltage dependent resistor designed to begin to conduct as the voltage increases to supress very short duration overvoltage such as those associated with lightning strikes. In doing this, they absorb energy whilst the voltage is higher. If not rated suitably, surge arrestors may overheat and fail during REFCL operation, potentially obstructing the effectiveness of the REFCL in limiting the fault current.

AusNet Services has tested each type of surge arrester installed on its networks to determine the suitability of each type for REFCL protected networks.[4] To determine the volumes for the KLO network each surge arrestor site was inspected and the surge arrestor types installed confirmed to determine replacement requirements.

At KLO, the following surge arrestors need to be addressed.

[4] For further information, refer to REF 20-07 REFCL Program Line Hardening Strategy.

Table 3: KLO surge arrestor replacement volumes

Sites	Units
80	201

Source: AusNet Services

3.1.2 HV Cables

Insulated HV cables are susceptible to failure resulting from damage that can occur during operation at higher voltages. Periods of operation at higher voltage can cause immediate failure or initiate partial discharge that can continue to damage the cable after voltages have returned to normal. Premature cable failure can occur in the subsequent hours or days after the initiating overvoltage occurred. [5]

AusNet Services utilises offline testing for critical backbone portions of the feeder to identify cables requiring repair or replacement. A review of the cables database has been undertaken and cable failures and test results from REFCL tranche 1 and 2 investigations have been utilised to forecast the likely proportion of cables that will need to be tested and replaced for Tranche 3.

Table 4: KLO HV cable testing, repair and replacement volumes

Online tests	Offline tests	Repair Cable	Replace Cable
6	6	4	540m

Source: AusNet Services

3.1.3 Other Assets

Other asset classes may exhibit issues with the voltages introduced by operation of REFCL technology and will be replaced when they fail as it is impractical to proactively identify which ones may fail. The most common items are:

- Distribution transformers; and
- Line insulators – especially in areas on the coast where salt contamination can cause current tracking to ground failures at REFCL voltages

From previous stress testing, AusNet Services has not experienced extensive failures of other distribution assets excluding cables and HV Aerial Bundled Cable (**ABC**) addressed in section 3.1.2. AusNet Services does not anticipate failures of other assets.

3.2 Capacitive balancing

Capacitive balance is a key enabler of achieving the performance requirements of the Amended Bushfire Mitigation Regulations. Neutral voltage caused by capacitive imbalance decreases the sensitivity of the REFCL technology. [6]

A number of balancing activities are required to achieve the necessary capacitive balance level including:

- Installation of a 3rd conductor on single phase spurs where only a few spans are required;
- Conversion of single phase cable spurs to three (3) phase by connecting the 3rd phase;

[5] For further information, refer to REF 20-07 REFCL Program Line Hardening Strategy

[6] For further information refer to REF 20-06 REFCL Program Network Balancing Strategy

- Phase rotations of single phase spurs;
- Installation of single phase capacitor banks at the beginning of single phase spurs;
- Installation of 3 phase capacitor banks for each automatically switchable section; and
- Removal of fuses on network segments with excessive capacitive current as single phase fuse operation will cause excessive imbalance causing the GFN to trip the feeder. Therefore, to solve the excessive imbalance, it is essential AusNet Services remove existing fuses and replace the fuse elements with solid links and to install fuse savers where required for network protection.

Whilst the KLO network is relatively short and it has a number of automatic switching sections to provide reliability in the heavily tree covered areas it serves.

This necessitates an increased quantum of balancing activities for the relatively short network compared to longer, less automated, networks. Network data has been analysed to identify the material sources of imbalance and the optimal mixture of balancing works to achieve the necessary level of capacitive balance for the KLO network.

Table 5: KLO network capacitive balancing volumes

Spans of 3rd phase	Unbonded 3rd phase (cable)	Single phase spur phase rotations	Single phase balancing capacitors	Three phase balancing capacitors	Solid links	Fuse Savers Sites
0	0	24	1	14	2	9

Source: AusNet Services

Note: The volumes noted above do not include works required in the Jemena managed feeders.

3.3 Compatible equipment

Some existing network equipment is incompatible with the operation of REFCL technology. This equipment includes:

- Automatic Circuit Reclosers (**ACRs**);
- Sectionalisers; and
- HV voltage regulators.

3.3.1 ACRs

Existing ACRs have non-directional fault detection and may 'mal' operate during REFCL operation due to the capacitive charge flowing back through healthy parts of the network to the fault. Replacement ACRs have VTs installed to determine when the REFCL is displacing the neutral voltage and supress tripping for reverse fault current direction. [7]

Existing ACRs require upgrades or replacement to operate successfully with REFCL technology. Each ACR on the KLO network has been identified from network data and its type confirmed through protection setting data to determine whether it can be upgraded or must be replaced.

The general Distribution Feeder Automation (**DFA**) and sectionaliser algorithm will require an ACR or equivalent to be present at key points on each feeder to allow the DFA/Sectionalisers to locate a fault with the GFN in service. Without these additional devices the DFA/Sectionaliser

[7] For further information, refer to REF 20-08 REFCL Program Automatic Circuit Recloser Strategy

algorithm will not be able to identify which feeder is faulted. As a result, four (4) additional ACRs are required to be installed on the KLO network.

Furthermore, as part of the fuse review detailed above in section 3.2, additional ACRs are required as a least cost alternative to the replacement of many fuse sites within a network segment and utilising the much larger protection coverage of the ACR. There is also considerable labour cost savings to be gained from adapting this method. As a result, no additional ACRs are required to be installed on the KLO network.

Table 6: KLO ACR upgrade and replacement volumes

Additional	Upgrade	Replacement
4	3	1

Source: AusNet Services

Note: The volumes noted above do not include works required in the Jemena managed feeders.

3.3.2 Sectionalisers

Existing sectionalisers, that are a key part of AusNet Services Service's DFA Scheme to provide customer reliability benefits, do not have high accuracy CTs that are compatible with the low fault currents that the REFCL introduces.[8]

Existing sectionalisers require replacement to operate successfully with REFCL technology.

On the KLO network there are a number of automatic switchable sections involving sectionalisers to ensure a reliable service for the customers served. Each sectionaliser on the KLO network has been identified from network data and individually confirmed as non-compliant with REFCL requirements.

Table 7: KLO Sectionaliser update and replacement volumes

Upgrade	Replacement
0	13

Source: AusNet Services

Note: The volumes noted above do not include works required in the Jemena managed feeders.

3.3.3 HV voltage regulators

Some HV voltage regulators have individual phase voltage tap controls. These controllers are not compatible with REFCL operation as they may try to tap voltages whilst the REFCL is compensating and introduce further imbalance reducing the effectiveness of the REFCL.[9]

The KLO network has no HV voltage regulators.

3.4 HV customers

HV customers are connected directly to the 22 kV network rather than the Low Voltage (**LV**) networks and are therefore impacted by the increased voltages introduced by the REFCL technology. This can cause issues for customers including:

- requirements to harden their equipment to withstand the increased voltages;
- updates to protection equipment and settings; and

8 For further information, refer to REF 20-13 REFCL Program Distribution Feeder Automation (DFA) Strategy

9 For further information refer to REF 20-09 REFCL Program Line Voltage Regulator Strategy

- interruption to the customer's business operation.

In some cases, it may be more economical to isolate the customer from the REFCL voltage profiles rather than address each of the issues listed above.

The dedicated REFCL Program HV Customer Lead has proactively engaged with impacted HV customers to share the learnings from Tranche 1 and to provide guidance on the most appropriate solution for the HV electrical assets to either be harden to withstand, or isolated from, REFCL operations

3.4.1 HV customers serviced by the KLO network

There are three (3) HV customer connections in the KLO network which are the three (3) Jemena 22kV feeders (KLO21, KLO22 and KLO13).

AusNet Services proposes to relocate two of these fully underground 22kV feeders, KLO13 and KLO21 to the new, non-REFCL, zone substation.

The remaining Jemena 22kV feeder, KLO22, is comprised of overhead and underground cables. AusNet Services will install isolation transformers to isolate large underground residential developments supplied by the KLO22. Refer to section 2.1.1 options analysis for further information.

Although the above solution is the currently preferred option, a joint AusNet Services/Jemena network planning engagement has commenced, conducted by a third party, to confirm the least cost, technically acceptable solution for both Jemena and AusNet Services.

4 Proposed Site Plan

The following figures provides an aerial view of the current KLO ZSS with the proposed sites of the new REFCL-related assets and control room.

Figure 5: Aerial view of the KLO ZSS

Source: AusNet Services

Figure 6: Aerial view of the proposed new ZSS

Source: AusNet Services

5 Referenced Documents

Supporting documents referenced in this document:

- REF 20-06 REFCL Program Network Balancing Strategy
- REF 20-07 REFCL Program Line Hardening Strategy
- REF 20-08 REFCL Program Automatic Circuit Recloser Strategy
- REF 20-09 REFCL Program Voltage Regulator Strategy
- REF 20-13 REFCL Program Distribution Feeder Automation Strategy
- REF 30-04 REFCL Program Arc Suppression Coil Sizing Policy
- REF 30-16 REFCL Program Operating Modes Policy