Rapid Earth Fault Current Limiter (REFCL) Program

Equipment Building Block Functional Descriptions

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1 PURPOSE OF THIS DOCUMENT

This document provides a functional description of the equipment building blocks required due to the introduction of Rapid Earth Fault Current Limiter (REFCL) technologies throughout our distribution network. This document is a live document and can be used to assist with project scoping and change management, as technical standards are being developed. This document is intended for internal use only.

2 PROGRAM OBJECTIVES

The objectives of the Equipment Building Block Functional Descriptions are:

1. Successfully deploy REFCL technology as efficiently as possible at nominated sites as per the amended Bushfire Regulations;
2. Reduction of network fire related incidents through implementation of this program;
3. Compliance with regulatory obligations without compromising reliability and other service standards;
4. The most economical and workable whole of life design;
5. Effective change management;
6. Establishment of design and construction resource model to deliver the program to agreed timelines;
7. Effective integration of the program with AusNet Services' other planned works program; *and*
8. Maintain AusNet Services' values and commitment to Mission Zero.

3 ABBREVIATIONS AND DEFINITIONS

Term	Definition
ABC	Aerial Bundled Cable
AC	Alternating Current
ACR	Automatic Circuit Recloser
ASC	Arc Suppression Coil
CB	Circuit Breaker
CT	Current Transformer
DFA	Distribution Feeder Automation
EF	Earth Fault
ESV	Energy Safe Victoria
FPE	Faulted Phase Earthing
GFN	A type of REFCL manufactured by Swedish Neutral
HV	High Voltage
LLS	Line Line Sequence
MCCB	Moulded Case Circuit Breaker
NER	Neutral Earth Resistor
NMS	Non Metallic Screen
PBST	Powerline Bushfires Safety Taskforce
PRF	Powerline Replacement Fund

RCC	Residual Current Compensation
REFCL	Rapid Earth Fault Current Limiter
RMU	Ring Main Unit
SEF	Sensitive Earth Fault
SOFT test	A test performed by the GFN controller to confirm that a fault is permanent.
SSFCL	Solid State Fault Current Limiters
SWER	Single Wire Earth Return
TFB	Total Fire Ban
VBRC	Victorian Bushfires Royal Commission
VESI	Victoria Electricity Supply Industry
VT	Voltage Transformer

Table 1 Abbreviations and Definitions

4 BACKGROUND

Following the 2009 Black Saturday bushfires, the 2009 Victorian Bushfires Royal Commission (VBRC) was established and provided a range of recommendations accepted by the Victorian Government. Recommendations 27 & 32 were of sufficient complexity that they were assigned to a panel of experts, the Powerline Bushfires Safety Taskforce (PBST) that made a number of recommendations that Government accepted.

The accepted recommendations essentially require the implementation of a range of initiatives over a ten year period that will reduce the risk of bushfire ignition by distribution networks by 'nearly two thirds'. The outworking of these recommendations is through the Government's Powerline Bushfire Safety Program (PBSP) taskforce.

In addition to the PBSPs current $200M Powerline Replacement Fund (PRF) targeted for completion by 2022, amendments to the Electricity Safety (Bushfire Mitigation) Regulations require three distinct programs of work to be undertaken by AusNet Services;

- AusNet Services to install REFCLs in 22[1] zone substations by December 2022,
- Network bushfire design standards for specified line replacement works within defined areas.

Furthermore, the installation of REFCLs must comply with the following, in the event of a phase-to-ground fault:

a) 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

b) 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 —

   i. 1,900 volts within 85 milliseconds; and

   ii. 750 volts within 500 milliseconds; and

   iii. 250 volts within 2 seconds; and

c) during diagnostic tests for high impedance faults, 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 0.1;

[1] Refer to Appendix A for a list of nominated zone substations and proposed schedule

5 INFORMATION CONSIDERED (INPUTS)

This document has been completed in reliance on the following information:

1. ACIL Allen, Regulatory Impact Statement, Bushfire Mitigation Regulations Amendment, 17 November 2015
2. Marxsen Consulting, REFCL technologies test program Final Report, 4 December 2015
3. Marxsen Consulting, REFCL Trial: Ignition Tests, 4 August 2014
4. AusNet Services, Electricity Distribution Price Review 2016-20, Regulatory Proposal
5. Electrical Safety (Bushfire Mitigation) Amendment Regulations 2016

6 WHAT ARE REFCLS

A REFCL is a protection device that reduces the risk of fires caused by powerlines and is installed on the zone substation transformer neutral. It does this by rapidly limiting the electricity that is released in certain types of powerline faults, known as earth faults. As such the REFCL device protects the 22kV network from phase to ground earth faults.

There are various types of technology that fall under the REFCL umbrella, however the only type of REFCL currently considered suitable by the Victorian Electric Supply Industry (VESI) for bushfire safety is known as the Ground Fault Neutraliser (GFN), a proprietary product by Swedish Neutral. Presently the GFN is the only device that can meet the performance criteria of the Regulations.

Other varieties of REFCLs exist which can be a combination of an Arc Suppression Coil (ASC) or Solid State Fault Current Limiters (SSFCL) coupled with faulted phase earthing (FPE). At present these alternative REFCLs cannot meet the performance criteria specified in the Regulations.

7 CURRENT NETWORK

The AusNet Services distribution network currently employs three methods of zone substation earthing (transformer neutrals). The following table summarises the neutral grounding arrangement across our network:

	REFCL Zone Substations (23)	**Non-REFCL Zone Substations (42)**	**All Zone Substations (65)**
Solidly grounded system	4 (17%)	7 (17%)	11 (17%)
Resistive grounded system	17 (74%)	32 (76%)	49 (75%)
Neutral Earthing Compensator	2[2] (9%)	3[3] (7%)	5 (8%)

Table 2 Distribution Zone Substation Grounding Arrangements

The network design of non-REFCL networks have been based on traditional methods which may no longer be applicable or need modification to suit REFCL networks. These traditional methods generally resulted in lower initial investment costs and adequate insulation co-ordination considering the age of the installations.

[2] NEC installed to provide the zero sequence path on 22kV delta tertiary windings at BETS and WOTS

[3] NEC installed to provide the zero sequence path on delta tertiary windings at HYTS (22kV), MPS (11kV) and YPS (11kV)

Our network fundamentally consists of:

- Neutral Earthing Resistors (NER) installed to limit earth fault currents on high capacity networks.
- Earth fault over current protection that trips the feeder.
- Earth fault protection systems dispersed along length of feeders i.e. Automatic Circuit Reclosers (ACR)
- Auto reclose control systems used to restore supply after momentary faults have been cleared by a brief supply interruption.
- Master earth fault protection to enable Sensitive Earth Fault (SEF) protection in adjacent protection schemes.
- Network sectionalising schemes (DFA) that use multi-shot reclose to identify and isolate the section of the network containing a permanent earth fault.
- Non-direction earth fault protection which acts when earth fault current flow is detected without information on its direction, i.e. whether the fault is 'upstream' or 'downstream'.
- High levels of network imbalance or dissymmetry due to single phase sections (spurs) on our HV feeders
- Insulation coordination of equipment based on solid or low impedance grounding of the zone substation transformer neutral
- Three phase equipment with an earthed neutral configuration i.e. Capacitor banks
- Single phase open-delta regulators displace the system neutral voltage by regulating line-line voltages on two phases as opposed to three.

8 REFCL ENABLED NETWORK

As mentioned previously the GFN is currently the only REFCL technology available that has demonstrated compliance against the bushfire regulations amendments.

The GFN employs resonant earthing with an additional 'residual current compensation feature' (RCC) which involves injecting current into an arc suppression coil at 180° out of phase with the residual fault current.

The fundamental principle of resonant earthing is that in the event of a phase-to-earth fault, the tuned ASC creates a resonant circuit between the downstream network and neutral connection of the zone substation transformer resulting in a peak voltage displacement across the neutral.

This leads to the faulted phase voltage becoming virtually zero, with the phase to ground voltages of the healthy phases increasing from 12.7kV to 22kV (and potentially 24.2kV, being 22kV plus 10%).

The neutral voltage displacement caused by this resonant circuit effectively leads to very low earth fault currents in comparison to non REFCL networks as the faulted phased voltage is too small to drive large currents. The power factor of the fault also approaches unity reducing arc flash risk, hence the name Arc Suppression Coil.

Consequently, the elevated phase to ground voltages on the healthy phases requires all equipment to be rated to withstand the overvoltage and consequently reduce the risk of cross country faults. Uprating of this equipment is also known as 'hardening' and equipment inside the zone substation and out on the distribution lines will need to be addressed accordingly.

Standards and policy documents relating to capacitive balancing, surge arrestors, fused spurs, cable selection, REFCL operation, DFA, zone substation earthing and protection will also need to be amended or created to assist all asset management and service delivery work streams to carry out their responsibilities. For more information on the development of these, please refer to the REFCL Program directory in ECM.

9 NETWORK COMPONENTS

Installation of REFCLs will require a paradigm shift in how our network is designed, operated and maintained as we transition from a low impedance grounded network into a high impedance grounded network. As such all components of the entire 22kV distribution network will need to be examined accordingly to understand

and determine the requirements of a REFCL enabled network. Please refer to the REFCL Program directory in ECM for the latest documentation associated with network components.

The following is a functional description of the key equipment to be developed under the REFCL program building blocks work stream.

9.1 ZONE SUBSTATION EQUIPMENT

9.1.1 PRIMARY

9.1.1.1. REFCL

The GFN is a package of products (under the REFCL umbrella), which consist of a tuneable ASC, RCC and a control system.

The ASC is connected to the power transformer 22kV neutral and is located in the switchyard. The GFN ASC is oil filled (hermetically sealed) consequently requiring its own bund. The ASC's purpose is to compensate for the network's capacitive coupling current during an earth fault leaving only a low residual fault current. As such the size of the ASC is determined by the size of the network. In order to compensate for the network's capacitive coupling current the ASC must be tuned to the network. The tuneable ASC is of a fixed inductance and variable capacitance type with auxiliary windings. The auxiliary windings are used for the LV tuning capacitor banks located on top of the ASC and for the RCC. The LV tuning capacitors will have eight capacitor banks that can be configured to offset the inductance of the ASC in order to tune the coil to the network capacitance. This adjustment enables the ASC to fully compensate for all scenarios, where feeders or sections in the network have been switched in or out. A tuning limitation will be set dictating the size of the ASC per zone substation. This is required in order to achieve detection compliance to the Regulations. For more information, please refer to REF 30-06 REFCL Program – REFCL Arc Suppression Coil sizing policy.

The RCC is an AC-DC-AC converter that is housed in the zone substation control building or switch room. Its purpose is to neutralize the remaining residual fault current. The size of the RCC Inverter is determined by the size and characteristics of the network. Because the ASC compensates the capacitive coupling current, the RCC Inverter can be designed with limited power to only compensate for the residual active current. The RCC Inverter also needs to compensate for capacitive coupling current caused by any mismatch of the ASC.

The control system of the GFN completes the protection and control functions tying all the components together. The panel houses the Master and Slave relays and also includes the Neutral Manager (HMI) which is used for operating the device. The GFN control system is then interfaced to the station via the interface controller discussed later in the document. For more information, please refer to REF 20-03 REFCL Program - Earth Fault Management Strategy.

For hardening purposes the operation of the GFN will be limited to 3 minutes unless advised otherwise. For more information, please refer to REF 30-07 REFCL Program - Annual Insulation and Compliance Testing.

9.1.1.2. 22KV CAPACITOR BANKS

The function of the station capacitor banks has not changed however it must be reconfigured such that it remains unearthed. Preliminary audit suggest we have eighteen sites with 22kV station capacitor banks, fifteen of which will require the star point to be unearthed.

As a result of removing the star point earth, the capacitor banks may need to be upgraded if the insulation of the capacitor cans cannot withstand the elevated voltages. This calls for a case by case assessment to be completed with the following upgrade options:

- replacement of existing capacitors with rated capacitors; or
- retrofitting capacitors in series; or
- replacement of the capacitor bank

The current balance protection and control scheme must also be upgraded or replaced to reflect the new earthing arrangement. Current Transformers (CTs) are to be replaced and upgraded accordingly.

9.1.1.3. STATION SUPPLIES

The added station Alternating Current (AC) load will dramatically increase due to the RCC loading demand. Typically the RCC kVA rating will be 10-15% of the ASC kVA rating. As such our station service transformers will need to be upgraded in order to supply the RCC load together with the station load. Preliminary calculations suggest that we will require at least 500kVA station service transformers at most of our zone substations with 750kVA and 1MVA required for a minority. It is proposed that the new station service supplies will be a kiosk Ring Main Unit (RMU) including two Moulded Case Circuit Breakers (MCCBs) that will each feed the station AC changeover board and a new REFCL changeover board. The 22kV insulation of the RMU must also withstand the elevated phase to ground voltages due to REFCL operation.

Our existing specifications, standards and period order contract have been revised to accommodate the new requirements.

9.1.1.4. NEUTRAL BUS SWITCHBOARD

The introduction of the REFCL requires a neutral bus, enabling different earthing arrangements to be configured automatically. It is proposed that the neutral bus will be located in the switchyard and be housed as a kiosk with four Circuit Breaker (CB) elbow connections for a power transformer, REFCL, NER and an adjacent neutral bus or an additional power transformer. A neutral switchboard will be required on a per REFCL basis.

One mode of the REFCL will automatically switch in the NER and will have a separate controller to manage the operation of each neutral bus CB. A solidly grounded earthing connection can be achieved via the NER bypass CB or at the transformer neutral connection.

The neutral bus switchboard specification, standard and period order contract has been developed.

9.1.1.5. NER

No NERs will be made redundant by the installation of a REFCL, rather modified to ensure the NER can be switched into service by the REFCL interface controller when required.

For all sites the inline NER CB will be provided by the neutral bus switchboard. As such, any site with an existing inline CB can be locked closed with the controls being completed by the neutral bus controller.

For sites with a NER bypass CB, this shall remain the preferred method to solidly ground the transformers when it hasn’t been taken out for maintenance. All REFCL sites with existing NERs will require a bypass CB. No new installation of NERs will be required under the REFCL Program.

9.1.1.6. STATION SURGE ARRESTORS

Due to the elevated phase to ground voltages during REFCL operation, 22kV station surge arrestors will need to be assessed and replaced accordingly.

Each neutral bus will also require a surge arrestor rated accordingly and installed as close as possible to the power transformer neutral.

The specifications for these surge arrestors are currently being revised.

9.1.1.7. 22KV CABLING

All 22kV cables will be required to withstand the overvoltage during REFCL operation. It is expected that our current cables can withstand an overvoltage for 3 minutes.

Any upgrades or installation of new cables are to be rated to ensure insulation levels are sufficient and the network capacitance seen by the REFCL is kept at a minimum. As such a new low capacitance cable specification is being developed for use in our network.

9.1.2 22KV SWITCHGEAR

Installation of new switchboards will vary from station to station depending on the insulation ratings of existing switchgear and the availability of accurate VTs and CTs to achieve compliance. An assessment is required for 22kV switchgear in each of the nominated zone substations. The assessment for nominated stations in the first tranche is complete and will dictate whether existing switchgear is sufficient for REFCL operation or proposed replacement.

The specification and period order for both urban and rural switchboards are currently being revised to consider REFCL requirements.

9.1.3 22KV STATION VT'S

Due to the elevated phase to ground voltages during REFCL operation our station VTs and CVTs will need to be assessed and replaced accordingly.

Each REFCL will also require a neutral voltage measurement for the transformer/bus it is connected to. This can be provided by a VT directly installed on the transformer neutral or from open delta VTs (located in the REFCL control panel) supplied via the 22kV bus VTs.

9.1.4 SECONDARY

9.1.4.1. STATION EARTH FAULT

The station earth fault protection philosophy will now change as we introduce a resonant earthed configuration at the zone substation. The operating mode will change day to day depending on weather conditions and operating experience. For phase-to-ground faults the REFCL will be used as the primary protection scheme with the backup protection currently being developed. There will be three main operating modes of the REFCL which will cater Total Fire Band (TFB) days, Non TFB day (Summer) and Non TFB day (Winter). . The following will be required in order to implement the resonant earthing protection philosophy.

Master Earth Fault (MEF) Protection

Automatically blocked when the REFCL is in service (via the NER status) and unblocked once the NER is in service.

The MEF relay will also provide test modes for commissioning the REFCL and provide a means of back up protection to the REFCL (until alternative backup options are developed).

The MEF relay must also be to the current standard (ABB REF630) to facilitate the additional functionality.

Back Up Earth Fault (BUEF) Protection

Similarly with the MEF protection, the BUEF will also be automatically blocked by the REFCL interface controller when the REFCL is in service and unblocked once NER is in service.

The BUEF relay must also be to the current standard, which is the GE F35 UR7 series.

For more information, please refer to REF 20-03 REFCL Program - Earth Fault Management Strategy.

9.1.4.2. FEEDER PROTECTION

Earth Fault (EF) and Sensitive Earth Fault (SEF) will be automatically blocked when the REFCL is in service and unblocked once the NER is in service. This is completed via the MEF relay which enables these elements in the feeder protection relays.

The feeder protection relay must also be to the current standard (F650 or REF630) to facilitate automatic blocking.

9.1.4.3. DISTRIBUTED FEEDER AUTOMATION (DFA)

DFA relies on the ability of line protection devices to locate faults. This ability is currently not compatible with the operation of a REFCL. For this reason, ACRs and gas switches need to be upgraded to provide added functionality for fault localisation as well as other functionalities to allow compatibility with the GFN.

The DFA system must be modified to include new targets from the upgraded ACRs and Gas Switches. It is envisaged that the installation of enhanced ACRs and Gas Switches will begin in 2018. Until this has been updated the DFA will only be effective when the REFCL is out of service.

Currently a manual process is required for the CEOT controller to ensure the DFA is disabled when the REFCL is in service however this process could be automated using the REFCL neutral bus CB status.

For more information, please refer to REF 20-13 REFCL Program – DFA Strategy.

9.1.4.4. REFCL PROTECTION AND CONTROL

Main Earth Fault Protection and Control

The REFCL protection and control panel will provide the main earth fault protection for the network and also provide local control of all REFCL components when the REFCL is in service.

The earth fault protection is a voltage based scheme which monitors the neutral voltage displacement and operates once the detection threshold has been exceeded. Upon detection the control panel engages the RCC such that the inverter injects a 180° out phase current into the ASC to compensate for the residual current that remains from the resonance circuit.

For a GFN, a grid balancing and isolation cubicle will accompany the RCC inverter cubicle. The purpose of the grid balancing and isolation cubicle is to increase or decrease the GFN detection sensitivity by adjusting the capacitors within the panel. This panel also provides isolation of supply to the RCC inverter cubicle by means of a fused isolator switch.

For more information, please refer to REF 20-03 REFCL Program - Earth Fault Management Strategy and REF 30-08 REFCL Program – GFN Protection and Control Policy.

Back Up Earth Fault Protection

The current REFCL comes with a backup protection scheme with certain functions being used however this is not completely independent therefore a new back up protection standard will be required to be installed such that it is in line with our protection and control standards and policies.

The current Back Up protection involves independent monitoring of Neutral voltage and reversion to the pre-REFCL earthing configuration i.e. NER or solidly earthed. Alternative back up protection options are currently being assessed with standards development to follow.

For more information, please refer to REF 20-03 REFCL Program - Earth Fault Management Strategy.

Interface Controller

There will be two REFCL interface controller relays (currently GE C30s) for each REFCL. The purpose of the interface controllers is to:

- Act as the main SCADA interface point with the REFCL relays (master and slave units)

- Provide the controls to enable various operating modes

The standard is currently being developed and it is envisaged that one of these interface controllers will be housed in the REFCL protection and control panel with the other housed in either the station earth fault panel, new standalone panel or in the switch room control room (for sites with urban switchboards). The exception for this arrangement will be at KMS and WYK where we have existing REFCL cubicles installed.

The standard will also need to cater for the operation of multiple REFCLs at a site. Where possible it is envisaged that each REFCL can protect all feeders however if the network capacitance size exceeds limits then each REFCL must operate independently or at a reduced detection sensitivity.

For more information, please refer to REF 30-08 REFCL Program – GFN Protection and Control Policy.

9.1.4.5. 22KV CAPACITOR BANK PROTECTION AND CONTROL

All REFCL nominated sites which have a station capacitor bank will need to have the current balance protection and control scheme modified or replaced to reflect the new earthing arrangement. Neutral Current unbalance protection CTs are to be replaced and upgraded accordingly.

9.1.4.6. TRANSFORMER VOLTAGE REGULATION

For sites with multiple REFCLs, the transformer voltage regulation schemes may need to be modified or upgraded in order to facilitate closed bus or split bus configurations. Sites with multiple REFCLs may need to be operated as a split bus to achieve detection sensitivity on high bushfire risk days. Existing voltage regulation schemes will need to be assessed on a case by case basis when developing the project scope and estimate. The outcome of the assessment may lead to additional schemes auto-close to be developed which will then be factored into the project accordingly.

9.1.4.7. NEUTRAL BUS CONTROLLER

The neutral bus controller will control each CB in the neutral bus kiosk ultimately determining the earthing arrangement. The earthing arrangements available at each site will be:

1. REFCL in service (Closed REFCL neutral bus CB)
2. NER in service (Closed NER neutral bus CB)
3. Solidly grounded (Closed NER neutral bus CB and Close NER by pass CB)

Note: The NER in service arrangement will only be available if the nominated zone substation has a previous installation of an NER.

The standard is currently being developed with the location of the new controller preferred to be within the control room.

9.1.4.8. NETWORK MONITORING

Network monitoring will be required for each bus at the zone substation. As a minimum the following quantities must be monitored:

- Three phase bus voltages.
- Neutral voltage for station.
- Three phase current for transformer and bus tie CBs.
- Neutral current for feeders.

The meter specified is the Elspec G5 with its location preferably to be in the control room. For sites with existing or new modular switchboards these meters may be housed in the adjacent switch room.

The meters will be the main tool to prove compliance to the Regulations and will also be connected to a main server PC for data logging.

For more information, please refer to REF 30-07 REFCL Program - Annual Insulation and Compliance Testing.

9.1.4.9. SERVER PC

The server PC will be located in the main control room. The purpose of the server PC is to store all data points from the meters and to enable remote engineering access via a web interface.

The architecture of network monitoring and server pc arrangements are still under development.

For more information, please refer to REF 30-07 REFCL Program - Annual Insulation and Compliance Testing.

9.2 NETWORK PLANNING

9.2.1.1. CAPACITIVE LINE BALANCING

To satisfy the legislated performance criteria the network leakage current will need to be at a minimum under normal operating conditions. The leakage current required will vary site to site however the target is less than 0.1A.

To achieve such a small leakage current, each phase for each feeder and its sections must be capacitively balanced to minimise the zero sequence current imbalance.

The practical solution to achieve this is to implement a combination of the following:

- Add a third conductor to a single-phase spur (practical for cable) to convert it to three-phase
- Install LV balancing capacitor banks at single-phase spur take offs
- Install LV balancing capacitor banks on the three-phase back bone
- Perform single-phase spur rotations (e.g convert a RW spur to RB)
- Perform single-phase distribution substation phase connection changes

The approach to scope the works will be in two stages:

First stage: Known as coarse balancing which involves excel modelling of the capacitance of the network and selecting a combination of works above to achieve the less than 0.1A network leakage current.

Second stage: After performing measurements of switching sections, fine balancing may be performed which will require tuning of the above solutions.

For more information, please refer to REF 20-06 REFCL Program – Capacitive Balancing strategy.

9.2.1.2. NETWORK AUGMENTATION

Due to the balancing requirement for a GFN protected network, in order to maintain the balance, any material network augmentation will require sign off from the Network Planning team. A policy is to be written to cover such scenarios with design guidelines produced for each GFN protected network.

For more information, please refer to ECM for latest capacitive balancing, switching and augmentation related policies.

9.3 LINES EQUIPMENT

9.3.1 CABLES

All 22kV cables will be required to withstand the overvoltage during REFCL operation. It is expected that our current cables can withstand an overvoltage for 3 minutes.

Critical 22kV cables need to be tested as per the standard maintenance instruction to prove condition prior REFCL operation. Should installation of new cables be required as a result of the tests then the replacement of the cable is preferred to be of a low capacitance with suitable insulation levels. As such our current specification is being revised accordingly. Moreover, single-phase cable (two single core conductors) will not be used as this prevents third-phase energisation at a later stage.

For more information, please refer to REF 30-03 REFCL Program – Low Capacitance cable policy.

9.3.2 SURGE ARRESTORS

Due to the elevated phase to ground voltages during REFCL operation our surge arrestors on our feeders will need to be assessed and replaced accordingly.

The specification for these surge arrestors is currently being revised with HV tests completed on existing types to confirm the surge arrestor replacement strategy.

Historically, our line surge arrestors catered for single phase faults up to 19kV; with REFCL technology they must now cater for single phase faults up to 24.2kV. The distribution network has many line surge arrestors that are not capable of operation at 22.4kV. When an earth fault occurs on a REFCL-protected network, overvoltage on un-faulted phases can lead to failure of line surge arrestors not rated for operation at 22.4kV. Such equipment failure constitutes a second earth fault on the network, termed a 'cross-country fault' because it is usually remote from the initial fault and is always on one of the un-faulted phases subject to over-voltage stress caused by REFCL response.

REFCLs can only deal with multiple earth faults if they are all on a single phase. With a cross-country fault, the network has a two-phase-to-earth fault and high currents will flow in both fault locations; two fire starts are possible, i.e. a worse result than if a REFCL had not been installed.

AusNet Services and Powercor Australia have undertaken laboratory tests on a statistically reliable percentage of all types of line surge arrestors. Testing has concluded that two particular types of line surge arrestors (refer below) that make up 60% of the population of AusNet Services' line surge arrestor fleet do not need replacing as they are capable of withstanding the increased voltages associated with the operation of a REFCL.

Material		Model No	Reference Code	Surge Arrestor	Scope Requirement
Porcelain	Silicon Carbide	A	SILICON_CARBIDE_BOWTHORPE	BOWTHORPE 1982-1988	Acceptable
		B	GREY_SILICON_CARBIDE_BOWTHORPE	BOWTHORPE 1980-1981	Remove & Replace
		C	SILICON_CARBIDE_BOWTHORPE	BOWTHORPE 1973-1978	Remove & Replace
		D	SILICON_CARBIDE_ASEA	ASEA 1978-1982 Fitted with adaptor for ELD	Remove & Replace
		F	ZINC_OXIDE_BOWTHORPE	BOWTHORPE 1988-1992	Remove & Replace
		G	ZINC_OXIDE_BOWTHORPE	BOWTHORPE 1980-1983	Remove & Replace
		H	SWER_SILICON_CARBIDE_BOWTHORPE	BOWTHORPE 1973-1978	Remove & Replace
	Zinc Oxide	E	SWER_SILICON_CARBIDE_BOWTHORPE	BOWTHORPE 1985-1989	Remove & Replace
	Unacceptable Models	I	BLACK_UNACCEPTABLE_STANGER	STANGER ARCING HORN 1961-1962	Remove & Replace
		J	BROWN_UNACCEPTABLE	BROWN PORCELAIN-ALL S	Remove & Replace
		K	GREY_UNACCEPTABLE_BOWTHORPE	BOWTHORPE 1972	Remove & Replace
		L	GREY_ASEA_UNACCEPTABLE_XBE	ASEA XBE 1986-1987	Remove & Replace
		M	NO_EARTH_LEAD_DISCO_BOWTHORPE	BOWTHORPE 1985-1995	Remove & Replace
Polymeric		N	POLYMERIC_MVK_ABB	ABB MVK 1995-1999	Remove & Replace
		O	POLYMERIC_MWK_ABB	ABB MWK 1995-1999	Remove & Replace
		Q	POLYMERIC_EMP_BOWTHORPE	BOWTHORPE EMP 1991 & EGB 1995-1997	Remove & Replace
		R	POLYMERIC_HEB_BOWTHORPE	BOWTHORPE HEB 1995-1997	Remove & Replace
		S	POLYMERIC_HEA_BOWTHORPE	BOWTHORPE HEA 1995-1997	Remove & Replace
		T	H.D.A_POLYMERIC_RAYCHEM	Raychem I 1992	Remove & Replace
		V	POLYMERIC_VARISTAR_AZLP_COOPER	COOPER VARISTAR AZLP 1992	Remove & Replace
		W	POLYMERIC_VARIGAP_AZLP_COOPERS	COOPER VARIGAP AZLP 1992	Remove & Replace
		X	ULTRASIL_CLASS_A_(FIRE)_COOPER	COOPER ULTRASIL 1999-Class A	Acceptable
		Y	ULTRASIL_CLASS_C_COOPERS	COOPER ULTRASIL 1999-Class C	Acceptable
		SIEM-A	3EK7_SD_SIEMANS	Siemens 3EK7 2008	Remove & Replace
		ABB-A	POLIM_D_SD_ABB	ABB POLIM D	Remove & Replace
		CLAH	CLAH	CURRENT LIMITING ARCHING HORN	Remove & Replace
		ABB-K	POLIM_K22-80_SD_ABB	ABB POLIM K 22	Acceptable
		HUB-C	HUBBELL-C8AA-24kV	HUBBELL	Acceptable
		UNKNOWN	UNKNOWN	UNKNOWN	Remove & Replace

Above: Lists details of which lines surge arrestors are acceptable for REFCL operation.

For more information, please refer to REF 20-07 REFCL Program – Surge Arrestor strategy.

9.3.3 INSULATORS

As with surge arrestors, line insulators will also be susceptible to failure due to the elevated phase to ground voltages during REFCL operation. An assessment on all insulator types will be required to identify risk items to be replaced.

9.3.4 AUTOMATIC CIRCUIT RECLOSERS

The ACRs are to be upgraded to avoid maloperation when the REFCL is in operation. The current magnitudes and direction for a phase to ground fault on a REFCL protected network differ to a low impedance or solidly grounded network. Currently this poses a risk that our ACRs can trip on their nondirectional EF or SEF protection functions. For this reason, EF and SEF needs to automatically be blocked during REFCL operation until devices can provide the required functionality.

ACRs on the network will need to be of the latest standard which utilises the NOJA OSM38 until other solutions have been developed.

For more information, please refer to REF 20-08 REFCL Program – ACR strategy.

9.3.5 FUSE SAVERS

Fusesavers will become redundant for phase-to-ground faults (70%-80% of faults) as a result of a REFCL installation. Where fusesavers have been installed on REFCL protected feeders, an economic assessment will need to be developed to provide direction on the removal of or replacement of these devices with other protection equipment at the end of their battery life (approximately 7 years).

For more information, please refer to REF 20-10 REFCL Program – Fusing strategy.

9.3.6 FUSES

Depending on the equivalent capacitance of the fused section, the REFCL may operate under a phase to phase fault condition. An assessment is being performed to understand the contribution this may have to the imbalance of the network to ensure that the REFCL doesn't think there is a phase to ground fault should fuses operate on a phase fault.

Where fuses are deemed not required, the tubes shall be replaced with solid links until a time when the unit can be removed from the pole as a part of other works.

For more information, please refer to REF 20-10 REFCL Program – Fusing strategy.

9.3.7 REGULATORS

Open delta regulators (or two tank regulators) are not compatible with the GFN as they displace the system neutral voltage by regulating line-line voltages on two phases as opposed to three. Any installations that we may have on the network must be converted to a full three-phase set. All single phase controllers will need to be replaced with a three phase controller so that voltages across all phases remain consistent to avoid asymmetrical voltages.

For more information, please refer to REF 20-09 REFCL Program – Voltage Regulator strategy.

9.3.8 GLOVE AND BARRIER

All glove and barrier equipment will need to be assessed to ensure it can be used safely on a REFCL protected feeder. Work Practices will be responsible for the assessment which will identify issues with previously approved equipment and also determine recommendations moving forward.

For more information, please refer to REF 20-12 REFCL Program – Personal Protective Equipment policy.

9.3.9 NON METALLIC SCREEN HIGH VOLTAGE AERIAL BUNDLED CABLE

Non Metallic Screen (NMS) High Voltage (HV) Aerial Bundled Cable (ABC) has been identified as a cross country fault risk during REFCL operation. NMS HV ABC replacement programs are currently underway and coordination of this program with the REFCL Program is imperative to ensure maximum benefit is achieved with both programs.

APPENDIX A. NOMINATED REFCL ZONE SUBSTATIONS

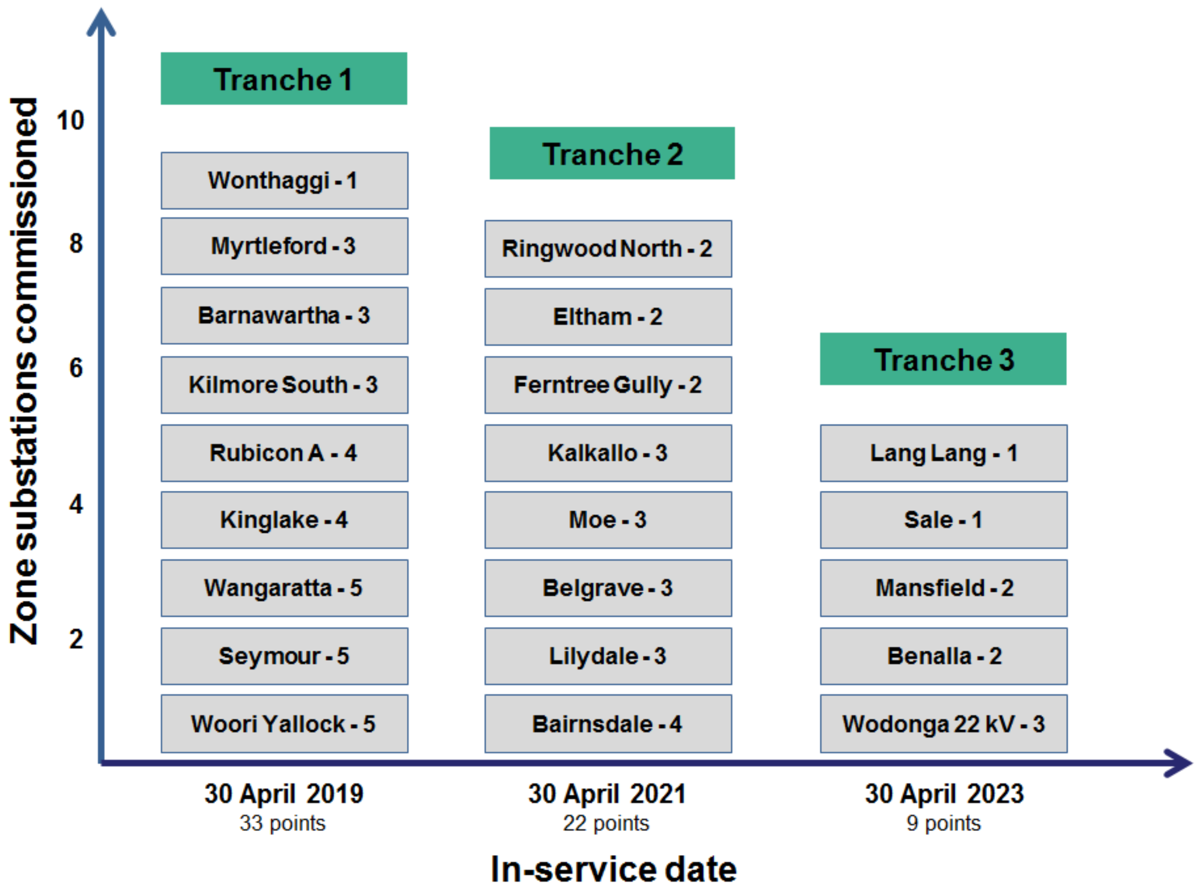

Figure 1 Proposed REFCL Zone Substation Installation Schedule