
Rapid Earth Fault Current Limiter (REFCL) Program

HV Customer Policy for REFCL Protected Networks (Load & Generator)

| Document Details | |
|------------------|---------------|
| Document Number: | REF 30-10 |
| Version number: | 3 |
| Status: | Approved |
| Approver: | Matthew Ch'ng |
| Date of approval | 25/04/2019 |



HV Customer Policy for REFCL Protected Networks (Load & Generator)

REVISION HISTORY

| Issue Number | Date | Description | Author |
|--------------|------------|--|------------------------|
| 1 | 23/01/2018 | First Issue | A Ziusudras M Ch'ng |
| 2 | 18/04/2018 | Hardening solution updated. Conceptual isolation transformer single line diagram updated. | A Ziusudras M Ch'ng |
| 3 | 25/04/19 | Modified to include draft decision changes of the Electricity Distribution Code and its effects. | M Ch'ng |

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1 PURPOSE AND BACKGROUND

1.1 Purpose

The aim of this document is to advise AusNet Services' policy for HV customers, which are connected to a REFCL, protected electricity distribution network. This document is intended to be utilised by existing and new HV customers, AusNet Services Asset Management and Delivery personnel with the intent to provide guidance on technical REFCL requirements to maintain:

- Health and safety of AusNet Services' and HV customer personnel and the public;
- Compliance with *Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016*;
- Compliance with *Electricity Distribution Code*;
- Integrity and reliability of the AusNet Services' network assets and HV customer's assets; *and*
- Protection and control Coordination with HV customer assets

1.2 Background

AusNet Services' electrical distribution network is located in areas of extreme bushfire risk. These conditions warrant significant investment to mitigate bushfire risk.

Following these events, the Victorian Government established the Victorian Bushfire Royal Commission, which made several recommendations with respect to fires initiated from distribution electricity networks. Subsequently, the Victorian Government established the Powerline Bushfire Safety Program to research the optimal way to deploy REFCLs for bushfire prevention. This research led the Government to introduce the Electricity Safety (Bushfire Mitigation) Amendment Regulations 2016 ("*Regulations*").

As outlined in these *Regulations*, AusNet Services (AST) is required to meet the performance levels ("*Required Capacity*") in the event of a phase-ground fault event on a polyphase line at 22 distribution zone substations sites. The *Required Capacity* aims to:

- 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;

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2 Referenced Documentation

The following referenced documents including the latest edition and amendments of undated references, are indispensable for the application of this document.

- ANSI/IEEE C37.90 Standard for Relays and Relay Systems Associated with Electric Power Apparatus
- AS 60076 Power Transformers
- AS 2067 Substations and HV Installations Exceeding 1kV a.c.
- Distribution Connection Policy
- Electricity Distribution Code
- Electricity Safety (Bushfire Mitigation Duties) Regulations
- Electricity Safety (Installation) Regulations
- Service & Installation Rules 2014 (Incorporating Amendment 1 - April 2017)
- IEC 60255 Measuring Relays and Protection Equipment - Part 1: Common Requirements
- REF 10-07 REFCL Program Definition of REFCL Areas
- REF 20-17 REFCL Program Operating Modes.
- REF 30-16 REFCL Program Operating Modes Policy
- SOP11-16 Protection Requirement for Embedded Generator

3 Abbreviations and Definitions

| Term | Definition |
|--------------------|---|
| ACR | Auto Circuit Recloser |
| ASC | Arc Suppression Coil |
| AST | AusNet Services |
| CEOT | Customer Energy Operation Team |
| Code | <i>Code</i> refers to the Electricity Distribution Code |
| Connection Point | Point of supply to a customer |
| DFA | Distribution Feeder Automation |
| Embedded Generator | A generator who has embedded generating units are connected to a distribution system. (Note the definition applies irrespective, if energy is exported from the generator to the electricity network at the connection point) |
| ESC | Essential Services Commission |
| GFN | Ground Fault Neutralizer |
| HV | High Voltage |
| Islanding | Disconnection of section of network from the rest of the grid while power supplied by distributed a generator connected to the section. |
| LV | Low Voltage |
| MGS | Manual Gas Switch |

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| Term | Definition |
|-------------------|--|
| NER | Neutral Earth Resistor |
| RCC | Residual Current Compensator |
| RCGS | Remote Controlled Gas Switch |
| REFCL | Rapid Earth Fault Current Limiter |
| Regulations | <i>Regulations</i> refer to the Network Safety (Bushfire Mitigation) Amendment Regulations 2016 |
| Required Capacity | <i>Required Capacity</i> refer to the performance criteria stipulated in the Network Safety (Bushfire Mitigation) Amendment Regulations 2016 |
| TFB | Total Fire Ban |
| VESI | Victorian Electricity Supply Industry |
| ZSS | Zone Substation |

Table 1: Definitions

4 List of REFCL Feeders

To comply with the *Regulations*, all 22kV feeders originating from the nominated zone substation must be protected by a REFCL whilst ensuring the *Required Capacity* performance has been achieved. Due to the dynamic nature of the electricity distribution network the feeder configuration must be defined. As such, defining REFCL and non-REFCL protected feeders must be clear.

For more information, please refer to document number REF 10-07, "Definition of REFCL areas" for list of REFCL and non-REFCL protected feeders.

5 What is a REFCL?

The REFCL is a protection device that reduces the risk of fires caused by powerlines and is installed on the zone substation transformer 22kV side neutral. It does this by rapidly limiting the current that is released in a phase to ground earth fault only.

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 specified in the *Regulations*.

The GFN consists of four main components:

- Arc Suppression Coil (ASC)
- Residual Current Compensator (RCC)
- Grid Balancing Unit
- Control System

These components are all housed within AusNet Services' distribution zone substations.

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6 Earth Fault Treatment by REFCL Technology

The GFN employs resonant earthing with an additional residual current compensation feature, 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%).

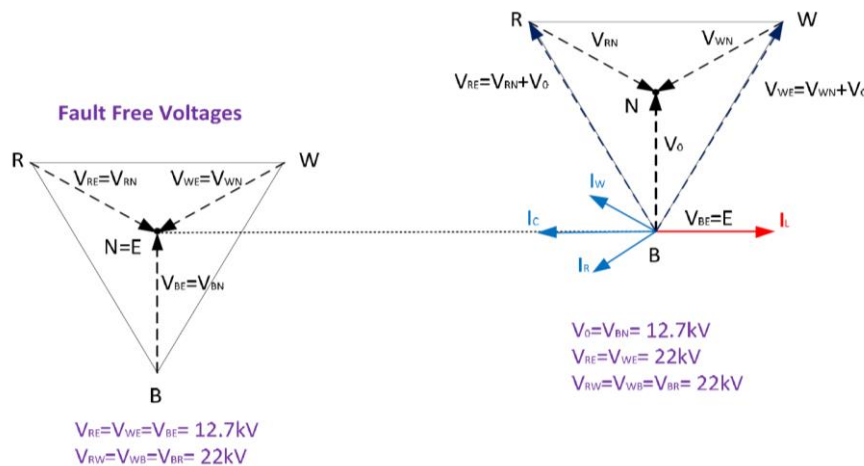


Figure 1: Voltage and current response on networks with resonant earthing

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 phase 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 a strategy to be implemented in accordance with this document for our HV customers. This involves 'hardening' of primary assets, installation of an isolation transformer, or conversion to low voltage.

7 REFCL Operating Modes

AusNet services will operate the REFCLs in three modes of operation with each operating modes providing a different reliability and fire ignition risk profile. The three modes of operation that will be utilised are:

- **Fire Risk Mode** – applicable on Total Fire Ban and Code Red Days
- **Standard Mode** – applicable during periods of elevated bushfire risk that are not Total Fire Ban or Code Red Days
- **REFCL-NER Mode** – applicable during periods of lower bushfire risk

If the REFCL experiences equipment failure then, irrespective of the operating mode, the REFCL will be taken out of service and the ZZS NER will be entered into service. AST will be required to reinstate the REFCL back into service as soon as practicably possible however should this be for a prolonged period of time, AST will contact the HV customer and advise them accordingly.

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For more information on the three operating modes please refer to REF 20-17 REFCL Program Operating Modes. Furthermore, REF 30-16 REFCL Program Operating Modes Policy provides guidance on how AusNet Services intends to select the operating mode of the REFCL.

8 REFCL Impact On High Voltage Customer

8.1 Technical Impact

During a phase-ground fault, the neutral voltage may increase up to 13.9kV consequently leading to elevated phase to ground voltages on the two un-faulted phases. The Electricity Distribution Code ('Code') refers to this voltage response as a *REFCL Condition*. The un-faulted phases are required to withstand 24.2 kV for a maximum duration as stipulated in the *Code*.

The REFCL also automatically adapts to network conditions while in service known as an inverter tuning sequence. This may result in each individual phase-ground voltage being increased by 20% (16.7 kV phase to ground) at a time for a duration of 45 seconds. This tuning sequence may occur multiple times during a day.

The voltage changes only relate to phase-to-earth voltages. Phase-to-phase voltages are unaffected by REFCL operation. Because only phase-to-earth voltages are changed by REFCL action the only customers can be affected are those that are supplied at high voltage.

Given this impact on HV customers, AusNet Services has recommended three technically acceptable solutions to our HV customers. This is 'hardening' of primary assets, installation of an isolation transformer and conversion to low voltage are further described in this document.

Furthermore, there are secondary effects that will incur varying impacts on HV customers with respect to, but not limited to, the following:

- Fault levels
- Power quality
- Earthing arrangements
- Protection and control
- Operating protocols
- Connections agreements
- Overvoltage variations on equipment and devices
- Design of the HV solution to mitigate overvoltage
- Construction, operation and maintenance activities
- Physical arrangements at the point of connection

It is recommended that these factors be investigated by the HV customer to understand the full impact on their assets.

9 Electricity Distribution Code

The *Code* was established in the 1990s as part of industry restructure. Its purpose was, among other things, to codify the quality of customer supply to be provided by network owners and operators. Clause 4.2.2 of the *Code* specifies the allowable variations in supply voltage for different durations. It specifies allowable variations in two voltages:

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- Phase-to-phase voltage – this is directly reflected in the supply voltage to customer loads, whether they are high voltage customers or customers supplied by distribution substations at a nominal voltage of 22kV.
- Phase-to-earth voltage – variations in this voltage do not affect the voltage of supply to customer loads. Rather they determine the level of voltage that high voltage network assets must withstand, including assets within customer facilities supplied at high voltage direct from the network.

The current *Code* clause 4.2.2 specifies variations with respect to nominal value of both of these voltages in a single table as follows however with the introduction of REFCLs on the 22kV polyphase network a Voltage Standards Review was completed:

| STANDARD NOMINAL VOLTAGE VARIATIONS | | | | |
|-------------------------------------|--------------------------------|--------------------|--|---------------------------|
| Voltage Level in kV | Voltage Range for Time Periods | | | Peak Impulse Voltage (kV) |
| | Steady State | Less than 1 minute | Less than 10 seconds | |
| < 1.0 | +10% -6% | +14% -10% | Phase to Earth +50% -100% Phase to Phase +20% -100% | 6 kV |
| 6.6 | ±6 % (±10 % Rural Areas) | ±10% | Phase to Earth +80% -100% Phase to Phase +20% -100% | 60 kV |
| 11 | | | | 95 kV |
| 22 | | | | 150 kV |
| 66 | ±10% | ±15% | Phase to Earth +50% -100% Phase to Phase +20% -100% | 325 kV |

Table 2: Permissible Voltage Variations for a Non-REFCL Condition

9.1 Voltage Standards Review

In August 2018, a review was completed in accordance with the *Regulations* with consideration of the operational aspects associated with the implementation of REFCL devices on the distribution 22kV network. A summary of the key amendments, which directly impact HV customers are listed below:

- Amendment of clause 4.2.2 and introducing a new clause, clause 4.2.2A, for voltage variations under REFCL operation on a 22kV distribution network extending to but not beyond equipment functionally similar to an isolating transformer.
- Amendment of clause 16(c) relating to liability obligations for the HV customer.
- Amendment of clause 4.2.7 relating to compensation obligations for the 22kV network distributor.
- Insertion of 9.3.1(i) relating to the customer's obligation to provide any information relevant to the distributors operation of REFCL.

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9.1.1 Voltage Variations

The review stipulates that during proper operation of the REFCL equipment, the phase to earth voltages or 22kV distribution system in clause 4.2.2 shall not apply resulting in variations to Phase to phase voltages only as outlined in table 3 below. The removal of the limitation on phase to earth voltages during a REFCL condition means that the elevated phase to earth voltages inherent to REFCL technology can now occur continuously.

| STANDARD NOMINAL VOLTAGE VARIATIONS | | | | |
|-------------------------------------|--------------------------------|--------------------|------------------------------|---------------------------|
| Voltage Level in kV | Voltage Range for Time Periods | | | Peak Impulse Voltage (kV) |
| | Steady State | Less than 1 minute | Less than 10 seconds | |
| 22 | ±6 % (±10 % Rural Areas) | ±10% | Phase to Phase +20% -100% | 150 kV |

Table 3: Permissible Voltage Variations for a REFCL Condition

9.1.2 Liability and Compensation Obligations

The review amends the clause in Section 16(c) relating to liability obligations. The *Code* change aims to ensure that HV customers take reasonable measures to safeguard their assets to mitigate the effects of overvoltage which are generated during REFCL operation. This clause also aims to facilitate discussions between the 22kV network distributor and the HV customer and allow flexibility towards an outcome that is unique to the HV connection.

As a result of the *Code* amendments, the legal obligation to implement a HV customer connection solution is outlined as follows:

- Tranche 1 – AusNet Services' obligation (This is on-going as per the Code prior to August 2018)
- Tranche 2 – HV Customer's obligation
- Tranche 3 – HV Customer's obligation

Lastly, the review also amended clause 4.2.7 which aims to compensate any HV customer due to voltage variations outside the limits as described in clause 4.2.2 and 4.2.2A

10 HV Customer Engineering Solutions

There are three technically acceptable engineering solutions currently available for HV customers in Tranche 1:

- Install isolating transformer & ACR
- Primary assets hardening with ACR/RCGS
- Conversion to low voltage (LV)

For Tranche 2 and Tranche 3, the HV customer is not limited to the abovementioned and has the flexibility to implement a solution appropriate to their HV connection. At the point of connection AusNet Services will install an ACR/RCGS for isolation, communication, protection and control purposes.

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10.1 Isolating Transformer Solution

One method of preventing voltage stress on HV customer assets when the REFCL equipment operates is to electrically isolate the zero sequence of the HV customer installation from AusNet Services' distribution network by installing an isolating transformer at the HV customer's point of connection. As the isolating transformer is installed at customer point of connection, any earth fault downstream of isolating transformer will NOT be detected or cleared by the REFCL equipment. Consequently, the intent of the Regulations will require no bare overhead conductor downstream from the isolating transformer such that bushfire risk has been mitigated.

A total of two ACRs shall be installed, one on either side of the isolating transformer, for isolation, communication, protection and control purposes. Please refer to conceptual single line diagram in Appendix 1. However, during detailed design, if deemed the ACR on the AusNet Services network is no longer required, then it may be omitted.

10.1.1 REFCL Operation During a Fault

Under the Isolation transformer solution, the following REFCL operations can occur during a fault condition:

| Fault Scenario | Operation with REFCL in Service | Operation with REFCL Out of Service |
|-----------------|--|--|
| Phase to ground | A fault within the AST's 22kV network (upstream of the isolation transformer) will be detected and cleared by the REFCL and field devices. | No change from existing practices for a fault within AST's 22kV network. |
| | A fault within the HV customer's 22kV network (downstream of the isolation transformer) will be detected and cleared by customer's own protection equipment and AST's isolation transformer ACR. | |
| Phase to phase | No change from existing practices for a fault within AST's 22kV network. | No change from existing practices for a fault within AST's 22kV network. |
| | A fault within the HV customer's 22kV network (downstream of the isolation transformer) will be detected and cleared by customer's own protection equipment and AST's isolation transformer ACR. | |

Table 3 REFCL response with HV isolation transformer solution

10.1.2 Isolating Transformer Sizes

There are three sizes of isolating transformer being considered for existing HV customers based on their load requirements.

- 5 MVA
- 7.5 MVA
- 10 MVA

Note that two isolating transformers can be connected in paralleled for larger customer loads provided that they are of rating (e.g. 7.5 MVA can be paralleled with 7.5 MVA for total of 15 MVA load).

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AST's Network Planning team will determine the size or combination of isolating transformer required to be used for each high voltage customer connection in accordance with existing connection agreements.

10.1.3 Ferroresonance

Ferroresonance is a non-linear resonance phenomenon that can affect power networks. The abnormal rates of harmonics and transient or steady state over-voltages and over-currents that it causes are often dangerous for electrical equipment. Some unexplained breakdowns can be ascribed to this rare, non-linear phenomenon. Should AST believe there is a risk of ferroresonance, a study and/or practical damping pre-cautions must be completed.

10.1.4 Protection Requirements

Two ACRs will be required for each site, one on the AST side of the isolating transformer and another ACR on the HV customer side. The ACR's protection requirements are:

Supply side ACR (AST side):

- Phase overcurrent element to detect phase faults on supply and customer side of isolating transformer up to the customer side ACR;
- Ground overcurrent element to detect ground faults on supply side of isolating transformer;
- Negative sequence overcurrent element to detect faults on the customer side of isolating transformer up to the customer side ACR (ie. Including customer side transformer winding);
- Time delay of 0.3 second maybe required for grading with upstream protection device;
- Auto-Reclose function required to be available and normally OFF. To be switched ON manually if circuit is in By-Pass;

Customer side ACR:

- Phase overcurrent element to detect phase faults on customer side of isolating transformer for the remaining length of feeder;
- Ground overcurrent element to detect ground faults on customer side of isolating transformer for the remaining length of feeder;
- Auto-Reclose function required to be provided and normally ON. To be switched OFF when circuit is in By-Pass;
- As long as the HV customer protection equipment coordinates with customer side ACR, there is no special setting required on HV customer protection equipment.

10.1.5 HV Customer Protection Setting

Since the REFCL is detecting and clearing the earth faults up the AST side of the isolation transformer, the customer is not required to change their protection settings.

For information regarding Protection Requirement for Embedded Generator, please refer to SOP11-16 document.

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10.1.6 Maintenance

As per the *Regulations*, the REFCL equipment shall be in service, and is required to be set to a most sensitive setting on TFB and Red Code days regardless of whether the isolating transformer and its ACR's are in or out of service.

No maintenance shall be performed on TFB or code red days.

It is recommended that maintenance of the isolating transformer and the ACRs be conducted during winter or seasons with low bushfire risk.

10.2 Primary Assets Hardening Solution

The second method which prevents voltage stress on HV customer assets during REFCL operation is to identify primary assets which are not capable of being able to withstand an elevated voltage of 24.2kVrms for at least 3 continuous minutes. These primary assets shall then undergo an evaluation and then be replaced accordingly. It is recommended that the hardening of primary assets shall comply with AST's Primary Assets Hardening Strategy which is summarized in the subsequent Sections for the most common primary plant.

An ACR will be installed at the point of connection for isolation, communication, protection and control purposes. Protection requirements of embedded generators document shall comply with SOP11-16 Protection Requirements of Embedded Generators < 5 MVA (LV + HV up to 22KV).

10.2.1 REFCL Operation During a Fault

Under the Primary Assets Hardening Strategy, the following REFCL operation can occur during a fault condition:

| Fault Scenario | Operation with REFCL in Service | Operation with REFCL Out of Service |
|-----------------|--|--|
| Phase to ground | A fault within the AST's 22kV network will be detected & cleared by the REFCL. | No change from existing practices for a fault within AST's 22kV network. |
| | A fault within the HV customer's 22kV network will be initially detected and cleared by the REFCL. AST will attempt to restore the network with the HV customer disconnected until it is confirmed that the fault is within the HV customer's network. If found to be the case, once the fault has been cleared, the HV customer connection will then be restored. | No change from existing practices for a fault within the HV customer's 22kV network. |
| Phase to phase | No change from existing practices for a fault within AST's 22kV network. | |
| | No change from existing practices for a fault within the HV customer's 22kV network. | |

Table 4 REFCL operation with Customer Hardening solution

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10.2.2 Lines Design and Capacitive Network Balancing

In order for the REFCL technology to work effectively, the network's zero sequence capacitive current must be balanced.

It is the HV customer's responsibility to maintain the capacitive balance of their 22 kV network. Any HV customer augmentation works shall not introduce any imbalance. Capacitive balance designs shall be submitted and approved by AST prior to construction. In addition, single phase switches shall be avoided as AST may place operational restrictions on these switches subject to the capacitive balance assessment.

Lines Design Requirements are detailed in REF 30-06 Network Capacitive Balancing Policy and REF 30-09 Maintaining Capacitive Balance Policy.

10.2.3 Transformers

Any HV customer's HV transformer is required to withstand 24.2kV for at least 3 continuous minutes on the 22kV connected side.

This requirement can be confirmed through condition assessments of the bushings and a desktop analysis of the equipment's specification. Testing of the insulation of the transformer's windings and insulators shall be conducted to relevant Australian Standards or equivalent international standards. Test activities include:

- Insulation resistance for each bushing to earth (2.5kVdc for 1 minute)
- Insulation resistance for each winding to earth (2.5kVdc for 1 minute)
- Overvoltage and PD on main windings
- Overvoltage and DDF tests on bushings

Any unsatisfactory test results must be addressed by the HV customer to ensure the transformer meets or exceeds overvoltage magnitude and duration during REFCL operation.

10.2.4 Circuit Breakers

A HV customer's transformer is required to withstand 24.2kV for at least 3 continuous minutes on the 22kV connected side. This requirement can be confirmed through condition assessments of the bushings and a desktop analysis of the equipment's specification. Testing of the insulation of the circuit breaker shall be conducted to relevant Australian Standards or equivalent international standards. Test activities include:

- Insulation resistance for each bushing to earth (2.5kVdc for 1 minute)
- Overvoltage and DDF test for each bushing

Any unsatisfactory test results must be addressed by the HV customer to ensure the circuit breaker meets or exceeds overvoltage magnitude and duration during REFCL operation.

Notwithstanding the abovementioned tests and assessments, the internals of the circuit breaker shall be cleaned and refurbished.

10.2.5 Switchboards

A HV customer's switchboard and all 22kV connected equipment including but not limited to circuit breakers, earthing switches, surge arrestors, instrumentation transformers, and busbar compartments are required to withstand 24.2kV for at least 3 continuous minutes.

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This requirement can be confirmed through condition assessments of the bushings and a desktop analysis of the equipment's specification. Testing of the insulation of the switchboard shall be conducted to relevant Australian Standards or equivalent international standards. Test activities include:

- Insulation resistance for each busbar to earth (5kVdc for 1 minute)
- Overvoltage and PD monitoring

Any unsatisfactory test results must be addressed by the HV customer to ensure the switchboard meets or exceeds overvoltage magnitude and duration during REFCL operation.

10.2.6 Surge Arrestor

Surge arrestors fitted to a REFCL protected network must be capable of sustaining the elevated voltages of 24.2 kV Phase to ground for at least 3 continuous minutes.

The volt-amp curve from surge arrester tests or the manufacturer shall be supplied to determine if the surge arrester is satisfactory for use on AST's network. If the surge arrester is determined to be unsuitable, they shall be replaced by the HV customer.

10.2.7 Underground Cables

A HV customer's 22kV underground cable including their joints and terminations to be visually inspected and tested to ensure that the cable can withstand an elevated voltage of 24.2kV for at least 3 continuous minutes.

This requirement can be confirmed through condition assessments of the bushings and a desktop analysis of the equipment's specification. Testing of the insulation of the cables shall be conducted to relevant Australian Standards or equivalent international standards. Test activities include:

- PD testing
- Sheath integrity
- Dielectric spectroscopy or Dielectric Dissipation Factor testing
- HV withstand testing

If it is determined that the cable, its joints or terminations are unsuitable, they shall be replaced by the HV customer.

10.2.8 Instrumentation Transformers

Typically, the instrument transformers shall be able to withstand the elevated voltages created by operation of the REFCL. In this case, a condition assessment, a desktop analysis of the datasheet, and confirmation from the manufacturer of withstand capability may suffice.

If required, a testing shall be conducted to relevant Australian Standards or equivalent international standards. A test plan shall be derived in consultation with AusNet Services on a case by case basis

If it is determined that the instrumentations transformers are unsuitable, they shall be replaced by the HV customer.

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10.2.9 Metering

A HV customer's metering and voltage transformer shall comply with the voltage factor for GFN installation in the Victorian "Service & Installation Rules" document.

10.2.10 Insulators

All insulator types on the customers HV network are required to withstand 24.2kV for at least 3 continuous minutes on the 22kV connected side.

This requirement can be confirmed through a condition assessment, desktop analysis of the insulator specification, condition assessment.

If required, testing of the insulator shall be conducted to relevant Australian Standards or equivalent international standards. A test plan shall be derived in consultation with AusNet Services on a case by case basis.

Any unsatisfactory test results must be addressed by the HV customer to ensure new insulators meets or exceeds overvoltage magnitude and duration during REFCL operation.

10.2.11 High Voltage Customer Protection Setting

Since the REFCL is detecting and clearing the earth faults in the customer HV network, the customer may be required to undertake the following:

- Adjust the following protection elements (if applicable):
 - ANSI code 27 (Undervoltage)
 - ANSI code 46 (Phase balance)
 - ANSI code 51 (Overcurrent)
 - ANSI code 59 (Overvoltage)
 - ANSI code 81R (Rate of change of frequency)
 - ANSI code 81O (Over frequency)
 - ANSI code 81U (under frequency)
- Ideally HV customers require to have ONE set of protection settings to cater for scenarios whereby the REFCL is in or out of service. (Note: AusNet Services may take REFCL out of service for maintenance purpose).
- If desired by the HV customer, two sets of protection settings can be applied. With one protection active at any one time. One protection setting shall cater for a REFCL "in-service" and the other protection setting shall cater for a REFCL "out of service".

HV customer are required to submit their proposed protection settings to AusNet Services Asset Maintenance & Support team for review and approval.

For information regarding Protection Requirement for Embedded Generator, please refer to SOP11-16 document.

10.3 Conversion to Low Voltage

The third engineering solution available that prevents voltage stress on HV customer assets during REFCL operation is for the HV customer to convert their HV primary assets to LV. AST will then supply a transformer to convert 22kV voltage to 415V.

The process for this connection will be guided by the Distribution Connection Policy Document which can be found on the AusNet Services website.

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11 Equipment Out of Service

During its lifecycle, the equipment utilised to mitigate the effects of overvoltage due to REFCL operation may come out of service to undergo maintenance or repairs due to failure.

AusNet Services personnel and HV customer shall refer to Appendix 2 which outlines responsibilities, actions and key outcomes for various scenarios which consider:

- REFCL operating modes (Refer to Section 7)
- HV customer overvoltage mitigation solution (Refer to Section 10.1 and 10.2)
- Equipment Type (Isolation transformer or ACR)
- Outage type (General maintenance or faulty equipment)

12 Communication Topology

Communications between the HV customer and AST CEOT shall be conducted following any REFCL related equipment out of services scenarios as detailed for the Primary Asset Hardening and Isolation Transformer solution in this document.

Responsibilities for communicating notifications of events shall be in accordance with the individual HV Customer Operating Protocol and Connection Agreements

13 Connection Agreements

Due to the deployment of REFCL technology introduced by the Regulations, there will be commercial impacts upon the supply to the HV customers.

AST will initiate discussions with each HV customers to renegotiate the terms and conditions of their existing connection agreement with the intention that the Required Capacity in the Regulations are achieved in a safe, prudent, cost effective and timely manner.

14 HV Customer Operating Protocols

A Customer Operating Protocol shall be developed for the HV customer. The document details the ongoing operating protocols to be used in conjunction with the conditions specified in the Network Connection Agreement.

15 HV Customer Protection Coordination

REFCL technology fundamentally changes the method in which neutral treatment and phase to ground earth faults are managed on the electricity distribution network. As such it will be prudent for the HV customer to be aware of the change and understand the impact it has on their physical assets and protection schemes.

The HV customers proposed protection schemes and settings must be submitted for review by AST's Asset Maintenance & Support team to ensure protection coordination is maintained. The review will be limited to only ensuring that the HV customer's protection relay is appropriately selected to include the necessary protection elements required to achieve coordination. Settings associated with these protection elements will be reviewed.

Any protection elements designed or installed which do not impact REFCL coordination will not be reviewed and the onus will continue to be on the HV customer to ensure their protection

HV Customer Policy for REFCL Protected Networks (Load & Generator)

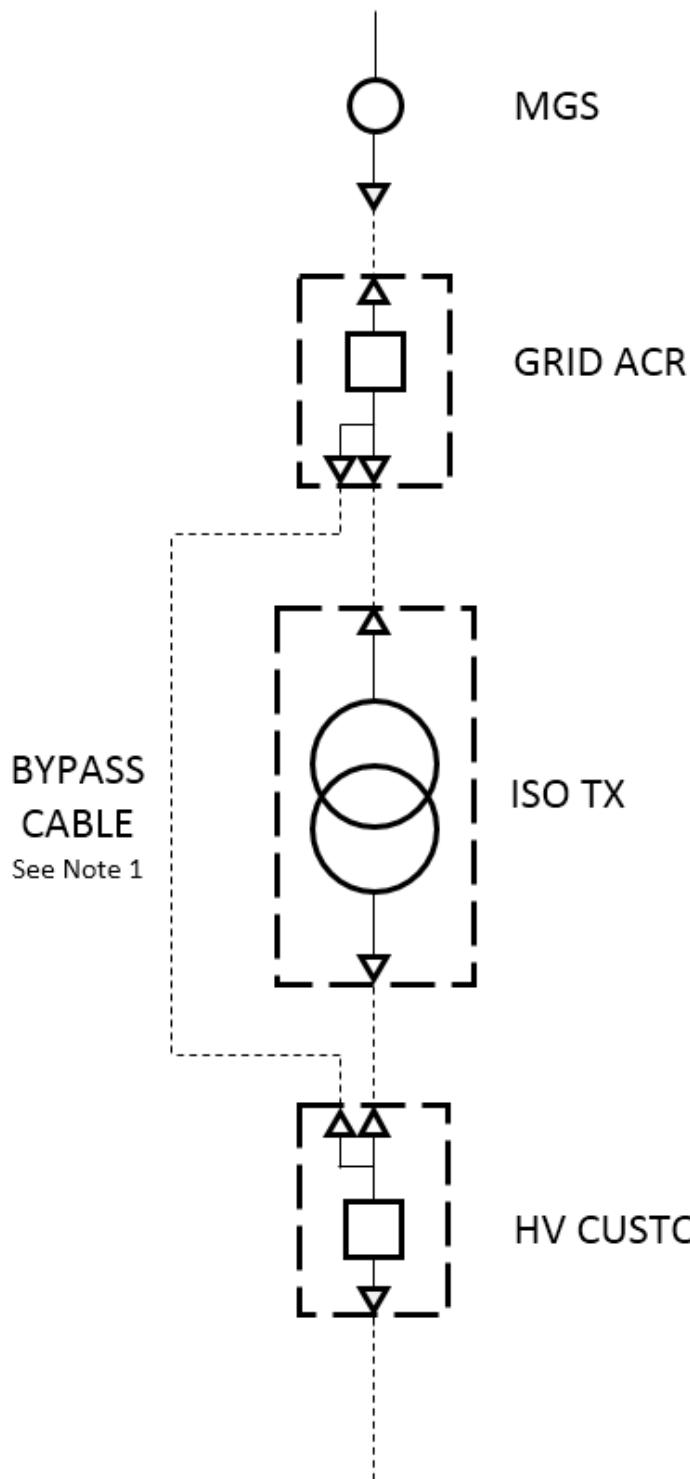
scheme and settings are fit for protecting their assets. It is highly recommended that the HV customer complete a full protection review of their assets.

16 HV Customer Harmonic Treatment

The *Code* defines acceptable limits for harmonic voltage and current which are applicable to the Distributor and Customer. Even though the harmonics generated by customers comply with the *Code*, the presence of harmonics may impact the ability of a REFCL protection network to operate at *Required Capacity*. Experience in demonstrating the REFCL performance standard has highlighted that harmonics, in some cases, will need to be mitigated to performance levels higher than specified in the *Code*. As such, the HV customer shall provide harmonic current and voltage data at the point of metering to AusNet Services to determine the level of harmonic treatment required. This data includes but is not limited to the following:

- Individual and total voltage distortion
- Individual and total current distortion

Appendix 1 - HV Customer Isolation Transformer Single Line Diagram



Note 1: The bypass connection shall be normally disconnected from the ACR's

If the isolation transformer needs to be bypassed, the isolation transformer cables shall be disconnected from the ACR's and the bypass cable shall be connected to the Grid ACR and HV Customer ACR.

HV Customer Policy for REFCL Protected Networks (Load & Generator)

Appendix 2 – Key Outcomes for Equipment Out of Service

| | REFCL Operating Modes | HV Customer Overvoltage Mitigation Solution | Equipment Type | Outage Type | Key Outcomes |
|---|-----------------------|---|-----------------------|---|---|
| 1 | Fire Risk Mode | Isolation Transformer | Isolation Transformer | Maintenance | <ul style="list-style-type: none"> No maintenance shall be conducted. |
| 2 | Fire Risk Mode | Isolation Transformer | Isolation Transformer | Equipment Failure | <ul style="list-style-type: none"> REFCL remains in service. The isolation transformer is taken out of service. The HV customer will be disconnected from supply until the faulty equipment is reinstated into service. AST is required to complete the repair/replacement. The HV customer is not required to change their protection settings. |
| 3 | Fire Risk Mode | Isolation Transformer | HV Customer ACR | Maintenance ¹ | <ul style="list-style-type: none"> No maintenance shall be conducted. |
| 4 | Fire Risk Mode | Isolation Transformer | HV Customer ACR | Equipment Failure (ACR control box or ACR recloser) | <ul style="list-style-type: none"> REFCL remains in service. The HV customer ACR is taken out of service. The HV customer will be disconnected from supply until the faulty equipment is reinstated into service. |

¹ As per AusNet Services Standard Maintenance Guideline document SOP 70-03 issue number 45, maintenance frequency for primary equipment (ACR/RCGS/MGS) is every 10 years. Maintenance frequency for secondary equipment is:

- I. Every 36 months: Battery replacement.
- II. Every 6 years: Control box maintenance.

HV Customer Policy for REFCL Protected Networks (Load & Generator)

| | REFCL Operating Modes | HV Customer Overvoltage Mitigation Solution | Equipment Type | Outage Type | Key Outcomes |
|---|-----------------------|---|-----------------|---|--|
| | | | | | <ul style="list-style-type: none"> • AST is required to complete the repair/replacement. • The HV customer is not required to change their protection settings. |
| 5 | Fire Risk Mode | Isolation Transformer | HV Customer ACR | Equipment Failure (ACR comms) | <ul style="list-style-type: none"> • REFCL remains in service. • The HV customer remains in service. • AST is required to complete the repair/replacement. • The HV customer is not required to change their protection settings. |
| 6 | Fire Risk Mode | Isolation Transformer | AST ACR | Maintenance | <ul style="list-style-type: none"> • No maintenance shall be conducted. |
| 7 | Fire Risk Mode | Isolation Transformer | AST ACR | Equipment Failure (ACR control box or ACR recloser) | <ul style="list-style-type: none"> • REFCL remains in service. • The AST ACR is taken out of service • The HV customer will be disconnected from supply until the faulty equipment is reinstated into service. • AST is required to complete the repair/replacement. • The HV customer is not required to change their protection settings. |
| 8 | Fire Risk Mode | Isolation Transformer | AST ACR | Equipment Failure (ACR comms) | <ul style="list-style-type: none"> • REFCL remains in service. • The HV customer remains in service. • AST is required to complete the repair/replacement. • The HV customer is not required to change their protection settings. |
| 9 | Fire Risk Mode | Isolation Transformer | AST MGS | Maintenance | <ul style="list-style-type: none"> • No maintenance shall be conducted. |

HV Customer Policy for REFCL Protected Networks (Load & Generator)

| | REFCL Operating Modes | HV Customer Overvoltage Mitigation Solution | Equipment Type | Outage Type | Key Outcomes |
|----|-----------------------|---|----------------|---|---|
| 10 | Fire Risk Mode | Isolation Transformer | AST MGS | Equipment Failure | <ul style="list-style-type: none"> REFCL remains in service. The AST MGS is taken out of service. AST is required to complete the repair/replacement. The HV customer remains in service. The HV customer is not required to change their protection settings. |
| 11 | Fire Risk Mode | Primary Assets Hardening (Load Customers or Generation <1.5MW) | AST RCGS | Maintenance | <ul style="list-style-type: none"> No maintenance shall be conducted. |
| | Fire Risk Mode | Primary Assets Hardening (Load Customers or Generation <1.5MW) | AST RCGS | Equipment Failure (MGS switch) | <ul style="list-style-type: none"> REFCL remains in service. The AST RCGS is taken out of service. The HV customer will be disconnected from supply until the faulty equipment is reinstated into service. AST is required to complete the repair/replacement. The HV customer remains in service. The HV customer is not required to change their protection settings. |
| 12 | Fire Risk Mode | Primary Assets Hardening (Load Customers or Generation <1.5MW) | AST RCGS | Equipment Failure (Control box or communications) | <ul style="list-style-type: none"> REFCL remains in service. The AST RCGS remains in service. The HV customer remains in service. AST is required to complete the repair/replacement. The HV customer is not required to change their |

HV Customer Policy for REFCL Protected Networks (Load & Generator)

| | REFCL Operating Modes | HV Customer Overvoltage Mitigation Solution | Equipment Type | Outage Type | Key Outcomes |
|----|-----------------------|---|----------------|---|---|
| | | | | | protection settings. |
| 13 | Fire Risk Mode | Primary Assets Hardening (Generation >1.5MW) | AST ACR | Maintenance | No maintenance shall be conducted. |
| 14 | Fire Risk Mode | Primary Assets Hardening (Generation >1.5MW) | AST ACR | Equipment Failure (ACR control box, ACR recloser) | <ul style="list-style-type: none"> REFCL remains in service. The AST ACR is taken out of service. The HV customer will be disconnected from supply until the faulty equipment is reinstated into service. HOWEVER if the customer agrees to reduce their generation to less than 1.5MW, the HV customer can <u>remain in service</u> AST is required to complete the repair/replacement. The HV customer is not required to change their protection settings. |
| 15 | Fire Risk Mode | Primary Assets Hardening (Generation >1.5MW) | AST ACR | Equipment Failure (ACR communications) | <ul style="list-style-type: none"> REFCL remains in service. The HV customer remains in service. AST is required to complete the repair/replacement. The HV customer is not required to change their protection settings. |
| 16 | Fire Risk Mode | Primary Assets Hardening (Generation >1.5MW) | AST MGS | Maintenance | <ul style="list-style-type: none"> No maintenance shall be conducted. |
| 17 | Fire Risk Mode | Primary Assets Hardening (Generation >1.5MW) | AST MGS | Equipment Failure | <ul style="list-style-type: none"> REFCL remains in service. The HV customer remains in service. The AST MGS is taken out of service. |

HV Customer Policy for REFCL Protected Networks (Load & Generator)

| | REFCL Operating Modes | HV Customer Overvoltage Mitigation Solution | Equipment Type | Outage Type | Key Outcomes |
|----|-----------------------------|--|-----------------------|-------------------|---|
| | | | | | <ul style="list-style-type: none"> • AST is required to complete the repair/replacement. • The HV customer is not required to change their protection settings. |
| 18 | Fire Risk Mode | Primary Assets Hardening (Generation >1.5MW) | AST HV Disconnectors | Maintenance | <ul style="list-style-type: none"> • No maintenance shall be conducted. |
| 19 | Fire Risk Mode | Primary Assets Hardening (Generation >1.5MW) | AST HV Disconnectors | Equipment Failure | <ul style="list-style-type: none"> • REFCL remains in service. • The HV customer remains in service. • AST is required to complete the repair/replacement. |
| 20 | Standard Mode and REFCL-NER | Isolation Transformer | Isolation Transformer | Maintenance | <ul style="list-style-type: none"> • The isolation transformer is taken out of service. • The REFCL is taken out of service. • The zone substation NER shall be put in service. • The isolating transformer shall be bypassed to ensure continuity of HV supply to the HV customer. AST is required to complete maintenance. • The HV customer remains in service. • The HV customer is not required to change their protection settings. |
| 21 | Standard Mode and REFCL-NER | Isolation Transformer | Isolation Transformer | Equipment Failure | <ul style="list-style-type: none"> • The isolation transformer is taken out of service. • The REFCL is taken out of service. • The zone substation NER shall be put in service. • The isolating transformer shall be bypassed to ensure continuity of HV supply to the HV customer. |

HV Customer Policy for REFCL Protected Networks (Load & Generator)

| | REFCL Operating Modes | HV Customer Overvoltage Mitigation Solution | Equipment Type | Outage Type | Key Outcomes |
|----|-----------------------------|---|-----------------|---|--|
| | | | | | <ul style="list-style-type: none"> The HV customer remains in service. AST is required to complete the repair. The HV customer is not required to change their protection settings. |
| 22 | Standard Mode and REFCL-NER | Isolation Transformer | HV Customer ACR | Maintenance | <ul style="list-style-type: none"> The REFCL shall remain in service. The HV customer ACR shall remain in service. The HV customer remains in service. AST is required to complete the maintenance. The HV customer is not required to change their protection settings. |
| 23 | Standard Mode and REFCL-NER | Isolation Transformer | HV Customer ACR | Equipment Failure (ACR control box or ACR recloser) | <ul style="list-style-type: none"> The REFCL shall remain in service. The HV customer ACR is taken out of service. The HV customer will be disconnected from supply until the faulty equipment is reinstated into service. AST is required to complete the repair/replacement. The HV customer is not required to change their protection settings. |
| 24 | Standard Mode and REFCL-NER | Isolation Transformer | HV Customer ACR | Equipment Failure (ACR comms) | <ul style="list-style-type: none"> REFCL remains in service. The HV customer remains in service. AST is required to complete the repair. The HV customer is not required to change their protection settings. |

HV Customer Policy for REFCL Protected Networks (Load & Generator)

| | REFCL Operating Modes | HV Customer Overvoltage Mitigation Solution | Equipment Type | Outage Type | Key Outcomes |
|----|-----------------------------|---|----------------|---|--|
| 25 | Standard Mode and REFCL-NER | Isolation Transformer | AST ACR | Maintenance | <ul style="list-style-type: none"> • The REFCL shall remain in service. • The AST ACR shall remain in service. • The HV customer remains in service. • AST is required to complete the maintenance. • The HV customer is not required to change their protection settings. |
| 26 | Standard Mode and REFCL-NER | Isolation Transformer | AST ACR | Equipment Failure (ACR control box or ACR recloser) | <ul style="list-style-type: none"> • The REFCL shall remain in service. • The AST ACR is taken out of service. • AST is required to complete the repair/replacement. • The HV customer will be disconnected from supply until the faulty equipment is reinstated into service. • The HV customer is not required to change their protection settings. |
| 27 | Standard Mode and REFCL-NER | Isolation Transformer | AST ACR | Equipment Failure (ACR comms) | <ul style="list-style-type: none"> • REFCL remains in service. • The HV customer remains in service. • AST is required to complete the repair. • The HV customer is not required to change their protection settings. |
| 28 | Standard Mode and REFCL-NER | Isolation Transformer | AST MGS | Maintenance | <ul style="list-style-type: none"> • The REFCL shall remain in service. • The AST MGS shall remain in service. • AST is required to complete the maintenance. • The HV customer remains in service. |

HV Customer Policy for REFCL Protected Networks (Load & Generator)

| | REFCL Operating Modes | HV Customer Overvoltage Mitigation Solution | Equipment Type | Outage Type | Key Outcomes |
|----|-----------------------------|---|----------------|-------------------|--|
| | | | | | <ul style="list-style-type: none"> The HV customer is not required to change their protection settings. |
| 29 | Standard Mode and REFCL-NER | Isolation Transformer | AST MGS | Equipment Failure | <ul style="list-style-type: none"> The REFCL shall remain in service. The AST MGS is taken out of service. AST is required to complete the maintenance. The HV customer will be disconnected from supply until the faulty equipment is reinstated into service. The HV customer is not required to change their protection settings. |
| 30 | Standard Mode and REFCL-NER | Primary Assets Hardening (Load Customers or Generation <1.5MW) | AST RCGS | Maintenance | <ul style="list-style-type: none"> The REFCL shall remain in service. The AST RCGS shall remain in service. AST is required to complete the maintenance. The HV customer remains in service. The HV customer is not required to change their protection settings. |
| 31 | Standard Mode and REFCL-NER | Primary Assets Hardening (Load Customers or Generation <1.5MW) | AST RCGS | Equipment Failure | <ul style="list-style-type: none"> The REFCL shall remain in service. The AST RCGS is taken out of service. AST is required to complete the maintenance. The HV customer will be disconnected from supply until the faulty equipment is reinstated into service. The HV customer is not required to change their protection settings. |
| 32 | Standard Mode | Primary Assets Hardening | AST ACR | Maintenance | <ul style="list-style-type: none"> The REFCL shall remain in service. |

HV Customer Policy for REFCL Protected Networks (Load & Generator)

| | REFCL Operating Modes | HV Customer Overvoltage Mitigation Solution | Equipment Type | Outage Type | Key Outcomes |
|----|-----------------------------|--|----------------|---|---|
| | and REFCL-NER | (Generation >1.5MW) | | | <ul style="list-style-type: none"> The AST ACR shall remain in service. AST is required to complete the maintenance. The HV customer remains in service. <p>The HV customer is not required to change their protection settings.</p> |
| 33 | Standard Mode and REFCL-NER | Primary Assets Hardening (Generation >1.5MW) | AST ACR | Equipment Failure (ACR control box, ACR recloser) | <ul style="list-style-type: none"> The REFCL shall remain in service. AST is required to complete the repair/replacement. The HV customer will be disconnected from supply until the faulty equipment is reinstated into service HOWEVER if the customer agrees to reduce their generation to less than 1.5MW, the HV customer can remain in service. The HV customer is not required to change their protection settings. |
| 34 | Standard Mode and REFCL-NER | Primary Assets Hardening (Generation >1.5MW) | AST ACR | Equipment Failure (ACR communications) | <ul style="list-style-type: none"> REFCL remains in service. The HV customer remains in service. AST is required to complete the repair/replacement. The HV customer is not required to change their protection settings. |
| 35 | Standard Mode and REFCL-NER | Primary Assets Hardening (Generation >1.5MW) | AST MGS | Maintenance | <ul style="list-style-type: none"> The REFCL shall remain in service The AST MGS shall remain in service. AST is required to complete the maintenance. The HV customer remains in service. The HV customer is not required to change their |

HV Customer Policy for REFCL Protected Networks (Load & Generator)

| | REFCL Operating Modes | HV Customer Overvoltage Mitigation Solution | Equipment Type | Outage Type | Key Outcomes |
|----|-----------------------------|--|----------------------|-------------------|--|
| | | | | | protection settings. |
| 36 | Standard Mode and REFCL-NER | Primary Assets Hardening (Generation >1.5MW) | AST MGS | Equipment Failure | <ul style="list-style-type: none"> • The REFCL shall remain in service. • The AST MGS is taken out of service. • AST is required to complete the repair/replacement. • The HV customer will be disconnected from supply until the faulty equipment is reinstated into service. • The HV customer is not required to change their protection settings. |
| 37 | Standard Mode and REFCL-NER | Primary Assets Hardening (Generation >1.5MW) | AST HV Disconnectors | Maintenance | <ul style="list-style-type: none"> • The REFCL shall remain in service. • AST is required to complete the maintenance. • The HV customer will be disconnected from supply until the faulty equipment is reinstated into service. • The HV customer is not required to change their protection settings. |
| 38 | Standard Mode and REFCL-NER | Primary Assets Hardening (Generation >1.5MW) | AST HV Disconnectors | Equipment Failure | <ul style="list-style-type: none"> • The REFCL shall remain in service. • AST is required to complete the repair/replacement. • The HV customer will be disconnected from supply until the faulty equipment is reinstated into service. • The HV customer is not required to change their protection settings. |