Rapid Earth Fault Current Limiter (REFCL) Program

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

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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

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1 PURPOSE AND BACKGOUND

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;

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.
- 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	*Code* refers to the Electricity Distribution Code
Connection Point	Point of supply to a customer
DFA	Distribution Feeder Automation
Embedded Generator	A generator who's 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
NER	Neutral Earth Resistor

Term	Definition
RCC	Residual Current Compensator
RCGS	Remote Controlled Gas Switch
REFCL	Rapid Earth Fault Current Limiter
Regulations	*Regulations* refer to the Network Safety (Bushfire Mitigation) Amendment Regulations 2016
Required Capacity	*Required Capacity* 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.

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%).

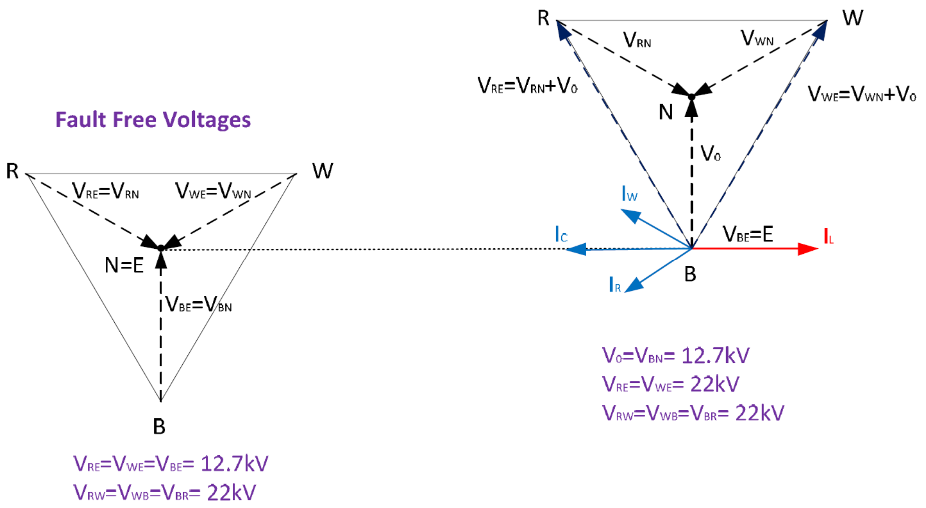


Figure 1: Voltage and current response on networks with resonant earthing

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 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 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.

For more information on the three operating modes please refer to REF 20-17 REFCL Program Operating Modes.

8 REFCL Impact On High Voltage Customer

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. These un-faulted phases are required to withstand 24.2 kV for up to 8 hours.

The REFCL also automatically adapts to network conditions while in service. This may result in individual phases voltages being increased by 20% (16.7 kV phase to ground) at a time for a total time period of 45 seconds. This 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 two 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
- 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 Electricity Distribution Code *('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. Section 4.2.2 of the Code specifies the allowable variations in supply voltage for different durations. It specifies allowable variations in two voltages:

- 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* Section 4.2.2 specifies variations with respect to nominal value of both of these voltages in a single table as follows (current wording shown with areas of proposed changes highlighted):

STANDARD NOMINAL VOLTAGE VARIATIONS				
Voltage Level in kV	Voltage Range for Time Periods			Impulse Voltage
	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 peak
1-6.6	± 6 % (± 10 % Rural Areas)	± 10%	Phase to Earth +80%-100% Phase to Phase +20%-100%	60 kV peak
11				95 kV peak
22				150 kV peak
66	± 10%	± 15%	Phase to Earth +50%-100% Phase to Phase +20%-100%	325 kV peak

Table 2: Permissible Voltage Variations (extract from Code)

Pending the ESC's review (currently underway) of the voltage standards, it is envisaged that the introduction of REFCL technology will result in the following permissible variations to phase to ground voltages in the *Code*.

STANDARD NOMINAL VOLTAGE RANGE (PHASE TO EARTH)				
Phase to earth voltage in kV	Voltage Range for Time Periods			
	Continuous	< 1 minute	< 10 seconds	Fast impulse (kV peak)
< 0.6	94% to 110%	90% to 114%	0% to 150%	6
0.6 – 3.8	0% to 190%			60
6.3				95
12.7 (polyphase)				150
12.7 (SWER)	90% to 110%	90% to 110%	0% to 120%	150
38.1	90% to 110%	85% to 115%	0% to 150%	325

Table 3: Proposed phase to ground variations to Code

10 HV Customer Engineering Solutions

There are three technically acceptable engineering solutions currently available:

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

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.

A total of two ACRs shall be installed, one on either side of the isolating transformer, for protection and control purposes, and a manual gas switch shall be installed on the supply side for isolation 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:

<table>
<tr><th>Fault Scenario</th><th>Operation with REFCL in Service</th><th>Operation with REFCL Out of Service</th></tr>
<tr><td rowspan="2">Phase to ground</td><td>A fault within the AST’s 22kV network (upstream of the isolation transformer) will be detected and cleared by the REFCL and field devices.</td><td>No change from existing practices for a fault within AST’s 22kV network.</td></tr>
<tr><td colspan="2">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.</td></tr>
<tr><td rowspan="2">Phase to phase</td><td colspan="2">No change from existing practices for a fault within AST’s 22kV network.</td></tr>
<tr><td colspan="2">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.</td></tr>
</table>

Table 4 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).

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 Ferroresonace

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.

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 the isolating transformer and the ACRs 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.

Furthermore as per Protection Requirements of embedded generators document SOP11-16.

10.2.1 REFCL Operation During a Fault

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

<table>
<tr><th>Fault Scenario</th><th>Operation with REFCL in Service</th><th>Operation with REFCL Out of Service</th></tr>
<tr><td rowspan="2">Phase to ground</td><td>A fault within the AST's 22kV network will be detected & cleared by the REFCL.</td><td>No change from existing practices for a fault within AST's 22kV network.</td></tr>
<tr><td>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.</td><td>No change from existing practices for a fault within the HV customer's 22kV network.</td></tr>
<tr><td rowspan="2">Phase to phase</td><td colspan="2">No change from existing practices for a fault within AST's 22kV network.</td></tr>
<tr><td colspan="2">No change from existing practices for a fault within the HV customer's 22kV network.</td></tr>
</table>

Table 5 REFCL operation with Customer Hardening solution

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.

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 8 continuous hours.

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 arrestor 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 and elevated voltage of 24.2kV for at least 8 continuous hours.

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 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.

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.

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.

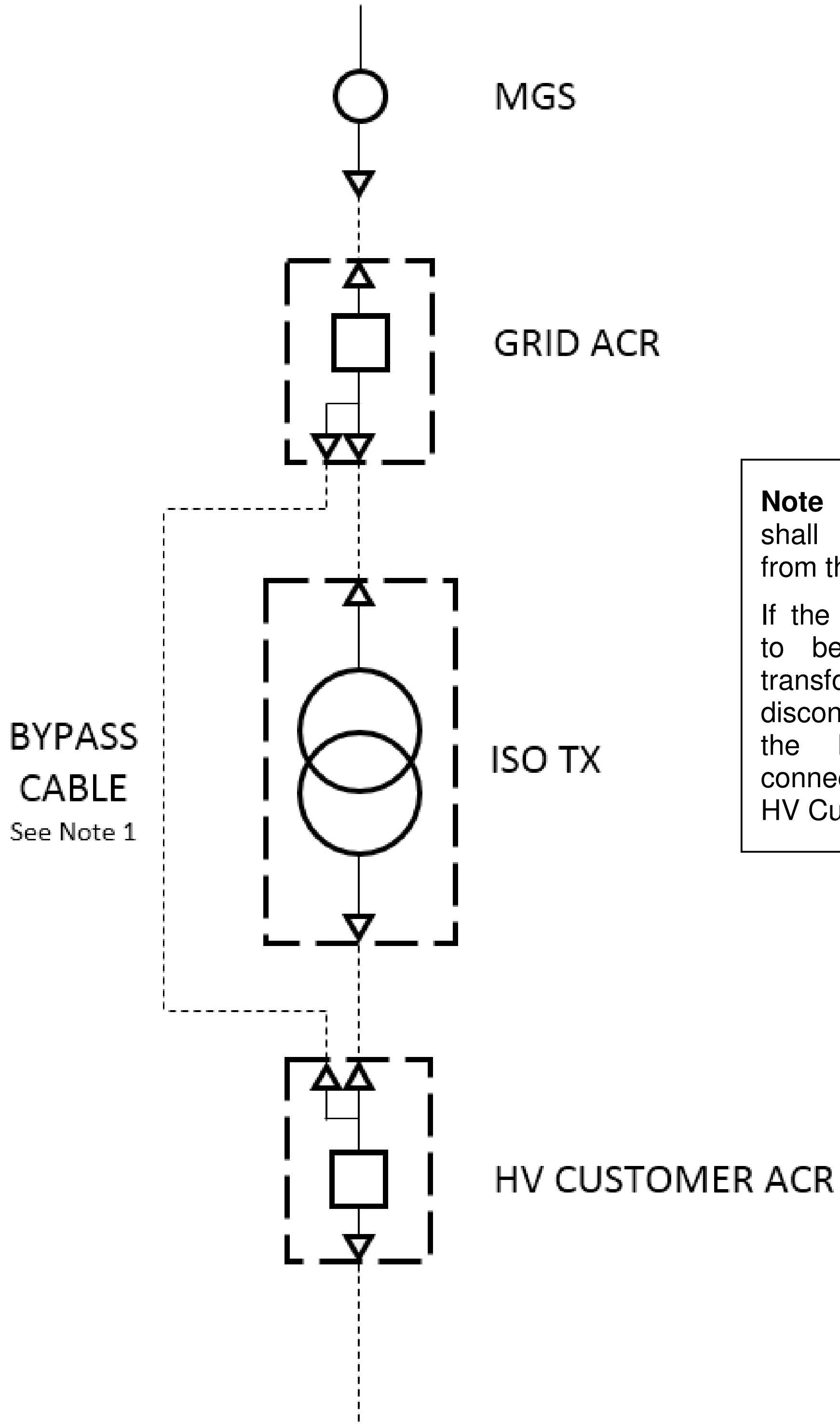
15 HV Customer Protection Coordination

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 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.

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.

Appendix 2 – Key Outcomes for Equipment Out of Service

	C-I-C	**C-I-C**	**C-I-C**	**C-I-C**	**C-I-C**
1	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
2	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
3	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
4	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

	C-I-C	**C-I-C**	**C-I-C**	**C-I-C**	**C-I-C**
5	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
6	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
7	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
8	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
9	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
10	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
11	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
12	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

	C-I-C	**C-I-C**	**C-I-C**	**C-I-C**	**C-I-C**
13	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
14	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
15	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
16	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
17	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
18	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
19	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
20	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
21	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

	C-I-C	**C-I-C**	**C-I-C**	**C-I-C**	**C-I-C**
22	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
23	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
24	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

	C-I-C	**C-I-C**	**C-I-C**	**C-I-C**	**C-I-C**
25	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
26	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
27	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
28	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

	C-I-C	**C-I-C**	**C-I-C**	**C-I-C**	**C-I-C**
29	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
30	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
31	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
32	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
33	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
34	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
35	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C

	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
36	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
37	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C
38	C-I-C	C-I-C	C-I-C	C-I-C	C-I-C