Standard

Protection of HV Busbars and Feeders Standard

Version 2.0

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Responsibilities

This document is the responsibility of the Secondary Systems Asset Strategy Team, Tasmanian Networks Pty Ltd, ABN 24 167 357 299 (hereafter referred to as "TasNetworks").

Please contact the Secondary Systems Asset Strategy Team Leader with any queries or suggestions.

- Implementation All TasNetworks staff and contractors.
- Compliance All group managers.

Minimum Requirements

The requirements set out in TasNetworks’ documents are minimum requirements that must be complied with by all TasNetworks team members, contractors, and other consultants.

The end user is expected to implement any practices which may not be stated but which can be reasonably regarded as good practices relevant to the objective of this document.

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### Record of revisions

<table>
<thead>
<tr>
<th>Section number</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wording added to sections 2.1 and 3.1.1 for frame earth leakage protection</td>
</tr>
<tr>
<td></td>
<td>Wording added to section 3.5.7 synchronism and voltage check</td>
</tr>
<tr>
<td></td>
<td>Wording added to section 3.5.8 under frequency protection</td>
</tr>
<tr>
<td></td>
<td>Wording added to section 4.2.9 synchronism and voltage check</td>
</tr>
<tr>
<td></td>
<td>Wording added to section 4.2.10 frequency protection</td>
</tr>
</tbody>
</table>
# Table of contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authorisations</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Responsibilities</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Minimum Requirements</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>List of figures</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>General</td>
<td>8</td>
</tr>
<tr>
<td>1.1</td>
<td>Purpose</td>
<td>8</td>
</tr>
<tr>
<td>1.2</td>
<td>Scope</td>
<td>8</td>
</tr>
<tr>
<td>1.3</td>
<td>Objective</td>
<td>8</td>
</tr>
<tr>
<td>1.4</td>
<td>Precedence</td>
<td>8</td>
</tr>
<tr>
<td>1.5</td>
<td>Abbreviations</td>
<td>9</td>
</tr>
<tr>
<td>1.5.1</td>
<td>Symbols</td>
<td>9</td>
</tr>
<tr>
<td>1.6</td>
<td>References</td>
<td>10</td>
</tr>
<tr>
<td>1.6.1</td>
<td>TasNetworks standards</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>Protection design policy</td>
<td>10</td>
</tr>
<tr>
<td>2.1</td>
<td>HV busbar protection</td>
<td>10</td>
</tr>
<tr>
<td>2.2</td>
<td>HV bus coupler protection and control</td>
<td>11</td>
</tr>
<tr>
<td>2.2.1</td>
<td>Auto close schemes</td>
<td>11</td>
</tr>
<tr>
<td>2.3</td>
<td>HV feeder protection and control</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>Protection arrangement</td>
<td>12</td>
</tr>
<tr>
<td>3.1</td>
<td>HV busbar protection</td>
<td>12</td>
</tr>
<tr>
<td>3.1.1</td>
<td>Frame earth leakage</td>
<td>12</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>3.1.2</td>
<td>Blocking scheme for busbar protection</td>
<td>13</td>
</tr>
<tr>
<td>3.2</td>
<td>HV feeder protection</td>
<td>13</td>
</tr>
<tr>
<td>3.3</td>
<td>HV feeder cross-boundary arrangements</td>
<td>13</td>
</tr>
<tr>
<td>3.4</td>
<td>HV busbar protection functionality</td>
<td>14</td>
</tr>
<tr>
<td>3.4.1</td>
<td>HIBP and LIBP</td>
<td>14</td>
</tr>
<tr>
<td>3.4.2</td>
<td>Arc detection and sudden pressure busbar protection schemes</td>
<td>14</td>
</tr>
<tr>
<td>3.5</td>
<td>HV feeder protection functionality</td>
<td>14</td>
</tr>
<tr>
<td>3.5.1</td>
<td>Overcurrent protection</td>
<td>15</td>
</tr>
<tr>
<td>3.5.2</td>
<td>Earth fault protection</td>
<td>15</td>
</tr>
<tr>
<td>3.5.3</td>
<td>Sensitive earth fault protection</td>
<td>15</td>
</tr>
<tr>
<td>3.5.4</td>
<td>Thermal overload protection</td>
<td>15</td>
</tr>
<tr>
<td>3.5.5</td>
<td>Negative phase sequence protection</td>
<td>16</td>
</tr>
<tr>
<td>3.5.6</td>
<td>Over voltage and under voltage protection</td>
<td>16</td>
</tr>
<tr>
<td>3.5.7</td>
<td>Synchronism and voltage check</td>
<td>16</td>
</tr>
<tr>
<td>3.5.8</td>
<td>Under frequency protection</td>
<td>16</td>
</tr>
<tr>
<td>3.5.9</td>
<td>Circuit breaker failure protection</td>
<td>16</td>
</tr>
<tr>
<td>3.5.10</td>
<td>Distance to fault</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>Protection application and control settings</td>
<td>16</td>
</tr>
<tr>
<td>4.1</td>
<td>HV busbar Protection</td>
<td>16</td>
</tr>
<tr>
<td>4.1.1</td>
<td>HIBP application</td>
<td>16</td>
</tr>
<tr>
<td>4.1.2</td>
<td>LIBP application</td>
<td>17</td>
</tr>
<tr>
<td>4.1.3</td>
<td>Protection settings</td>
<td>17</td>
</tr>
</tbody>
</table>
4.1.4...............................................................General information for HV busbar protection
7
4.1.5...............................................................Setting requirement for busbar protection
7
4.1.6...............................................................HIBP protection settings
7
4.1.7...............................................................LIBP protection settings
8
4.2...............................................................HV feeder protection
8
4.2.1...............................................................Live line setting group
8
4.2.2...............................................................Controls and indications for live line setting group
8
4.2.3...............................................................Time delayed overcurrent protection
8
4.2.4...............................................................Time delayed earth fault protection
9
4.2.5.............................................................Instantaneous elements for overcurrent and earth fault protection
9
4.2.6.............................................................Sensitive earth fault protection
10
4.2.7.............................................................Thermal overload protection
10
4.2.8.............................................................Negative phase sequence protection
10
4.2.9.............................................................Synchronism and voltage check
11
4.2.10............................................................Frequency protection
11
4.2.11.........................................................Protection of feeders with capacitor banks connected
11
4.2.12.........................................................General information supporting HV feeder protection settings
11
4.2.13.........................................................Other functions included in the HV feeder relay
12
4.2.14..........................................................Monitoring and control functions
12

List of figures

Figure 1..........................................HV busbar high impedance protection
12
Figure 2..........................HV bus and feeder back-up protection and feeder protection
........................................24

Figure 3.......................................................Busbar protection – blocking scheme
........................................24

Figure 4............................HV busbar protection – blocking scheme logic shown for one busbar
........................................25

Figure 5.................................HV busbar protection scheme employing directional blocking
........................................25
1 General

1.1 Purpose

The purpose of this document is to define the requirements and describe the application philosophy for the protection of High Voltage (HV) busbars and the protection and control of feeders connected to the HV network under the responsibility of Tasmanian Networks Pty Ltd (hereafter referred to as ‘TasNetworks’).

1.2 Scope

This document applies to the protection and control facilities installed within substations for HV busbars and feeders operating and emanating at voltages of 44 kV, 33 kV, 22 kV, 11 kV or 6.6 kV that are under the responsibility of TasNetworks. This standard also covers the installation of protection relays, owned by TasNetworks, installed remotely that provide input to the aforementioned protection schemes. This standard contains requirements for design of protection and control equipment and is to be applied to new installations as well as redevelopment of part or all existing installations.

This does not include the installation of fuses and reclosers.

1.3 Objective

TasNetworks requires design as covered in this standard to ensure:

(a) personnel and public safety;
(b) safety of TasNetworks’ assets;
(c) reliability and continuity of power supply to the power transmission network;
(d) that relevant Australian legal requirements are met;
(e) ease in operation and maintenance;
(f) minimum disruption to the HV supply system following a fault;
(g) that the requirements of TasNetworks’ corporate plan are met;
(h) that the exposure of TasNetworks’ business to risk is minimised; and
(i) that TasNetworks’ responsibilities under connection agreements are met.

1.1 Precedence

Any apparent conflict between the requirements of this standard and the law, mandatory requirements, industry standards, project specifications, non-statutory standards or guidelines, and any other associated documents should be brought to the immediate attention of TasNetworks for resolution and no action must be taken that might result in a breach of law or mandatory standard.

Where there may be a conflict between the requirements of this standard and any:

(a) law, mandatory requirement or industry standard, then that law or statutory requirements will prevail over this standard;
(b) non-mandatory standard, or guideline, then this standard will prevail over that standard or guideline; or
(c) project specification, then a deviation must be specifically requested and approved in writing by TasNetworks’ Secondary Systems Asset Strategy Team Leader.
Approval for a deviation to this standard may only be accorded if it does not reduce the quality of workmanship, pose a safety risk to personnel or equipment and does not deviate from the intent of this standard.

### 1.1 Abbreviations

- **CB**: Circuit Breaker
- **CBF**: Circuit Breaker Failure
- **CT**: Current Transformer
- **DNP3.0**: Distributed Network Protocol version 3.0
- **EHV**: Extra High Voltage
- **HMI**: Human Machine Interface
- **HV**: High Voltage
- **IEC**: International Electrotechnical Commission
- **I/O**: Inputs and Outputs
- **LAN**: Local Area Network
- **MCB**: Miniature Circuit Breaker
- **MPOLD**: Metering and Protection One Line Diagram
- **NOCS**: Network Operational Control System
- **POW**: Point on Wave
- **SCADA**: Supervisory Control and Data Acquisition
- **SOE**: Sequence of Events
- **TCS**: Trip Circuit Supervision
- **VT**: Voltage Transformer

### 1.1.1 Symbols

- \( R_{s1} \): System source resistance to EHV busbar in p.u on 100 MVA
- \( X_{s1} \): System source reactance to EHV busbar in p.u. on 100 MVA
- \( R_{t1} \): Positive sequence resistance of supply transformer on transformer rating at nominal ratio
- \( X_{t1} \): Positive sequence reactance of supply transformer on transformer rating at nominal ratio
- \( R_{t0} \): Zero sequence resistance of supply transformer(s) on transformer rating
- \( X_{t0} \): Zero sequence reactance of supply transformer(s) on transformer rating
- \( R_{f1} \): Positive sequence resistance of HV feeder on 100 MVA
- \( X_{f1} \): Positive sequence reactance of HV feeder on 100 MVA
- \( R_{f0} \): Zero sequence resistance of HV feeder on 100 MVA
- \( X_{f0} \): Zero sequence reactance on HV feeder on 100 MVA
1.2 References

As a component of the complete specification for a system, this standard is to be read in conjunction with other standards and documents as applicable. In particular, this includes the project specifications and the literature mentioned below.

1.2.1 TasNetworks standards

Protection of HV Capacitor Banks Standard R245703
Protection and Control of Supply Transformers Standard R245707
DC Distribution System Standard R522693
High Voltage System Standard R565983
SCADA Systems Standard R246439
Testing, Commissioning and Training Standard R246497
Secondary Equipment Testing Standard R244782
HV and LV Cable System Standard R590630
General Substation Requirements Standard R522687

2 Protection design policy

2.1 HV busbar protection

The protection of HV busbars shall be designed to ensure that:

(a) faults on any part of an HV busbar installation are detected by a high speed independent protection scheme and a back-up protection scheme capable of initiating fault clearance as shown in figure 1 and figure 2. Back-up protection is provided by overcurrent and earth fault elements in the incomer relay or as part of the transformer protection and in the bus coupler relay;

(b) at substations with more than one busbar or busbar section, the busbar protection shall be capable of discrimination between the busbars to ensure that the minimum number of circuit breakers (CB)s are tripped to clear the fault;

(c) the protection scheme is arranged to ensure that no ‘dead zone’ exists and no part of the primary busbar system is unprotected;

(d) the protection scheme is capable of independently tripping the CBs so as to clear the fault within 100 milliseconds;

(e) the busbar protection shall remain stable for all through fault conditions; and

(f) the busbar protection shall have auxiliary tripping relays to trip all circuits on the busbars. Such auxiliary relays shall have adequately rated contacts, be electrically-reset and shall have sufficient spare contacts to cater for the final proposed development of the substation.

Note: HV metal enclosed busbar protection methods utilising physical principles other than electrical quantities, e.g. arc detection or sudden pressure devices, are considered as suitable busbar protection provided they conform to the requirements outlined in this document.
2.1 HV bus coupler protection and control

Each HV bus coupler CB shall be fitted with a relay of identical type as those used on the feeder and incomer CBs. This shall include facilities required for CB operation, interlocks and trip circuit supervision as the main functions. The protection function of the relay is to be utilised for the back-up protection only.

2.1.1 Auto close schemes

Automatic close schemes for bus coupler CBs shall be implemented as follows:

(a) For a particular substation arrangement, the HV bus coupler CB may be designed to be open under normal conditions to limit the fault level on the HV feeders. In the event that one transformer is tripped, the bus coupler CB must be closed automatically to maintain continuity of supply.

(b) Operation of any busbar main or back-up protection scheme shall block the auto close scheme from operating.

(c) The auto closing scheme on the bus coupler CB shall be capable of being enabled and disabled locally or remotely by an operator command.

(d) With the exception of auto close, facilities for bus coupler CB protection, operation and control shall be identical to those applied to incoming and outgoing feeders.

(e) The logic for the bus coupler CB auto close will be implemented within the bus coupler relay. However, the project specification will describe the preferred location for the logic as it is acceptable to utilise the main substation remote terminal unit (RTU) to perform this function.

2.1 HV feeder protection and control

For most installations a single relay is used to provide protection, control, metering and monitoring for each HV feeder. On sub-transmission or critical infrastructure HV feeders, line differential protection and direct inter-tripping has been installed in addition to overcurrent and earth fault protection. Since the merger of the DNSP and TNSP the TasNetworks policy for protecting HV feeders is not to provide duplicated protection and control for any new installations. Where line differential protection is required, a separate overcurrent and earth fault protection relay is not required.

The HV feeder protection and control scheme shall be designed to ensure that:

(a) the protection scheme shall be adaptable and adequate for the protection of the entire HV feeder including any in-zone transformer;

(b) the feeder protection must grade with downstream protection to maintain coordination;

(c) faults on any part of the HV feeder shall be detected by at least two protection devices capable of fault clearance. For HV feeders with only one relay, it is imperative that in the event of relay failure, faults shall be detected and cleared by the bus coupler or transformer incomer protection;

(d) where line differential protection is provided, the relay must have the ability to also provide overcurrent and earth fault protection;

(e) distribution substation transformer inter-tripping is deployed when two or more distribution substation transformers are paralleled at LV for load reasons. The intertripping is required to prevent back feeding transformer faults; and

(f) where embedded generation is connected to the HV feeder it shall be stated in the project specification. In this case the integrity of TasNetworks’ assets shall be maintained as follows:

   (i) A voltage transformer shall be installed on the feeder in order to detect feeder voltage and apply the appropriate auto re-closing regime.
(ii) Where a busbar blocking scheme is utilised the relay should be directional and send a blocking signal for forward looking faults only.

(iii) The protection on the feeder with the embedded generation should be directional to maintain coordination with adjacent feeders.

(iv) Provision should be made for an inter-trip from the embedded generator to the TasNetworks feeder CB.

3 Protection arrangement

3.1 HV busbar protection

The busbar protection scheme shall consist of any of the following types:

(a) High Impedance Busbar Protection (HIBP) for each bus section.

(b) Low Impedance Busbar Protection (LIBP) for each bus section or all bus sections if the IED is capable.

(c) Arc Flash Detection where metal enclosed switchgear and busbars are supplied.

(d) Frame Earth Leakage Protection where existing.

(e) Sudden Pressure Detection where such devices are capable of application to metal enclosed switchgear and busbars.

(f) Overcurrent Blocking.

In the case of LIBP or HIBP schemes, the main protection relay(s) are preferred to be microprocessor technology to allow for self-supervision and waveform capture during operations. The busbar protection scheme must have the following fundamental features:

(g) Provide zones of protection, consistent with the busbar configuration, so that the minimum number of CBs are tripped to clear a busbar fault.

(h) Initiate CB tripping via hard wiring direct to the ‘A’ and ‘B’ trip coils of each associated CB.

(i) HIBP and LIBP schemes shall be equipped with CT supervision for alarm.

(j) Arc flash or sudden pressure detection systems shall be checked by an independent high speed overcurrent device.

(k) For arc flash and sudden pressure detection systems, operation must trigger the waveform capture in all feeder, incomer and bus coupler relays to allow for an accurate determination of the correct operation of the equipment.

(l) Where possible, arc flash and pressure detection systems should be designed to allow testing of each sensor without removing the busbars from service or opening service hatches which will expose live equipment.

3.1.1 Frame earth leakage

TasNetworks does not prefer the application of frame earth leakage for HV busbar protection on new HV switchboard installations; however, for existing switchboards where the installation of high impedance, low impedance, arc or pressure protection methods are not feasible to replace an existing frame earth leakage protection scheme, the frame earth leakage detection method shall be retained. In this case, the frame earth leakage scheme shall be arranged in the following way:

(a) The frame earth leakage protection scheme shall be accompanied by an overcurrent blocking protection scheme.
(b) The earth leakage relays shall be checked by the earth fault element connected to the HV neutral of the supply transformer(s). In the case of two supply transformers with a bus coupler CB, both transformer check relays will check all of the bus section earth leakage relays.

(c) Each bus section shall have a dedicated earth leakage relay.

(d) A time delay of 60ms shall be applied for the trip operation of the faulted bus section. All breakers connecting to the faulted bus section shall be tripped by the frame earth leakage scheme.

(e) A further 300ms time delay shall be applied to back-trip adjacent bus sections. On operation, all breakers connecting to the adjacent bus sections shall be tripped by the frame earth leakage scheme.

3.1.1 Blocking scheme for busbar protection

TasNetworks does not prefer the application of a blocking scheme for HV busbar protection on new HV switchboard installations; however, a refurbishment of a substation may demand that the existing overcurrent blocking method is retained. The blocking scheme shall be arranged in the following way:

(a) The blocking scheme shall utilise the instantaneous or starting elements of the overcurrent and earth fault protection covering each in-feed to the relevant busbar section in conjunction with the phase and earth fault instantaneous elements on the feeder protection relays as shown in figure 3.

(b) A time delay of 50 to 100 ms shall be applied to the operation of the incomer protection in order to avoid a contact race that may result in an inadvertent outage due to incomer instantaneous overcurrent or earth fault elements operating before the feeder overcurrent or earth fault elements. Refer to figure 4 for the logic diagram.

(c) Where a source is connected to the feeder due to a parallel connection with a feeder from another substation or a generator on a particular feeder, the blocking scheme shall be supplemented by the application of directional elements applied in conjunction with the feeder instantaneous elements such that the particular feeder instantaneous protection does not operate for current inflow to the faulted busbar.

3.1 HV feeder protection

The arrangement of the HV feeder protection shall:

(a) consist of a single multi-function feeder protection relay;

(b) provide line differential protection for sub-transmission or critical infrastructure HV feeders;

(c) provide for direct inter-tripping between downstream substation protection where required;

(d) initiate CB tripping via hard wiring direct to the CB ‘A’ and ‘B’ trip coils respectively;

(e) provide local and remote control of the CB;

(f) be fed from the protection cores of the feeder current transformers (CT); and

(g) use an appropriate voltage transformer (VT) secondary circuit for its voltage input. Any voltage input to the protection relay shall be routed via an MCB.

3.1 HV feeder cross-boundary arrangements

In some instances, HV feeders will also have a line differential protection relay provided by the customer of the feeder circuit. TasNetworks shall still provide a feeder relay with enabled protection functions as backup to the line differential protection. Additional to tripping the local CB, the TasNetworks relay shall provide a contact for inter-tripping of the remote end CB via the line differential protection relay.

TasNetworks shall provide the following facilities for the customer’s line differential protection relay:
Protection of HV Busbars and Feeders Standard

(a) CT secondary current supply from the appropriate protection CT.
(b) DC auxiliary voltage via a dedicated circuit originating from the ‘B’ battery. TasNetworks protection supply is derived for the ‘A’ battery.
(c) Tripping supplies from the appropriate TasNetworks circuitry.

The following signals shall be directed from the customer’s relay to the TasNetworks relay:
(d) Protection trip and inter-trip signal for alarm logging in TasNetworks’ relay.
(e) Auto reclose blocking signal.
(f) Blocking of CB closing.

Note: All tripping and inter-tripping signals from the customer’s relay shall be hardwired to the TasNetworks CB trip coils.

3.1 HV busbar protection functionality

3.1.1 HIBP and LIBP

The following protection functionality shall be provided in each protection scheme:
(a) Capability to detect and operate for all types of shunt faults on the HV busbar.
(b) Phase segregated measurement and phase identification for the faulted phase.
(c) Insensitive to harmonic and dc components in the fault current.
(d) Stabilisation for faults external to the bus zone and CT saturation.
(e) Capability of operation from one Amp CT secondary connections or five Amp CT secondary connections. It shall be stated in the project specification if five Amp secondary inputs are required. The relays shall be capable of continuously withstanding at least two times the nominal rating.
(f) Provision of supervision of current inputs to detect open circuited CTs.

Note 1: In the unlikely event that CT secondary circuits are required to be switched, HIBP shall not be applied.

Note 2: Application of HIBP or LIBP on HV busbars requires each HV feeder and bus section to have CT inputs to busbar protection. If during protection upgrading of an existing substation, the required CTs for unit busbar protection does not exist or installation of new CTs cannot be justified, then the existing protection scheme should be retained.

3.1.1 Arc detection and sudden pressure busbar protection schemes

Arc detection and sudden pressure busbar protection schemes shall provide the following functionality:
(a) Capability to detect all faults on the busbar.
(b) Trip only the faulted section of the busbar and remain stable for faults in other busbar zones.
(c) Capable of identifying the faulted chamber i.e. cable, bus, circuit breaker chambers, etc.
(d) Indication of the faulted busbar zone.

3.1 HV feeder protection functionality

The HV feeder protection relay shall have at least two independent setting groups.
Protection of HV Busbars and Feeders Standard

The following sections define the functions that shall be available in each setting group of the HV feeder protection relay.

3.1.1 Line differential protection
Where line differential protection is required, the relays selected shall be multi-function relays and shall:
(a) be capable of digital biased differential protection function;
(b) be capable of communications over either optical fibre or metallic pilot cables;
(c) be capable of in-zone transformer protection;
(d) be capable of three ended differential protection;
(e) be able to cater for small tapped loads on the HV feeder; and
(f) have capability to transfer trip signals from the remote substation(s).

3.1.1 Overcurrent protection
Overcurrent protection shall be provided to detect phase faults on the HV feeder.
The protection shall have:
(a) four independent selectable overcurrent elements;
(b) an instantaneous characteristic immune against operation for inrush current conditions associated with the energisation of distribution transformers connected to a feeder and capable of being blocked by the operation of the auto re-close function;
(c) selectable delayed operation characteristics of definite time and inverse time selectable between the IEEE and the IEC standard inverse time characteristics; and
(d) capability of both directional and non-directional operation.

3.1.1 Earth fault protection
The earth fault protection shall have the same characteristics and capability as detailed above for the overcurrent protection. It is preferred the earth fault protection to respond only to the fundamental component of current.

3.1.2 Sensitive earth fault protection
The sensitive earth fault protection shall be capable of:
(a) both directional and non-directional operation;
(b) detecting high impedance earth fault currents on the HV feeder having a minimum primary value of 5 Amps;
(c) operating on a definite time delay characteristic; and
(d) responding only to the fundamental component of current.

3.1.1 Thermal overload protection
This protection shall be provided for cabled feeders or other devices such as motors or transformers. This protection shall not be enabled unless identified within the project specification.
3.1.2 Negative phase sequence protection

Negative phase sequence protection shall be provided to respond to high values of negative sequence phase current. This protection may be used for detection of low phase to phase feeder faults. It shall not be enabled unless identified within the project specification.

3.1.3 Over voltage and under voltage protection

Over and under voltage protection shall be provided but in most applications, this protection will not be enabled. This protection shall not be enabled unless identified within the project specification.

3.1.4 Synchronism and voltage check

Where embedded generation is installed on the feeder, the protection relay must be capable of synchronism and voltage checking for blocking of CB closure.

3.1.5 Under frequency protection

Under frequency protection shall be available in order for the HV feeder to be included in the Tasmanian Under Frequency Load Shedding (UFLS) scheme if required. The relay must be able to provide multiple independent frequency stages with dedicated time delays and rate of change of frequency functionality combined with a set frequency level.

3.1.6 Circuit breaker failure protection

Circuit breaker failure (CBF) protection shall not be installed on the feeder CB. However, CBF shall be applied to the incomer CB and the bus section CB. For this protection, the tripping time delay setting shall be 250 ms after initiation by main protection.

3.1.7 Distance to fault

The feeder relay shall be capable of calculating distance or impedance to fault and send this information to the NOCS via the SCADA system.

4 Protection application and control settings

4.1 HV busbar Protection

The HV busbar protection covered by this standard will be applied to metal enclosed switchgear.

4.1.1 HIBP application

The following principles shall be applied:

(a) The DC supply shall be derived from the ‘A’ DC supply system.

(b) One CT core per connection is required to support the HIBP scheme. A check zone is not required for HV applications.

(c) All CTs associated with the HIBP shall have the same ratio and performance designation.

(d) The protection shall employ overlapping CTs for bus section applications where there is usually a protection zone boundary.
Protection of HV Busbars and Feeders Standard

(e) The alarm from the CT supervision relay shall be connected to the SCADA.

4.1.1 LIBP application

The requirements for LIBP application is the same as HIBP except for the following:

(a) The DC supply shall be derived from the ‘A’ DC supply system.
(b) All CTs associated with the LIBP do not require to have the same ratio and performance designation.
(c) If required, CBF protection for HV CBs may be incorporated within the LIBP scheme.

4.1.1 Protection settings

The setting requirements mentioned in this document are not the full requirement for settings but represent the basic setting requirements for the protection. The contractor shall supply to TasNetworks the complete list of settings and criteria to be met prior to tripping, including configuration details, in accordance with the manufacturers setting sheets.

4.1.2 General information for HV busbar protection

The following general information shall be supplied with the HV busbar protection settings:

(a) Name of the substation at which the protected busbar is located.
(b) Busbar identification.
(c) CT ratio.
(d) Manufacturer of protection equipment.
(e) Model number.
(f) Positive sequence maximum and minimum system source impedances to substation EHV busbar \((R_s + jX_s) - \text{p.u. on 100MVA base}\).
(g) Positive sequence impedance of substation transformer(s) \((R_t + jX_t) - \text{p.u. on transformer rating at nominal ratio}\).
(h) Zero sequence impedance of substation transformer(s) \((R_0 + jX_0) - \text{p.u. on transformer rating}\).
(i) Substation earth mat resistance (ohms).
(j) Maximum load current supplied by each supply transformer (Amps).
(k) Maximum and minimum three phase and single phase to ground fault at the HV busbar.
(l) Existing protection scheme and settings (if applicable).

4.1.1 Setting requirement for busbar protection

The primary operating current of the protection shall not exceed 30 per cent of the minimum fault current at the protected busbar. It should be noted that the minimum fault current is likely to be a phase to earth fault with one transformer in service where Yyn0 supply transformers are installed.

4.1.2 HIBP protection settings

The following is a list of settings to be provided for the HIBP busbar protection:

(a) The effective primary operating current. The protection shall be set to not operate for an inadvertent CT open circuit on the heaviest loaded feeder.
(b) Operating voltage for the protection.
Protection of HV Busbars and Feeders Standard

(c) Value of stabilising resistor.
(d) The CT supervision shall be set to operate for current less than 10 per cent of load current on the lightest loaded feeder, generating an alarm after 3 seconds.

4.1.1 LIBP protection settings

The following is a list of settings to be provided for the LIBP busbar protection:

(a) The effective primary operating current. The protection shall be set to not operate for an inadvertent CT open circuit on the heaviest loaded feeder.
(b) Slope settings characteristic.
(c) The CT supervision shall be set to operate for current less than 10 per cent of load current on the lightest loaded feeder, generating an alarm after 3 seconds.

4.1 HV feeder protection

4.1.1 Live line setting group

A live line setting group is intended for selection when vegetation management is being conducted and shall be configured in each outgoing feeder relay with the following parameters:

(a) Auto re-close disabled.
(b) Overcurrent, earth fault and sensitive earth fault elements definite time 0.1 seconds.
(c) Overcurrent, earth fault and sensitive earth fault operating values shall be as per the default setting group. The default setting group is that setting group applied to the protection during normal service.

4.1.1 Controls and indications for live line setting group

The following controls and indications are to be configured on each outgoing feeder relay, on the local SCADA HMI and the remote SCADA:

(a) Live line settings enabled/disabled.
(b) Auto re-close enabled/disabled.
(c) The application of the live line setting group shall disable the auto re-close and the indication shall reflect its disabled status when the live line settings group is enabled.
(d) The auto re-close shall remain disabled when the live line setting group is removed from service.

4.1.1 Line differential protection

Settings for the line differential protection should be applied for the given line parameters including the charging current and the maximum fault level. Hence the settings need to be calculated individually according to relay documentation. However, the settings are likely to be in the order of minimum operation equal to 0.2 In with dual slopes of 0.3 and 1.5 for a restrained characteristic.

4.1.2 Time delayed overcurrent protection

Under normal system operation, the requirement for overcurrent protection settings is as follows:

(a) The time delay characteristic for the overcurrent protection shall preferably be an IEC inverse time characteristic.
Protection of HV Busbars and Feeders Standard

(b) The overcurrent pick-up setting should be above maximum cold load pick-up and above maximum feeder load with 5 years load forecast.

(c) In any case, the particular inverse time characteristic applied shall be graded with the time delay characteristics of any downstream protection. However, compatibility may not be able to be achieved if the difference between the minimum fault level at the substation HV busbar and the maximum load current is insufficient to allow the application of an inverse time characteristic thus requiring the application of a definite time characteristic.

(d) The feeder protection setting should grade with upstream over current protection settings for all fault levels and types with a safety margin of at least 0.3 seconds.

(e) Inclusive of the feeder CB operating time, the time delayed over current protection shall be set to clear a three phase fault located near to the substation HV busbar in a time not exceeding 0.5 seconds.

(f) In the event that a source is located on the feeder or at the remote line end, a directional characteristic may need to be applied.

(g) The operation of the overcurrent protection shall initiate auto re-closure of the feeder CB.

(h) Where the protection is required to detect faults at the end of a long feeder and where the protection settings are above the equivalent fault levels at the end of the feeder, voltage controlled overcurrent protection shall be applied.

4.1.1 Time delayed earth fault protection

Under normal system operation, the requirement for earth fault protection settings is as follows:

(a) The pick-up of earth fault relay is preferred to be in the range of 40-200A primary.

(b) The time delay characteristic for the earth fault protection shall be compatible with the time delay characteristic of any downstream and upstream earth fault protection.

(c) The feeder earth fault protection setting should grade with upstream earth fault protection setting for all fault levels with at least 0.3 seconds safety grading margin.

(d) Inclusive of the feeder CB operating time, the time delayed earth fault protection shall be set to clear a phase to earth fault located close to the substation HV busbar in a time not exceeding 0.5 seconds.

(e) In the event that an earthed source is located on the feeder or at the remote line end, a directional characteristic may need to be applied.

(f) The operation of the earth fault protection shall initiate auto re-closure of the feeder CB.

4.1.1 Instantaneous elements for overcurrent and earth fault protection

The requirement for overcurrent and earth fault instantaneous protection settings are as follows:

(a) Under conditions of maximum source impedance, the instantaneous function of the overcurrent and earth fault protection shall be set to detect phase to phase and phase to earth faults respectively, located beyond the first distribution pole mounted re-closer from the substation. The DC asymmetrical factor should be considered in calculation of phase to phase and phase to earth faults.

(b) Where a Shunt Capacitor Bank (SCB) installation is directly connected to the feeder, the instantaneous function of the feeder protection shall be set such that faults located between the reactor and the capacitor terminals are not detected by this function. When discrimination between close-in feeder faults and faults between the reactor terminals and the SCB cannot be achieved by settings, a signal from the SCB instantaneous protection shall block the feeder protection initiated CB auto re-close function.
Protection of HV Busbars and Feeders Standard

(c) Where there is a considerable length of cable between feeder CB and SCB CB, the instantaneous protection of the feeder CB shall be set and cover the whole length of the cable even if grading coordination with instantaneous element of SCB CB cannot be achieved.

(d) The instantaneous overcurrent element shall be set such that the protection shall remain stable for the inrush currents of distribution transformers along the feeder during manual energisation of the feeder either via NOCS or by site personnel.

(e) The overcurrent and earth fault instantaneous protection functions shall initiate auto re-closure of the circuit breaker in all cases except when the protection operates during manual energisation events. In such cases the auto re-close function shall be locked out of service.

(f) Following initiation, the operation of the auto re-close function shall lock the instantaneous function out of service for the duration to the reclaim timer of the auto re-close function. This is to allow the operation of protection elements in pole mounted re-closers.

(g) In the event that instantaneous functions or short time delay definite time functions are required for application in a blocking scheme for busbar protection, a second instantaneous function shall be enabled in the feeder protection relay. The current setting shall be 0.3 times the minimum fault current for faults located on the busbar, lower than the current settings on the instantaneous elements on the transformer incomer protection and 1.5 times the maximum load current of the feeder. Where possible, the starting element of overcurrent and earth fault protection of the feeder relay should be used to send the blocking signal to upstream protection.

4.1.1 Sensitive earth fault protection

The parameters below shall be followed when applying and setting the sensitive earth fault protection:

(a) In order to ensure that the protection operates for actual fault conditions as opposed to unbalanced conditions caused by paralleling of substation feeders in the field, the operation of the feeder sensitive earth fault protection shall be checked by the operation of the sensitive earth fault check relay connected to the CTs in all supply HV neutral, the earth connections of the relevant supply transformers. Note that the check function will not ensure against sensitive earth fault operation due to unbalanced conditions when paralleling feeders associated with different substations via single phase switching devices.

(b) The current setting for the sensitive earth fault function shall be set to 10 Amps.

(c) In the event that a power supply source is located on the feeder or at the remote line end, a directional characteristic may need to be applied. For this application a negative phase sequence polarising quantity shall be applied if the zero sequence polarising quantity proves to be inadequate.

(d) The time delay setting for the feeder sensitive earth fault protection shall be 5 seconds.

(e) The operation of the sensitive earth fault relay shall not initiate auto re-closing of the feeder CB.

4.1.1 Thermal overload protection

The requirement for thermal overload protection application and settings are as follows:

(a) For feeders consisting of substantially overhead conductors, the thermal overload protection shall be disabled.

(b) The project specification shall detail the settings for the thermal overload protection if required for application to feeders consisting substantially of HV cable.

4.1.1 Negative phase sequence protection

This protection shall not be enabled unless requested in the project specification.
4.1.2 Synchronism and voltage check

Where embedded generation is connected to an HV feeder, the HV feeder protection relay must be configured to apply a synchronism and voltage check before allowing the CB to be closed. The settings include a voltage, phase and frequency difference. The settings to be applied must be sought from TasNetworks.

4.1.3 Frequency protection

Where under frequency load shedding is to be applied on HV feeders, a frequency element will be enabled in each relay only tripping the load of the associated feeder. The settings of the frequency elements will be supplied in the project specification as per the settings of the Tasmanian Under Frequency Load Shedding (UFLS) scheme.

4.1.4 Protection of feeders with capacitor banks connected

In order to ensure that the feeder CB does not trip for faults on the capacitor bank installation, the following protection arrangements shall be implemented:

(a) The time delayed protection associated with the capacitor bank shall grade with the time delayed elements of the feeder protection.

(b) The high-set overcurrent and earth fault elements on the capacitor bank shall be set lower than those on the feeder to cover faults located between the terminals of the reactor and the terminals of the capacitor.

(c) The high-set overcurrent on the feeder and capacitor bank protection shall be set above maximum capacitor inrush current as calculated according to Appendix D of IEEE standard C37.99-2000 and consideration of detuning reactor.

(d) The time delayed overcurrent protection of feeder and capacitor bank CB shall not operate for capacitor inrush current. For this purpose definite time characteristic with low time setting is not recommended.

(e) If the feeder is a dedicated feeder for capacitor bank, auto re-close functionality of feeder relay shall be disabled.

(f) The feeder protection should inter-trip the capacitor bank CB.

4.1.1 General information supporting HV feeder protection settings

The following general information shall be supplied with the feeder protection settings:

(a) Name of substation at which the feeder protection is located.

(b) CT and VT ratios.

(c) Manufacturer of protection equipment.

(d) Model number.

(e) Positive sequence maximum and minimum system source impedances to substation EHV busbar \((R_{s1} + jX_{s1} - \text{p.u. on } 100\text{MVA base})\).

(f) Positive sequence impedance of substation transformer(s) \((R_{t1} + jX_{t1} - \text{p.u. on transformer rating at nominal ratio})\).

(g) Zero sequence impedance of substation transformer(s) \((R_{t0} + jX_{t0} - \text{p.u. on transformer rating})\).

(h) Feeder positive sequence impedance \((R_{f1} + jX_{f1} - \text{p.u. on } 100\text{MVA})\).

(i) Feeder zero sequence impedance \((R_{f0} + jX_{f0} - \text{p.u. on } 100\text{MVA})\).
Protection of HV Busbars and Feeders Standard

(j) Maximum load current on feeders(s) based on 3-5 years load forecast.
(k) All grading coordination calculation and characteristics.
(l) Maximum and minimum fault levels calculation for both three phase and single phase to ground fault at locations where grading coordination is required.

4.1.1 Other functions included in the HV feeder relay

The following requirements shall be applied for the additional functions of the HV feeder relay:

(a) Three phase auto reclose facility which includes:
   (i) The ‘dead time’ setting shall be 20 seconds and the ‘reclaim time’ setting shall be 30 seconds.
   (ii) Where there is a source located along the feeder, a feeder auto re-close operation shall only be permitted in the event of a ‘live bus’ and ‘dead line’ condition being fulfilled.
   (iii) The auto re-close function shall be a repetitive single shot.
   (iv) The auto re-close function shall be capable of being switched out of service both manually and via SCADA. When switched out of service during live line work, any protection normally blocked by the re-close function shall be unblocked.

(b) Synchronising and voltage check function shall be enabled in the event that the feeder has a generating source connected to it. The operation of the auto re-close function shall be contingent on the synchronising and voltage conditions being fulfilled.

(c) Trip Circuit Supervision (TCS) shall be arranged to supervise the health of each tripping circuit and trip coil of the CB in both the open and the closed states.

(d) The fault locator shall measure the impedance to the fault and shall display the impedance in ohms. If the relay cannot display fault impedance, a ratio of one ohm per kilometre should be used.

(e) Oscillographic fault recording and Sequence of Events (SOE) recording includes:
   (i) time synchronising for this feature shall be via an IRIG B input;
   (ii) the oscillographic fault recorder shall be set to record 0.5 seconds of pre-fault data and 1.5 second of post fault data;
   (iii) the oscillographic channels shall record all phase voltages and all phase currents including the residual current;
   (iv) the digital signals shall be arranged to record all protection tripping operations and CBF protection operation; and
   (v) under voltage and residual overcurrent elements shall be programmed to trigger the fault recorder; and

(f) Self-monitoring and diagnosis functions shall be arranged such that the feeder protection relay ‘watchdog’ contact shall, on operation, be set to block the protection relay and to provide an alarm to the NOCS. The watchdog contact shall be wired to the bus section RTU.

4.1.1 Monitoring and control functions

The monitoring and control functions shall be included in the feeder relay. These functions are:

(a) CB and disconnector status monitoring via SCADA to the NOCS.
(b) CB control.
(c) Disconnector interlocking.
(d) CB condition monitoring.
(e) CB racked in/out position status.

(f) CB earth position.

(g) The capability to change protection setting groups and in particular shall be capable of selecting and displaying the live line setting group, the default setting group and the auto re-close function ‘enabled’ and ‘disabled’.

(h) The communication protocol between HV feeder relay and station RTU should be via DNP3.0 or IEC 61850 protocol.

(i) For metering purposes, the HV feeder relay shall be supplied by the selected voltage of either the ‘A’ bus or ‘B’ bus voltage transformers.

(j) The circuit breaker control functions for remote and manual operations shall be derived from the ‘A’ battery.

Figure 1 HV busbar high impedance protection
Figure 2  HV bus and feeder back-up protection and feeder protection

Figure 3  Busbar protection – blocking scheme
Figure 4  HV busbar protection – blocking scheme logic shown for one busbar

Figure 5  HV busbar protection scheme employing directional blocking
Appendix 1 – Standard secondary equipment

Where possible standard equipment must be used to ensure the most efficient design and maintenance practices are able to be undertaken. The following table shows the standard equipment types that are currently used by TasNetworks in HV substation protection installations.

<table>
<thead>
<tr>
<th>Device number</th>
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<td>P1J269366</td>
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