Standard

Protection and Control of Supply Transformers

R245707

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Authorisations

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Review cycle	30 months	

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.

Record of revisions

Section number	Details
1.2	Clarity provided on scope of transformers and clarity on retro-fitting vs new complete schemes
1.4	Deviation from standard from project specification modified
1.5	Removed the SEF acronym reference
1.6	Added cyber and IEC 61850 standard references
Figure 1	Removed the 564ST relay from the typical arrangement
2.2.2	Removed section for 564ST relay
3.3	Removed section for 564ST relay
4	Added reference to the new IEC 61850 standard and the cyber requirements
4.6	Removed section for 564ST relay
4.8.1	Added requirement for remote setting of AVR target voltage
4.8.2	Changed the default target voltage from 1.02 to 1.0 p.u.
Appendix 1	Appendix removed

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1 General

1.1 Purpose

The purpose of this document is to define the requirements for the application of protection and control to supply transformers under the responsibility of TasNetworks.

1.2 Scope

This standard contains requirements for application design of all new and complete supply transformer protection and control scheme installations under the responsibility of TasNetworks. This standard does not apply to the retro-fitting of individual relays of existing transformer protection and control schemes; however, when retro-fitting individual relays, other than additional requirements listed in the project specification, existing functions must be maintained.

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) that the requirements of the National Electricity Rules are met;

(f) ease in operation and maintenance;

(g) minimum disruption to the EHV supply system following a fault;

(h) that the requirements of TasNetworks’ strategic plan are met; and

(i) that the exposure of TasNetworks’ business to risk is minimised.

1.4 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.

1.5 Abbreviations

AVR	Automatic Voltage Regulator
CB	Circuit Breaker
CBF	Circuit Breaker Failure
CT	Current Transformer
DC	Direct Current
EHV	Extra High Voltage
HV	High Voltage
IBPCU	Integrated Bay Protection and Control Unit
IED	Intelligent Electronic Device
LED	Light Emitting Diode
LV	Low Voltage
I/O	Inputs and Outputs
MCB	Miniature Circuit Breaker
MTA	Maximum Torque Angle
NER	National Electricity Rules
NOCS	Network Operational Control System
OLTC	On-Load Tap Changer
PTP	Precision Time Protocol
SCADA	Supervisory Control and Data Acquisition
SOE	Sequence of Events
TCS	Trip Circuit Supervision
VT	Voltage Transformer

1.6 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 standards mentioned below.

Secondary Cable and Wiring Standard (R1744962)

Secondary Equipment Testing Standard (R244782)

Protection of EHV Busbars Standard (R246414)

EHV Current Transformer Standard (R522690)

EHV Voltage Transformer Standard (R586391)

Extra High Voltage System Standard (R586386)

General Substation Requirements Standard (R522687)

Supply Transformer Standard (R527890)

Protection of Transmission Lines Standard (R246427)

Protection of HV Busbars and Feeders Standard (R246419)

SCADA Systems Standard (R246439)

Substation Lightning Protection and Earthing Standard (R522692)

Testing, Commissioning and Training Standard (R246497)

IEC 61850 Protection and Automation Standard (R1606300)

Technology Asset and Change Management Standard (R1400111)

Security Event Logging and Monitoring Standards (R1313426)

1.7 TasNetworks drawings

All project specific application design drawings shall be prepared using the appropriate TasNetworks' standard protection scheme design template. This suite of standard design drawings for the supply transformer protection scheme will be issued together with the project specification for each project which should be customised by the designer for specific site application.

New standard panel design drawings shall only be developed with prior approval from TasNetworks' Secondary Systems Asset Strategy Team Leader.

2 Supply transformer protection design policy

The supply transformer protection and control scheme shall be designed to ensure that:

(a) all high current faults within the transformer protection zone shall be detected by at least two independent protection devices that have the capability of initiating fault clearance within the critical clearance times specified within clause S5.1a.8 of the National Electricity Rules (NER). Very low current and/or incipient faults may be capable of detection only by the single Buchholz protection;

(b) the transformer protection scheme shall utilise current transformer (CT) cores that are positioned to provide overlapping zones of protection with adjacent protection schemes;

(c) all local tripping functions shall be hard-wired from the protection relay to the respective trip coil on the associated circuit breaker(s).' The 'A' protection trips the 'A' trip coil of each circuit breaker and the 'B' protection trips the 'B' trip coil of each circuit breaker. Where the primary winding circuit breaker is located remotely from the substation the protection trips shall be transferred through appropriate teleprotection equipment to the remote circuit breaker;

(d) auto reclose facilities shall not be applied to the transformer circuit breakers;

(e) the protection scheme applied to the transformer shall be adaptable and adequate for the protection of the entire transformer and provide backup protection for the associated HV busbars and feeders; and

(f) for metal enclosed switchgear, the HV CTs will be located on the cable side of the incomer circuit breaker in which the transformer protection associated with those CTs shall also be utilized for the protection of the cables.

2.1 Supply transformer arrangement

The configuration of a new TasNetworks supply transformer shall be as per the Supply Transformer Standard and includes the following:

(a) Two or three winding transformer (vector group YNyn0 for a two winding transformer and YNyn0yn0 or YNyn0d11 for a three winding transformer).

(b) The secondary winding shall be connected to one of the following voltage levels: 44 kV, 33 kV, 22 kV, 11 kV, or 6.6 kV and the primary winding shall be connected to either 44 kV, 110 kV or 220 kV.

(c) Incorporate an on-load tap changer (OLTC) in the primary winding of the transformer.

2.2 Supply transformer protection and control arrangement

The protection scheme shall be housed within one panel located within the substation control room. The transformer guard devices will be fitted on the transformer.

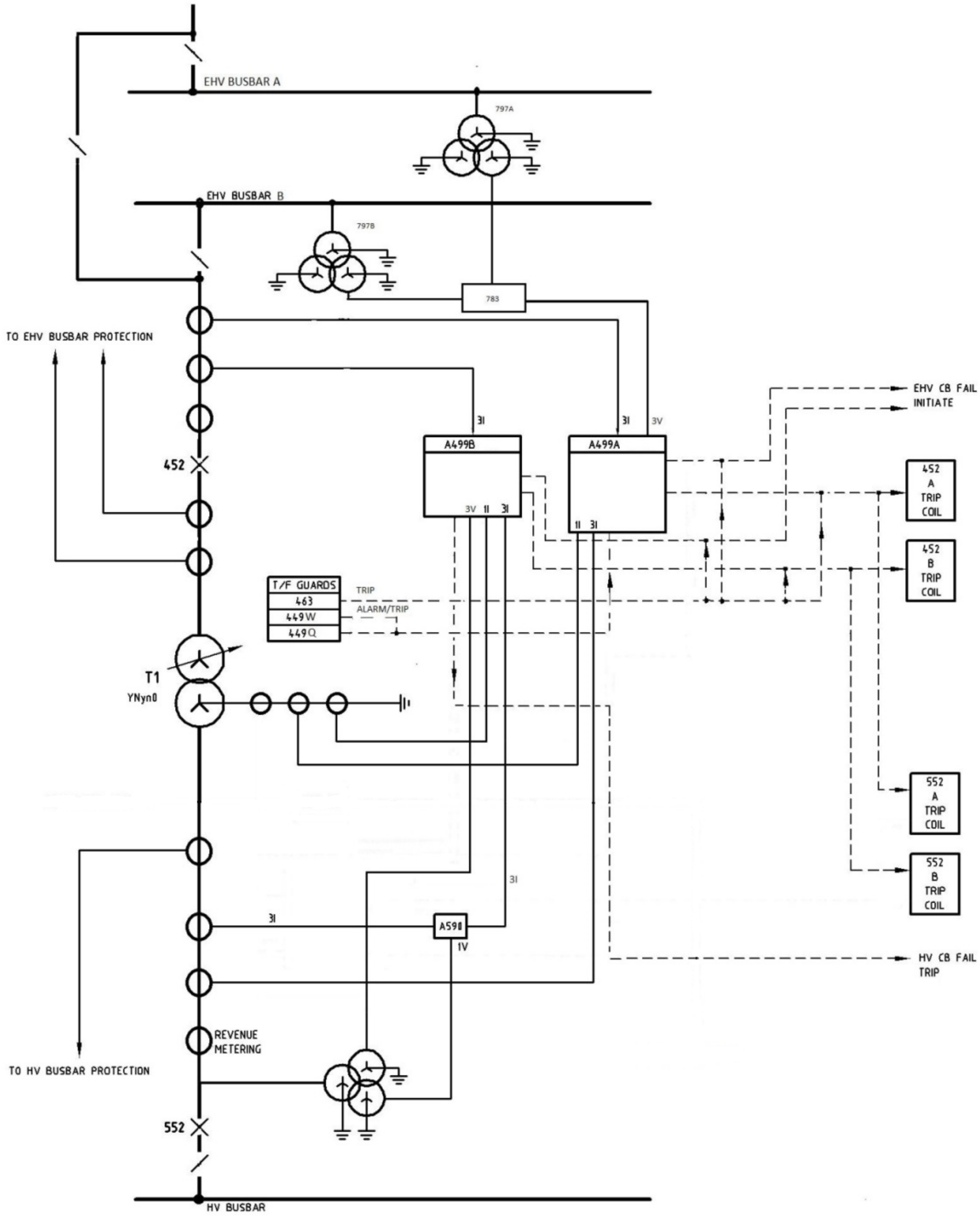
The supply transformer protection shall consist of two independent 'main' protection relays designated '499A' and '499B', an independent automatic voltage regulator (AVR) relay designated '590' and transformer guard devices as fitted with the supply transformer. Figure 1 shows a typical supply transformer protection scheme arrangement.

For the arrangement of supply transformer protection and/or transmission line protection for an H busbar configuration, see the Protection of EHV Busbars Standard.

Application of the 599 switchboard incomer protection relay is provided in the Protection of HV Busbars and Feeders standard.

For information regarding integration of the protection relays to the SCADA system, refer to the SCADA System Standard.

Figure 1 Typical protection arrangement for a supply transformer



2.2.1 499A and 499B protection relay physical requirements

The 499A and 499B protection relays shall:

(a) be from different manufacturers to achieve redundancy and diversity;

(b) be numerical multifunction relays capable of accepting one set of three phase voltages and multi sets of three phase currents as required. External current summation is not acceptable;

(c) be capable of self-supervision and have a watchdog contact;

(d) be connected to a separate DC supply derived from the 'A' and 'B' batteries respectively;

(e) be capable of communicating all parameters including protection settings and recorded events to the substation SCADA system and shall be capable of being programmed and interrogated remotely;

(f) have inbuilt oscillographic disturbance and event recorder with time and date tagging;

(g) have heavy duty output contacts for direct tripping of both primary and secondary side circuit breakers;

(h) be capable of multiple communications protocols with a minimum of DNP3 and IEC61850 GOOSE and MMS functionality;

(i) be capable of communicating on the SCADA network via Ethernet RJ45 or fibre connection;;

(j) capable of time synchronisation via PTP (preferred option) or IRIG B;

(k) have adequate configurable inputs and outputs based on application;

(l) be capable of operating from 5 Amp or 1 Amp rated CT secondary circuits; and

(m) be connected to independent CT cores on each side of the transformer and use independent voltage transformer (VT) secondary circuits for voltage input to associated relays.

2.2.2 590 AVR relay physical requirements

The 590 AVR relay shall:

(a) be a numerical device;

(b) be capable of self-supervision and have a watchdog contact;

(c) accommodate multiple operating modes for running transformers in parallel or independent and voltage set points;

(d) be capable of accepting 4-20mA signalling for transformer temperature monitoring;

(e) have configurable settings;

(f) be capable of communicating on the SCADA network via Ethernet RJ45 or fibre connection; and

(g) be capable of multiple communications protocols with a minimum of DNP3 and IEC61850.

2.3 Protection relay functional requirements

2.3.1 499A protection relay

The 499A protection relay shall be capable of:

(a) low impedance biased current differential protection with user configurable slope characteristics;

(b) low impedance biased restricted earth fault protection with user configurable slope characteristics;

(c) thermal overload protection;

(d) overcurrent and earth fault protection;

(e) CT supervision and saturation detection;

(f) Trip Circuit Supervision (TCS) for each independent ‘A’ trip circuit;

(g) CBF scheme for EHV side circuit breaker(s) when not available within the busbar protection scheme;

(h) CBF initiation of secondary winding breaker;

(i) bay interlocking for EHV disconnectors;

(j) primary side transformer operational metering;

(k) remote/local open and close of EHV bay circuit breaker and disconnectors; and

(l) management of alarms for the transformer guard devices.

2.3.2 499B protection relay

The 499B protection relay shall be capable of:

(a) low impedance biased current differential protection with user configurable slope characteristics;

(b) low impedance biased restricted earth fault protection with user configurable slope characteristics;

(c) thermal overload protection;

(d) directional and non-directional overcurrent and earth fault protection;

(e) CT supervision and saturation detection;

(f) TCS for each independent ‘B’ trip circuit;

(g) CBF scheme for secondary winding side breaker;

(h) remote/local open and close of secondary winding side circuit breaker; and

(i) secondary winding side transformer operational metering.

2.3.3 590 AVR relay

The 590 AVR shall be capable of:

(a) initiating raising and lowering of supply transformer tap position to maintain the HV voltage within a set bandwidth including fast tap down;

(b) interpreting tap position of the transformer from a resistor chain, and transducer mA values;

(c) accepting 4-20mA signalling to provide transformer temperature readings to the SCADA system;

(d) blocking its operation when the load current exceeds 1.2 times the value of the nominal rated current of the OLTC or when voltages exceed upper or lower limits;

(e) detecting and minimising circulating current when transformers are connected in parallel;

(f) operating in manual, automatic or independent modes;

(g) remote setting of the target voltage via the SCADA system;

(h) configuration for line drop compensation;

(i) tap changer runaway detection;

(j) user configurable initial and inter-tap time delay;

(k) user configurable over and under voltage alarms; and

(l) communicating via DNP3 and IEC 61850.

2.4 Protection elements

The following sections describe the functionality, application and settings for each protection and control element of the supply transformer protection scheme.

The following arrangements shall be applied to the application of the main protection relays:

(a) At sites where IEC 61850 process and/or station bus is implemented, all design requirements shall be in accordance with the TasNetworks IEC 61850 Protection and Automation Standard.

(b) The following software controls and cyber monitoring must be implemented:

  (i) Change the device default password.

  (ii) Disable or remove unused interfaces.

  (iii) Disable built-in or default user accounts.

  (iv) If possible, record:

    a. what activity was performed (e.g. setting changes on protection relay);

    b. who performed the activity (e.g. engineer or operator); and

    c. when the activity was performed (e.g. time and date).

2.4.1 Low impedance biased differential protection

2.4.1.1 Functionality

The low impedance biased differential protection shall provide the following functionality:

(a) Stabilised, multiple slope current differential protection to protect all windings, including dual HV winding transformers, for short circuit and inter-turn faults.

(b) Fast operation time even during partial saturation of associated CTs.

(c) Stability for maximum through fault conditions.

(d) Operate at the fundamental frequency only.

(e) Second harmonic restraint for transformer inrush current. The restraint level must be configurable in the relay.

(f) Unrestrained high set current differential element.

(g) Fifth harmonic restraint for transformer over-excitation. The restraint level shall be configurable and shall be capable of being disabled.

(h) Capability of catering for a wide range of CT ratios and vector corrections including the variation of the star point connection on the CT cores using numerical settings.

2.4.1.2 Application

(a) Auxiliary CTs for ratio or vector corrections are not permitted.

(b) Where required all current inputs to the differential protection shall contribute to the relay bias current in order to avoid possible protection mal-operation for through faults.

(c) The CT secondaries used for the biased differential protection may be used for other protection devices so long as the CT can supply the connected burden without saturating during maximum offset through fault conditions.

(d) The output of the relay shall trip all circuit breakers associated with the supply transformer and initiate CBF protection. The trip output and indications shall be latched with remote and local reset capability.

2.4.1.3 Settings

(a) The relay differential pickup setting shall be set from 20 per cent to 25 per cent of the ONAN rated current of the transformer. This setting shall be checked if the range of transformer tapping is significant.

(b) The slope 1 bias characteristic settings shall be set to ensure that the relay remains stable under maximum loading condition with the transformer OLTC at the extreme ends of the tapping range and maximum CT error.

(c) The slope 2 bias characteristic settings shall be set to ensure that the relay remains stable for maximum through fault conditions with CT saturation.

(d) In most cases, the manufacturer's manual should be utilised for getting guidance on calculation of pickup and slope characteristic as applicable.

(e) The unrestrained high set differential element should be set above the maximum through fault current.

(f) Second harmonic restraint shall be set to 15 per cent of the fundamental current with cross-blocking enabled for a time period between one to five cycles depending on transformer design and requirement.

(g) Where the fifth harmonic restraint setting is available and enabled, the setting shall be set to 30 per cent of the nominal fundamental current.

2.4.2 Low impedance HV restricted earth fault protection

2.4.2.1 Functionality

The restricted earth fault protection shall provide the following functionality:

(a) Operate on the low impedance biased principle to supplement the biased current differential protection and detect faults close to neutral point of the transformer.

(b) Be supervised or checked by ground current where not provided internally by the relay.

(c) Operate at the fundamental frequency only.

(d) Applied on each star earthed winding of the transformer.

2.4.2.2 Application

(a) The protection shall be connected to a CT core located between the transformer neutral and earth connection. In the event that insufficient cores are available, an additional neutral CT core shall be installed.

(b) The restricted earth fault protection shall trip all circuit breakers associated with the supply transformer and initiate CBF protection. The trip output and indications shall be latched with remote and local reset capability.

2.4.2.3 Settings

The low impedance restricted earth fault protection shall be set to operate at 10 per cent of nominal current of the relay secondary rating with appropriate bias/slope to prevent spurious operation due to CT saturation on a through fault. In most applications the restricted earth fault characteristic has only one slope and it shall be set to 40 per cent with no intentional time delay.

2.4.3 Directional protection

2.4.3.1 Functionality

The directional protection shall provide the following functionality:

(a) Must have inverse and definite time overcurrent and earth fault characteristics settable in forward or reverse direction.

(b) Must have adjustable relay characteristic angle.

2.4.3.2 Application

(a) The primary purpose of the directional protection is to remove fault infeed from HV busbar to the transformer.

(b) The directional overcurrent protection shall be enabled in the 499B relay where there is a possibility of reverse power flow or fault infeed i.e. HV to EHV side of the transformer.

(c) The polarising signal for directional protection is to be derived from the incomer VT.

(d) The directional protection shall trip the HV circuit breaker of the supply transformer and initiate CBF protection.

2.4.3.3 Settings

(a) Directional protection should be set to pick up for all possible fault in-feeds either from parallel transformers or from any HV feeders.

(b) The time delay and pickup should be graded with HV bus coupler and EHV protection.

2.4.4 Thermal overload protection

2.4.4.1 Functionality

The overload protection shall provide the following functionality:

(a) Overload protection shall be based on the thermal capability of the transformer.

(b) Two setting stages, one of which will provide an alarm, based on current only and the second stage to trip the HV circuit breaker based on the thermal time constant of the supply transformer.

2.4.4.2 Application

(a) Where the thermal time constant of the supply transformer is not available to appropriately set the thermal overload characteristic of the protection relays, the thermal overload protection element shall not be applied.

(b) If enabled, the output of the protection shall trip the HV circuit breaker associated with the transformer only and initiate CBF protection.

2.4.4.3 Settings

(a) The alarm shall be set to rated current of the transformer whereas the trip function must co-ordinate with the transformer damage curve and be graded with upstream and downstream overcurrent protection.

(b) The settings of the thermal overload protection must consider the overload capability of the terminal cables and associated CTs.

2.4.5 Overcurrent and earth fault protection

2.4.5.1 Functionality

(a) Three phase definite, inverse time and instantaneous overcurrent and earth fault protection shall be provided for the primary and secondary sides of the transformer.

(b) The instantaneous overcurrent and earth fault protection shall be second and fifth harmonic restrained or sensitive only to the fundamental component of the current.

2.4.5.2 Primary side overcurrent protection application

(a) Where duplicate differential protection is available for the supply transformer and the HV busbars have sufficient main and back up protection, primary side overcurrent protection shall not be applied.

(b) In cases where sufficient CT cores are not available on the secondary side to install two differential protection devices, an independent primary side overcurrent protection relay shall be installed with inverse and definite time elements enabled.

2.4.5.3 Primary side overcurrent protection settings

(a) The current setting for the definite time protection shall be set above the maximum through fault current (with consideration of the asymmetrical factor) for the transformer and should detect 30 per cent of the minimum phase to phase fault current. The second harmonic restrained definite time overcurrent function shall be enabled for this application. The definite time delay shall be 50 milliseconds. If the definite time overcurrent protection does not provide second harmonic restraint, the pickup setting shall be above the inrush current of the transformer.

(b) The inverse time overcurrent function shall be set to detect the minimum phase to phase through fault current condition but shall not operate for short term overloads on the transformer. The inverse time function shall be set to grade with the secondary side overcurrent and earth fault protection.

2.4.5.4 Primary side earth fault protection application

The earth fault protection shall be enabled to detect earth faults in the transformer EHV winding. The definite time characteristic shall be enabled.

2.4.5.5 Primary side earth fault protection settings

The relay current setting shall be set to a primary value of 10 per cent of minimum phase to earth fault current at the primary winding terminals and a definite time delay of 50 milliseconds.

2.4.5.6 Secondary side overcurrent and earth fault protection application

The overcurrent protection, phase and earth fault shall be equipped with inverse time/ definite time characteristics together with instantaneous overcurrent elements. The definite time elements are to be used for HV bus blocking scheme if required.

2.4.5.7 Secondary side overcurrent and earth fault protection settings

The settings applied to the backup protection shall grade with the feeder overcurrent phase and earth fault settings. If the protection is used as a portion of the busbar protection scheme, both phase and earth fault definite time elements shall be enabled for use in conjunction with the blocking scheme. For more information on setting the HV overcurrent and earth fault protection see the Protection of HV Busbars and Feeder Standard.

2.4.6 Buchholz, pressure and temperature protection

2.4.6.1 Functionality

The Buchholz and temperature protection shall provide the following functionality:

(a) A Buchholz relay shall be factory-fitted with the supply transformer to the main tank and a pressure device to the OLTC and as such will be calibrated by the transformer manufacturer as per the Supply Transformer Standard. The Buchholz relay and pressure device must be able to provide as a minimum, two normally open contacts for trip and one normally open contact for alarm.

(b) Mechanical temperature devices will also be factory-fitted to measure the temperature of the transformer winding and the temperature of the transformer oil. The temperature devices shall be capable of providing a 4-20mA signal to represent the actual temperature measurements. These signals will be supplied to the AVR for routing to the SCADA system.

(c) The over temperature devices shall each be capable of two settings, 'stage 1' and 'stage 2'. More information regarding the mechanical temperature devices is contained in the Supply Transformer Standard.

2.4.6.2 Buchholz protection application

The following arrangement shall be implemented for the Buchholz protection:

(a) The Buchholz protection shall trip the 'A' trip coil of each circuit breaker via the master trip auxiliary relay.

(b) The alarm outputs shall be routed to NOCS via the 499A.

(c) The output of the relay shall trip all circuit breakers associated with the supply transformer and initiate CBF protection.

2.4.6.3 Temperature protection application

The following arrangement shall be implemented for the temperature protection:

(a) Unless otherwise stated in the project specification, the over-temperature tripping function **shall not** be connected to the transformer circuit breaker trip circuits.

(b) The over-temperature tripping function (if enabled) shall trip the 'A' trip coil of each circuit breaker via a master trip auxiliary relay.

(c) Alarms shall be provided for both 'stage 1' and 'stage 2' operation regardless of trip function.

(d) The alarm outputs shall be routed to the NOCS via the 499A relay.

2.4.6.4 Temperature protection settings

Settings for the 'stage 1' and 'stage 2' oil and winding alarms shall be set based on the Supply Transformer Standard and project specification.

2.4.7 Local emergency trip and close control switches

2.4.7.1 Functionality

The local emergency trip and close control switches shall:

(a) be provided for the EHV circuit breakers to perform an emergency trip and close direct to trip circuit of the respective circuit breaker;

(b) be key lockable type; and

(c) have an additional contact of each control switch to be hard wired into the associated relay to record the operation of the switch.

2.4.8 Automatic voltage regulator (AVR)

2.4.8.1 Application

The AVR shall be configured to regulate the HV bus voltage. The voltage set point will be advised by TasNetworks. The AVR of parallel transformers must operate to minimise circulating current between the transformers. The control functionality of the relay must be configured to cater for the opening of the HV bus coupler or incomer breaker causing the transformers to operate independently.

The AVR must be configured to allow for remote setting of the target voltage by the TasNetworks operational control room via the SCADA system.

2.4.8.2 Settings

Generally TasNetworks will advise the Contractor of the voltage set point for the AVR. In the absence of this advice, the following philosophy shall be applied for setting of the AVR:

(a) AVR settings must be coordinated with any shunt capacitors installed at the site in order to avoid hunting.

(b) The voltage set point must be a value which can provide acceptable bus voltage under normal and contingency conditions.

(c) The dead-band setting should be based on the voltage change produced by a single tap interval. The minimum percentage bandwidth should be ≥ 0.6 times the tap changer increment.

(d) The temporary voltage control shall be set with a target voltage of 1.0 per unit.

(e) The AVR shall be blocked when the voltage exceeds the following limits:

  (v) Lower limit shall be set to 80% of nominal voltage.

  (vi) Upper limit shall be set to 135% of nominal voltage.

(f) The AVR shall be blocked when the current exceeds 1.2 times the rating of the OLTC.

(g) Application and setting of line drop compensation should provide a reasonably flat voltage profile along the whole length of the feeder.

2.4.9 Circuit Breaker Failure (CBF) Protection

2.4.9.1 CBF application

The following apply for the application of HV CBF protection:

(a) The CBF of the EHV circuit breaker of the transformer shall be implemented either in the EHV busbar protection scheme or in the 499A relay. For details of EHV CBF protection, refer to the Protection of EHV Busbars Standard.

(b) The CBF of HV circuit breaker of the transformer shall be implemented in the 499B relay and shall trip the EHV circuit breaker(s) and adjacent HV busbar circuit breakers that may feed a fault beyond the transformer HV circuit breaker.

(c) Any protection that trips the HV circuit breaker shall also initiate its CBF scheme.

(d) All CBF trip and indication signals shall be latched.

2.4.9.2 HV CBF settings

The following apply when setting the HV CBF protection:

(a) The setting on the 499B CBF overcurrent check or under current reset shall be set to detect a fault current having a value of 50 per cent of the current generated by a solid phase to phase fault located on the HV busbar under minimum generation conditions.

(b) Ideally the overcurrent check should not operate for maximum load current of the transformer with a safety factor of 1.2. However, in the event that the difference between the magnitude of load current and 50 per cent of the phase to phase fault current under minimum generation conditions is marginal, it is permissible to set the overcurrent protection to a value less than maximum load current.

(c) The overcurrent check for HV CBF protection shall be set if possible to detect low current faults within the transformer winding or HV busbar.

(d) The CBF timer shall be set to 250ms.

3 Substation disturbance recorder

Where a new or existing substation disturbance recorder is to monitor the power flows of the supply transformer circuit, the disturbance recorder shall be wired downstream of the 499B device current circuit(s).

4 Master trip auxiliary relays

The use of master trip auxiliary relays is applicable where the main protection device cannot provide sufficient output trip contacts or a latching function.

(a) The auxiliary relays shall be of a robust design preferably from a previously used manufacturer and operated by 125V DC with sufficient number of contacts to cater for operation of the circuit breaker trip coil and SCADA system.

(b) The relays shall be supervised for open circuit condition.

(c) The operation of the master trip auxiliary relay shall be latched with electrical reset and remote reset of the relay shall be configured through the SCADA system.

(d) The contacts shall be capable of making the operate current of the circuit breaker trip coil with operate time of less than 10ms without contact bounce.

5 Circuit breaker open/close commands

The following guidelines shall be applied:

(a) Circuit breaker open command and protection trip shall not be blocked on alarms from circuit breaker spring charge, SF6 'stage 1' and motor supply fail.

(b) 'Stage 2' SF6 alarm shall block all protection trip, open and close commands.

(c) Circuit breaker close command shall be blocked on alarms from circuit breaker spring charge and SF6 low gas alarm and motor supply fail.

(d) Circuit breaker close command shall be blocked if there are simultaneous operations of both A and B TCS of a single circuit breaker. The operation of one TCS shall not block the close command.

(e) The operation of TCS shall not block the open command or protection trip.