Standard

Protection and Control of Network Transformers Standard

R246242

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Authorisations

Action	Name and title	Date
Prepared by	Anthony Januba, Senior Asset Strategy Engineer	30/08/2022
Reviewed by	Satendra Bhola, Principal Asset Engineer	26/09/2022
Authorised by	Michael Emmett, Team Leader Substations Asset Strategy	21/11/2022
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Responsibilities

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

Please contact the Asset Strategy 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
1.7	Added cyber and IEC 61850 standard references
2.2	Removed the independent AVR relay 590
2.2.1	Added AVR functions to the 499A relay
3.1.1	Added point on wave switching to the 499A relay
3	Removed thermal overload and over fluxing protection elements
3.6	Removed the emergency by-pass control switches
4.1	Added reference to the new IEC 61850 standard and the cyber requirements
4.1	Added reference to the testing, commissioning and training standard
4.6	Added point on wave switching
4.6	Added information for PRD tripping and alarming arrangement
4.6	Removed the sync check function
4.7	Modified the tripping logic of the over temperature devices
4.11	Added point on wave switching
Appendix 1	Appendix removed

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1 General

1.1 Purpose

The purpose of this document is to define the requirements, philosophy and the application of protection and control schemes for network transformers in the Tasmanian interconnected power system under the responsibility of Tasmanian Networks Pty Ltd (hereafter referred to as "TasNetworks").

1.2 Scope

This standard contains requirements for application design of new network transformer protection and control scheme installations under the responsibility of TasNetworks. This standard applies, in part, 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. 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.

1.3 Objective

TasNetworks requires designs 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' corporate 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' 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 Regulation
CB	Circuit Breaker
CBF	Circuit Breaker Failure
CT	Current Transformer
DC	Direct Current
DNP	Distributed Network Protocol
EHV	Extra High Voltage
I/O	Inputs and Outputs
IEC	International Electrotechnical Commission
IRIG B	Inter-Range Instrumentation Group timecode B
MU	Merging Unit
NER	National Electricity Rules
OLTC	On-Load Tap Changer
ONAN	Oil Natural Air Natural
POW	Point-On-Wave
PTP	Precision Time Protocol
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.

1.7 TasNetworks standards

SCADA Systems Standard (R246439)

Testing, Commissioning and Training Standard (R246497)

Secondary Equipment Testing Standard (R244782)

Protection of EHV Busbars Standard (R246414)

Network Transformer Standard (R527893)

IEC 61850 Protection and Automation Standard (R1606300)

Technology Asset and Change Management Standard (R1400111)

Security Event Logging and Monitoring Standards (R1313426)

1.8 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 network transformer protection scheme will be issued together with the project specification for each project.

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

2 Design Philosophy

2.1 General design requirements

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

(a) the protection scheme applied to the network transformer is adaptable and adequate for the protection of the entire transformer;

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

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

(d) all tripping functions shall be hard wired from the protection relays to the respective trip coil of the associated circuit breakers;

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

(f) the protection and control scheme shall consist of two independent protection relays that must be from different manufacturers or different models to achieve redundancy and diversity; and

(g) control for each of the associated primary bays including status, interlocking, metering and control functions shall be integrated into the A and B protection relays. The 110 kV and 220 kV bay control functions shall be provided by different relays.

2.2 Protection and control scheme arrangement

The network transformer protection shall consist of independent protection relays designated ‘499A’ and ‘499B’, and transformer mechanical devices.

The 499A and 499B protection relays shall:

(a) be numerical multifunction devices capable of accepting more than two, three phase CT inputs;

(b) 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;

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

(d) be connectable for 1 Amp or 5 Amp current transformer secondary connections;

(e) be connectable for VT secondary phase voltages of 110 V or 110/√3 V;

(f) have heavy duty output contacts for direct tripping of both 220 kV and 110 kV circuit breakers;

(g) have configurable digital outputs for alarm, annunciation and external CBF initiation;

(h) be fed from independent CT cores on each side of the transformer and VT secondary circuits for voltage input to associated devices;

(i) be configurable to accommodate sufficient I/O with a minimum of four each additional as spare;

(j) be capable of providing the AVR where required;

(k) be capable of communications via Ethernet RJ45 or fibre connections using DNP as a minimum. Where IEC 61850 communications is required, it will be specified in the project documentation; and

(l) be capable of time synchronisation via PTP (preferred option), DNP time synchronisation, or IRIG B.

2.2.1 499A Protection relay

The 499A protection relay shall provide the following functionality:

(a) Low impedance phase segregated current differential protection for common and serial windings of the transformer. Where phase segregation is not possible on the common winding, low impedance biased differential and low impedance restrictred earth fault protection shall be applied.

(b) Remote metering of individual circuit breakers for double breaker busbar arrangements.

(c) CT supervision including saturation detection.

(d) Trip circuit supervision for the ‘A’ trip coil.

(e) Circuit breaker failure for both 220 kV and 110 kV side circuit breakers, when not available within the busbar protection scheme.

(f) Bay interlocking for all associated 220 kV disconnectors.

(g) 220 kV side transformer metering.

(h) Remote/local open and close of circuit breakers and disconnectors of the 220 kV bay.

(i) Back-up impedance protection for the 220 kV busbars.

(j) VT selection logic for the 220 kV bus VTs.

(k) Management of up to two 220 kV circuit breakers.

(l) Management of alarms for the transformer mechanical devices.

(m) Point-on-wave switching.

(n) Initiating raising and lowering of the transformer tap position to maintain the 110 kV voltage within a set bandwidth including fast tap down.

(o) Interpreting tap position of the transformer from a resistor chain, and transducer values.

(p) Blocking tapping operation when the load current exceeds 1.2 times the value of the nominal rated current of the on-load tap changer or when voltages exceed upper or lower limits.

(q) Detecting and minimising circulating current when transformers are connected in parallel.

2.2.2 499B Protection relay

The 499B protection relay shall provide the following functionality:

(a) Low impedance transformer biased differential protection.

(b) Low impedance biased restricted earth fault protection.

(c) Earth fault protection.

(d) CT supervision including saturation detection.

(e) Trip circuit supervision for the ‘B’ trip coil.

(f) Circuit breaker failure for both 220 kV and 110 kV side circuit breakers when not available within the busbar protection scheme.

(g) Bay interlocking for all associated 110 kV disconnectors.

(h) 110 kV side transformer metering.

(i) Remote/local open and close for circuit breakers and disconnectors of the 110 kV bay.

(j) Back-up impedance protection for the 110 kV busbars.

(k) VT selection logic for the 110 kV bus VTs.

(l) Management of up to two 110 kV circuit breakers.

2.3 General application requirements

The following arrangements shall be followed for the application of the main protection relays:

(a) The protection relays are to be connected to two independent cores on each side of the transformer.

(b) Separate DC supplies are derived from the 'A' and 'B' DC supply systems.

(c) Circuit breaker tripping is initiated via hard wiring direct to the 'A' and 'B' trip coils respectively.

(d) The protection scheme shall be housed within two panels located directly beside each other within the substation control room. One panel shall house the 499A relay and the other panel shall house the 499B relay.

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

(f) Testing and commissioning of the network transformer protection and control scheme shall be undertaken in accordance with the Testing, Commissioning and Training and the Secondary Equipment Testing standards.

(g) Protection functions that indicate an internal transformer fault shall latch, with resetting at site only.

(h) 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.

(i) Any new protection and control scheme must follow the requirements of the Technology Asset and Change Management, and Security Event Logging and Monitoring Standards. As such, 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).

3 Transformer protection functions

The following protection functionality shall be provided by the network transformer protection scheme.

3.1 Biased differential protection

The biased differential protection shall provide:

(a) low impedance stabilised current differential protection to protect the winding from short circuit faults;

(b) fast operation time even during partial saturation of associated CTs;

(c) stability for maximum through fault conditions;

(d) restraint for transformer inrush current;

(e) unrestrained high set current differential element;

(f) restraint for transformer over-excitation. The restraint level shall be configurable and shall be capable of being disabled; and

(g) capability of catering for a wide range of current transformer ratios and vector corrections including the variation of the star point connection on the CT cores using numerical settings – please note that external matching or interposing CT will not be acceptable for these purposes.

The following arrangement shall be implemented for the biased differential protection:

(h) The CT ratios used shall be appropriate the low impedance differential protection.

(i) Use of auxiliary CTs is not permitted.

(j) The CT secondaries used for the low impedance differential protection may be used for other protection devices provided the CT can supply the burden without saturating during maximum offset through fault current conditions.

(k) The output of the transformer differential protection shall trip all circuit breakers associated with the network transformer and initiate CBF. Trip and alarm indications shall be latched with local reset capability only.

The following settings are applicable for the biased differential protection:

(l) 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.

(m) 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.

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

(o) It is recommended that the manufacturer's manual be utilised for getting guidance on calculation of pickup and slope characteristic as applicable.

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

(q) Second harmonic restraint shall be set to 15 per cent of the fundamental current and where available, cross-blocking enabled for a time period of three cycles depending on transformer design.

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

3.2 Restricted earth fault protection

The restricted earth fault protection shall operate on the low impedance biased principal and is added to supplement the biased transformer differential protection by detecting fault currents of a magnitude below that capable of being detected by the biased current differential protection.

The following arrangement shall be implemented for the low impedance restricted earth fault protection:

(a) The 499A relay shall utilise CTs located before formation of the transformer neutral. This arrangement will provide protection against phase and earth faults. In case where phase segregated neutral CTs are not available then use of a single CT between neutral and earth connection should be used. This arrangement will provide protection against earth faults only.

(b) The 499B relay is only required to connect to a single phase CT located in the transformer neutral.

(c) The output for the restricted earth fault protection shall trip all circuit breakers associated with the network transformer and initiate CBF protection. Trip and alarm indications shall be latched with remote reset capability.

The low impedance restricted earth fault protection shall:

(d) be set to operate at 10 per cent to 15 per cent of nominal current with appropriate bias/slope to prevent spurious operation due to CT saturation on a through fault; and

(e) be set sensitive enough to pick up faults anywhere on the winding with no intentional time delay.

3.3 Delta tertiary winding earth fault protection

The delta tertiary winding earth fault protection shall be capable of selectable inverse time and definite time earth fault protection.

The following arrangement shall be implemented for the tertiary winding earth fault protection:

(a) The earth fault protection shall be connected to the secondary winding of the CT located in the delta tertiary to earth connection.

(b) The protection should be incorporated within the '499B' protection device associated with the transformer.

(c) The output of the protection shall trip all circuit breakers associated with the transformer and initiate circuit breaker failure (CBF) protection. Trip and alarm indications shall be latched with remote reset capability.

The following settings are applicable for the delta tertiary winding earth fault protection:

(d) The current setting shall be set to detect low levels of earth fault current having a primary value of 50 Amps.

(e) In order to ensure the sensitivity of the protection, the associated CT ratio shall be as low as possible while still catering for the maximum phase to earth fault.

(f) The definite time characteristic shall be set for a time delay of 100 milliseconds.

3.4 Impedance protection

The impedance protection shall have a settable definite time characteristic for multiphase and earth impedance based fault detection.

The primary purpose of the impedance protection is to provide back-up to bus faults in case of a failure or scheduled maintenance of a single busbar protection scheme. The following arrangement shall be implemented for the impedance protection:

(a) The impedance protection shall only be enabled to back-up a single busbar protection scheme.

(b) The impedance protection shall be set to reach in the reverse direction to detect busbar faults.

(c) The output of the protection shall trip the circuit breakers of the network transformer connecting to the associated busbar and initiate CBF protection.

(d) If impedance protection is required, it is to be derived from the busbar VTs, and voltage selection facilities are required.

The following settings are applicable for the impedance protection:

(e) The reach of the reverse zones shall be set to 0.2 x zone 1 of the shortest transmission line from the EHV busbar.

(f) An appropriate zero sequence compensation factor K0 should be set.

(g) The time delay setting shall be 400 milliseconds.

3.5 Mechanical protection

The mechanical protection consists of Buchholz, pressure relief, and temperature devices and shall provide the following:

(a) The Buchholz relay will be supplied with the network transformer and as such will be calibrated by the transformer manufacturer as stated in the Network Transformer Standard. The Buchholz relay must be able to provide as a minimum, two normally open contacts for trip and one normally open contact for alarm.

(b) The pressure relief device(s) will be supplied and fitted with the network transformer and will be pre-calibrated by the manufacturer.

(c) The winding and oil temperature devices will also be supplied with the network transformer and as such will be calibrated by the transformer manufacturer as stated in the Network Transformer Standard. The over temperature devices measure the temperature of the transformer ‘hot spot’ and the temperature of the transformer oil. The over temperature devices shall be capable of two over temperature settings, stage one and stage two and shall provide alarms only.

The following arrangement shall be implemented for the mechanical protection:

(d) The Buchholz protection shall trip the ‘A’ trip coil of each circuit breaker via a separate trip relay.

(e) The Buchholz alarm output shall be routed to SCADA via the 499A protection relay.

(f) The output of the relay shall trip all circuit breakers associated with the network transformer and initiate CBF protection. Trip and alarm indications shall be latched with remote reset capability.

(g) The pressure relief device shall trip the ‘B’ trip coil of each circuit breaker via a separate trip relay.

(h) The pressure relief device trip relay shall also provide and alarm output routed to SCADA via the 499B relay.

(i) The stage one and two output of the temperature devices shall be hard wired to binary inputs of the main protection relays (shared to minimise I/O usage). These outputs shall be configured as alarms only.

3.6 Circuit breaker failure (CBF) protection

For the application and setting of CBF on network transformer circuit breakers, see the Protection of EHV Busbars Standard.

4 Transformer control functions

4.1 Local control switches

The local control switches shall:

(a) be provided for each 110 kV and 220 kV circuit breaker;

(b) perform an emergency trip directly to the trip circuit of the respective circuit breaker;

(c) perform a close, via the bay control functions, of the respective circuit breaker;

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

(e) have the switches associated with the 220 kV circuit breaker mounted close to the 499A relay and the switches associated with the 110 kV circuit breaker mounted close to the 499B relay.

4.2 CB open and close commands

The following functions shall be applied:

(a) CB open commands should not be blocked on alarms from CB spring charge, SF6 and motor supply fail.

(b) CB close commands shall be blocked on alarms from CB spring charge, SF6 and motor supply fail.

(c) CB close commands shall be blocked on simultaneous operations of both ‘A’ and ‘B’ TCS.

(d) The operation of one TCS shall not block the close command.

(e) The operation of one TCS shall not block the open command.

The CB control open and CB protection trip commands shall use the same output contacts and be wired directly to the CB trip coils. However, logic within the relays shall be provided to mimic the local/remote control switch functions of the CB, as follows:

(f) CB controlled open commands shall not operate the output contact when the CB control switch is in local.

(g) CB protection trip commands shall operate the output contact regardless of CB control switch status.

4.3 Point-on-wave switching

To reduce the effects from in-rush currents and voltage fluctuations during energisation of large network transformers, point-on-wave switching of the 220 kV circuit breaker shall be applied via the 499A relay. The point-on-wave switching feature shall be utilised for circuit breaker closing only but shall not be applied to the trip function of the protection relay.

The point-on-wave switching feature must be set in accordance with the manufacturers manual.

4.4 Automatic voltage regulation (AVR)

The following arrangement shall be implemented for the AVR:

(a) Where voltage support is required for the 110 kV busbar, the AVR shall be configured within the 499A relay using the 110 kV voltage as the reference voltage. The Contractor shall consult with TasNetworks to determine TasNetworks’ requirements for voltage support before placing the AVR into service following commissioning.

(b) The AVR of parallel transformers must be configured for inter-AVR communications for overall substation voltage control. The control functionality of the device must be configured to cater for the loss of inter-AVR communications or the opening of the 110 kV bus coupler so that the transformers can operate independently.

The following philosophy shall be applied for setting of the AVR:

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

(d) The dead band setting should be based on the voltage change produced by a single tap interval. This should preferably be set to 105 per cent of the voltage change produced by a single tap interval.

(e) Where required, the voltage control range and target voltage shall be provided by TasNetworks.

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

  (i) Lower limit shall be set to 80 per cent of nominal voltage.

  (ii) Upper limit shall be set to 135 per cent of nominal voltage.

(g) The AVR shall be blocked when the transformer capacity exceeds 150 per cent of nominal load.