Standard

Secondary Equipment Testing

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Authorisations

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Review cycle	30 months	

Responsibilities

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

Please contact the Substations 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
1.3	Added objective, AEMO’s Standard for Power System Data Communications
1.5	Removed unused references
1.6	Added abbreviation
2.2	Re-worded sentence
3.3	Re-worded sentence
3.4	Re-worded sentence
4.2	Re-worded sentence
5.5	Order of testing, rewording and added test
7.7	Reference to standard updated
8.2	Re-worded sentence
10.1	Added in new test
11.2	Telecommunications added in test and some re-wording
11.3	Re-worded sentence
13.3	Re-worded sentence
14.2	Re-worded sentence
16	Recommissioning table updated

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1 General

1.1 Purpose

To define general requirements for testing of secondary equipment, in particular protection, control and SCADA schemes under the responsibility of Tasmanian Networks Pty Ltd (hereafter referred to as "TasNetworks").

1.2 Scope

This standard applies to all commissioning, re-commissioning and routine maintenance testing, undertaken by TasNetworks' Contractors or operational personnel, of protection, control and SCADA equipment under the responsibility of TasNetworks for the following asset categories:

(a) EHV and HV Busbars and Bus Couplers.

(b) Network Transformers.

(c) Supply Transformers.

(d) Transmission Lines.

(e) EHV and HV Capacitor Banks.

(f) HV Feeders.

(g) Substation SCADA Systems.

This standard is to be applied to new installations as well as existing installations.

1.3 Objective

TasNetworks requires work to be carried out 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) AEMO's Standard for Power System Data Communications;

(g) ease in operation and maintenance;

(h) minimum disruption to the EHV and/or HV supply system following a fault;

(i) that the requirements of TasNetworks' corporate plan are met; and

(j) 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' Substations 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 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 documents mentioned below.

(a) HV and LV Cable Systems Standard (R590630)

(b) Communications and Data Cabling Standard (R1043989)

(c) Notice of Alteration form (R244925)

(d) Secondary System Defined Task Procedure (R244926)

(e) Testing, Commissioning and Training Standard (R246497)

(f) Protection Testing General Requirements Guide (R213844)

(g) Busbar Protection Testing Guide (R211566)

(h) Capacitor Bank Protection Testing Guide (R211569)

(i) HV Feeder Protection Testing Guide (R211567)

(j) Transformer Protection Testing Guide (R211565)

(k) Transmission Line Protection Testing Guide (R211562)

(l) Testing Commissioning and Training Standard (R246497)

(m) IEC 61850 Protection and Automation Standard (R1606300)

(n) Technology Asset and Change Management Standard (R1400111)

(o) Security Event Logging and Monitoring Standards (R1313426)

1.6 Abbreviations

AC	Alternating Current
ALF	Accuracy Limit Factor
CB	Circuit Breaker
CBF	Circuit Breaker Failure
CT	Current Transformer
DC	Direct Current
DCE	Data Communications Equipment

DTE	Data Terminal Equipment
EHV	Extra High Voltage (110 kV and 220 kV)
HV	High Voltage (6.6 kV to 44 kV)
I/O	Inputs and Outputs
MCB	Miniature Circuit Breaker
MU	Merging Unit
NER	National Electricity Rules
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SOE	Sequence of Events
SOTF	Switch On To Fault
VA	Volt-Amp (Apparent Power)
VT	Voltage Transformer

For the purpose of this standard where the term commissioning is referred, reference to re-commissioning also applies.

2 Policy

TasNetworks' policy is to:

(a) ensure secondary equipment is thoroughly tested and commissioned prior to asset acceptance and before being put into continuous service;

(b) prove protection and control equipment to be available for service and fully operational prior to livening the associated primary equipment;

(c) conduct re-commissioning tests when existing equipment has been modified to ensure that the above criteria are met; and

(d) monitor the condition of the secondary equipment at routine intervals as specified in the relevant TasNetworks' asset management plan.

2.1 Secondary equipment

Secondary equipment is equipment which is not energised at primary voltage. This includes all equipment connected to:

(a) CT and VT secondaries;

(b) control and monitoring circuits of primary equipment;

(c) the station protection and control DC supplies; and

(d) data communications equipment connected to the protection and control and SCADA networks.

The boundary between the secondary equipment and the communications circuit is the copper connection to the telecommunications main distribution frame or the optical fibre connection at the telecommunications optical patching panel. Where required, the conversion of telecommunications circuits from optical fibre to RS232 copper is the responsibility of Protection and Control personnel.

2.2 Secondary equipment tests

Commissioning tests are carried out on equipment prior to it being put into service for the first time.

Re-commissioning tests are similar to commissioning tests which are made after existing equipment has been modified or disturbed.

Routine maintenance tests are performed on individual Intelligent Electronic Devices (IED's) to assess the health and condition of the IED and are conducted at routine intervals as specified in the relevant TasNetworks' asset management plan.

During and after any secondary equipment testing, the following software controls and monitoring features are to be checked or implemented:

(a) Change the device default password.

(b) Disable or remove unused interfaces.

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

(d) If possible, record:

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

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

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

3 Introduction

3.1 Purpose of testing

TasNetworks requires comprehensive testing to ensure that:

(a) the secondary equipment is fit for service;

(b) the secondary equipment is constructed and installed as designed;

(c) the secondary equipment performs the required functions;

(d) test results are clearly recorded for future reference;

(e) details of the secondary equipment are properly recorded on the relevant documentation and enterprise asset management database; and

(f) for previously commissioned equipment, any defects or failure data are captured and recorded in the enterprise asset management database.

3.2 When a defective design is suspected

Among other things, testing is a "safety net" for defective design, but in modifying a design to correct a defect, another problem may be created. Where a defect in design is suspected, the following applies:

(a) Changes to the design shall not be made without notifying TasNetworks.

(b) Any changes made shall be recorded on the relevant documentation.

(c) The equipment shall function in accordance with the relevant Australian and TasNetworks' standards and fulfil the requirements of TasNetworks' functional specification for the design intent.

3.3 Testing principles

For all testing activities, the following principles shall apply:

(a) Metering, SCADA, and control circuits are continually proven by 'day to day' use and do not require specific testing at routine maintenance intervals. However, alarms should be verified back to the network control centre and local human machine interface whilst testing any protection scheme.

(b) While secondary equipment is tested against the circuit design, testing personnel must understand the purpose and function of the equipment, since they are the last line of defence against documentation or design errors. Ideally, a 'black box' approach should be implemented to any equipment testing.

(c) During routine maintenance testing, the first injection test result should be recorded as this is how the merging unit and the protection relay would have behaved under system fault conditions.

(d) Testing should simulate in-service conditions as far as practicable with minimal (temporary or otherwise) secondary systems or settings modifications.

(e) For protection, tests to prove non-operation are as significant as tests to prove operation. Non-operation checks, such as stability on through fault or correct trip output function from different protection element operations, are generally a more stringent test of the protection than are operation checks.

3.4 Piecemeal versus overall commissioning testing

Overall (end to end) testing is superior to piecemeal testing. Where piecemeal testing is unavoidable, careful consideration shall be given to overlap, and supplementary tests must be conducted to overcome the disadvantages of piecemeal testing. Where piecemeal testing is proposed, agreement is required with TasNetworks with respect to the scope and procedure of testing.

For example, if primary injection from a distance relay CTs and VTs through to tripping the CB was not possible, the following sequence of piecemeal tests may be used:

(a) Primary injection of CT circuits with correct currents observed at test links.

(b) Inject VT circuits as close to the VT secondary terminals as possible without back livening bus or line through VT. Simultaneously inject CT circuits at a point in the circuit which "overlaps" so that each test link has been proven in either first or second test. Trip the CB during this second test.

(c) Prove the links in the closed position.

(d) Since VT primary injection was not possible, confirm VT phasing after livening, and relay direction by checks using line charging current.

As a further example, if a trip test from busbar protection to the CBs is not possible, the following sequence of piecemeal tests could be used:

(e) During injection of Merging units and/or differential relays, observe that all the appropriate trip outputs have operated.

(f) Measure trip output contact resistances and confirm them to be OK at the CB trip links.

(g) Overlap by bridging the internal side of CB trip links and prove that the CB trips.

(h) Check that the main fuse or MCB for a group of CBs is rated to carry, without damage, the tripping current of all CBs in the group that might be tripped simultaneously for a bus fault.

3.5 Safety with CT and VT circuits

The following safe practices must be followed when working on CT and VT circuits:

(a) DO NOT OPEN CIRCUIT CT SECONDARIES IN SERVICE – When CTs are open circuited in service or during injection testing, the resulting high voltages can be lethal. This can damage the CT insulation and damage other connected equipment and flash over can result in burns or eye damage to people in the vicinity.

(b) DO NOT BACK ENERGISE VT PRIMARY IN SERVICE – When testing VT secondary circuits there is a risk of back energising the high voltage equipment at full primary voltage through the VT secondary.

(c) DO NOT SHORT CIRCUIT VT SECONDARY IN SERVICE – Before energising a VT from primary voltage, ensure that no short circuit exists on the secondary of the VT. Also, ensure that test meters are set correctly to measure voltage when applying to the secondary of an energised VT. A short circuit applied to the secondary of an energised VT will develop a damaging current on the secondary winding of the VT.

3.6 Revenue metering

Liaison with the appropriate Metering Service Provider for a metering installation is required prior to commencing any work on circuits connecting to instrument transformers, or work on the instrument transformers themselves, which are associated with revenue metering. Failure to do this may result in a non-compliance being issued under the NER, particularly associated with security of a metering installation and associated metering data.

3.7 Permit to work

All work on TasNetworks equipment connected to in-service circuits is to be undertaken in accordance with the requirements of the Power System Safety Rules.

Certain tasks are able to be undertaken by authorised personal under the Secondary System Defined Task Procedure. A job safety analysis review is mandatory prior to undertaking any works.

4 Planning of test programme

Planning of the test programme is mandatory. The time required for planning can be several days for a complex installation.

4.1 Purpose of planning

The purpose of planning is to:

(a) devise a series of tests which cover the required aspects of all equipment and yield valid results;

(b) identify the resources (personnel, equipment and time) required;

(c) identify if and how in-service equipment and circuits are to be isolated;

(d) integrate testing with other site work;

(e) minimise outage durations; and

(f) minimise the resources and time required on site by completing all preparatory and planning work in the office and laboratory.

4.2 Considerations while planning

As a minimum, planning shall include:

(a) familiarisation with the IED's and other devices involved;

(b) study of the circuit and network diagrams, to determine the equipment details and the inter-relationship of the equipment being tested to other equipment and functions;

(c) based on the above, defining the required functional checks in terms of pass/fail criteria for each test;

(d) consideration of system security implications;

(e) consideration of regulatory requirements;

(f) listing the tests required and the order in which they will be carried out (critical path planning methods may be necessary); and

(g) preparation of forms, to allow rapid on-site test documentation.

5 Order of testing

The order in which tests are performed requires careful consideration. The test programme should be flexible where possible, to allow for site conditions and access problems due to project schedule changes etc. However:

(a) insulation and continuity tests shall precede all other energisation tests;

(b) fibre optic cable attenuation and termination loss factors test; and

(c) any wiring changes made after injection and functional checks shall be proven by re-test.

Table 1 lists the commissioning requirements in an idealised sequence, assuming no external constraints on the testing programme. Where such a sequence is not possible due to external constraints, additional testing may be required to achieve these requirements. The tests are presented as a sequence, but in practice some tests may be combined for efficiency for example some aspects of primary and secondary injection and phasing/polarity checks may be combined.

* Signifies test types to be conducted / considered for routine maintenance.

These tests are further discussed in sections 7 to 15.

Table 1: Required tests and scope

Test	**Brief description**	**Aims**	**Details (refer to)**
Visual Inspection	Brief check for workmanship, technique and completeness	To confirm equipment installed is correct and record details of equipment (model number, serial number, nameplate details etc.). To get any major corrective work done so circuits are not disturbed later, with resulting need to re-test.	Section 7
Detailed Checks*	Detailed checks prior to energisation	Detect errors which may cause damage if energised. Check installation against circuit diagram and standards. Check continuity of circuits, resistances of coils, etc.	Section 8

Test	Brief description	Aims	Details (refer to)
Insulation Tests	Checks made using insulation tester	Check insulation resistance. Prove earthing (single point, always earthed). Check for “sneak” connections between circuits.	Section 9
Fibre optic (between IED’s within substation)	Fibre performance	Cable attenuation and termination loss factors test.	Based on manufactures minimum recommendations and IEC 61280-4
Secondary Injection Tests*	Apply current and voltage signals to secondary circuits	Acceptance test of each secondary equipment item (often done in laboratory). Prove circuit is ready for primary injection. Prove secondary equipment operation at service settings in conjunction with primary injection if not possible by primary injection alone. Measure burdens and voltage drops.	Section 10
Protection Signalling Tests*	Prove protection communications locally and remotely	To ensure protection communications is reliable, secure, and timely and allocations are correctly aligned and functional.	Section 11
Polarity and Phasing Tests	Prove polarity/phasing from primary conductors to secondary equipment terminals	Prove polarity of CT and VT circuits from primary (HV or EHV) to secondary equipment terminals. Prove relative polarity within a group of CTs or VTs and between groups where relevant. Verify phasing throughout circuit, especially with star/delta or star open-delta connections.	Section 12
Primary Injection Tests	Energising secondary equipment from CT primary, (but usually not from VT primary)	Prove that required CT ratio has been obtained. Prove that transformer differential protection and differential earth fault protection is stable. Ideally, inject CT primary and prove that secondary equipment, especially protection, operates at the service settings. If not possible prove by overlapping primary and secondary injection tests.	Section 13
Functional Tests*	Check operation/non-operation of circuits	Prove all important functions of the equipment. Prove that equipment operates for required conditions and does not operate for all other conditions. Prove that circuit connections are correct.	Section 14

Test	Brief description	Aims	Details (refer to)
Post Livening and Load Tests*	Checks not practical by primary or secondary injection	Confirm relative polarity of CT and VT e.g. protection direction check. Verify phase rotation. Prove connections of differential protection. Other final checks.	Section 15

6 Documentation and reporting

6.1 Aim

The aim of documenting and reporting on tests is:

(a) to record temporary alterations and restoration;

(b) to record all tests without ambiguity;

(c) to update all circuit diagrams; and

(d) to record all defects and actions outstanding.

6.2 Preparation of forms

Forms for on-site recording of test data must be prepared in advance. These forms perform a dual function:

(a) They provide the testing personnel with step by step details of the tests to be carried out, with pass/fail criteria where appropriate.

(b) The completed form must be submitted to TasNetworks as part of the test results and provides assurance to TasNetworks of the outcome of the test results.

Forms must be sent to TasNetworks for approval and acceptance prior to commencement of testing.

The following details are required on the forms:

(c) Company carrying out tests.

(d) Date of tests.

(e) Tester's name, signature and designation.

(f) Manufacturer, type, serial number and calibration date of all test equipment used for each test (not just a list of all test equipment at the site).

(g) Purpose of the test.

(h) Full details of the test method, with diagrams.

(i) Equipment under test, manufacturer, model number, firmware revision, serial number and TasNetworks' identification code (as used on the circuit diagram).

(j) Settings applied, either listed (e.g. for CT ratio or simple settings) or a reference to a record of settings (date and file or document number).

(k) All instrument readings recorded during testing, e.g. primary and secondary current values during primary injection, insulation resistance values etc.

(l) Interpretation of instrument readings (associated calculations if relevant) and comments to demonstrate that the equipment is/is not fit for service.

6.3 Test records

Recording of the test results shall be carried out during testing and the on-site records (or photo-copies) submitted to TasNetworks.

A works report / test plan detailing the testing must be submitted to the relevant TasNetworks' project manager or representative upon completion.

6.4 Alterations and isolations check list

Where it is necessary to disconnect or otherwise interfere with wiring or equipment, an "alteration and isolation check list" (pre-prepared form) shall be used to record each step taken. The following rules apply to the check list:

(a) For planned works the check list is to be prepared during the planning of the works.

(b) A separate check list is required for each protection scheme test activity, not for a complete project.

(c) The check list is to be reviewed by a qualified person prior to the commencement of testing activities to ensure critical circuits are isolated such as protection trips, protection communication and signalling, current transformer secondaries, circuit breaker fail initiations, etc.

(d) The check list should also consider nonphysical isolations, such as "script calcs" and system protection schemes that will be derived from metering quantities or CB status simulated by secondary injection tests.

(e) The check list shall be used when restoring the circuits to ensure that nothing is overlooked.

(f) The check list shall be signed by the testing personnel doing or overseeing the work, included in the test report and submitted as part of the test results.

(g) The use of "alteration and isolation check lists" is mandatory.

6.5 TasNetworks protection testing guides

TasNetworks have developed a suit of protection testing guides for Contractors or internal maintenance personnel. The guides list the requirements for testing protection and control equipment of EHV and HV busbars, EHV and HV capacitor banks, HV feeders, supply and network transformers and transmission lines. There are also guides for the general tasks required to prepare for testing activities and for the tasks required for emergency response activities. The guides are listed in the references section of this standard.

6.6 Report of defects and outstanding actions

All defects and other actions outstanding at the end of testing shall be detailed in a written report to TasNetworks within three days of testing the relevant plant and three days before commissioning.

Critical defects on equipment that is to be returned to service must be communicated to TasNetworks before the equipment is returned to service.

Defects found during maintenance testing are to be recorded for entry into the enterprise asset management database to be used for asset management planning purposes.

6.7 Notification of alteration

Following the commissioning or re-commissioning of any secondary equipment where-by the equipment has the potential to impact the operation of the transmission and distribution system, a “Notice of Alteration” form must be submitted to the relevant TasNetworks project representative, the TasNetworks’ project manager and TasNetworks’ Network Control room.

6.8 As-built documentation

All equipment and wiring changes shall be clearly marked on the "station" and "as-built" copies of circuit diagrams (and layout drawings if appropriate). A single master drawing and documentation set of all as-built documentation shall be prepared, with each drawing signed, dated and stamped “as-installed” by the commissioning personnel. Drawings or documentation issued for construction which has not been subject to alteration shall also be signed, dated and stamped “as-installed” and be included in the as-built master drawing set.

Once prepared, the master drawing set may be temporarily removed from site for the duration reasonably required for a copy to be made. This copy shall then be returned to, and left onsite immediately following commissioning.

The master drawing set, in addition to any amended settings and all other project settings and drawings, shall be forwarded to TasNetworks for drafting and processing, with a second version to be scanned and/or copied onto a CD and submitted to TasNetworks within 1 week of completion of the work.

7 Visual inspection

The first stage of testing is a visual inspection of the equipment.

7.1 Aim

The aim of the visual inspection is to ensure that workmanship is satisfactory and the equipment is correct and appears ready for test, checking for issues which:

(a) if discovered later would lead to delays and/or the need to re-test after they were corrected; and

(b) may result in incorrect operation of other, in-service equipment.

7.2 Physical details

Check for:

(a) correct delivery and installation of equipment to site. Model numbers verified, serial numbers recorded, nameplate details recorded and checked against design specifications;

(b) adequate vermin sealing, weather protection, drainage holes, vents, heating;

(c) safety flaps on all trip push buttons;

(d) switch mechanisms with positive action which cannot be accidentally knocked to the wrong position;

(e) safe working space and adequate lighting, in and around equipment to allow for work with the secondary circuits live;

(f) cabinet doors which open and latch easily;

(g) tidy wiring;

(h) cabinets and heavy components are correctly restrained; and

(i) compliance with general arrangement drawings.

7.3 Earthing

Check that:

(a) earth conductors are as short and direct as possible (without sharp bends) to minimise inductance at high frequencies;

(b) all cabinets, junction boxes, terminal boxes, etc. have an earthing terminal which is directly connected to the station earth grid;

(c) all equipment with accessible conducting parts which may become accidentally live, is earthed by a minimum 2.5mm^2 copper wire via the local earthing terminal;

(d) all secondary equipment earth terminals are earthed by a minimum 2.5mm^2 wire via the local earthing terminal. Where more than two earth conductors are to be connected to the earth terminal, they are marshalled at a group of linked terminal blocks;

(e) all cable armour and screens are earthed at both ends, with the exception of twisted pair RTU cabling and when earth leakage protection is implemented, in these cases single end earthing is to be applied; and

(f) only TasNetworks approved cable glands are used (refer to the HV and LV Cable Systems Standard).

7.4 Identification

Check that:

(a) each wire is identified at both ends with ferrules showing the conductor reference;

(b) cables are permanently identified at each end;

(c) all equipment is identified by the reference used in the circuit diagrams (accuracy of labelling is checked later). Items mounted through a panel are labelled front and rear;

(d) labels are not on covers which can be swapped with other covers;

(e) controls and indicating devices used by station operators are identified by standard labels; and

(f) the TasNetworks wire colour code has been used (refer to the HV and LV Cable System Standard).

7.5 Hazardous equipment

Check that:

(a) AC wiring rated 230V or higher is segregated and marked to TasNetworks standards; and

(b) hazardous equipment is shrouded and marked to indicate the hazard.

7.6 Wiring

Check that:

(a) all wires in the cabinet have been terminated, or if spare properly insulated, neatly bundled with the cable number attached and restrained;

(b) only one wire connects to each terminal of clamping type terminal blocks or terminals;

(c) bootlace ferrules have been properly crimped onto all stranded conductors connecting to clamping type terminals;

(d) all wires to stud terminals have been terminated with properly applied insulated crimp lugs;

(e) terminations to wiring terminals conform with the HV and LV Cable Systems Standard;

(f) adequate clearance exists between circuits at equipment terminals;

(g) where special terminal lugs are required to connect to equipment these are a type specified by the equipment manufacturer; and

(h) terminations appear to have been made with correct crimping tools/dies for the type of lug.

7.7 Cabling

Check that the requirements of the HV and LV Cable Systems Standard have been met. Particularly that all circuitry relating to a switchgear group shall be in a separate set of cables. Copper communications cables installed physically separate from power frequency cables, and optical fibre cabling installed suitably mechanically protected and clearly identified as optical fibre as per the Secondary Cable and Wiring standard.

8 Detailed checks

8.1 Aim

The aim of these checks is to identify:

(a) problems which could damage secondary equipment when it is energised; and

(b) discrepancies between the installation and documentation or standards.

8.2 General checks

During the general checks, the testing personnel should ensure:

(a) the identifier on the label for each component is the identifier used on the circuit diagram (check by the conductor references of connected wiring). Check the labels both on the panel front and inside the cabinet;

(b) switch and relay contacts are suitable for the purpose, with particular attention paid to the danger of open circuiting a CT. Contact action, (i.e. "make before break" and "break before make") shall be proved by test;

(c) equipment has the correct auxiliary supply rating, and correct value of series resistor in the auxiliary power circuit if applicable; and

(d) optical fibre patching and cables are adequately mechanically protected and installed as per manufactures minimum recommendation.

8.3 Wiring checks

Check that:

(a) the conductor reference and the cable maker's core number correspond at both ends of each core of each multi-core cable and align with the drawings;

(b) all wiring connections are tight (tug at each wire, check tightness of each terminal screw);

(c) all wiring is correctly sized and fused; and

(d) where cable cores or wires are in parallel for lower resistance, measure total resistance to check that the expected resistance is obtained.

8.4 CT and VT circuit checks

Check that:

(a) the CT/VT is correctly located (as per the circuit diagram) relative to the adjacent electrical plant (for example the bus section CT is correctly located relative to its associated CB and to the design of bus zone and CBF protection);

(b) the CT primary terminals are connected as per the circuit diagram (i.e. polarity of primary is correct);

(c) CT continuous current rating is not exceeded at the selected ratio and emergency current rating;

(d) input ratings of secondary equipment are compatible with the connected CT/VT;

(e) the number, location and type (bolted link) of earth links is correct and each is identified as in the circuit diagrams;

(f) terminal blocks are appropriate for CT circuits;

(g) CT circuits to include an approved voltage limiter connected so that if the CT secondary becomes open circuited adequate protection is provided for CT and the secondary equipment;

(h) voltage limiters which have an internal burden resistor are connected with the resistor adjacent to a transducer side limiter terminal;

(i) auxiliary CTs and VTs are the correct type (ratio, class, VA) and correctly connected according to the circuit diagram;

(j) where rupturing of a VT circuit fuse or operation of a MCB renders protection or revenue metering inoperative, an alarm is initiated; and

(k) VT MCBs and fuses are appropriately graded.

9 Insulation tests

9.1 Aim

The aim of insulation tests is to prove that circuits are:

(a) adequately insulated;

(b) only connected to earth at one point;

(c) not disconnected from earth by switch action; and

(d) not interconnected.

9.2 Test equipment

Insulation testers shall be either brushless or static type to avoid damage to static secondary equipment. The test voltage shall be 500V DC.

9.3 Warning

Some secondary equipment has suppression components to earth which cannot withstand the insulation test. Check the maker's instructions and disconnect or isolate if necessary before the test.

9.4 Tests

The following tests shall be carried out:

(a) Check that insulation resistance of secondary circuits is satisfactory having regard to the atmospheric conditions. Atmospheric conditions shall be noted.

(b) CT and VT circuits shall be tested by opening the bolted earth link provided for the purpose. The labelling and connection of the bolted link shall be verified against the circuit diagram as follows:

  (i) Connect to one phase conductor of CT or VT circuit.

  (ii) Open the appropriate bolted link identified by label against circuit diagram and measure insulation resistance.

  (iii) Close the link, verify (using insulation tester) before disconnecting tester, that circuit is earthed.

(c) Verify that CT and VT secondaries are always earthed, and never earthed at more than one point.

(d) The station DC distribution system should be earthed only at the supply. Verify that each sub-circuit is free of earth when both sub-circuit supply fuses are out or MCB open.

(e) Check for sneak circuits between DC1, DC2, Alarm, VT, and CT circuits by earthing all circuits except the one under test. For example when testing a CT circuit, all other circuits, including circuits connected to other cores of the same CT, should be earthed.

10 Secondary injection checks

Secondary injection tests apply current and voltage signals directly to the secondary circuits. Injection may be from the CT or VT terminals, via test facilities or at the secondary equipment terminals as detailed below or as appropriate.

10.1 Aim

The aim of secondary injection tests is:

(a) to prove the circuit is ready for primary injection;

(b) to prove secondary equipment operation at service settings in conjunction with primary injection tests;

(c) to measure burdens and voltage drops;

(d) to determine the health of non-self-supervised protection relays;

(e) to determine calibration drift of merging units and/or protection relays outside of acceptable tolerance levels that will have an effect on grading with adjacent protection schemes;

(f) to confirm the correct operation of alarms and SOE, and calibration of operational metering sent directly through the SCADA system; and

(g) Confirmation of sample value streams are received by all relevant devices.

10.2 Factory acceptance tests

These are detailed tests normally done at the factory to prove all design functions of secondary equipment.

For details of factory acceptance tests refer to the Testing, Commissioning and Training Standard.

10.3 Proving circuits prior to primary injection

The following tests shall be applied:

(a) Equipment can be damaged if energised while unearthed. Prior to this first livening of the equipment, make a final check that all secondary equipment has been correctly earthed.

(b) Service settings shall be applied to the secondary equipment. This includes any internal link and switch settings and/or software configuration which define the secondary equipment function and calibration.

(c) Auxiliary supplies shall be connected to the secondary equipment (any disconnections to isolate incomplete circuitry shall be listed in the alteration & isolation check list).

(d) CT circuits shall be injected, each phase in turn, from the main CT secondary terminals using test equipment which will tolerate open circuits. CT test links etc. shall be operated to prove that the CT will not be open circuited. Current flow in the correct circuit of the secondary equipment shall be confirmed via both secondary measurements and observation of both local and remote primary metering values where available.

(e) VT circuits shall be injected, each phase in turn, from the VT fuse or MCB (with VT secondary isolated and VT primary earthed). Voltage at the correct terminals of the secondary equipment shall be confirmed via both secondary measurements and observation of both local and remote primary metering values where available.

10.4 Measure burdens and voltage drops

10.4.1 VT circuits

The following shall be checked by injection and measurement and results recorded for each VT secondary winding:

(a) In VT circuits, the current per phase resulting from voltage injection (between phase and neutral) between VT secondary terminals does not give rise to a calculated burden that exists outside the following ranges under minimum and maximum VT circuit loading conditions for compliance with class error limits:

  (i) Where specified by nameplate rating, the rated burden must reside within that range specified by the manufacturer.

  (ii) For VTs with rated burden <10VA, burden must not exceed rating, but may reside below 25% of rated output if in accordance with transformer nameplate specification and/or designated instrument transformer standard.

  (iii) Where not specified by nameplate, for VTs with rated burden >10VA, burden must reside within 25% and 100% of rating.

  (iv) The connection of a suitable resistor shall be used to increase burden to within a specified limit where required. As a guide, a burden of 50% rated output is an appropriate value, however thermal considerations of the resistor dictate 50% rating may not always be practical.

(b) Irrespective of the total burden, the voltage drop (measured between phase and neutral) between VT secondary terminals and the device supplied does not exceed the following values under maximum VT loading conditions:

 (i) Metering: 0.2V.

 (ii) Protection: 2.5V.

(c) TasNetworks shall be notified in the event burden or voltage drops exceeds a specified limit.

10.4.2 CT circuits

The following shall be checked by injection and measurement and results recorded for all CTs:

(a) For class <1M metering CTs, that the burden is within 25% and 100% of rated burden (unless otherwise specified by nameplate) and is not exceeded at rated current and under worst case conditions.

(b) For classes 3M and 5M metering CTs, that the burden is within 50% and 100% of rated burden (unless otherwise specified by nameplate) and is not exceeded at rated current under worst case conditions.

(c) For P, PX, PR and PL class protection CTs that the burden does not exceed the specified value at rated current and under worst case conditions:

 (i) For P class CTs the rated output may be provided directly. Alternatively the derived output at rated secondary current can be obtained by VA = Vref * Isec / ALF. This information can be provided by TasNetworks if nameplate specifications are unavailable.

 (ii) For PX, PR and PL class protection CTs, the rated output may also be provided directly, or provided as the rated resistive burden in ohms which shall not be exceeded. This information may otherwise be provided by TasNetworks if unavailable by specification.

(d) For CTs supplying high impedance protection circuits, the high impedance circuit burden should be confirmed to ensure within design specifications, not within rated output of the CT.

10.5 Full test

Where it is not practical to prove the function of secondary equipment at the service setting by primary injection, this shall be proven by secondary injection. Care is required to ensure that this test overlaps with the primary injection test so that the total circuit has been proven. A full secondary injection test for protection shall:

(a) operate the merging unit and/or protection and associated trip relay or CB;

(b) operate at the expected current/voltage/phase-angle and time(s), for example all zones of a distance relay shall be tested;

(c) prove the effect of other inputs (such as distance relay inputs "signal receive", "CB close" etc.) on the device;

(d) prove the action of "AC" features such as AC line check/SOTF, VT supervision and power swing blocking; and

(e) prove that the protection is stable under through faults or other conditions for which it should not operate.

11 Protection communications and signalling checks

These tests are required to be done where protection and/or control equipment shares or otherwise passes information between devices for purposes of protection and control. Such devices may be located at the same location, or be physically remote and require high speed protection signalling mechanisms to be provided.

11.1 Aim

The aim of these checks is to:

(a) prove the integrity of local communications infrastructure;

(b) prove reliability and security of protection communications; and

(c) prove inter-operability between devices (signalling functional allocations align with correct status).

11.2 Telecommunications integrity

The following checks/tests shall be carried out by the Protection technician:

(a) Establish communications between devices. For devices between remote substations, establish signalling propagation time delay between devices <10ms.

(b) The operational telecommunications paths between devices shall be tested for dropped packets and bit errors over a 24 hour period to verify the following link integrity criteria:

Packet loss ratio:

$$Acceptable\ Packet\ Loss\ Ratio < 1 \times 10^{-3}$$

Where:

$$Packet\ Loss\ Ratio = \frac{Number\ of\ lost\ packets\ during\ transfer}{Number\ of\ succesfully\ transferred\ packets}$$

Packet Error Ratio:

$$Acceptable\ Packet\ Error\ Ratio < 1 \times 10^{-4}$$

Where:

$$Packet\ Error\ Ratio = \frac{Number\ of\ packets\ transferred\ with\ errors}{Number\ of\ packets\ transferred\ without\ errors}$$

The logged results shall be collected and analysed after the 24 hour test period has elapsed. If these criteria are not met, the TasNetworks' SCADA technical representative shall be notified.

All aspects of the IEC 61850 communications within the substation shall conform to the protection and automation standard.

11.3 Communications functionality

The following checks/tests shall be carried out by the Protection technician:

(a) Check addressing of signalling equipment is unique within the Substation such that a cross-over of communications circuits between adjacent lines will not result in protection operation (e.g. due to current differential unbalance).

(b) For inter-tripping signalling, check alignment of inter-tripping signal (including GOOSE and SV) allocations between ends. Check status at each end is correctly transmitted to remote equipment. Status check must be done via actuation of primary plant (e.g. CB must be opened/closed to confirm correct CB status) or secondary injection (e.g. zone 2 fault simulated to cause permissive inter-trip to be transmitted).

(c) Check failure of communication defaults status of protection and control functions to fail-safe state, i.e. failure of communications does not cause acceleration of tripping due to default state of inter-tripping I/O.

(d) Check that communications failure is alarmed to the local human machine interface and TasNetworks control centre.

(e) Check for correct remote transfer of binary signals, e.g. transfer of remote alarms or primary equipment status, etc.

(f) For current differential telecommunications circuits, perform the following tests:

    (i) Establish direction of power-flow between line ends. Inject balanced secondary current at each end based on the lowest CT ratio at either end to simulate ‘through–current’. Check stability (all restraint/bias, zero spill/differential).

    (ii) Reverse polarity of injection at one line end only. Check instability (zero restraint/bias, all spill/differential).

    (iii) For three terminal lines, assume a power flow direction between one terminal and the remaining two. Inject balanced current to sum to zero. Perform test for all three line ends under load, in turn reversing the polarity of two line ends to confirm correct stability and instability of scheme. Repeat tests between a pair of line ends with the third at zero current.

    (iv) Inject balanced current and remove telecommunications circuits. Check relays remain stable.

    (v) Inject single phase current to cause operation of the local relay, one at a time at each end, to check correct reception of correct phase inter-trip at remote end.

    (vi) Check that failure of telecommunication channel enables backup protection element (either distance/impedance protection or emergency over-current as per functional specification).

    (vii) Check the phase angle variance between ends for a scheme where one end is SV and the other is conventional.

12 Polarity and phasing checks

12.1 Aim

The aim of the polarity and phasing checks is to:

(a) prove polarity of CT and VT circuits from primary (HV or EHV) to secondary equipment terminals;

(b) prove relative polarity within a group of CTs or VTs and between groups where relevant (e.g. busbar protection); and

(c) verify phasing throughout circuit especially with delta/star, star/delta or star/open-delta connections.

12.2 Polarity

When testing polarity, the following shall apply:

(a) Newly installed VTs and CTs shall be tested to prove polarity.

(b) The polarity of connections from the CT or VT primary terminals shall be proven through to the secondary equipment terminals. Separate polarity checks shall be made from the CT/VT side of auxiliary CTs and VTs to prove there are not 2 "cancelling" polarity errors.

12.3 Phasing of VT circuits

When verifying the phasing of VT circuits, the following shall apply:

(a) VT phasing checks cannot be completed until after livening. Since these tests are also a check of primary system phasing it is essential with 3 phase VT units that the phase markings of the secondary terminals are confirmed against the primary terminals as a first step.

(b) For a "green field" station the phasing of the primary connections at the first VT to be livened shall be identified before livening. This shall be verified against another station by the application and removal of an earth stick adjacent to each phase of the VT being "seen" from the remote station by "Linescope", or other means. Once this first VT has been livened, phasing of others can be done as below.

(c) Phasing of the VT shall be verified by voltage measurements and physical/visual tracing of primary conductors against an existing VT at the station. The physical connections of the busbar must be carefully traced prior to these phasing checks, since it is possible for two errors to cancel and go undetected until livening or connecting load.

(d) Where phasing of a new VT on one side of a newly installed transformer has to be checked against an existing VT on the other side of the transformer, the phase shift through the transformer shall first be verified.

12.4 Phasing of CT circuits

For simple star connected CT circuits involving one set of CTs, a polarity check plus a phasing check of primary connections as above is a sufficient check of phasing. For more complex circuits additional tests are necessary.

When verifying the phasing of CT circuits, the following shall apply:

(a) The phasing of transformer differential protection and differential earth fault protection shall be verified by primary injection tests before livening.

(b) The phasing of earth fault protection measuring the residual current of a set of three CTs shall be verified by primary injection tests before livening.

(c) The phasing of busbar protection CTs shall be verified by primary injection via the busbars, of two sets of CTs at a time. Preferably one of these sets of CTs is to be a master used to test all other sets. At large stations several "master" CTs may be required with phasing checked against each other.

13 Primary injection checks

13.1 Aim

The aim of the primary injection checks is to:

(a) prove that the required CT ratio has been obtained;

(b) prove that transformer differential protection and differential earth fault protection is stable (check for phasing and ratio errors);

(c) prove correct operation of directional relays; and

(d) ideally, inject the CT primary and prove that secondary equipment, especially protection, operates at the service settings. If not possible this shall be proven by overlapping primary and secondary injection tests.

13.2 Tests

When performing the primary injection tests, the following shall apply:

(a) Primary injection of VT circuits is not required due to the cost of suitable test equipment and practical difficulties of combining this with primary injection of CTs (in some cases a test of the VT itself is required).

(b) Primary injection of a multi-core CT requires care as all cores and connected circuits are affected (consider open circuits, overloads and short time rated relays, metrosils, resistors etc.).

13.3 Current operated protection

Primary injection tests allow current operated protection (or other secondary equipment) to be tested without disturbing the secondary wiring.

If possible the required current shall be injected into the CT to:

(a) operate the merging unit and/or protection and associated trip relay or CB;

(b) operate the merging unit and/or protection at the expected current and time; and

(c) prove that the merging unit and/or protection is stable under through faults or other conditions for which it should not operate.

As a minimum, primary injection shall prove:

(d) the ratio of each CT core after the service ratio has been selected and wiring completed; and

(e) that the correct current is flowing in each conductor up to a point which overlaps with secondary injection tests.

13.4 Transformer differential and restricted earth fault protection

Experience shows that transformer differential protection often reaches the commissioning stage with circuit errors, either in design or wiring. The circuits necessary to correct for transformer vector group are easy to get wrong.

For differential earth fault protection the setting is low and small turn’s ratio differences may lead to operation on through fault or load.

The connections shall be proven by passing current through the power transformer and associated CTs to simulate in zone faults and through fault or load conditions. This may be difficult to achieve in some cases, requiring perhaps a large mobile 400V generator, but is mandatory to ensure that the protection is correct before energising the transformer. The required current capacity of the test supply shall be calculated and appropriately rated equipment used.

13.5 Secondary equipment with both CT and VT inputs

Since primary injection of VT circuits is not normally possible, this equipment shall be given a minimum primary injection. Operation, correct setting and stability as above shall be proven by secondary injection with a final direction check after livening.

14 Functional checks

14.1 Aim

The aim of the functional checks is to:

(a) prove all important functions of the equipment;

(b) prove that equipment operates when required and not at other times; and

(c) prove that circuit connections are correct.

14.2 Tests

When performing the functional tests, the following shall apply:

(a) Functional tests are the part of commissioning which requires the most planning. These tests are based on a detailed study of the circuit design and understanding of the function of the equipment. The tests prove that each item works when required and not at other times.

(b) Functional checks shall be devised to test each aspect of the equipment, both operation and non-operation. Checks shall be expressed on the pre-prepared sheets in terms of pass/fail criteria.

(c) Most AC circuit function tests have been mentioned under injection testing, but further AC injection may be necessary to prove the action of associated DC circuits.

The function of each aspect (wire, contact, diode, device etc.) shall be proven by functional check. The following list is not exhaustive, but illustrates the range of functional tests required:

(d) Functional check of CB, tripping and closing from controller etc.

(e) Protection trip test from all tripping contacts.

(f) Prove operation of protection and CB tripping at 100% and 80% auxiliary voltage.

(g) Prove auto-reclose sequences, blocking and initiation circuits, trip-close-trip sequences etc., at 100% and 80% auxiliary voltage in conjunction with the above trip tests.

(h) Prove protection signalling functions, at 100% and 80% auxiliary voltage, in conjunction with the above trip tests.

(i) Prove the independence of secondary equipment supplied by DC1 or DC2 from the other supply.

(j) Prove that the CB will trip correctly via trip circuit 2 without DC supply 1 (look at low pressure interlocks etc.).

(k) Prove the action of the "scheme disable" (trip interrupt etc.) feature of test blocks and for IEC 61850 sites “test mode”.

(l) Prove operation of DC supervision, Trip Circuit Supervision and Trip Coil Supervision relays and all electrical functions of voltage supervision relays.

(m) Prove immunity to capacitive discharge during DC earth faults (see notes below).

(n) Prove that momentarily shorting Trip Circuit Supervision/Trip Coil Supervision or series resistor will not trip CB.

(o) Prove operation and resulting action of time delay relays and auxiliary relays.

(p) Check of all alarm functions.

(q) Check of all SCADA functions including metering values and time stamping of events.

(r) Check of all indication functions.

(s) Check all logic and interlocking of primary plant such as circuit breakers and disconnectors.

14.3 Independence of secondary equipment on separate DC supplies

To verify the separation of DC supplies, the following tests shall be performed:

(a) Correct operation of each protection of a duplicated protection set shall be verified with the other DC supply removed and the tests repeated with both DC supplies in service.

(b) Correct operation of a CB with duplicate trip circuits shall be verified with each trip circuit (in turn) dead. A further test with both trips applied simultaneously shall also be performed.

14.4 Capacitive discharge effects

Prove that trip relays are immune (where necessary) to mal-operation on DC earth fault current. This test is applicable to trip relays initiated by contacts in the switchyard. After ensuring no pre-existing earth fault by measurement and confirmation of voltage rail symmetry, it is carried out by momentarily earthing the terminal of the trip relay coil that is connected to the initiating contact via a fused lead (maximum 10A fuse).

15 Post-livening and load checks

15.1 Aim

The aim of post-livening and load checks is to:

(a) confirm relative polarity of CT and VT (e.g. protection direction check);

(b) verify VT phasing and phase rotation;

(c) prove connections of differential protection; and

(d) check SCADA analogue displays for correct readings.

15.2 Directional checks

Where the relative polarities of VT and CT inputs are significant, these shall be checked after energisation. The following shall be checked:

(a) The direction of directional protection shall be proven using line charging current in preference to load current since line charging current direction is always known.

(b) The output polarity and correct direction of SCADA analogue values shall be confirmed.

15.3 VT phasing, phase rotation and burden

To confirm VT phasing, phase rotation and burden, the following tests shall be performed:

(a) The phasing and polarity of the VT shall be confirmed by measurement against known VT. See section 12.3(b) for phasing of VT at 'Green Field' sites.

(b) Once VT phasing has been confirmed, phase rotation shall be checked with a phase rotation meter connected as close as possible to the VT terminals.

(c) After each VT has been energised, measuring as close as practical to the VT secondary terminals (usually the VT junction box), check circuit burden of VT secondary and compare to value obtained via secondary injection to confirm no short-circuit/low impedance paths in the secondary circuit.

15.4 Differential protection

Confirm the differential protection with the following checks:

(a) With the plant carrying load, the voltage across the CT circuit inputs of the differential relay shall be measured and noted together with the load current magnitude. The differential "spill" current of biased differential relays shall be checked and noted.

(b) Differential protection shall generally be in service when the plant is livened. The exception is when commissioning busbar protection which has been retro-fitted to a station which has pre-existing and in-service busbar protection already available during the commissioning period. In this case, the post-livening tests shall be done before putting the busbar protection into service.

(c) While doing the post-livening busbar protection checks, carry out switching of all isolators to ensure that all circuits have been significantly loaded during at least one check, with correct imaging and busbar stability confirmed for each yard configuration.

(d) Check differential stability (Idiff and Ibias) for the onloads for SV/conventional hybrid schemes are within limits for high loads.

15.5 CT circuit burden

After the plant has been loaded, the circuit burdens for each CT shall be taken as close to the instrument transformer terminals as practical (usually the CT junction box) and compared to values obtained via secondary injection to ensure no high-impedance circuits CTs.

The expected secondary circuit burden at any secondary current value can be extrapolated from the nominal burden measured during secondary injection.

15.6 Other final checks

The following checks are required:

(a) After the plant has been livened, the secondary voltages at the relays shall be checked for magnitude and polarity.

(b) Once the plant is carrying load, the CT currents at protection relays shall be checked for magnitude and polarity. This shall be done without disconnecting wiring.

16 Re-commissioning

There is frequently a need to disturb or alter existing circuits, protection settings and/or configurations in order to install additional equipment, replace a faulty component etc. The circuits affected may be secondary or primary circuits. For example, changing a CB and associated CTs affects both the primary and secondary circuits and re-commissioning tests shall include checks for incorrect re-connection of the primary circuit.

The risk of errors can sometimes be reduced by careful labelling of each wire removed and making sketches etc.

The following are some possible problems to be detected during re-commissioning of an existing circuit:

(a) Design or wiring error in the new part of the circuit affecting the function of existing circuit.

(b) Inadvertent alteration to existing circuit.

(c) Damaged or loose wire or terminal in existing circuit leading to high resistance, open circuit or loss of dielectric strength. Wiring with older brittle types of insulation may be damaged by being "pushed around" even though not disconnected or altered.

Circuits which have been disturbed shall be proven to be ready for service by a series of commissioning tests sufficient to detect the above problems. This is particularly important for protection circuits. This will involve as a minimum:

(d) Insulation tests of wiring which has been disturbed.

(e) Functional tests for circuits which have been disturbed. For example where any wiring work has been done in a protection cabinet, a secondary injection test that trips the CB shall be made from a point outside the protection cabinet.

(f) Where CT secondary circuits have been disturbed, secondary injection tests of the CT circuit from a point between the CT and the disturbed part of the circuit. Inject phase to neutral, each phase in turn and check magnitude at secondary equipment.

(g) Where VT secondary circuits have been disturbed, comparison of each phase voltage at secondary equipment terminals with each phase of an (undisturbed) VT supply derived from the same primary bus. Nine voltage measurements are required, comparing R-R, B-B, Y-Y is not sufficient (e.g. no voltage R-R is expected, but could be due to a break in meter circuit or one VT secondary not earthed).

(h) Where busbar protection or transformer differential protection CT circuits have been disturbed, proof of stability by primary injection.

(i) For directional protection relays a direction check is required if the CT circuit has been disturbed.

(j) For directional earth fault protection relays with residual voltage derived external to the relay, a direction check is required if either the CT or VT circuits have been disturbed.

(k) Whenever any primary changes have been made, including a break in the primary circuit, tests to confirm primary connections are mandatory. These tests shall especially confirm primary connections to CTs and VTs, CT polarity and correct phasing of the primary plant. For differential protections (including differential earth fault protection), a primary injection test is mandatory for all primary changes within the protection zone.

The requirements for testing after setting and configuration modifications are provided in Table 2.

Table 2: Testing after setting and configuration modification

Device Type	Changes	Minimum Test Requirements
Electromechanical relays/Static Relays	Relay Setting	Test modified elements
Microprocessor based protection relays/Control Devices (includes numerical)/Network switches/GPS clocks	Relay setting/Configuration	Compare new setting file with existing relay setting file New configuration elements to be fully tested Complete protection relay re-test (required if comparison not possible)
Microprocessor protection Relays/Control Devices/HMI's/Network switches/GPS clocks	Firmware	Lab type test for new firmware before site rollout (may depend on manufacturer recommendation) Complete equipment re-test required if lab type test not possible
Gateway	Signal list/Configuration	Test new and modified SCADA points and functions Test setting file differences
Gateway	Firmware	Spot test functions and alarms E.g. 20% of all types of signals (binary and analogue etc.) including communication to all connected devices